The Role of Cultural Familiarity, Musicianship and Explicit learning in the perception of Long Rhythmic Cycles.

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Abstract

Rhythmic cycles from North Indian Classical Music (NICM) commonly contain 6 to 16 beats per cycle. Despite their prominence in NICM, these long rhythmic cycles remain unexplored in rhythm perception research, which has concentrated mainly on Western meters or the short/fast meters characteristic of musical traditions like those of Turkey and the Balkans. Long rhythmic cycles from NICM also raise questions about whether isochrony is considered easier to perceive as compared to non-isochrony (based on research on short/fast meters) and remains so when the rhythmic cycles are longer than those previously studied. This study addresses this gap by investigating two prominent rhythmic cycles from NICM: the 16-beat ISO-Teental and the 7-beat NI-Rupaktal. Given the significant role of cultural familiarity and musicianship in shaping rhythm perception, the study examines four participant groups: Culturally Familiar Musicians (N = 32), Culturally Familiar Non-Musicians (N = 44), Culturally Unfamiliar Musicians (N = 34), and Culturally Unfamiliar Non-Musicians (N = 30). Additionally, a novel short-term explicit learning paradigm is employed to explore whether it can influence the effects of enculturation observed in prior research.

Culture-specific musical expertise, rather than mere familiarity with the culture or musicianship alone, is the most relevant in the similarity perception of the structure of these long rhythmic cycles. An effect of short-term explicit learning was observed in NI-Rupaktal for Culturally Familiar Non-musicians and Culturally Unfamiliar (western) Musicians. This effect was not observed for the ISO-Teental rhythmic cycle, unlike the previous studies, which we attribute to the cognitive load in the perception of the long ISO-Teental cycle.

Keywords: Rhythm Perception, Cross-cultural, Long Rhythmic cycles, Learning, Indian Music

Word count: 4745 words in Text Body, 904 words in Reference.

The Role of Cultural Familiarity, Musicianship and Explicit learning in the perception of Long Rhythmic Cycles.

The study of rhythmic perception has often focused on shorter meters, typically lasting no more than 2 seconds and consisting of only a few beats within the rhythmic cycle. This leaves the perceptual impact of longer rhythmic cycles, such as those found in North Indian Classical Music (NICM), relatively underexplored (Clayton, 2020; Clayton, 2008). Rhythmic cycles from NICM commonly comprise 6 to 16 beats, spanning durations from less than 2 seconds to over a minute (Clayton, 2008). These NICM rhythmic cycles incorporate both isochronous (ISO) and non-isochronous (NI) patterns[1], in the sense that their equal beats are collected into groups of beats (called vibhag), which can be of either equal or unequal length. An example of a non-isochronous rhythmic cycle in NICM is Rupaktal, which consists of 7 beats grouped as 3+2+2 (Clayton, 2020). NICM also uses rhythmic cycles which are long and ISO; for example, one of the most commonly used rhythmic cycles, Teental from NICM, is completely ISO and has a long cycle of 16 beats subdivided into four equal beat groups (4+4+4+4). ISO-Teental, with its longer rhythmic cycle, demonstrates the use of long isochronous meters in NICM. This feature sets it apart from many other musical traditions, focusing on shorter rhythmic cycles with fewer beats.

Hannon et al. (2012a) examined how American and Turkish listeners (non-musicians) respond to three different types of stimuli using a discrimination (Same or Different) task: a simple ISO meter (4/4) common in both American and Turkish music, a unique NI meter (7/8)

[1] London (2012) defines 'Non-isochronous (NI)' meters as ones which make use of unequal beats or unequal subdivisions of beats that can be categorized into long and short; we extend this to include these unequal beat groups. In contrast, most of the common western music rhythms are 'isochronous (ISO)', being organized around a regular beat (albeit one that can vary in tempo) which is subdivided into equal parts and combined into measures comprising an equal number of beats

present in Turkish music, and a highly complex NI meter (15/8) that is rare even in Turkish music. Turkish non-musicians performed better than American non-musicians in NI rhythms, and neither group differentiated highly complex NI rhythms. Both groups recognised the simple meter, a result also observed by other studies using tapping responses (Cameron et al., 2015; Polak et al., 2018) and similarity rating tasks (Yates et al., 2017). Most studies that explore the differences between isochrony and non-isochrony in meters focus only on short rhythmic cycles that do not go beyond 2 seconds, also called aksak meters (Brailoiu, 1951; London, 1995). While the perception of ISO meters (as studied for shorter meters) is often regarded as universal across cultures, a gap exists in the literature regarding the perception of isochrony within longer rhythmic cycles in music like NICM. It remains unclear whether isochrony remains (still) easier to perceive than non-isochrony when they are longer in duration.

The perception of NI meters is considered highly dependent on enculturation and musicianship (Collier & Wright, 1995; Essens & Povel, 1985; Povel & Essens, 1985; Hannon & Trehub, 2005a, 2005b; Repp et al., 2005; Snyder et al., 2006; Cameron et al, 2015; Bouwer et al., 2016; Matthews et al., 2016; Polak et al., 2018). This suggests that people familiar with that culture and music can recognise NI meters better than those unfamiliar with it. For example, Bulgarians trained in folk music are better at synchronising with NI meters at a slow tempo than Bulgarians with Western classical training and musicians in Germany and Mali (Polak et al., 2018), emphasising culture-specific musical training. Another study using a similarity perception task found that musicians, irrespective of their cultural familiarity, performed better than non-musicians to complex aksak Turkish meters (Yates et al., 2017). Participants who even occasionally listened to Indian music also noticed metrical variations in Turkish music (Kalender et al., 2013), emphasising the effect of mere exposure to culture without any musical training.

