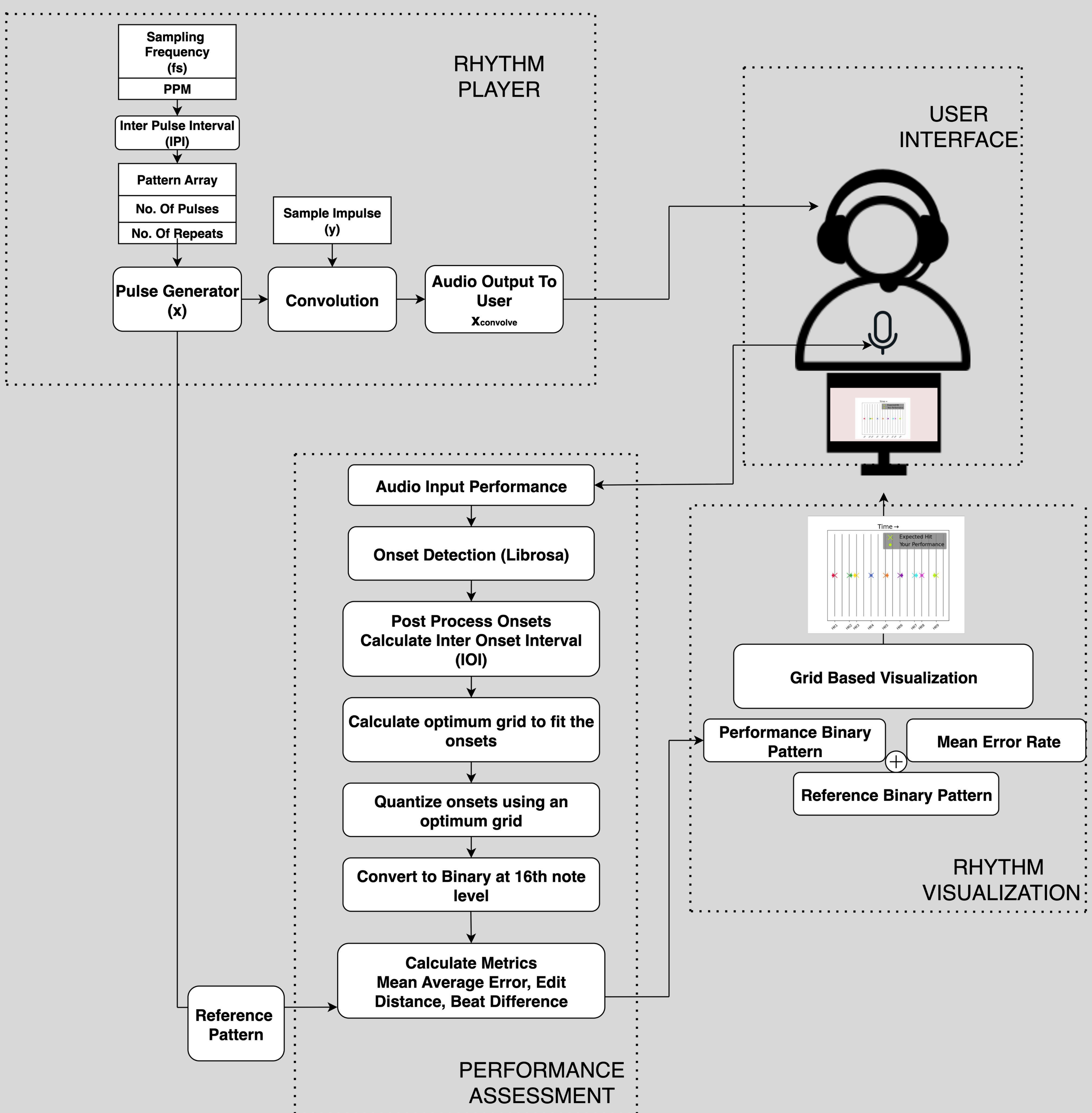
Bridging Computational Rhythm Analysis and Learner Progression in Pattern Replication Tasks

Many computational metrics have been proposed that quantify and characterize a group of monotonic rhythmic patterns' **complexity** (Thul, 2008) and **similarity** (Toussaint et al., 2011).

We implement
1. Cao et al.'s **Family Theory of rhythms** as a metric for rhythmic similarity (Cao et al., 2012)
2. and an **entropy-based coded-element** metric of rhythmic complexity (Vitz and Todd, 1969, Thul, 2008).

