A ROLE OF METRICAL STRUCTURE IN IMPLICIT MEMORY OF RHYTHM PERCEPTION: TOWARD A COMPUTATIONAL MODELING OF PERCEPTION PROCESS OF METRICAL STRUCTURE

Yasuhiro GOTO
Department of Psychology and Applied Communication
Faculty of Humanities
Hokusei Gakuen University

ABSTRACT

Memory for rhythmic tone sequence plays an important roll in rhythm perce ption and variety of study has been made on it. Previous study suggests, for instance, that more easily it is perceived, more easily it is memorized. In recent years there has been renewal of interest in implicit memory for musical information. In this study, the implicit memory for rhythmic tone sequence was examined. The aim of this study was to investigate the implicit memory for musical rhythm from the viewpoint of cognitive psychology.

An experiment using priming and recognition tasks was performed to clarify the nature of implicit memory for rhythmic tone sequences. Two types of measure, " binary " meter tone sequence and " ternary " meter tone sequence, were used in experimental variables. In the experiment, encoding strategy was manipulated as an independent measure. In the study phase, half of participants were asked to perform "foot tapping task" and the others were asked to "note counting task." Foot tapping task means that participants tap their foot to the tone sequence. Note counting task means that participants count the number of the tones. In the test phase, half of the participants performed a priming task: they were asked to judge the familiarity on a 7-point scale (1= not familiar at all, 7= completely familiar). The rest of the participants performed a yes/no recognition test. The pitch height (A4) and timber (piano sound) were the same in both the study phase and the test phase. Priming effect was defined as difference between rating value of familiarity for old tone sequence and new one.

The following results were obtained: 1) priming effect was observed in both binary meter and ternary meter tone sequence when listeners were asked to performed "foot tapping task", 2) priming effect for binary meter tone sequence was bigger than that for ternary meter tone sequence, 3) no significant main effect was observed in the recognition task. These results lead to the conclusion that an implicit memory for musical rhythm exists and the type of metrical structure plays an important role in perceptual priming of rhythmic tone sequences. This may associate with the preference for binary metrical type in rhythm perception.

1. INTRODUCTION

The purpose of this paper is to investigate the nature of implicit memory of the musical rhythm, and to gain the finding s in order to construct a computational model of process of metrical structure in music perception.

In the psychological field, a great deal of recent studies about memory have been devoted to examining the relation between explicit and implicit forms of memory. Explicit memory refers to conscious or intentional recollection of previous experiences, as assessed by recall and recognition tasks; implicit memory, in contrast, refers to unconscious retrieval of previously acquired information on tests that do not require conscious recollection of a specific prior episode, such as word stem and fragment completion, lexical decision and word identification tasks. Current research has revealed dissociations between explicit and implicit memory.

Implicit memory can be confirmed by examining what is called the priming effect. Priming is a phenomenon where processing of a proceeding stimulus influences processing of a succeeding stimulus and is classified into two types: direct priming and indirect priming. Direct priming is observed when the preceding stimuli are exactly the same as the succeeding stimuli. Therefore, it is also called repetition priming or perceptual priming. In contrast, indirect priming is observed when there is a semantic relation between the preceding and succeeding stimulus. In this article, the term " priming " is used to refer to direct priming.

Research concerning implicit memory has focused almost exclusively on tests involving visual processing. Studies using verbal materials, for example, word identification (e.g.,[1]-[2]), fragment and stem completion (e.g., [3]-[4]), and lexical decision (e.g.,[5]-[6]) have been used as tests involvingvisual processing. There are also many papers about implicit memory fornonverbal objects such as picture completion (e.g., [7]-[8]), picture naming (e.g., [9]-[10]), object decision (e.g., [11]), and pattern completion and identification (e.g., [12]).

Similarly, some researches have explored implicit memory in the auditory domain. Several studies have demonstrated priming effects on auditory-word identification and sentence-identification tasks (e.g., [13]-[15]), on an auditory stem-completion tasks ([16]-[17]), and the like. It is true that there is relatively little research in this field, but over the past few decades a number of studies have been made on the implicit memory in the auditory domain.