These findings exploring cultural familiarity and musicianship further suggest that the level of familiarity ranges from cultural and musical expertise to general cultural familiarity, and musicianship in Western forms differently affects the perception of rhythmic cycles. Although the studies above explore how enculturation and musical training influence the perception of non-isochronous (NI) patterns, they leave a gap in understanding their role in isochronous (ISO) patterns. This gap is especially true for longer patterns, in terms of duration and number of beats, such as ISO-Teental (described above).

A short exposure to unfamiliar rhythmic patterns does not improve the performance of adults (Hannon & Trehub, 2005b), likely due to a lack of long-term cultural familiarity (Hannon, 2012b). However, the exposure in these studies has been passive and does not inform unfamiliar participants about the rhythmic meter. Rhythmic cycles from NICM, as Clayton (2008) argued, are "cognitively constructed rather than directly perceived". Hence, learning and perceiving these rhythmic cycles from NICM should require top-down processing, mainly because of their long nature (Clayton, 2020). This reinforces the notion that rhythm perception is an explicit process that demands focused, immediate, and short-term attention (Bouwer, Werner, Knetemann, & Honing, 2016; Geiser, Sandmann, Jäncke, & Meyer, 2010; Large & Jones, 1999). This contrasts with implicit processing, where rhythmic structures are often automatically perceived without significant cognitive effort (Damsma & Rijn, 2017; Foldal et al., 2020; Salidis, 2001). Hence, in terms of learning or exposure to rhythmic patterns from NICM, the current study assumes that participants without prior exposure to NICM will require explicit learning to facilitate effective recognition of these patterns. This applies regardless of the isochrony or non-isochrony of the meter, as even ISO meters in NICM can be lengthy and challenging to perceive. Notably, such meters have yet to be empirically examined in music

psychology and rhythm perception research.

Current Study Objectives

The previous focus on shorter rhythmic cycles leaves gaps in understanding how longer rhythm cycles, such as those used in NICM, are perceived. Hence, this study uses a common, 16-beat ISO rhythmic cycle in North Indian Classical Music (NICM) called Teental and a 7-beat NI rhythm cycle, Rupaktal. We examine the differences between the similarity perception of these two rhythmic cycles among 4 groups of participants: Culturally Familiar Musicians (experts trained in NICM), Culturally Familiar Non-Musicians (non-musicians familiar with Indian culture), Culturally Unfamiliar Musicians (musicians unfamiliar with Indian culture and NICM) and Culturally Unfamiliar Non-Musicians (non-musicians unfamiliar to Indian culture and NICM). In this way, we aim to explore the effects of musicianship and cultural familiarity, as well as those between the two patterns (which may be due to the difference in the number of beats, length of the cycle, or the NI/ISO distinction).

Regarding recognising and learning NI meters, Hannon et al. (2012b) utilise a passive exposure, where unfamiliar participants were exposed to the specific cultural music for 2 weeks and showed no effect of the exposure. However, participants in the study lacked explicit instruction about the meter itself, and adult musicians unfamiliar with the culture were not a part of the study. Thus, another objective of the current study is to determine the effects of short-term explicit learning in the perception of these rhythmic cycles from NICM among the above groups of participants varying in familiarity and musicianship.

We utilise Similarity Rating as a proxy for recognising metrical structure, as it has been previously utilised to reflect the perceptual difference between isochrony and non-isochrony in meters (Yates et al., 2015; Hannon et al., 2012b) and provides more information than the

discrimination (same/different) task (Hannon et al., 2012a). Similarity ratings are useful when one wants to avoid using conceptual categories or constructs that are culture or language-dependent (see Daikoku et al., 2023). In this study, participants are exposed to three types of rhythmic cycles (Stimuli-Types, see Methods): those identical to the ones used during short-term explicit learning, metrically similar versions, and a metrically altered version. This design enables a nuanced evaluation of whether participants perceive similarity in rhythmic cycles and the role of enculturation in their perception, which is more than what a differentiation task would have provided.

Methods

Participants

The participants for this study were recruited using convenience sampling through social media, mailing lists and crowdsourcing. The participation was online, and the study was built using Qualtrics Software (2020, Provo, UT). Before participating, all participants were contacted in English and confirmed they could communicate in English. An information sheet and consent form were provided on the first page before the start of the study. Approval for the study was secured from the ethics committee of Durham University, Approval Number: MUS-2023-12-31T16_07_54-dhsl91. Participants who completed over 96% of the tasks within a minimum of 4 minutes were included, totalling 140 individuals.

To be divided into groups based on familiarity and musicianship, participants were asked about their ethnicity, nationality, and musicianship. Based on the ethnicity and nationality of participants, if the participants used the term ‘Indian’, they were classed into the group Culturally Familiar or Culturally Unfamiliar. The musicianship was determined using the 5-item inventory

(Ollen, 2006), where those who identified themselves as musicians (either amateur musicians, semi-professional musicians, or professional musicians) were classified as musicians (see Zhang & Schubert, 2019).

