

From acoustical sound to “music”: On cognitive modeling of the processes for rhythm perception

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The cognitive process of both metrical and tonal organization are essential for perceiving a sequence of tones as a melody. In this study a computational model about the process of metrical organization was constructed. At first, a psychological experiment was performed to investigate the property of the listener's process of metrical interpretations. Musical tone sequences were presented and participants were required to describe staff-notation for each sequence. The results were summarized as follows: 1) Listeners recognized the beat in a real-time range, between about 250ms and 1000ms. 2) In an earlier stage of sequence, the interpretation was both simple and provisional. 3) Listeners preferred some limited and simple types of metrical interpretation of the sequences. 4) Listeners tried to avoid syncopation as much as possible. The result was compared with the output of the two models previously proposed by Lee(1985) and Povel and Essens(1985) to evaluate the psychological validity of each. On the ground of the results, a more plausible model was proposed, which could explain not only such listener's characteristics but also their emotion evoked by music. The algorithm of the new model reflects the psychological findings about “tempo” of music. The model also takes into account the “implication-realization” process, which tries to explain the aspect of emotion evoked by music. In order to evaluate the validity of the model, computer simulations were performed for the musical tone sequences used in the experiment. The results of simulation showed that the model could predict the metrical time units correctly.

1 Introduction

A purpose of this study is to examine the basic nature of music perception in order to propose a computational model between the processes of music perception and the evocation of emotion.

For that purpose, an psychological experiment was performed in order to clarify the nature of “metrical organization,” which is an essential process in music cognition. On the base of the results, cognitive model was considered.

2 Psychological Experiment

To clarify the process of the “metrical organization,” psychological experiment was performed. Metrical organization is an essential process for perceiving the metrical structure of tone sequence, and as a result of that we listeners can perceive the metrical structure of tone sequence such as beat, meter and measure.

2.1 Method

2.1.1 Participants

20 western style musicians were participated in the experiment. Mean musical experience was 16.8 years. All par-

ticipants understood the concept of “metrical structure.”

2.1.2 Materials

24 tone sequences were used as materials. They were various types of metrical structure; eight tone sequences were 4/4, eight were 3/4, and the rest eight were 6/8. They were all “equitonal” tone sequence: that is, all the physical features except for note value were held constant.

2.1.3 Task

Participants were asked to describing staff notation for presented sequence each tone stage, that is, writing down note value, time-signature and bar-line. Then, they rated their confidence for the metrical interpretation in 9-point scale(see Figure 1).

2.2 Result and Discussion

All descriptions were analyzed in terms of metrical structure that participants interpreted; that is, note value, time signature and bar-line. Results are summarized as follows:

1. In the early stage of the sequence, listeners try to interpret the sequence tentatively in some limited and

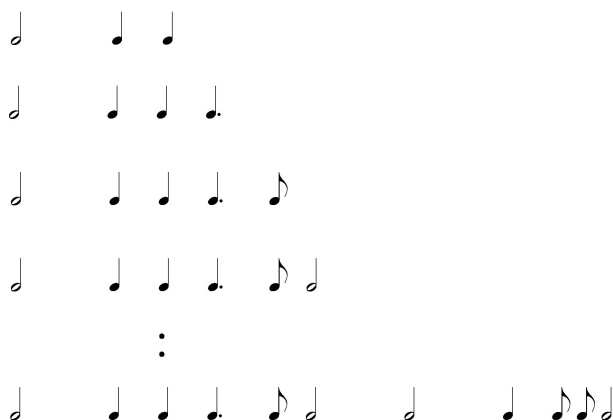


Figure 1: Example of presentation of tone sequence.

simple type of meter.

2. As the sequence progressing, listeners confirm or changed metrical interpretation in a gradual manner.
3. Preference for binary meter; Listeners prefer a binary metrical structure like 4/4 or 2/4 to trinary or mixed one (Figure 2).
4. The time range of perceived units; Listeners perceive units in a certain real time range. "Beat" is perceived between about 250ms and 1000ms.

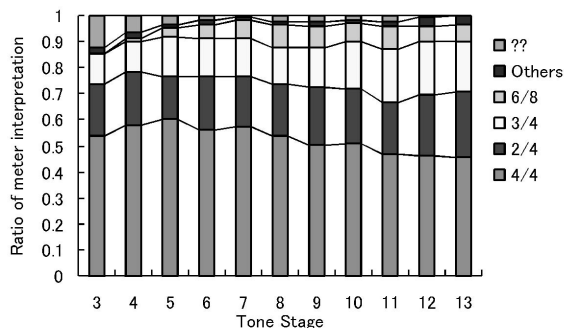


Figure 2: Ratio of meter interpretation at each tone stage.

3 For cognitive modeling

To construct a new cognitive model two models were examined; the models proposed by Lee(1985) [1] and Povel and Essens(1985)'s one[2]. They tried to describe listener's perceptual processes for the rhythms of musical sequences. Algorithms of both models were implemented as a computer program to analyze their behaviors (see Table 1).

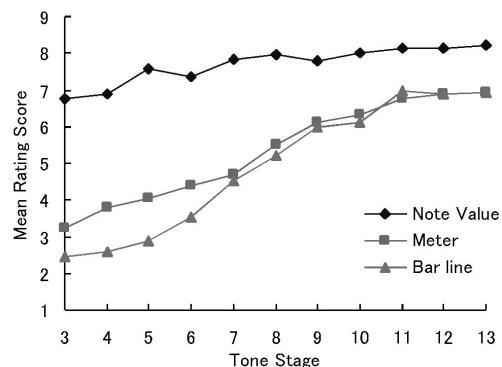


Figure 3: Mean rating score for note value, meter and bar-line.

