PERCEPTION OF ASYMMETRIC RHYTHMS IN TRADITIONAL GREEK MUSIC

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ABSTRACT

This paper explores aspects of rhythmic perception within the context of traditional Greek music, more specifically Demotika songs, which display a rich variety of asymmetric rhythmic patterns, *i.e.* patterns comprising beats of different durations. A listening experiment with volunteer university music students was conducted, in order to investigate basic questions regarding timing accuracy and meter structure as perceived by subjects. This study suggests that identifying accurately rhythmic meter patterns in traditional Greek music is not an easy task, even among Greek music students, although statistically significant differences may be observed depending on cultural background. Statistical analysis also reveals correlations between elements associated with the difficulty of the task, such as the degree of agreement between participants, the response times and the number of times each excerpt was heard, and musical aspects such as tempo, meter structures and symmetry/asymmetry of rhythms.

1. INTRODUCTION

Musical time is commonly organized around a hierarchic metrical structure, having as most salient metric level the beat level, also referred to as tactus (Lerdahl & Jackendoff, 1983). Most western musics assume an isochronous beat level, and divergences from isochrony are treated as exceptions or special cases. In traditional musics from the Balkan and Middle-East, on the other hand, rhythms commonly feature non-isochronous metric structures, referred to as *additive* or *aksak* or *asymmetric meters* (Fracile, 2003; Moelants, 2006). Such metric structures are based on asymmetric beat levels comprising repeating asymmetric patterns of long and short beats at a 3:2 temporal ratio, such as 5/8 (3+2), 7/8 (3+2+2), 8/8 (3+3+2) and so on; this asymmetric beat level stands between a lower isochronous sub-beat level and a higher isochronous metric level (Cambouropoulos, 1997). Enculturated listeners spontaneously use an asymmetric tactus to measure time (clapping hands, tapping feet), since this is presumably the most plausible and parsimonious way to organize given rhythmic stimuli from specific musical idioms. In a sense, asymmetric beat structures organize time similarly to how asymmetric pitch scales organize pitch/tonal spaces (Fouloulis et al., 2012, 2013).

The main driving question behind this study is: do listeners with different backgrounds perceive asymmetric rhythms the same way in terms of beat structure and beat accents? This question entails follow-up questions such as: are there differences in perceptual timing accuracy and perceived beat ordering due to enculturation? The interest in these questions is not restricted to analytical or psychophysical considerations; empirical data may also aid in developing novel Music Information Retrieval methods accounting for both beat asymmetry and subjectively perceived accents (one such method is proposed in Fouloulis et al. (2012)).

The main goal of this paper is to present and discuss experimental data of a listening test dealing with actual examples of traditional Greek music and the rhythmic patterns used to represent their metric structure. This classification experiment was conducted with volunteer university-level music students in Greece, in Brazil and in several other countries. Through statistical analysis of the collected answers it is possible to have an idea of the difficulty of this classification task as a function of the types of patterns encountered in traditional Greek music, of musical aspects such as tempo, harmony or instrumentation, and of the cultural background of the participants.

Recent work dealing with Greek rhythmic patterns include Fracile's study of aksak structures in Balkan folklore (Fracile, 2003), mapping the occurrences of their most common forms, Moelants' discussion of the influence of tempo in the ratio between long and short beats during performance of aksak metres (Moelants, 2006), and Fouloulis, Pikrakis and Cambouropoulos' investigation on automatic beat-tracking systems when confronted with asymmetric repertoire (Fouloulis et al., 2012, 2013), where basic implementation premises, such as the existence of a steady pulse, fail. In an experimental study motivated by questions similar to ours, Tekman et al. (2003) compared listeners familiar and unfamiliar with musical idioms that frequently use asymmetric meters in a recognition task, in which musicians and non-musicians classified pairs of symmetric/asymmetric/irregular meter structures as *same* or *different*; their results did not provide support for the existence of schematic representations of asymmetric meters. Our work, on the other hand, proposes an identification task for musicians, classifying perceived

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rhythms according to formal symbolic music notation, and investigates how this task is affected by meter structure, tempo and cultural background.