Participants who suggested they were both musicians and of Indian ethnicity were asked, "Have you studied North Indian Classical Music?" If they selected 'Yes' or 'A little' to the question, they were given a further check to assess their familiarity with NICM through a familiarity scale developed initially by Lahdelma et al. (2023). We included a question in the familiarity scale to test for rhythm: "How many mantras are there in total?" Participants who scored above 4 on the familiarity scale were classified into the Culturally Familiar Musician (expert) group. At the same time, those who did not meet this threshold were categorized into the Culturally Familiar Non-Musician Group alongside other non-musician Indian participants. Overall, we have 76 culturally familiar (Indian) participants with a mean age of 27.67 years (SD = 9.54), of whom 44 are Culturally Familiar Non-musicians and 32 are Culturally Familiar Musicians (trained in NICM). A total of 64 culturally unfamiliar participants (45 British and European, 16 Asian and Chinese, 2 American, 1 Turk) with a mean age of 27.85 (SD = 13.06) with no experience performing or listening to NICM participated in this study; 34 are musicians, and 30 are non-musicians.

Materials

Stimuli are all based on one of two north Indian talas (rhythmic cycles), namely Teental (16 beats divided 4+4+4+4, coded ISO or ISO-Teental for isochronous) and Rupaktal (7 beats divided 3+2+2, coded NI or NI-Rupaktal for non-isochronous), and were created by generating sequences of tabla drum sounds in Pro Tools (2019.6.0) using MIDI extensions for Tabla samples in Kontakt (5.8.1) Factory Library. In each case, we created a rhythmic cycle coded as

'Reference', which is an easily recognizable version of the tabla pattern (theka) for the tala, which we used for the training phase and as a reference for the similarity rating task. Both the rhythmic cycles were set at 120 bpm. Thus, one cycle of NI-Rupaktal was 3.5 seconds long, and ISO-Teental was 8 seconds long. We then created 4 altered versions of the Reference stimuli for each tala.

The Rhythmic Stimuli or Stimuli-Types are broadly categorized into 3 groups: 1. Reference (as explained above). 2. Metrical, comprising three versions containing the same number of beats as Reference: 'Basic', a simplified version of the Reference; 'Complex', an idiosyncratic version of the Reference; and 'Structurally Same', a version of the Reference stimulus including an extra drum stroke at the start of the original rhythm, such that the number of beats remains the same. These three were utilized for one category of 'Metrical' to control any confounding or idiosyncratic factors introduced by a single stimulus. 3. Altered, a metrically altered version of the Reference rhythmic cycle, including an extra drum stroke at the start of the rhythm, such that the number of beats is increased by one. The stimuli visualization and audio are provided in the Supplementary Materials.

The video for the explicit learning session (one each for Rupaktal and Teental) included audio-visual instructions on the Reference stimuli. All the videos and audio were created by the experimenter.

Design

The study uses a learning framework which includes a before and after training paradigm (described in Procedure). The 7-point Likert Scale was adopted from Hannon et al. (2012b) as a measure of perceived similarity. Each participant (in all the groups) either participated in the ISO-Teental or the NI-Rupaktal. There were four cycles of each of the 5 stimuli presented

randomly, which the participants heard and rated once before and once after training. This study has between-subject factors (Cultural Familiarity: Familiar, Unfamiliar), (Musicianship: Musician, Non-Musician) and (Rhythmic Patterns: Teental, Rupaktal); and within-subjects factors (Learning Conditions: Base, Test), (Stimuli-Types: Reference, Metrical, Altered).

Procedure

After providing informed consent and answering questions on age, ethnicity, and musicianship, participants proceeded to the study tasks. The study involved three parts: the base, explicit learning, and the test.

Base Session (Base Learning Condition): Participants were presented with four rhythm cycles of the "Reference" stimuli of either ISO Teental or NI Rupaktal, followed by a question (on the next page) which asked them, "Now rate the following patterns from "Not at all similar" to "extremely similar" (7-point Likert scale) based on how similar they are to the one you just heard". They were then presented with 5 stimuli (1 Reference, 3 Metrical, and 1 Altered) in a random order, and they selected one rating for each based on the options: "Not at all similar", "Not Similar", "Slightly Similar", "Moderately Similar", "Similar", "Very Similar", "Extremely Similar".

Short-Term Explicit Learning Session: The short-term Explicit-Learning involved an audio-visual video introducing the participants to the "Reference" stimuli of ISO or NI rhythmic cycle, explaining the number of beats and a count along with the rhythm. This was followed by a practice session with feedback, in which the participants selected the target rhythms (i.e., Teental and Rupaktal) from among another 5 NICM rhythmic cycles: Dadra: the cycle of 6 beats (3+3), Keherva: rhythm cycle of 8 beats (4+4), Jhaptal: rhythm cycle of 10 beats (2+3+2+3), Deepchandi: the cycle of 14 beats (3+4+3+4), and Teental or Rupak itself. The participants were presented with rhythms and given a binary choice of "Yes" or "No" to the question: "Is this teental/ rupak?" Participants proceeded to the testing phase when they answered 3 out of 5 questions correctly.