The result of the experiment described before section was compared with the output of both models and to evaluate the psychological validity of each(see Table2). The results suggested that the listeners processed sequences gradually and interpreted the metrical units (e.g., "beat") under a real time constraint, but the models didn't behave in that way.

On the basis of these considering, a new model proposed now must satisfy some constraints: 1) process model, 2) different levels of units, 3) real-time constraints, and 4) binary preference.

The outline of algorithm is shown in Figure4. Main algorithm of newmodel is based on Lee(1985)'s one.

As Figure 4 shows, this model works from left to right through the sequence. This represent the incremental process how listener process the tone sequence.

The second feature in this model is that it performs like listeners that it interprets the metrical structure of a sequence by accumulating the "metrical unit." Metrical units begin at the relatively long notes in a sequence.

The third point is that the new model considers the multiple levels of units corresponding to beat or measure listener can perceive.

The last and very important characteristic of this algorithm is that this model considers the temp of the se-

Table 1: Comparison of two models

	Model	
	Lee(1985)	P & E (1985)
Process	Incremental	Not incremental
Special feature	Metrical Unit	Internal clock
Important	Long tone	Accented tone
Hierarchy	Multiple	Single
Tempo	Not considering	

Table 2: Comparison between the reesults of experiment and output of two models

Type of fit	Degree of model fit (%)		
	“beat”	“measure”	“1st beat”
Fit completely	60.7	43.0	74.5
Fit in divisible			
by integer	1/2	10.3	15.0
	1/3	0.0	29.7
	1/4	0.3	0.3
Fit in integer			
multiple	2	8.7	0.0
	3	1.0	0.0
Sum	81.0	88.0	74.5

quence. This means that it can realize the real-time constraint. It shorten or lengthen the size of the units beyond the limits listeners can perceive as a “beat” or “measure.”

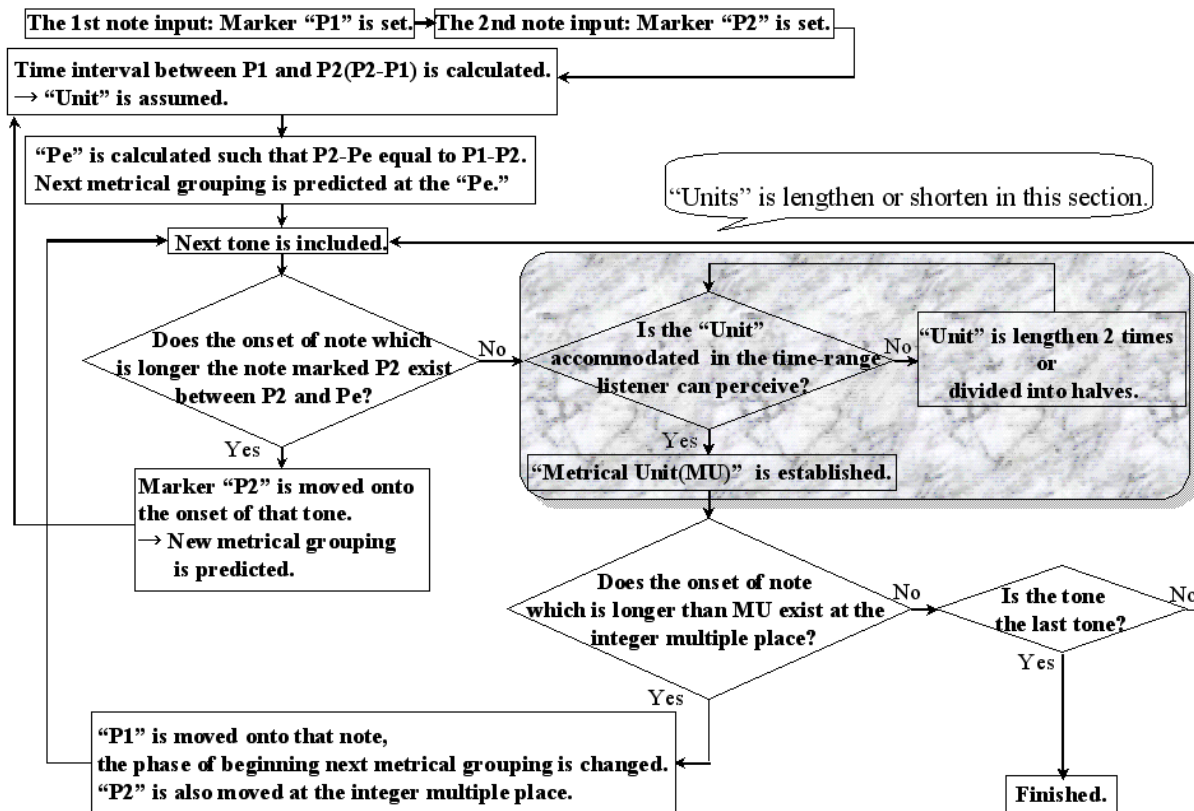


Figure 4: Outline of the algorithm of model.

4 General Discussion

New model proposed here is psychologically valid in that it considers the gradual process of listeners and the multiple units listeners can perceive.

Listeners interpret a sequence with preference for binary metrical structure, but such character is not reflected in some models.

Listeners also perceive metrical units in a certain time range, but almost all models proposed by now do not consider such character.

A new model is including such a findings, that is, a real-time constraints. As a result of that, it could predict the metrical structure that listeners perceived more correctly than other models.

To improve this model more plausibly, some features that listeners have must be included in the algorithm. For example, it is possible that explicit memory ([3]-[15]) and/or implicit memory ([16]-[23]) play a very important role in music perception. These findings must be realized in cognitive model of music perception for the future.

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