Factors Influencing the Perception of Rhythmic Similarity

Daniel Cameron
University of Western Ontario
dcamer25@uwo.ca

Keith Potter
Goldsmiths, University of London
k.potter@gold.ac.uk

Geraint Wiggins
Queen Mary, University of London
geraint.wiggins@eecs.qmul.ac.uk

Marcus Pearce
Queen Mary, University of London
marcus.pearce@eecs.qmul.ac.uk

ABSTRACT

In 2 experiments, we investigate the perception of rhythmic similarity using rhythmic figures from Reich's *Clapping Music*. We analyze ratings of pairwise similarity made by musicians and non-musicians when rhythms were heard in the context of the compositional process or in isolation, in two performance versions (MIDI or performance recording), and in different orders of presentation. Our results suggest that musical training provides an advantage in processing rhythmic information, that both expressive performance and *Clapping Music's* compositional process of rhythmic transformation can provide additional information used by listeners to distinguish rhythms, and that the perceived similarity of rhythms can depend on the order in which they are presented. Results are interpreted from, and consistent with, a perspective of information theory.

KEYWORDS

Rhythm perception, Similarity, Information theory

1. INTRODUCTION

Rhythm is the temporal distribution of auditory events and the cognitive processing of rhythm is a critical aspect of music perception that is not fully understood.

The perception of similarity is a useful indicator of the underlying cognitive processing of a category of stimuli. Perceptual similarity is accounted for in various ways, including feature-based [8], geometric [7], and transformational models [1]. Studies of perceptual similarity in music have investigated the cognitive processes underlying the perception of melody, including the use of participant ratings of perceived similarity [2], and parallel computational approaches [4]. Other approaches have considered information dynamics as the basis for expectation-based aspects of music cognition and neural processing [5], in line with a body of research focusing on implicit statistical learning and processing as central in music perception and cognition, as described by Huron [3]. Compared to melody, there is little research on the perception of rhythmic similarity or information-theoretic perspectives on rhythm.

In myriad studies, musical training has been shown to change the way auditory information is processed, influencing cognition, perception, and physiology. Performed music tends to use flexible timing, continuously variable timbre and intensity, as opposed to the discrete nature of music notation or digital representations (i.e. MIDI). Theoretic approaches to music which focus on micro-structure (i.e. discrete units of rhythm or melody) at the expense of considering the broader compositional context may be ignoring important sources of information. In the present study, our methods allow us to investigate the effects of musical training, expressive human performance, and musical context on the processing of rhythm information as measured by the perception of similarity. We interpret differences in perceived similarity as reflecting differences in implicit information processing in the brain.

We use the rhythmic material from Steve Reich's *Clapping Music* as stimuli because this piece uses a simple compositional process, is primarily rhythmic in content, can be easily expressed in a reduced (MIDI) representation which eliminates expressive performance information, and is a valid, commonly performed piece of contemporary music. In this piece, two performers clap a rhythm, first in unison and subsequently transformed by one performer shifting the phase of the rhythm relative to the original. The result is 12 distinct rhythmic figures each repeated 12 times.

2. METHODS

In Experiment 1, participants (20 musicians, 20 non-musicians) completed 78 trials, consisting of listening to all possible pairs of single iterations of rhythms, randomized, with each rhythm pair in one order and one performance version (MIDI or performed). After each trial, participants gave ratings of perceived rhythmic similarity on a 7 point scale.

In Experiment 2, participants listened to progressively longer excerpts of *Clapping Music* (starting with the first 2 rhythmic figures, up to the full 12 figures) in which rhythms were repeated 4 times each. After each excerpt, similarity ratings were made comparing the last rhythmic figure heard to each of the previous in that excerpt.

3. RESULTS

Similarity ratings were analyzed to investigate the influence of musical training (musicians vs. non-musicians), version (MIDI vs. performed) and presence of musical context (Experiment 1 vs. Experiment 2). Further analysis investigated the influence of order of presentation (for pairwise ratings from Experiment 1).

A mixed 2x2x2 ANOVA reveals effects and interactions of musical training, performance version, and musical context on perceived rhythmic similarity (see Figure 1). Figure 2 shows mean similarity ratings and standard deviations in all conditions.

Rhythms presented as individual pairwise comparisons (Experiment 1) allow analysis of order effects. Since rhythms occur in a particular order in their intended process, we use a paired t test for differences in perceived similarity between rhythm pairs in intended order and reverse order. Rhythm pairs presented in intended order have significantly higher similarity ratings than those in reverse order ($t(263)=2.73$, $p=.007$).