Test Session (Test Learning Condition): The test session was identical to the baseline, with an inclusion of a repeated Reference stimulus as a consistency check for the participant. This repeated question was included only in pre-processing the data and has been observed to be important to maintain quality in online data (Eerola, Armitage, Lavan, & Knight, 2021).

Results

Preprocessing

Preprocessing and analysis were done using R (version: 4.3.2). We computed the absolute difference between the similarity ratings of the Reference and Quality control (repeated Reference) rhythm cycle for both culturally familiar and culturally unfamiliar groups separately. To assess consistency, we calculated Cronbach's alpha for similarity ratings among culturally familiar musicians (mean $\alpha = 0.94$), culturally familiar non-musicians (mean $\alpha = 0.90$), culturally unfamiliar musicians (mean $\alpha = 0.93$), and culturally unfamiliar non-musicians (mean $\alpha = 0.90$).

Exclusion criteria included removing participants who had failed both the above, that is, have an absolute difference exceeding 2 and $\alpha < 0.70$. This excluded 7 participants, and a total of 133 were retained. The final sample for further analysis consisted of 61 unfamiliar participants (34 Culturally Unfamiliar Musicians, 27 Culturally Unfamiliar Non-musicians), and 72 familiar participants (32 Culturally Familiar Musicians, 40 Culturally Familiar Non-musicians).

First, to determine whether there are differences between the Metrical Stimuli-Type category across all participant groups, we performed a Linear Mixed Model for all participant groups for the two Rhythmic cycles (NI-Rupaktal, ISO-Teental) in both Learning Conditions (Base, Test), for only the three Metrical Stimuli-Types (Basic, Complex and Structurally Same). We found the main effects of Learning Conditions F (1,623.02) = 37.81, $P < 0.001$ and Metrical Stimuli-Type F (2,1152.03) = 147.46, $P < 0.01$. In a post hoc comparison adjusted for multiple

testing using Bonferroni correction, no significant differences were found between the three Metrical Stimuli-Types for any participant group in the Test Learning Condition. The only significant difference observed was for Culturally Familiar Musicians between Basic and Complex stimuli in the Base Learning Condition of ISO-Teental, $t(622.04) = 4.96$, $P = 0.01$. However, this difference became non-significant in the Test Learning Condition, $t(622.04) = 1.05$, $P = 1.00$. As none of the Metrical Stimuli-Types show any significant differences between each other, for any of the participant groups in Test Learning Condition, we combined the mean Similarity Ratings of the three Metrical Stimuli-Types into a single category, 'Metrical.' Figures for both the Base and the Test Learning Conditions in each of the participant groups have been provided in the supplementary materials.

Analysis

To examine the influence of Cultural Familiarity (Familiar, Unfamiliar) with NICM and Musicianship (Musician, Non-Musician) on the two rhythmic patterns (Teental, Rupaktal), and to assess the impact of learning across two Learning Conditions (Base, Test), we utilised a Linear Mixed Model to analyse the similarity ratings of the pre-processed data (with merged 'Metrical' and removed outliers). The fixed factors were Pattern (Rupaktal, Teental), Familiarity (Familiar, Unfamiliar), Musicianship (Musician, Non-Musician), Learning-Condition (Base, Test) and Stimuli-Type (Reference, Metrical, Altered), with Participants set as a random effect. We found main effects of Pattern $F(1,141.83) = 6.62$, $P < 0.01$, and Stimuli-Type $F(2,1152.03) = 147.46$, $P < 0.001$. There were main interactions between Pattern, Stimuli-Type and Learning-Condition $F(2,1152.03) = 3.34$, $P < 0.05$; Stimuli-Type, Pattern and Musicianship $F(2,1152.03) = 3.46$, $P < 0.05$; Stimuli-type, Pattern and Familiarity $F(2,1152.03) = 6.66$, $P < 0.001$. There was also a

significant interaction between Learning-Condition, Familiarity, Musicianship and Stimuli-Type F (2,1152.03) = 6.82, P < 0.001. The full table with interactions has been provided in Table 1 of the supplementary materials.

We further performed a post hoc comparison adjusted for multiple testing with Bonferroni correction to obtain the differences in the above-mentioned factors in four groups of participants. The results are summarised in Figure 1.