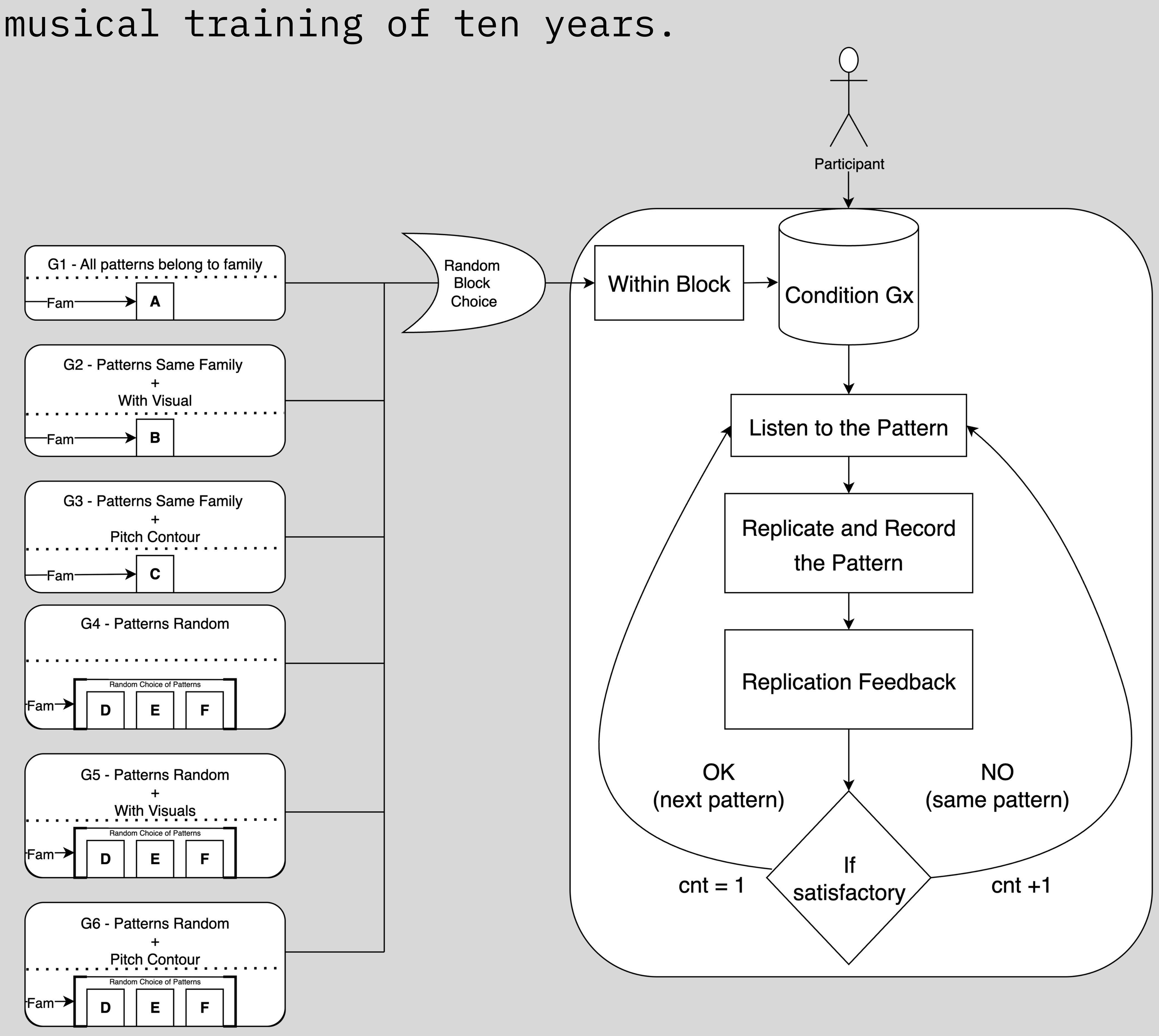
We aim to study whether a rhythmic syllabus structured using these metrics to guide the order in which patterns are introduced will influence the rate at which learners memorize and accurately replicate looping rhythmic patterns.

Experimental Interface



Methodology

A sample of 28 individuals (9 female) were recruited from the United States to partake in this study. Among the recruited participants, 24 had a background in music, with an average duration of musical training of ten years.

