Rhythmic similarity in Flamenco music: Comparing psychological and mathematical measures

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Background in Music Psychology. Previous research on simple synthetic rhythmic patterns revealed the categorical structure of rhythm perception in music [1]. However, further research is needed to investigate complex rhythmic structures. This paper investigates rhythmic similarity in terms of mathematical measures and psychological measures. This study focuses on flamenco music, which is characterized by hand-clapping patterns whose underlying meter is composed of a pattern of soft and accented claps.

Background in Computer Science. A mathematical analysis of the five 12/8 rhythmic patterns used in flamenco music was recently conducted to establish several musicological hypotheses [2], and specifically confirmed the existence of an ancestral rhythm for flamenco music. This analysis relied on the similarity between the rhythmic patterns. Such similarity was measured with two different rhythmic similarity measures: the chronotonic distance and the directed swap distance.

Aims. Presented in this paper are the results of a listening test conducted to evaluate the perceived similarity of the rhythmic patterns used in flamenco music (5 basic patterns + ancestral rhythm). The psychological ratings of similarity are then compared with the mathematical measures proposed in [2].

The goal of this experiment is compare mathematical measures of rhythmic similarity with psychological ratings of rhythmic similarity to determine which measure best matches human judgment. Two mathematical measures were proposed in [2], namely the directed swap distance and the chronotonic distance, and used for the phylogenetic analysis of flamenco hand-clapping patterns. These patterns can be represented as binary sequences, where an ‘x’ denotes an onset or accented clap and a ‘.’ denotes a silence or soft clap. All sequences have the same length since we are only considering ternary rhythms in 12/8 (flamenco music uses only one binary metric pattern, namely [.xxx] for all the binary styles of flamenco music).

The directed swap distance [3] between two binary sequences is defined as the minimum number of position interchanges of adjacent ‘x’s and ‘.’s needed to transform one sequence into the other. In addition, if one sequence S has more ‘x’s that another sequence T (i.e. the rhythmic pattern corresponding to S has more onsets that the one corresponding to T), every onset of T must receive at least one onset of S, and every onset of S must travel to some onset of T. To illustrate, let us look at the distance between Seguiriya and Fandango.
Seguiriya \[0 1 1 1 1\] 
\[\text{x . . x . . x . . x . . .}\]

Fandango \[\text{x . . x . . x . . x . . .}\]

4 position interchanges are required, so 
\[D_{D-S}(S,F) = 4\].

Using the chronotonic representation \[4\], the time dimension is represented both on x and y axes. The **chronotonic distance** \[2\] between 2 sequences is then represented by the area between the curves. The distance between Fandango and Bulería is represented in dark blue in Figure 1 below, where 
\[D_{C-D}(F,B) = 14\].

Based on these two measures, dissimilarity matrices were derived and a phylogenetic analysis of the 5 flamenco patterns was reported in \[2\]. The BioNJ phylogenetic program \[5\] was used to construct the phylogenetic tree corresponding to each distance. The trees corresponding to the directed-swap distance and the chronotonic distance are presented in Figures 2 and 3, respectively.

In addition, the phylogenetic tree with the directed swap distance yielded the ancestral rhythm: 
\[\text{x . . x . . x . . x . . x . . x . . x . . x . . x . . x . . x . .}\] closest to the center of the tree.

The listening test described below aims at comparing the representations derived from the mathematical measures with representations derived from psychological ratings of rhythmic similarity for the 6 patterns described above (5 basic patterns + ancestral rhythm). In a previous article, we describe a similar comparison in the case of the 5 basic patterns only \[6\].
Listening test

Fifteen listeners (mean age 27.2, SD 7.4) with an average of 3.9 years of musical training were recruited from the student population at McGill University. They received $10 for their participation.

The listeners listened to the six MIDI-generated patterns using Finale (hand clapping sounds from standard percussion kit). The six patterns used are the following:

1. Fandango \([x . . x . . x . . x . .]\)
2. Soleá \([ . . x . . x . . x . x . x . x . x]\)
3. Bulería \([ . . x . . x . . x . . x . x . x]\)
4. Seguiriya \([x . x . . x . . x . . x . . x]\)
5. Guajira \([x . . x . . x . . x . x . x . x . x]\)
6. Ancestral \([x . . x . . x . . x x . x . x . x]\)

The rhythms were generated at two different tempi, namely 70 and 90 dotted quarter notes per minute, respectively denoted Medium and Fast in Figure 4. The experiment took place in an acoustically treated room and consisted of 2 sessions corresponding to the aforementioned tempi. Half of the participants did the medium tempo first, while the other half started with the fast tempo. In each session, participants were first asked to listen to the 6 rhythmic patterns presented in the experiment to become familiar with the range of variation. After 3 randomly chosen practice trials, they were asked to rate the similarity for all possible non-identical pairs of the 6 patterns (15 pairs), presented in random order. Every pair was presented twice in counterbalanced order, resulting in 30 trials in total per session. Similarity ratings were made with the mouse on a scale presented on the computer screen with end points labeled "very similar" and "very different". Participants were instructed to keep their rating strategy as constant as possible.

A dissimilarity matrix was created for each participant based on their dissimilarity ratings. A global dissimilarity matrix was obtained by summing individual matrices across all 15 participants. The BioNJ phylogenetic program [3] was used to construct the phylogenetic tree for each tempo. The resulting trees are shown in Figure 4.

![Fig 4: Phylogenetic tree for the medium and fast tempi with the main clusters. Patterns with onsets on the 1st and 6th beats are circled in blue, patterns with anacrusis are circled in red.](image-url)
Results

No major differences were observed across tempi. In both cases, 2 main clusters emerge from the analysis, the first one contains Guajira, Fandango and Ancestral, which all have onsets on the 1st and 6th beats (circled in blue in Figure 4), the second one contains Soleá and Bulería, which both have anacrusis (circled in red in Figure 4). Seguiriya is isolated from the others.

Comparison with mathematical measures

The tree representations derived from the psychological ratings were found to best match with the directed swap distance tree shown in Figure 2. The trees indicate the clustering, one cluster for patterns with onsets on the 1st and 6th beats, and one for patterns with anacrusis. The clusters are shown on the directed swap tree in Figure 5. The trees also match in terms of most distinct meters (Seguiriya and Bulería have the largest distance to all other patterns). However, there is a difference regarding the ancestral rhythm. On both cases, it is very close to Fandango. However, with the directed swap tree, the ancestral rhythm is in the centre of the tree, but with the psychological measures it is not. In terms of the most similar meter (smaller distance to all other meters), the ancestral rhythm is the most similar at the medium tempo (in agreement with the directed swap distance), but Fandango is closer for the fast tempo.

Conclusion

To summarize, our results indicate that the directed swap distance matches human judgments of rhythmic similarity better than the chronotonic distance does [2]. In our second CIM paper [7], we present the result of a similar listening test with trained musicians and compare the strategy used by musicians and non-musicians. Further research includes investigating the effect of expertise with Flamenco musicians and the effect of presentation and metric structure with patterns repeated (with and without the underlying beat).

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References