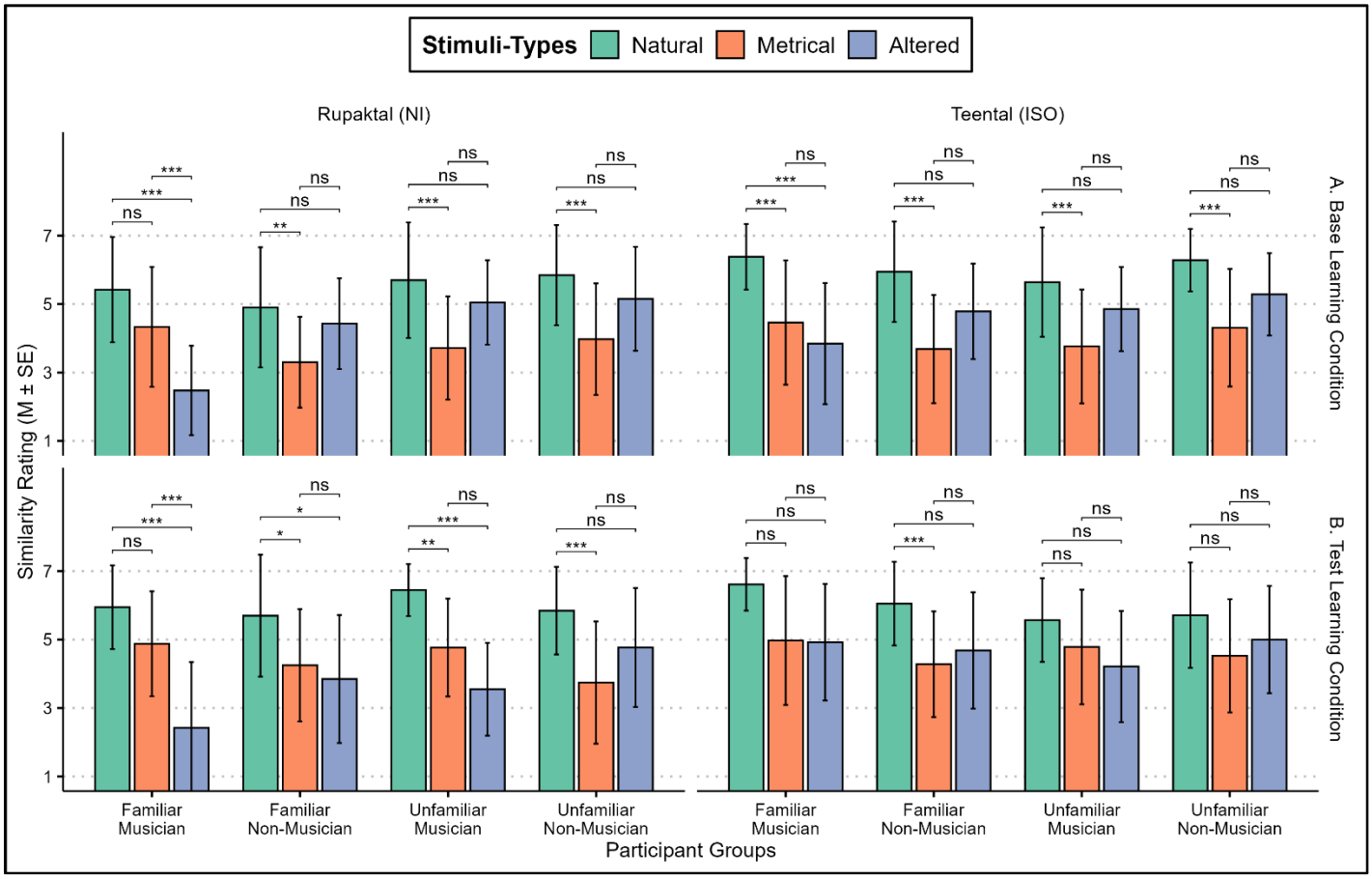

Figure 1: Similarity Ratings for NI-Rupaktal and ISO-Teental in A. Base Learning Condition and B. Test Learning Condition, for different groups of participants.

Culturally Familiar Musicians. In the Base Learning Condition (Figure 1A), significant differences were found in NI-Rupaktal, with participants distinguishing between Reference and Altered stimuli $t(1152.03) = 6.73$, $P < 0.001$, as well as between Structurally

Same and Altered stimuli $t(1152.03) = 5.20$, $P < 0.001$. These results suggest that culturally familiar musicians (experts) could perceive Altered stimuli as distinct and dissimilar to both Reference and Structurally Same stimuli for the NI-Rupaktal pattern. For the ISO-Teental rhythm cycle, significant differences were observed between Reference and Metrical $t(1152.03) = -4.456.80$, $P = 0.01$, suggesting that they found it difficult to perceive the similarity between Reference and Structurally Same stimuli for ISO-Teental. Significant differences between Reference and Altered $t(1152.03) = 4.79$, $P = 0.002$ indicate that participants could distinguish Altered as a non-similar rhythmic cycle in comparison to Reference.

In the Test Learning Condition (Figure 1B), significant differences were observed for the NI-Rupaktal between Structurally Same and Altered stimuli $t(1152.03) = 6.87$, $P < 0.001$, and Reference and Altered stimuli $t(1152.03) = 8.05$, $P < 0.001$. As significant differences were observed in both the Test Learning Condition and the Base Learning condition for this group, no effect of short-term explicit learning can be concluded for NI-Rupaktal. There were no significant differences observed for the ISO-Teental in the Test Learning Condition; hence, no effect of learning was observed for ISO-Teental either.

Culturally Familiar Non-Musicians. In the Base Learning Condition (Figure 1A), we observed a significant difference between Reference and Structurally Same stimuli $t(1152.03) = -4.71$, $P = 0.003$ in NI-Rupaktal. We also observed a significant difference between Reference and Metrical $t(1152.03) = -6.32$, $P < 0.001$ in ISO-Teental. This suggests that participants could neither perceive Altered as distinct nor could they perceive the similarity between Reference and Structurally Same stimuli before training for both NI-Rupaktal and ISO-Teental.

In the Test Learning Condition (Figure 1B), significant differences were observed between Reference and Metrical stimuli in the NI-Rupaktal $t(1152.03) = -4.16$, $P = 0.04$, for NI-Rupaktal.