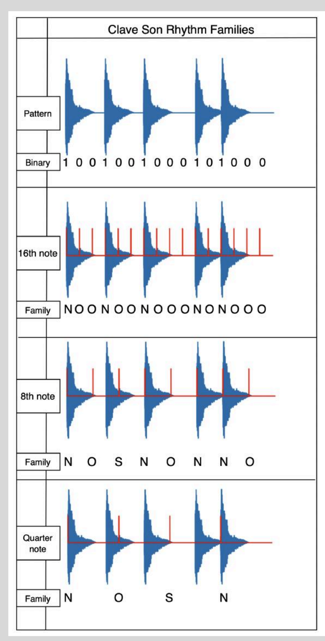


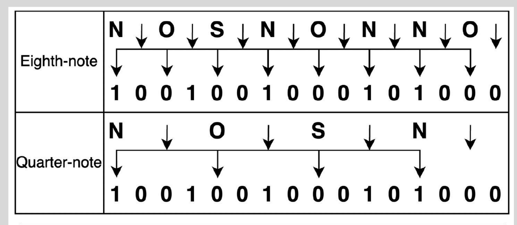
Material

Similarity Metric

Family Label	Family
A	'N', 'O', 'N', 'N', 'O', 'N', 'N', 'O'
B	'N', 'O', 'N', 'N', 'N', 'O', 'N', 'N'
C	'N', 'N', 'O', 'N', 'N', 'O', 'N', 'O'
D	'N', 'N', 'N', 'S', 'N', 'N', 'S', 'S'
E	'N', 'O', 'S', 'N', 'S', 'N', 'N', 'O'
F	'N', 'N', 'S', 'S', 'S', 'S', 'N', 'N'

Table 6.1: The six 'Families of Rhythm' used for the recreation study.





	N O S N O N N O
seed	1001001000101000
variant 1	100100100010100<u>1</u>
variant 2	1001001000<u>1</u>11000
variant 3	100100100<u>1</u>101000
variant 4	100100100<u>1</u>10100<u>1</u>
variant 5	10010<u>1</u>1000101000

Complexity Metric

$$H_{max}(\mathcal{X},\mathcal{Y},\mathcal{Z},\mathcal{W}) = H(\mathcal{X}) + H(\mathcal{Y}) + H(\mathcal{Z}) + H(\mathcal{W})$$

$$H_{joint}(\mathcal{X},\mathcal{Y},\mathcal{Z},\mathcal{W}) = H(\mathcal{X}) + H(\mathcal{Y}|\mathcal{X}) + H(\mathcal{Z}|\mathcal{X},\mathcal{Y}) + H(\mathcal{W}|\mathcal{X},\mathcal{Y},\mathcal{Z})$$

$$H(\mathcal{X}) = -\sum_{x\in X} p(x)\ log_2\ p(x)$$

$$H(\mathcal{X},\mathcal{Y}) = -\sum_{x\in X}\sum_{y\in Y} p(x)\ p(x,y)\ log_2\ p(x,y)$$

$$H(\mathcal{X}|\mathcal{Y}) = -\sum_{x\in X}\sum_{y\in Y} p(y,x)\ log_2\ p(y|x)$$

- (units) e_1 1001001000101000
- (runs)e_1^n (1)(00)(1)(00)(1)(000)(1)(0)(1)(000)
- (composite) e_2 (100)(100)(1000)(10)(1000)
- (runs) e_2^n (100100)(1000)(10)(1000)
- (composite) e_3 ((100100)(1000))((10)(1000))
- no run can be made
- (composite) e_3 ((100100)(1000)(10)(1000))

$$H_{code} = \sum_{k=1}^{n} H^k$$

Hypotheses

H1: When the 'Family Theorem' of rhythm determines the syllabus, it reduces the number of attempts to complete all the patterns in a given block.

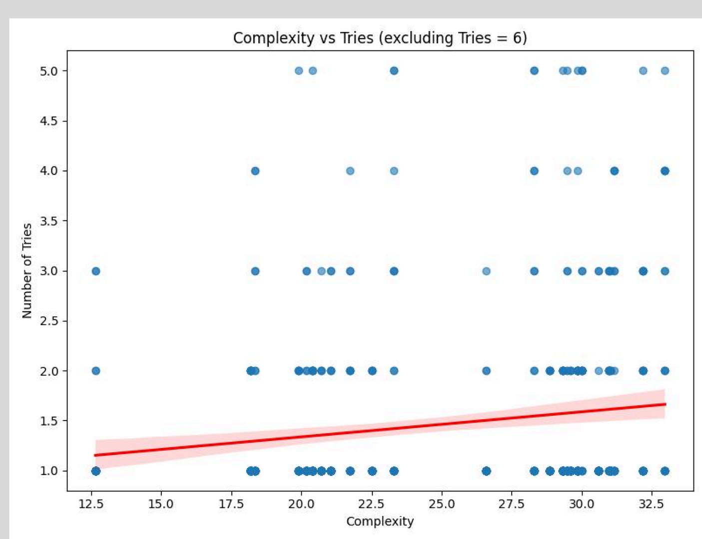
H2: The number of attempts taken to reproduce a rhythmic pattern is lower for those patterns where the complexity value calculated is low, and vice versa.