The next section brings a broad overview on the types of meter structure frequently found in traditional Greek music. Section 3 presents the experimental methodology and Section 4 brings experimental results and their discussion. Conclusions and open questions for future work are presented in Section 5.

2. ASYMMETRIC RHYTHMIC METERS IN TRADITIONAL GREEK MUSIC

Greek traditional music is a very important part of Greek education. Lullabies and cradle songs, chants of toddlers, nursery rhymes, carols for seasons greetings and even the sneering and satyric songs of carnival reflect popular customs throughout Greece, and offer important material for all stages of education. Having said that, it is not evident whether non-Greek listeners unfamiliar with Greek music would have a harder time (compared to Greek musicians) figuring out asymmetric meter structures found in ordinary Greek dances, such as *Kalamatianos* (a 7/8 measure of the form 𝄆 ♩. ♩ ♩ 𝄇 or 3+2+2) or *Karsilamas* (a 9/8 measure of the form 𝄆 ♩ ♩ ♩ ♩. 𝄇 or 2+2+2+3). It is also not evident whether any listener, Greek or non-Greek, would judge the longest beat of the former to be in the first position of the pattern (as **3**+2+2) whereas in the last position for the latter (2+2+2+**3**). Any asymmetric meter structure gives rise to rotated alternatives (*e.g.* 2+2+3 or 3+2+2+2) that might be perceived as more fitting for a particular music piece, according not only to beat durations, but other aspects such as musical dynamics (energy), positions of instrumental and vocal entries, articulations, etc.

Another important aspect of meter structures in this context is the fact that actual musical instances consist of several instruments playing varying rhythmic patterns, and not unusually alternating between patterns that fit several meter structures. As a simple example, a binary 4+4 (rhythmically equivalent to 2+2) would easily accommodate instrumental lines playing 4+2+2 and 3+3+2 and any of their rotations, in fact any other pattern that adds up to 8 eighth notes. The same applies to 6+4 (rhythmically equivalent to 3+2), which accommodates 2+4+2+2 and 3+3+2+2, among others. Saying that a piece adhere to the style of a certain dance or corresponds to a certain meter structure does not entail that all instruments will play homorhythmically, and thus listeners will judge the perceived meter structure according to subjective (and possibly unconscious) criteria.

3. EXPERIMENTAL METHODOLOGY

In a nutshell, the experimental session here proposed consists of a simple questionnaire with audio excerpts of Demotika songs, followed by a number of alternatives in music notation for representing them. Each experimental subject listens to each excerpt and chooses the rhythmic pattern that best matches the perceived meter structure.

3.1 Selection / Formatting of Audio Excerpts

Songs were included that reflect the diversity of rhythmic patterns found in traditional Greek music (and particularly Demotika songs). An attempt has been made to balance the selection across meter structures, with a varied palette within each rhythmic style (*e.g.* excerpts displaying different tempi, instrumentation, rhythmic ornaments, etc). In order to keep the difficulty of the task within a reasonable level, only excerpts with rhythmic patterns of up to four beats per measure were be included. Many other interesting and much more complicated rhythmic patterns surely exist in traditional Greek music, but exploring this repertoire is the subject of future work. We aimed at keeping the session at about 15 minutes, which allowed the inclusion of 30 excerpts of 30-seconds each. The selected songs are presented in Table 1 along with their corresponding rhythmic patterns [1] .

3.2 Selection of Rhythmic Patterns

In order to give the subject a wide range of options for the rhythmic representation of the meter structure of each song, a dictionary of meter structures was built by taking all the ground-truth formulae in Table 1, including all possible rotations of each asymmetric pattern, and also all patterns obtained from the above by replacing each long beat (a dotted quarter note) with a half note (*e.g.* 2+2+3 would give rise to a 2+2+4 alternative). This produced a set of 27 possible responses for each excerpt, classified according to the number of beats (one to four beats per measure).