Significant differences between Reference and Altered rhythmic cycles t(1152.03) = 4.33, P = 0.01, suggest an effect of the short-term explicit learning in NI-Rupaktal. For ISO-Teental, a significant difference was observed between Reference and Structurally Same stimuli t(1152.03) = -4.95, $P < 0.001$. As the participants could not significantly differentiate the altered stimuli from Reference or Metrical for ISO-Teental, no effect of learning can be concluded for the long isochronous rhythmic cycle.

Culturally Unfamiliar Musicians. In the Base Learning Condition (Figure 1A), we observed a significant difference between Structurally Same and Reference stimuli in both NII-Rupaktal $t(1152.03) = -5.69$, $P < 0.001$, and ISO-Teental $t(1152.03) = -4.52$, $P = 0.008$.

In the Test Learning Condition (Figure 1B), significant differences were observed for NI-Rupaktal between Structurally Same and Reference stimuli $t(1152.03) = -4.83$ $P = 0.002$. Significant differences between Reference and Altered stimuli in Test Learning Condition $t(1152.03) = 6.79$, $P < 0.001$, suggests an effect of short-term explicit learning for NI-Rupaktal. Although a difference was observed between Structurally Same and Altered stimuli for NI-Rupaktal, it was not significant $t(1152.03) = 6.79$, $P = 0.56$. No significant differences were observed for Altered stimuli for ISO-Teental, indicating no learning effects in the long isochronous rhythmic cycle.

Culturally Unfamiliar Non-Musicians. In the Base Learning Condition (Figure 1A), we observed a significant difference between Structurally Same and Reference stimuli in both NII-Rupaktal $t(1152.03) = -4.33$, $P = 0.02$, and ISO-Teental $t(1152.03) = -4.86$, $P = 0.001$.

In the Test Learning Condition, significant differences were observed between Structurally Same and Reference stimuli in only NI-Rupaktal $t(1152.03) = -4.74$, $P = 0.003$. However, this suggests no effect of learning in either NI-Rupaktal or ISO-Teental for Culturally Unfamiliar

Non-musician participants.

Discussion

This study examines how participant groups differing in cultural familiarity and musicianship levels perceive the longer rhythmic cycles as those in North India Classical Music (NICM). It uses two rhythmic cycles from NICM, the ISO-Teental and the NI-Rupaktal. For NI-Rupaktal, Culturally Familiar Musicians trained in NICM demonstrated the ability to perceive differences between Reference and Altered rhythmic cycles before and after training. Culturally Familiar Non-Musicians and Culturally Unfamiliar Musicians exhibited this differentiation following short-term explicit learning.

For ISO-Teental, the ability to perceive alterations in metrical structure was limited to expert musicians (Culturally Familiar Musicians) in only the Base Learning Condition. It was absent in other participant groups during both, the Base and Test Learning Conditions. This result implies that the cognitive demands associated with processing longer, isochronous rhythmic cycles may exceed the perceptual capabilities of listeners untrained in NICM. The absence of differentiation for ISO-Teental among all participant groups post short-term training suggests that the complexity of this rhythmic cycle ISO-Teental, due to its longer nature (16 beats), is less amenable to short-term explicit learning effects. This highlights the unique challenges posed by longer rhythmic patterns, even when they are isochronous.

Our results indicate the effects of culture-specific musical expertise in the similarity rating of ISO and NI rhythmic cycles to altered and unaltered (metrical) rhythmic cycles. All participant groups except the Culturally Unfamiliar Non-Musicians could differentiate between Reference and Altered stimuli in NI-Rupaktal (after training, Figure 1B). However, only

Culturally Familiar Musicians could significantly differentiate between Reference and Altered stimuli, Structurally Same and Altered stimuli, and perceived the similarity between Reference and Structurally Same stimuli in NI-Rupaktal both before and after training. This suggests that culture-specific musical expertise has a more profound impact on the perception of metrical structures in NI rhythmic cycles than mere cultural familiarity or musicianship alone. In contrast, for the longer ISO-Teental rhythmic cycle, as discussed above, only expert musicians could differentiate between the Altered and Reference stimuli prior to learning. However, this distinction did not remain significant following the explicit learning phase.

Additionally, musical training plays a crucial role in the perception of NI-Rupaktal among participants unfamiliar with NICM and Indian culture. Culturally Unfamiliar Musicians showed a positive effect of short-term explicit learning. In contrast, Culturally Unfamiliar Non-Musicians did not exhibit any difference in similarity perception even after the short-term explicit learning. This indicates that even brief explicit exposure can enhance rhythmic perception in those with some level of musical training. This further suggests that culture-specific expertise, cultural familiarity, and general musical training uniquely contribute to the perception of NI rhythmic cycles.