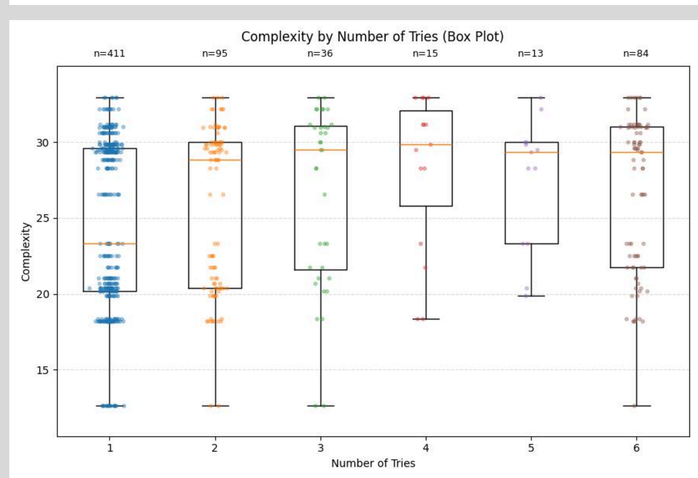
H3: The introduction of rhythm visualization and performance feedback reduces the number of attempts to reproduce all the rhythmic patterns in a given block.

H4: Rhythmic patterns paired with a pitch contour (two dimensions) reduce the number of attempts to reproduce the rhythmic patterns inside a block.

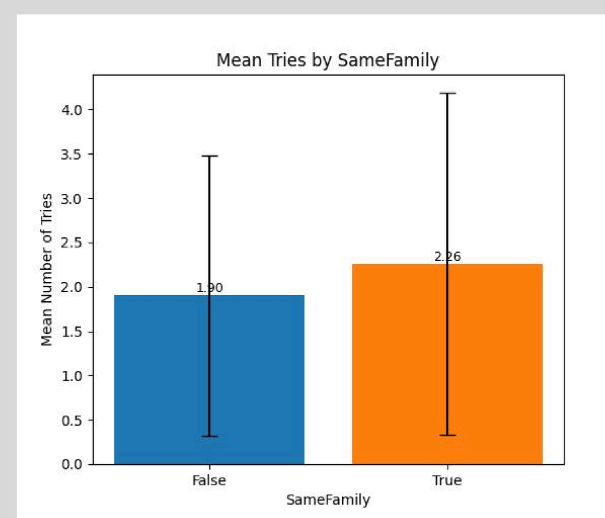
Results

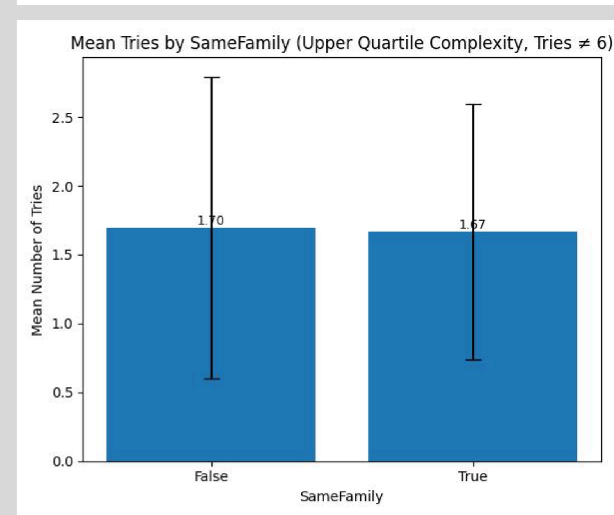
H2: Participant errors and complexity values are correlated
Spearman p = 0.182, p = 0.000012