For implicit memory about music, however, little attention has been focused. Only a few attempts have so far been made concerning implicit memory for music information. There are some studies of implicit memory about chord perception ([18]-[22]), melodyperception of alcoholic Korasakoff 's syndrome patients ([23]), and others ([24]-[25]), but only a few attempts have been made at implicit memory for rhythmic aspects of melody so far. It is odd, however, that implicit memory for rhythmic tone sequences has not been investigated despite the fact that evidence has been found for implicit memory in various other fields. Or rather, it is reasonable to expect that there is also implicit memory for musical rhythm perception as in other domains.

In the last few years, several articles have been devoted to the study of implicit memory for musical rhythm. Some studies by Goto ([26]-[29]) have found the evidence for the existence of perceptualpriming for musical rhythm experimentally, and have clarified the natureof it. He studied the implicit memory for musical rhythm in terms of two aspects: the physical aspect and the psychological aspect. As for the physical aspect, note value, pitch height and timbre were examined in regard to whether they influenced the perceptual priming for rhythm. At the same time, the priming effect for rhythm was also investigated from the psychological viewpoint such as the metrical structure that listeners perceived.

In those studies the following results were obtained: 1) note value, whi ch is independent of pitch height and/or timbre, is encoded in the memory representation of a rhythmic tone sequence, 2) information depending on the pitch height and/or timbre of the tone sequence is encoded in the memory representation, 3) implicit memory of musical rhythm is influenced by whether the tone sequence is metrical or non-metrical.

In this study, two factors were examined in order to deepen the findings about implicit memory for rhythm: the type of metrical structure and the strategy of encoding. Based on the results obtained in the previous studies, it seems reasonable to suppose that the type of metrical structure is related to the implicit memory for musical rhythm. In this experiment the type of metrical structure of tone sequence was both binary type and ternary type.4/4 meter tone sequence was used as binary type and 3/4 meter tone sequence as ternary type. Two types of encoding tasks were used in this experiment, a foot -tapping task and a note-counting task. The purpose of the first task was to promote encoding of a tone sequence by requiring participants to tap their foot to the tone sequence. To make the foot tapping, participants had to consider the tone sequence as a totally unified rhythmical entity and encode relations among its metrical components. In the second encoding task, the attention of participants ' was focused on local features of the tone sequence by having participants count the number of the tones making up the tone sequence. Accurate performance on this task required extensive processing of each sequence 's components but did not involve processing of the structural relations among them or listening to the tone sequence as a " total rhythm. " The type of encoding task was manipulated as a between-subject variable. All participants studied both binary and ternary tone sequences; no mention was made of the binary/ternary nature of the tone sequences during the study.

After completing the respective encoding tasks, half of the participants were given the familiarity judgment test, which was composed of binary and ternary tone sequences, of which half were studied and half were nonstudied. Implicit memory was inferred if familiarity judgment rating was higher for studied than for nonstudied items. The other half of the participants were given a yes/no recognition test that included the identical items but required participants to remember explicitly whether they had studied them.

In summary, the main hypotheses concerning the experiment were that (a) the type of metrical structure of tone sequence would be related to the perceptual priming for musical rhythm, (b) encoding the global total structure of tone sequence by making foot tapping would facilitate subsequent familiarity rating performance, whereas encoding local partial features by counting the number of notes would not produce any significant facilitation, and (c) recognition memory performance should be similar after the foot tapping and note counting tasks because participants acquire distinctive information about each tone sequence in both study tasks.

2. METHOD

2.1. Participants

Forty Hokusei Gakuen University undergraduates participated in the experiment. They were all normal hearing. They were randomly assigned to experimental conditions. Their mean musical experience was 16.8 years and understood the concept of metrical structure.

2.2. Apparatus

Each tone sequence was generated on a Roland Sound Canvas SC-88 tone generator using "Cakewalk Pro Audio" software. It was controlled by a PC/AT compatible computer. The operating system was Windows 98 by Microsoft Inc.. The tone sequences were presented through headphones.