Hannon et al. (2012b) suggested that a short (2-week) exposure to NI (aksak) meters does not affect the accuracy score among non-musician adults. Analogous findings were observed in our study for the Culturally Unfamiliar Non-Musicians. However, Culturally Unfamiliar Musicians and Culturally Familiar Non-musicians show an effect of short-term explicit learning, as they could differentiate the Reference (Same as learned) and the Altered rhythmic cycle (one added beat, changing the metrical structure) for NI-Rupaktal after learning (Figure 1 A to B). This indicates that although passive exposure might not have an effect, short-term explicit

learning influences the similarity perception of NI patterns among Culturally Unfamiliar Musicians and Culturally Familiar Non-musician participants. Hence, NI meters being susceptible to short-term explicit learning in these two participant groups has not been observed previously. Expert musicians (Culturally Familiar Musicians) likely did not show an effect of learning because they possessed a high level of cultural familiarity and expertise with the rhythmic cycles before the learning phase, making additional training less impactful. Interestingly, the shift in similarity perception between Reference and Altered rhythmic cycles in the two participant groups from the Base to Test Learning Condition (i.e., the effect of learning) was observed in NI-Rupaktal but not in the longer ISO-Teental. This suggests that the length of the rhythmic cycle may play a role in the learning process, with longer rhythmic cycles like ISO-Teental potentially being less susceptible to short-term explicit learning as it contains a greater number of beats (16), unlike commonly used ISO rhythmic cycles in Western music.

This study does not directly explore the cognitive processes behind the observed results; however, it is the first study to provide insights into the perception of similarity for longer rhythmic cycles as those existing in NICM. Clayton (2008) suggests that longer rhythmic cycles may impose greater cognitive demands on listeners, an effect suggested in this study. A possible explanation of the observed results for the longer ISO-Teental (especially in terms of no effect of learning observed in the Test Learning Condition) could be due to the involvement of a greater cognitive load in the discrete motor sequence learning (Krakauer et al., 2019) of the longer rhythmic cycles (in this case the ISO-Teental). As meter perception has been associated with discrete mental representations (Jacoby et al., 2024), longer rhythmic cycles may necessitate the grouping or 'chunking' of discrete elements (i.e., groups of beats), which could complicate their learning and perception. Previous studies have found that non-isochronous (NI) meters are rated

less accurately than isochronous (ISO) meters (Hannon et al., 2012a, 2012b; Cameron et al., 205; Yates et al., 2017; Polak et al., 2018); however the findings of this study suggest that, in longer rhythmic cycles, these distinctions between ISO and NI patterns in terms of perceived similarity may become less pronounced when ISO is longer than NI pattern, even after short term explicit learning. To conclusively determine the role of the length of the rhythmic cycle in determining perceptual distinctions between isochrony and non-isochrony in meters, further research is necessary. Future studies should systematically investigate whether the cycle length generally affects ISO-NI differentiation and its moderation by factors such as cultural familiarity and musical training. Furthermore, although careful considerations were taken while recruiting participants for this study, it was performed online, which has been suggested to underrepresent cultural differences (Jacoby et al., 2024).

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Footnotes

[1] London (2012) defines 'Non-isochronous (NI)' meters as ones which make use of unequal beats or unequal subdivisions of beats that can be categorized into long and short; we extend this to include these unequal beat groups. In contrast, most of the common western music rhythms are 'isochronous (ISO)', being organized around a regular beat (albeit one that can vary in tempo) which is subdivided into equal parts and combined into measures comprising an equal number of beats

Supplementary Materials

The audio files, raw data, preprocessing and data analysis has been provided through Annonymised Github: [Anonymized Repository - Anonymous GitHub (4open.science)]