3.3 Selection of Subjects / Volunteers

Due to the technical nature both of the listening task as well as the notation used to represent meter structure, participation in this experiment was restricted to trained musicians. This is not supposed to mean that such an experiment is impossible to conduct with non-musicians but it is understood that the training effort that would be necessary to allow non-musicians to express their rhythmic perceptions using a formal and quantitatively accurate music notation would jeopardize the feasibility of the experiment.

In order to reduce the heterogeneity of the population, the experiment was addressed at university-level (undergraduate and graduate) music students. On the one hand this is an audience that is used to

[1] For each of the songs, a 30-second excerpt was produced by cutting an arbitrary portion of the audio signal (between 1:00 and 1:30 from the beginning) and using 100ms fade-in and fade-out ramps, in order to ensure that each excerpt would start in an apparently random position (relative to the beginning of a measure).

Table 1: Dataset used in the experiment. The first column corresponds to the annotated ground-truth, and the second column displays the track information for each excerpt included. Excerpt #22 alternates between 2+2 and 3+3+2, having both as ground-truths.

Pattern	Style	Song/Artist
2+2, 𝄆 ♩ ♩ 𝄇	Syrtos/Sta Tria	#1=Perdika (Anastasios Xalkias), #2=Ta Matia ta Glika (Georgia Mittaki), #3=Kotsarin (Tsimaxidis), #22=Vlaxa Paei Gia Th Stani (Georgia Mittaki)*
2+3, 𝄆 ♩ ♩. 𝄇	Baiduska	#4=Vasilarxontissa, #5=At Xavasi, #6=Mia Kali Geitonopoula (Elina Papanikolaou)
3+2, 𝄆 ♩. ♩ 𝄇	Zagorisios/Tik	#7=Sou'pa Mana Pantrepse Me
3+3, 𝄆 ♩. ♩. 𝄇	Zonaradikos	#8=Aleksis Andriomenos (Elina Papanikolaou), #9=Vasil'kouda (Xronis Aidonidis)
2+2+2, 𝄆 ♩ ♩ ♩ 𝄇	Tsamiko	#10=Enas Aetos Kathotane (Giorgos Papasideris), #11=Pame sti Roumeli (Maikantis), #12=Davelis (Georgia Mittaki)
2+2+3, 𝄆 ♩ ♩ ♩. 𝄇	Mantilatos	#13=Hicaz Mantilatos, #14=Siko Koukounouda M', #15=Serenitsa
3+2+2, 𝄆 ♩. ♩ ♩ 𝄇	Kalamatianos	#16=To Papaki (Giorgos Papasideris), #17=M'Ekapses Geitonissa (Elena Maggel), #18=Pou Eisai Lenio Den Fainesai (Maikantis), #19=Tromaxton Laziko Xorontikon (Kemetze/Gkogkotsis)
2+3+3, 𝄆 ♩ ♩. ♩. 𝄇	Berati	#20=Berati
3+3+2, 𝄆 ♩. ♩. ♩ 𝄇	Nisiotikos Syrtos / Ballos	#21=Ta Ksila, #22=Vlaxa Paei Gia Th Stani (Georgia Mittaki)*, #23=Na'xa Ena Milo Na'rixna (Miltos Stanos), #24=To Paneigiri (Giorgos Papasideris)
2+2+2+3, 𝄆 ♩ ♩ ♩ ♩. 𝄇	Karsilamas / Zeibekikos	#25=Vasilepsen Avgerinos (Xronis Aidonidis), #26=Katsivelikos, #27=To Enteka, #28=Sfarlis
2+3+2+2, 𝄆 ♩ ♩. ♩ ♩ 𝄇	Argilamas	#29=Manio (Xaris Aleksiou), #30=Dimitroula Mou

take rhythmic perception tests, so that this experiment would not seem so out-of-the-ordinary (apart from the repertoire which might be unfamiliar); on the other hand, this would reduce the number of senior musicians and/or novices, which would have to be analysed as separate groups.