To explore the underlying source of this effect, we compare order-based differences in similarity ratings for pairs which contain one rhythm with an extreme number of rests (either 0 or 4) and one with a non-extreme number of rests (1 or 2), and pairs for which both rhythms contain either an extreme or non-extreme number of rests. A 2x2x2 ANOVA for the influence of extreme-rest congruence (congruent vs. incongruent), expressive performance, and musical training on order-based differences in similarity ratings shows a significant main effect of extreme-rest congruence ($F(1,262)=3.91$, $p=.049$), but no significant interactions or main effects of other factors. Mean order-based differences (intended – reverse) are greater for extreme-rest incongruent rhythm pairs (*M*=.269, *SD*=.96) than for extreme-rest congruent pairs (*M*=.037, *SD*=.94).

4. DISCUSSION

The set of results we see in ratings of perceived rhythmic similarity for the rhythmic figures of *Clapping Music* indicate influences on the perception of rhythm.

We are interested in subjective ratings of similarity in part because there is no basis for absolute and valid measurement of rhythmic similarity. Here, we do not aim to discern the absolute basis for the perception of rhythmic similarity (i.e. rhythm structure), but can consider lower similarity ratings as advantages in cognitive and perceptual distinction, and thus advantages in information processing. Thus, we can understand differences in mean similarity ratings across all rhythm-pairs, and across conditions for the same rhythm-pairs, as representing relative changes in information processing.

MIDI versions of rhythms, which eliminate the continuously dynamic levels of intensity, timbre and precise timing present in expressive human performance, are rated as more similar than performed rhythms, which provide more information in the form of more variability in those dimensions. This effect is significantly less present in musicians' similarity ratings, presumably due to their practice and experience in processing, discriminating, and comparing auditory rhythms as *conceptual* temporal entities, separate from their particular dynamic auditory characteristics. There is a reduction in overall perceived similarity when rhythms being compared are heard in the context of the transformative process in which the rhythms are originally intended, implying that the process itself is a source of rhythmic information. It is notable that differences in non-musicians' similarity ratings due to expressive performance disappear when rhythms are heard in the context of the transformative process.

Perhaps the most surprising result is of asymmetrical perception of rhythms, where the degree of similarity between two rhythms can depend on the order in which those rhythms are heard. Besides being supportive of particular theories and approaches to perception, such as that of Tversky [8], the apparent cause of the measured asymmetry corresponds directly to an information theoretic perspective where the information content of the first rhythm in a pair, changes the relative information of the second. In pairwise comparisons, the first stimulus may serve as a template against which the second is compared. In the case of our stimuli, when a rhythm containing an extreme number of rests (less likely, and thus having greater information content) is heard first, rhythms heard second which do not contain an extreme number of rests (more common) will maintain their relatively low information content. That is, they will fit the 'model' established by the first rhythm relatively well. By comparison, if a common rhythm with 1 or 2 rests is heard first, the relative information content of a more extreme rhythm with 0 or 4 rests, heard second, will be greater, providing a greater perception of dissimilarity.

Finally, beyond the primary aims of investigating the cognitive processing of rhythm, our study reflects on the musicological question of the perceptibility of process, which was a broad concern and intention of Reich [6]. Though explicit perception or awareness of the musical process may not arise from listening, changes in cognitive processing due to the process inform perception of the musical materials themselves.

5. CONCLUSIONS

Using rhythmic material from Reich's *Clapping Music*, this study demonstrates influences of musical training, expressive performance, and musical context on rhythm perception, as measured by subjective ratings of similarity. For pairwise comparison of rhythms, the order of presentation can change perceived similarity, and this asymmetry appears to occur for rhythm pairs with greater disparity of information content.

Along with providing some insight into the cognitive processing of musical rhythm, these results support information-theoretic approaches to music cognition, and represent an empirical approach to a musicological question regarding the perceptibility of process in minimalist music.

Table 1. Statistics for Effects and Interactions of Factors

	F	*p*
Musical Training	9.13	.003
Expressive Performance	7.24	.008
Musical Context	16.14	<.001
Training x Performance	.71	.40
Training x Context	14.42	<.001
Performance x Context	30.43	<.001
Training x Performance x Context	3.80	.052

Table 2. Ratings of Perceived Rhythmic Similarity by Musicians and Non-Musicians Across both Experiments and Versions

	Pairwise Presentation				*Contextual Presentation*			
	MIDI		*Performed*		*MIDI*		*Performed*	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Mus	3.88	1.2	3.74	1.1	3.55	.62	3.67	.72
Non	4.26	1.0	3.77	1.0	3.90	.53	3.91	.45

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