2.3. Design and materials

The main experimental design consisted of a 2 x 2 x 2 x 2(Foot-tapping vs. Note-counting study task x Familiarity judgment vs. Recognition Test x Binary meter vs. Ternary meter x Studied vs. Nonstudied tone sequence) mixed factorial. The first two factors were manipulated as between-subject variables, and the latter two were manipulated as

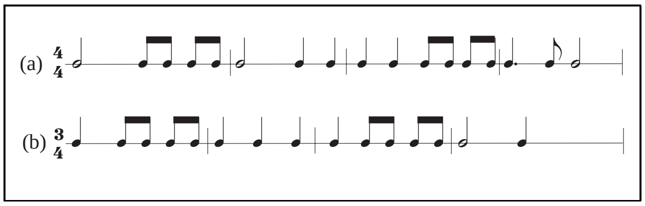

Figure 1. Sample stimuli used in this experiment. (a) shows binary meter tone sequence(4/4 meter) and (b) shows ternary meter tone sequence(3/4 meter).

within-subject variables. Dependent measures were either performance in the priming task or recognition task.

The experimental materials consisted of a total of 40 tone sequences, 20 binary tone sequences and 20 ternary tone sequence. Each tone sequence was a rhythmic tone sequences consisted in 13-17 notes. The kinds of notes constituting the tone sequence were “eight notes, ”“dotted eight notes,” “quarter notes,” “dotted quarter notes,” and/or “half notes.” The real time length of the note was 250msec, 375msec, 500msec, 750msec and 1000msec, respectively. The meter of half of the 40 tone sequences was “4/4,” which were binary metrical structure, and the rest were “3/4,” which was ternary metrical structure.

These tone sequences were generated to satisfy three constrains: (a) the tone sequence was consisted of by more than two kinds of note values, in other words, the tone sequence was NOT consisted of by one kind of note value; (b) the tone sequence was not extremely syncopated one; and (c) the tone sequence was metrical but not random one. The reason for these constrains was that the tone sequence consisted of only one note value was too simple and not appropriate as an experimental material, and that a “metrical” tone sequence was more difficult to memorize than that of metrical one (cf. [30]).

With regard to theconstraints (b) and (c), two musicians who did not participated in the present experiment rated all the candidate tone sequences in terms of “how each tone sequence was “4/4” on a 7-point scale(1= not 4/4 meter at all, 7= 4/4 completely) and the tone sequences which were judged “ 4/4” meter were used in the present experiment. “3/4” meter tone sequences werej selected in the same way.

They were all “equitonal” musical tone sequences, which had only the note-length information and all the other factors (e.g., pitch height, timbre, intensity) were equal. The pitch height of all these tones was the same, A4, and the timbre was piano sound. The sound pressure level of all tones was equal, at a comfortable listening level (about 75dB SPL). They were selected by two musicians, who did not participate in the present experiment. An example of stimuli is shown in Figure 1.

The participants studied 10 binary tone sequences and 10 ternary tone sequences. The remaining 10 binary sequence and 10 ternary sequences were not studied; they were included on the familiar judgment task in order to determine baseline levels of performance and on the recognition test as distractor items. The familiar judgment and recognition tests thus consisted of 40 critical items: 20 studied sequence (10 binary and 10 ternary). The presentation order of tone sequences on both tests was determined randomly for each participant. Binary and ternary tone sequences were randomly assigned to one of two material sets that were rotated through all experimental conditions. This procedure yielded a fully counterbalanced design in which each binary and ternary tone sequence appeared equally often in the foot tapping or note counting study tasks, as a studied or nonstudied item, and on the familiarity judgment and recognition tests.

2.4. Procedure

All participants were tested individually in a soundproof chamber. Each experiment was conducted under conditions of incidental encoding. Participants were told that they were participating in an experiment on the preliminary experiment of music perception, and no mention of a later memory test was made.

In the foot tapping study condition, participants were informed that rhythmic tone sequences would be presented by the speaker and their task was to tap to that tone sequence, and were told that was important for them to tap well-fitting to the tone sequences. On the other hand, in the note counting study condition, participants were informed that their task to count the number of tone sequence. This study phase then began with five practice items, followed by presentation of the 20 critical tone sequences in random order.