3.4 Interface and Experimental Session

The interface for the experiment (available in English, Greek and Portuguese) was implemented in PHP using SQL for accessing the database, and was made available on the Internet using a dedicated server. The entry page contained an explanatory text about the nature of the experiment and a consent term, along with a small form for personal data (name, email, institution and nationality, only to be used anonymously). The experimental session proceeded through 30 pages, one for each excerpt, as illustrated in Figure 1.

For each user the presented excerpts would follow a randomized order defined when the experiment begins. This is done to minimize the fatigue effect as well as other order-related effects. In a drop-down menu there was also an option labeled “I cannot decide”, to let the user skip an excerpt and continue the experiment.

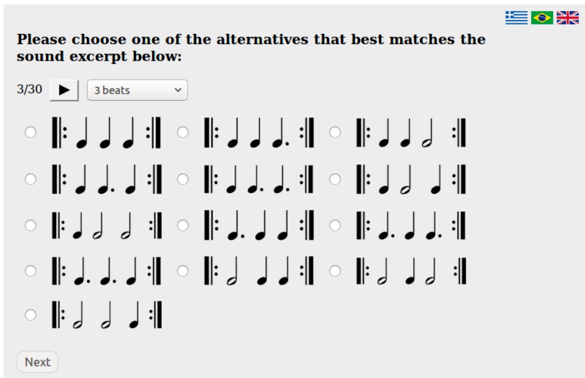


Figure 1: Interface of the experiment.

4. RESULTS AND DISCUSSION

The experiment was available between January 9th and February 9th, 2018, and had 56 participants (36 Greeks and 20 from other nationalities). The raw results of the experiment consist of a database that relates participants, nationalities, excerpts and meter structures. One of the first issues that must be addressed when dealing with these results is to define what is considered a correct answer. As discussed in the concluding paragraph of Section 2, many possible variations of a given notated pattern are musically meaningful and may be considered differences of interpretation rather than errors. Therefore, for a given ground truth, all answers that add up to the same amount of eighth notes [2] are considered equally valid/correct. These include all rotations of a given pattern (*e.g.* 3+2+2, 2+3+2 and 2+2+3), but also different patterns that could be easily superimposed, such as 2+2+2, 4+2 and 3+3. In the sequel, a series of analyses of different aspects of the experiment are considered.

When we consider the number of valid answers each participant produced (the participant's *score*), several relevant statistics may be extracted. The average of the score distribution is $\mu = 16.7$ valid answers per participant (out of 30), and the standard deviation is $\sigma = 7.4$; this sample, however, does not pass the D'Agostino and Pearson's normality test (the null hypothesis corresponding to the sample coming from a normal distribution is rejected with $p = 0.0002$), which renders such a Gaussian description a very poor statistical model for this data. Figure 2 displays the same data separated in two groups according to nationality (Greeks and non-Greeks). These two subpopulations pass the aforementioned normality test ($p = 0.0938$ for Greeks and $p = 0.2656$ for non-Greeks) and may be reasonably modeled as Gaussian distributions. Valid answers per participant amount to 18.6 ± 6.4 for Greeks and 13.4 ± 7.8 for non-Greeks; moreover, these averages may be considered significantly different ($p = 0.0104$ for a T-test, $p = 0.0230$ for a Kolmogorov-Smirnov or KS test). This difference may be explained due to enculturation of Greek participants, *i.e.* their lifelong immersion in a culture where such music is commonly heard. Yet it cannot pass unnoticed that, based on these numbers, the task does not appear to be easy even for Greek music students, as might be otherwise presumed.

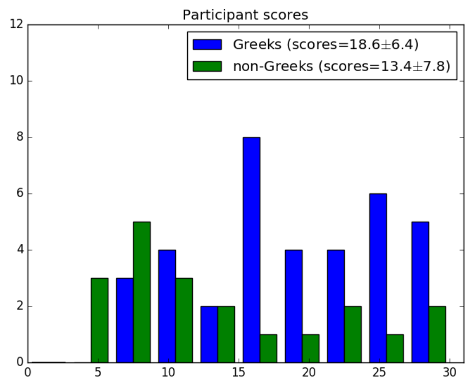


Figure 2: Number of valid answers given by each participant, grouped according to nationality.