Figures

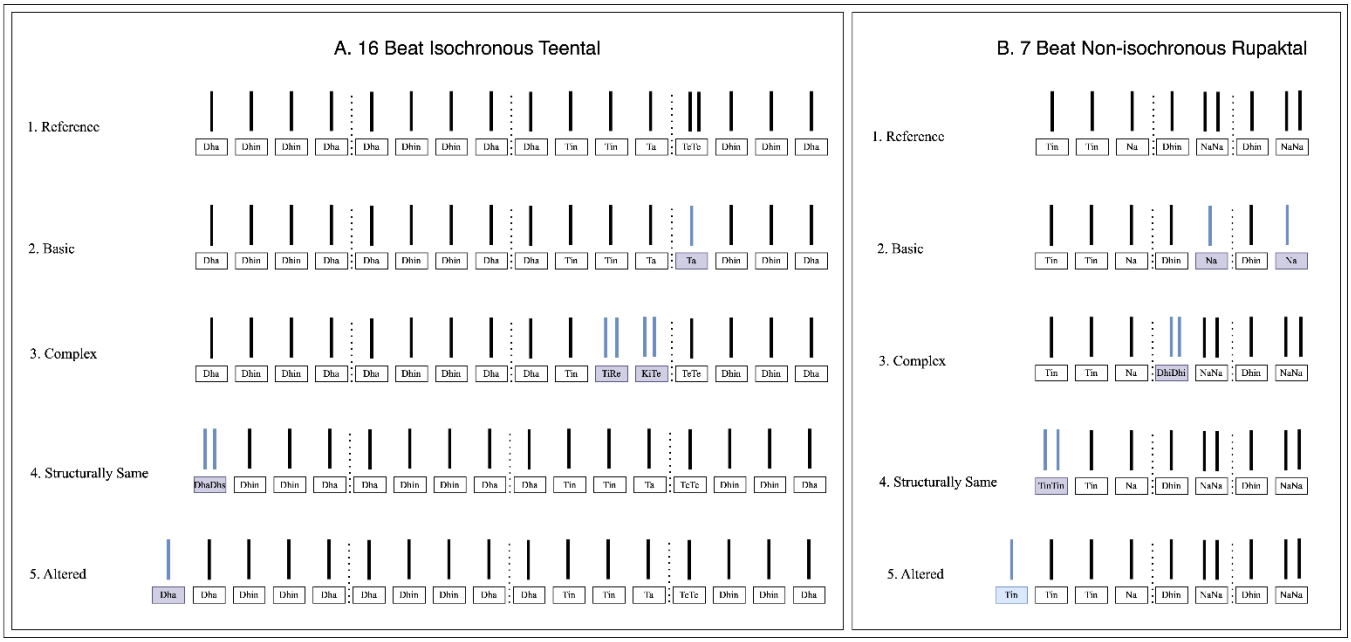

Figure 1. Visualizes all the tabla rhythms utilized in the study. These stimuli are categorised as 1. Reference, 2. Metrical (Basic, Complex and Structurally Same), and 3. Altered Meter Figure 1A represents Stimuli for ISO Teental, and 1B represents Stimuli for NI Rupaktal. Also available in html with sound files [Click here]

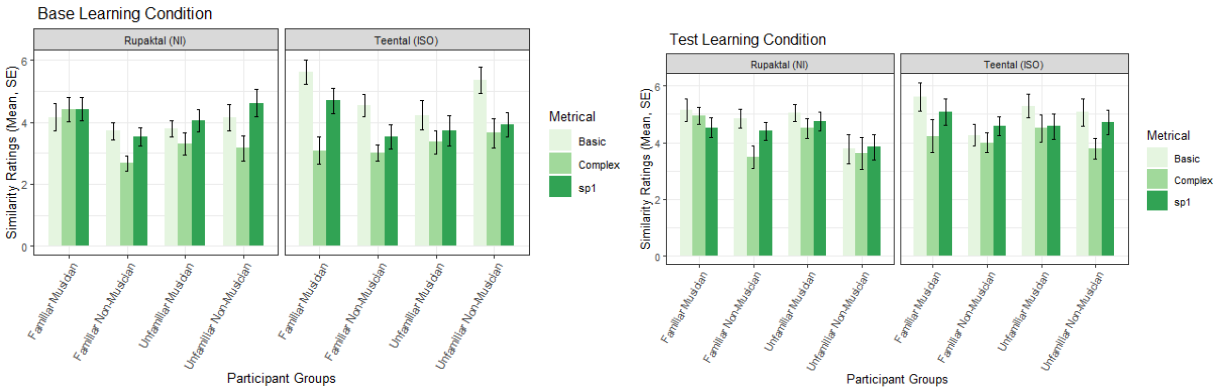

Figure 2: Comparing Metrical Stimuli Type (Basic, Complex, Structurally Same) Across different participant groups

Tables:

Table 1: Linear Mixed Method Model for the Analysis of this study.

Variable Name and Interactions	***df1***	***df2***	***F***	***p***
Learning-Condition	1	1153.29	3.51	0.06
pattern	1	141.83	6.62	0.01
Familiarity	1	141.83	2.32	0.12
Musicianship	1	141.83	0.14	0.70
Stimuli-Type	2	1152.03	147.46	< 0.001
Learning-Condition X pattern	1	1153.29	0.02	0.88
Learning-Condition X Familiarity	1	1153.29	6.26	0.01
Learning-Condition X Musicianship	1	1153.29	2.14	0.14
Learning-Condition X Stimuli-Type	2	1152.03	10.72	< 0.001
pattern X Familiarity	1	141.83	3.51	0.06
pattern X Musicianship	1	141.83	0.01	0.90
pattern X Stimuli-Type	2	1152.03	3.47	0.03

Familiarity X Musicianship	1	141.83	0.682	0.41
Familiarity X Stimuli-Type	2	1152.03	10.46	< 0.001
Musicianship X Stimuli-Type	2	1152.03	21.55	< 0.001
Learning-Condition X pattern X Familiarity	1	1153.29	0.02	0.87
Learning-Condition X pattern X Musicianship	1	1153.29	0.41	0.52
Learning-Condition X pattern X Stimuli-Type	2	1152.03	3.34	0.03
Learning-Condition X Familiarity X Musicianship	1	1153.29	0.11	0.73
Learning-Condition X Familiarity X Stimuli-Type	2	1152.03	1.42	0.24
Learning-Condition X Musicianship X Stimuli-Type	2	1152.03	0.38	0.67
pattern X Familiarity X Musicianship	1	141.83	1.48	0.22
pattern X Familiarity X Stimuli-Type	2	1152.03	6.66	0.001
pattern X Musicianship X Stimuli-Type	2	1152.03	3.46	0.03
Familiarity X Musicianship X Stimuli-Type	2	1152.03	3.67	0.02
Learning-Condition X pattern X Familiarity X Musicianship	1	1153.29	0.36	0.54
Learning-Condition X pattern X Familiarity X Stimuli-Type	2	1152.03	0.58	0.55
Learning-Condition X pattern X Musicianship X Stimuli-Type	2	1152.03	0.50	0.60
Learning-Condition X Familiarity X Musicianship X Stimuli-Type	2	1152.03	6.82	0.001
pattern X Familiarity X Musicianship X Stimuli-Type	2	1152.03	0.60	0.54
Learning-Condition X pattern X Familiarity X Musicianship X Stimuli-Type	2	1152.03	0.16	0.84