Immediately after study presentation, half of the participants were given instructions for the familiarity judgment test intermixed with examples of binary and ternary tone sequences. Participants were told that their task was to rate the “familiarity” of the tone sequences on a 7-point scale (1= not familiar at all, 7= completely familiar). The rest of participants were assigned to a recognition test. The recognition test was a surprise yes/no task. Participants were instructed to mark either “Hai” (“yes” in Japanese) on the sheet if they remembered hearing the tone sequence during the prior rating task, or “Iie” (“no” in Japanese) if they did not remember hearing the tone sequence.

3. RESULT

The results of the familiarity judgment and recognition tests are first considered separately and then followed by a contingency analysis of the relation between them.

3.1. Familiarity judgment

Difference between the rating score for the studied item and the one for the nonstudied item were defined as a priming effect in this experiment. The results were shown in Figure 2. Three important points should be noted about the results of the priming task. First, the priming effect was observed for both binary and ternary tone sequences in the foot tapping task. Participants rated more familiar

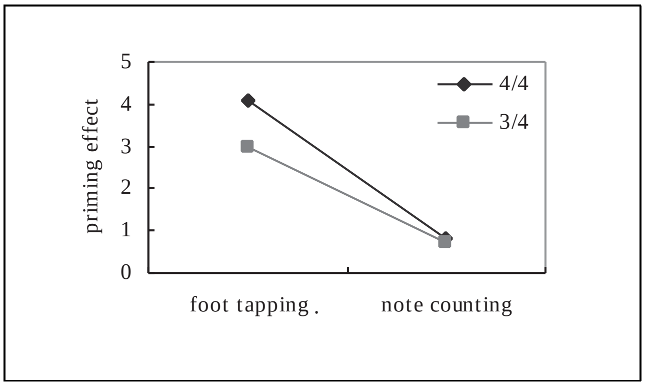

Figure 2. Result of priming.

for studied items than for nonstudied items. Second, the priming effect for binary tone sequence was larger than that for the ternary tone sequence. Third, the priming effect was not observed for either binary or ternary tone sequence in the note count task in study phase.

Analysis of variance (ANOVA) confirmed this description of the results. A significant Type of study Processing x Studied/Nonstudied tone sequence interaction, $F(1, 36) = 4.19, p < .05$, indicated that familiarity judgment performance was more facilitated in relation to baseline in the foot tapping than the note counting condition. In addition, a significant Type of metrical structure x Studied/Nonstudied tone sequence interaction, $F(1, 36) = 13.32, p < .001$, indicated that binary tone sequences were more facilitated than ternary tone sequences by prior study list exposure.

3.2. Recognition

Table 1 shows the result of recognition performance. Two different measures of recognition were subjected to an ANOVA: the hit rate and hit rate minus false alarm rate. Since both analyses led to an identical conclusion, only the result of the hit rate analysis was reported; this simply reflects the fact that false alarm rates were relatively constant across conditions. An overall ANOVA revealed no significant main effect of pitch shift. The difference between the result of the hit rate and the chance level in each condition was not significant (Table 1).

	Encoding condition		
	foot tapping	note counting	*M*
	binary meter tone sequence		
Studied	.60	.61	.61
Nonstudied	.23	.25	.24
	ternary meter tone sequence		
Studied	.59	.60	.60
Nonstudied	.25	.26	.26

Note. Studied=proportion of studied items called “old”(hit rate). Nonstudied=proportion of nonstudied items called “old”(false alarm rate).

Table 1. Recognition Performance

3.3. Contingency analysis of coherence judgment and recognition performance.

The purpose of the contingency analysis was to determine whether priming effects on coherence performance are dependent on, or independent of, recognition memory. In order to determine the relation between priming task and recognition task, the Yule Q statistic was used. Q is a measure of the strength of relation between two variables that can vary from -1 (negative association) to $+1$ (positive association); 0 indicates complete independence ([**?**]). For the present data, $Q = +.088$ at the binary condition and $+.093$ at the ternary condition. These values did not differ significantly from zero; significance was assessed by a chi-square test suggested by Hayman and Tulving, $\chi^2(1, N = 40) = 0.58$ at the binary condition and $\chi^2(1, N = 40) = 0.46$ at the ternary condition. The contingency analysis thus demonstrates stochastic independence between recognition and familiarity judgment performance.