The number of valid answers per excerpt may also be studied according to the groups defined above. Figure 3 displays these values separated for Greeks and non-Greeks. The two samples formed by these percentages may be compared through their Pearson's correlation coefficient $r = 0.5374$ ($p = 0.0022$), indicating that they do behave with a certain degree of correspondence (when the blue bar rises the green bar also tends to rise, and vice-versa). Both T and KS tests indicate that the averages of these two samples (62% of valid answers for Greeks and 44.5% for non-Greeks) are significantly different ($p = 0.0012$ for T test and $p = 0.0046$ for KS), reconfirming the observation that enculturation may render the task somewhat easier for Greeks, but not so much, as several counter-examples may be found (excerpts #1, #5, #7, #14, #20 and #22).

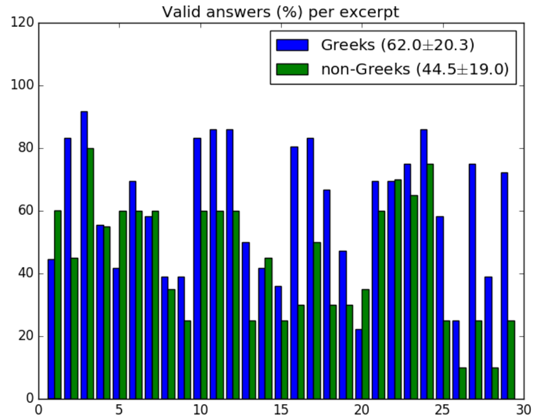


Figure 3: % of valid answers for each group / excerpt.

Considering specific excerpts with exceptionally low values of valid answers, a few patterns emerge. Excerpts #8 and #9 are symmetric compound binary pieces (3+3), both of which received more answers of type 2+2 than 3+3; these are binary meter structures that differ on the sub-beat representation level. It might be the case that some students were assuming the sub-beat level would use tuplets (which theoreticaly represent exception rather than rule), or else these are differing opinions on which were the metric and the tactus levels (phrases for these fast excerpts did comprise two measures). Excerpts #13, #14 and #15 corresponded to the structure 2+2+3, a rotated form of the popular Kalamatianos 3+2+2 that appeared in excerpts #16-#19, a well-known structure for Greek participants; invalid answers for these excerpts included 2+2, 4+2 and 2+2+4, all of which would imply an identification of the long-to-short-beat ratio of the form 2:1 rather than 3:2. Excerpt #20 (annotated 2+3+3, a rotated form of the popular Ballos 3+3+2) received the largest number of "I cannot decide" answers (35.7%), possibly due to its very slow tempo (more on tempo below). Finally, the quaternary asymmetric structures 2+2+2+3 and 2+3+2+2 (Excerpts #25–#30) were harder for non-Greek participants (but #26 reached only 25% of valid answers among Greeks).

Figures 4 and 5 present the average response times (in seconds, per excerpt) and average play counts (how

[2] For this characterization to be formally well-defined one needs to consider a rhythmic sort of "octave equivalence", allowing 2+2 for instance to be considered equivalent to 4+4, or 2+3 and 3+2 to be equivalent to 4+6 and 6+4, respectively.

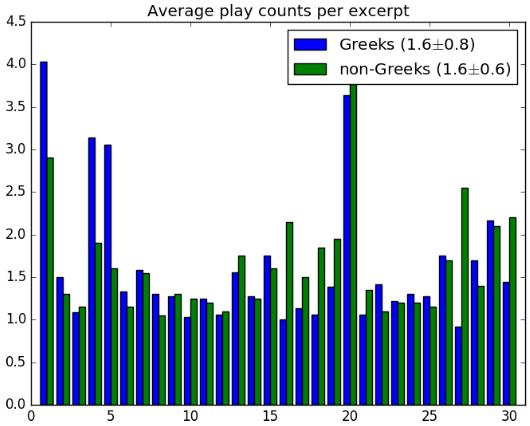


Figure 4: Average play counts for each excerpt.