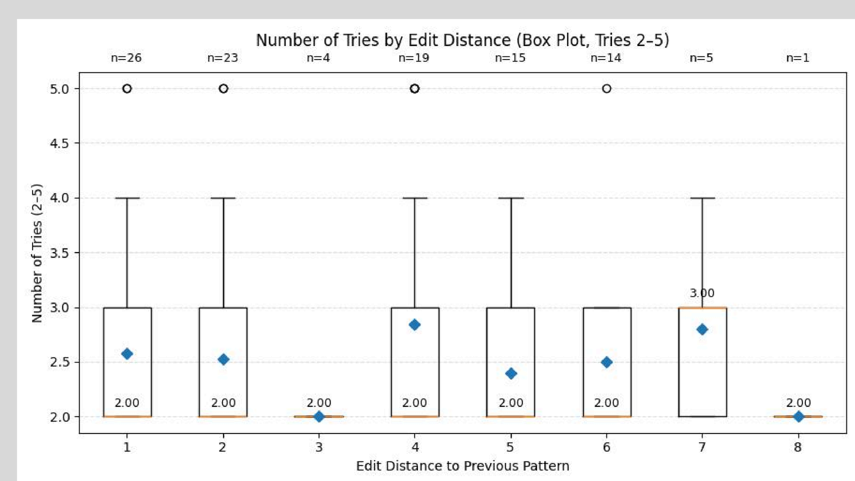


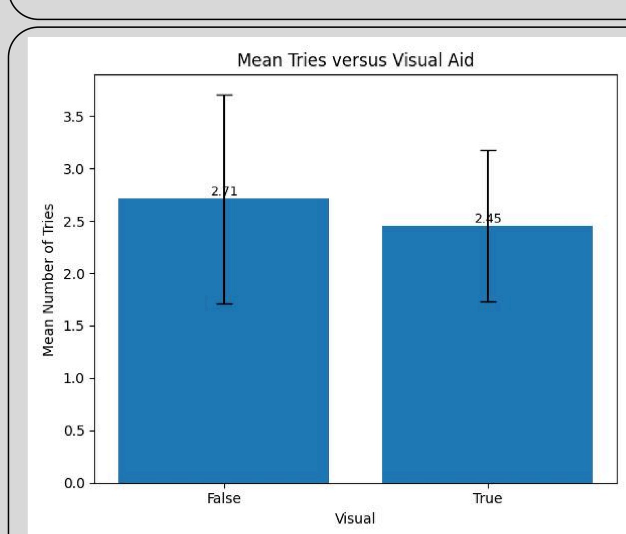


H1: No significant difference in participant errors when patterns within a block are from the same family

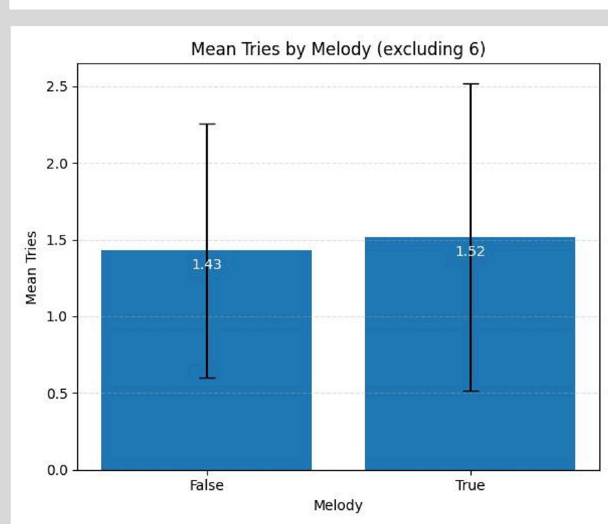








H3



H4

Discussion

1. Exploring the Effectiveness of Computational Music Theory Algorithms in Rhythm Pedagogy
2. *"If the mean number of errors had been used in their study instead of the simpler proportion of subjects who got the pattern completely correct, presumably a higher correlation with code would have resulted"* (Vitz and Todd, 1969)
3. *"The participants made more errors in the same family as the original rhythms(mean .60) than errors in a different family (mean 0.51), and the difference was significant (Wilcoxon, z 1.64, p<.05)" (Cao et al., 2012)*
4. Orff-Schulwerk, Kodály, and Gordon's Music Learning Theory all rely on the idea of gradual alteration: begin with a simple ostinato or chant, then introduce slight rhythmic/melodic changes (rests, ties, subdivisions, syncopation).This mirrors progressive alignment
5. Best suited as a drum machine?

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github

complexity values

References
1. Placek, Robert W. "Design and trial of a computer-assisted lesson in rhythm." Journal of Research in Music Education22.1 (1974): 13-23.
2. Cao, Erica, Max Lotstein, and Philip N. Johnson-Laird. "Similarity and families of musical rhythms." Music Perception: An Interdisciplinary Journal 31.5 (2012): 444-469.
3. P. C. Vitz and T. C. Todd, "A coded element model of the perceptual processing of sequential stimuli.," Psychological Review, vol. 76, no. 5, p. 433, 1969.
4. Alben, Noel, & H.G., Ranjani. (2022, June 7). 1e0a: A Computational Approach to Rhythm Training. https://doi.org/10.5281/zenodo.6797520

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