4. DISCUSSION

In this study, two factors about perceptual priming for musical rhythm were investigated. One was the type of metrical structure of the tone sequence. The priming effect was examined for both binary and ternary meter tone sequence by familiarity judgment task. The other factor was the type of encoding strategy. Either global encoding strategy or local encoding strategy was examined whether they related to the priming effect for musical rhythm.

Priming effect was observed for both binary and ternary tone sequence. This results is in agreement with previous studies concerning implicit memory of rhythm ([26]-[29]) . Also, because the priming effect for binary tone sequence was larger than that for the ternary tone sequence, it seems reasonable to suppose that the nature of implicit memory for music rhythm is influenced by the type of metrical structure. This suggests that implicit memory of music rhythm is related to the binary preference that we listeners have universally.

The results of this experiment indicate that performance on the familiarity judgment task was facilitated by prior encoding of the global structure of an unfamiliar tone sequence but not by encoding of local features. However, evidence for priming or facilitation of familiarity judgment performance was observed for both binary and ternary meter.

This experiment provides empirical support for the main hypothesis outlined earlier. The finding that familiarity judgment performance was facilitated only by prior encoding of global tone sequence is consistent with a transfer-appropriate processing account and supports the notion that familiarity judgment performance is facilitated by access to structural descriptions of musical rhythm. Recognition memory, by contrast, did not differ significantly in the two encoding conditions, which indicated that different types of information about both global and local tone sequence features could be used through explicit retrieval processes to support recognition performance. These findings provide some evidence for dissociation between implicit and explicit memory for unfamiliar tone sequences.

This research examined implicit memory of musical rhythm, and the nature of memory representation for rhythmic tone sequences was clarified focusing especially on both the type of metrical structure and the type of encoding strategy.

We cannot say that the whole nature of memory representation for rhythmic tone sequence was clarified by only the experiment described above. For example, whether other type of metrical structure is related to the priming for rhythm, whether other encoding strategy can influence on the implicit memory for rhythm, and implicit and explicit memory remain to be proved in future investigations.

5. REFERENCES

[1] Graf, P., & Ryan, L. ”Transfer-appropriate processing for implicit and explicit memory”, *J. Experiment. Psychol.: Learning, Memory, and Cognition*, 16, 978-992, 1990.

[2] Jacoby, L. L., & Dallas, M.(1981). ”On the relationship between autobiographical memory and perceptual learning”, *J. Experiment. Psychol.: General*, 110, 306-340, 1981.

[3] Hyman, C. A. G.,& Tulving, E. ”Contingent dissociation between recognition and fragment completion: The method of triangulation”, *J. Experiment. Psychol.: Learning, Memory, and Cognition*, 15, 228-240, 1989.

[4] Roediger, H. L. III, & Blaxton, T. A. ”Effects of varying modality, surface features, and retention interval on priming in word-fragment completion”, *Memory & Cognition*, 15, 379-388, 1987.

[5] Rueckl, J. G. ”Similarity effects in word and pseudoword repetition priming”, *Journal of Experiment. Psychology; Learning, Memory and Cognition*, 16, 374-391. 1990.

[6] Scarborough, D. L., Gerard, L., & Cortese, C. ”Accessing lexical memory: the transfer of word repetition effects across task and modality”, *Memory & Cognition*, 7, 3-12, 1979.

[7] Jacoby, L. L., Baker, J. G., & Brooks, L. R. ”Episodic effects on picture identification: Implications for theories of concept learning and theories of memory”, *Journal of Experiment. Psychology.: Learning , Memory, and Cognition*, 15, 275-281, 1989.

[8] Snodgrass, J. G. ”Sources of learning in the picture fragment completion task”, In S. Lewandowsky, J. C. Dunn, & K. Kirsner (Eds.), *Implicit memory: Theoretical issues* (pp. 259-282). Hillsdale, NJ: Erlbaum, 1989.

[9] Bartram, D. J. ”The role of visual and semantic codes in object naming”, *Cognitive Psychology*, 6, 325-356, 1974.