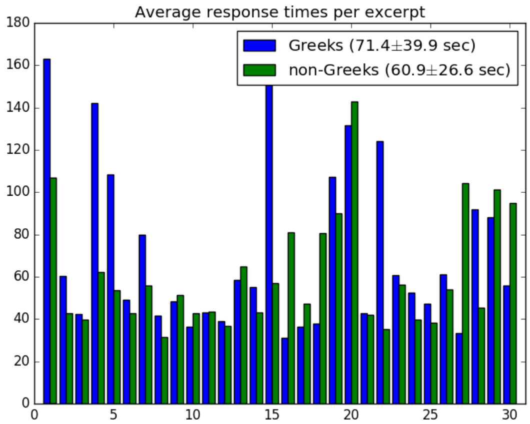


Figure 5: Average response times (s) for each excerpt.

many times in average each participant pressed 'play' for each excerpt), grouped according to nationality. Play counts as a function of the excerpt are highly correlated among Greeks and non-Greeks ($r = 0.6439$, $p = 0.0001$), and response times follow a similar trend ($r = 0.3600$, $p = 0.05071$). No significant differences between groups have been observed for these statistics ($p >> 0.1$ for T and KS tests in both cases). As should be expected, play counts and response times are highly correlated ($r = 0.8363$, $p < 0.0001$) and no relevant conclusions should be drawn from this correlation (it simply takes more time to hear an excerpt repeatedly).

Another indication of the perceptual difficulty of assigning a meter structure to each excerpt is the measure of *spread* of the answers obtained by each particular excerpt. The measure of spread adopted, also known as Gini-Simpson diversity index, is displayed in Figure 6 for each one of the 30 excerpts. This graph suggests that for a few excerpts a relatively high level of agreement (small spread) was obtained, such as excerpts #3, #16, #17 and #18. We have seen that play counts and response times are highly correlated, but less obvious are the correlations between play counts and spread ($r = 0.3915$, $p = 0.0324$), and between response times and spread ($r = 0.5216$, $p = 0.0031$) These observations might support the interpretation that play counts, response times and spread of answers have some underlying relationship with the difficulty of the task.

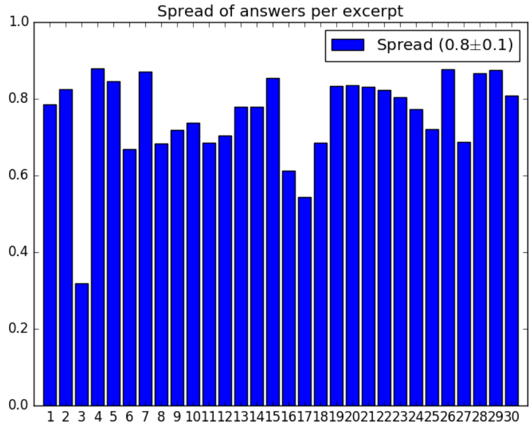


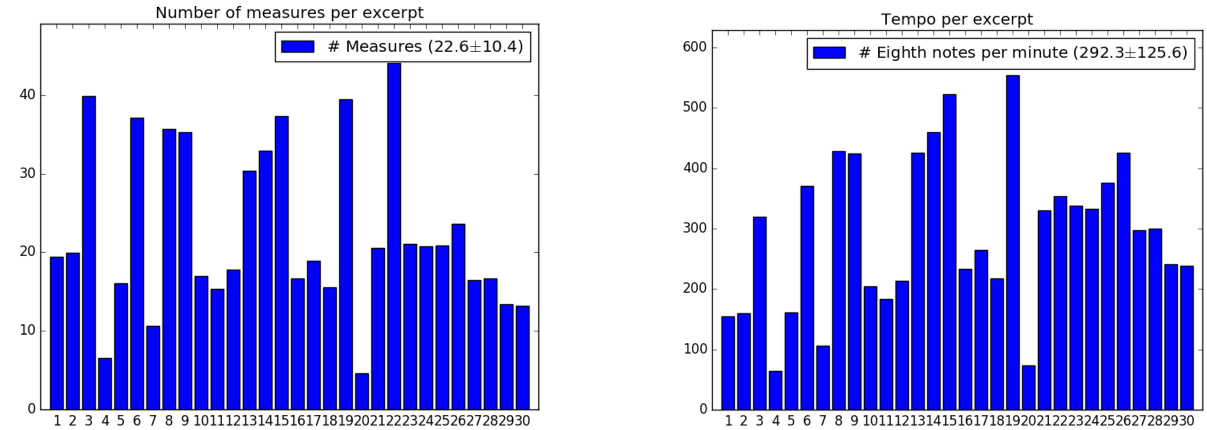
Figure 6: Measures of spread for each excerpt.