[10] Mitchell, D. G., & Brown, A. S. ”Persistent repetition priming in picture naming and its dissociation from recognition memory”, *J. Experiment. Psychol.: Learning , Memory, and Cognition*, 14, 213-222, 1988.

[11] Schacter, D. L., Cooper, L. A., & Delaney, S. M. ”Implicit memory for unfamiliar objects depends on access to structural descriptions”, *Journal of Experimental Psychology, General*, 119, 5-24, 1990.

[12] Musen, G., & Treisman, A. ”Implicit and explicit memory for visual patterns”, *Journal of Experimental Psychology; Learning, Memory and Cognition*, 16, 127-137, 1990.

[13] Franks, J. J., Plybon, C. J., & Auble, P. M. ”Units of episodic memory in perceptual recognition”, *Memory & Cognition*, 10, 62-28, 1982.

[14] Jackson, A., & Morton, J. ”Facilitation of auditory word recognition”, *Memory & Cognition*, 12, 568-574, 1984.

[15] Schacter, D. L., & Church, B. A. ”Auditory priming: implicit and explicit memory for words and voices”, *Journal of Experimental Psychology; Learning, Memory and Cognition*, 18, 915-930,1992.

[16] Bassili, J. N., Smith, M. C., & MacLeod, C. M. ”Auditory and visual word-stem completion: Separating data-driven and conceptually driven process”, *Quartely Journal of Experimental Psychology*, 41A, 439-453, 1989.

[17] MaClelland, A. G. R., & Pring, L. ”An investigation of cross-modality effects in implicit and explicit memory”, *Quarterly J. of Experiment. Psychol.*, 43A, 19-33, 1991.

[18] Arao, H. & Gyoba, J. ”Disruptive effects in chord priming”, *Music Perception*, 17: 241-245, 1999.

[19] Bharucha, J. J., & Stoeckig, K. ”Reaction time and musical expectancy: Priming of chords”, *Journal of Experimental Psychology: Human Perception and Performance*. 12, 403-410, 1986.

[20] Bharucha, J. J., & Stoeckig, K. ”Priming of chords: Spreading activation or overlapping frequency specta?”, *Perception and Psychophysics*, 41, 519-524, 1987.

[21] Kawaguchi, J., & Mikumo, M. ”Implicit memory for music information: Priming effect on majar-minor decision task for chord”, *Abstract of the 3rd Practical Aspects of Memory Conference*, Mayland, U.S.A. 107, 1994.

[22] Tekman, H. G., & Bharucha, J. J. ”Time course of chords priming”, *Perception and Psychophysics* 51, 33-39, 1992.

[23] Johnson, M. K., Kim, J. K., & Risse, G. ”Do alcoholic Korasakoff ’s syndrome patiendts acquire affective reactions?”, *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 11, 22-36, 1985.

[24] Peretz, I., Gaudreau, D., & Bonnel, A.M. ”Exposure effects on music preference and recognition”, *Memory & Cognition*, 26, 884-902, 1998.

[25] Wilson, W.R. ”Feeling more than we can know: Exposure effects without learning”, *Journal of Personality & Social Psychology*, 37, 811-821, 1979.

[26] Goto, Y. ”Implicit memory for rhythmic tone sequence: A pilot study on perceptual priming for short temporal pattern”, *Acoustical Science & Technology*, 22, 219–225, 2001.

[27] Goto, Y. ”Implicit memory for rhythm: An effect pitch height and timbre for repetition priming of musical tone sequence”, *Proceedings of the 7th ICMPC*, 2002.

[28] Goto, Y,”Implicit memory for musical rhythm (3) on relation between perceptual priming of rhythm pattern and metrical structure of tone sequence”, *Proceedings of The Japanese Psychological Association 68th Annual Meeting*(in Japanese).

[29] Goto, Y. ”An influence of metrical structure for implicit memory of rhythm: A comparison of defference between binary and trinary tone sequence”, *Proceedings of the 8th ICMPC*, 2004.

[30] Povel, D. J., & Essens, P. ”Perception of temporal patterns”, *Music Perception*, 2, 411-440, 1985.