Participants observed an apparent relationship between tempo of the excerpts and the difficulty in assigning a meter structure: the intuition was that for slower tempi we would pay more attention to the lower rhythmic levels (*e.g.* beats and beat subdivisions) than to the higher metrical levels (*e.g.* measures and beats). Figure 7 displays the number of measures for each excerpt, and also the estimated tempo (based on the number of measures and the ground truths for meter structure). Since beats are asymmetric in many examples, we have adopted a uniform tempo measurement in units of eighth notes per minute (an eighth note is the common beat subdivision in formulae such as 2+3 or 3+2+2).

Negative correlations between number of measures and play counts ($r = -0.4298$, $p = 0.0177$) and between tempo and play counts ($r = -0.4801$, $p = 0.0073$) appear to corroborate the observed point: the lower the tempo the higher the number of times participants heard the excerpt. On the other hand, no relevant correlations have been observed between number of measures or tempo on one hand and response times or spread on the other ($p > 0.1$ for all such correlations).

5. CONCLUSIONS

In this paper we approached an important and seldom studied issue in rhythmic perception, namely that of recognition of asymmetric rhythms in Greek traditional music by musically literate subjects based on an accurate symbolic rhythmic notation. An experimental task consisting of assigning rhythmic patterns in common music notation to audio excerpts was designed and applied to university-level music students in Greece and other countries. Statistical analysis of the responses led to preliminary results that answer some of the questions that motivated this study, while leaving other questions requiring further investigation.



(a) Number of measures.

(b) Estimated tempo.

Figure 7: number of measures per excerpt (a) and estimated tempo in eighth notes per minute (b).

One of the questions that was partially answered by empirical data is the relationship between enculturation and accuracy of rhythmic perception. Greek participants had a slight advantage in producing valid answers for the selected excerpts. On the other hand, relatively average-to-low scores even for Greek participants indicate that the proposed task is not as easy as one might assume. Some excerpts (such as #20) proved to be exceptionally hard for most participants, a fact associated to a high number of "I cannot decide" answers.

We also investigated other metrics that might relate to the difficulty of the proposed experimental task. Considering the time each participant required to arrive at a decision as a plausible indication of task difficulty, a significant correlation was observed between the spread of answers (representing the degree of disagreement between participants responses) and the temporal metrics of play counts and response times. This may be interpreted as evidence that all those factors are somehow interrelated, and maybe represent converging aspects of difficulty in the perception of complex rhythmic structures.

Another question for which a tentative answer was achieved refers to the relationship between task difficulty and tempo of the excerpts. Lower tempi meant a smaller number of measures covered by the fixed-length audio excerpts, which could undermine the ability of participants to match their perceived rhythms with the given written alternatives. Negative correlations between spread of answers and both tempi and number of measures in each excerpt may corroborate these intuitions.

This study barely scratched the surface of the problem of characterizing the underlying processes in the perception of asymmetric rhythms in traditional Greek music, and there are several questions that remain open. One such question is the relationship between symmetry / asymmetry of meter structures and the difficulty of the task. Another such question refers to temporal accuracy and the alternative interpretations of the ratios 3:2 and 2:1 for long:short beats. In order to address these questions it would be important to investigate the sources of individual variations in responses to specific meter structures and individual examples, by proposing musicological explanations for both valid and invalid rhythmic alternatives, and by trying to endorse or refute them based on further statistical analyses and possibly new experimental methodologies.

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