Predicting temporal attention in music with a damped oscillator model

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Introduction

Processing rhythmically structured sound streams, such as music or speech, requires a listener to increase attentional focus at certain points in time relative to others. Evidence suggests that such rhythmic structure can entrain attention in listeners, such that perception is enhanced at temporally salient moments (Large & Jones, 1999; Jones et al., 2002). A model that uses resonators to estimate a stimulus' metric structure (Tomic & Janata, 2008) holds promise in its potential for predicting temporal attentive processing. However, this potential has not been tested. As such, we use psychophysical procedures to test the predictions of Tomic and Janata's model with multi-timbral rhythmic stimuli.

Methods

Participants: UC Davis undergraduates
- Experiment 1: N = 28; 12 musicians (≥ 3 yrs training)
- Experiment 2: N = 39; 13 musicians
- All normal hearing

Stimuli: Five multi-timbre percussive patterns (Figure 1), each played back as a continuous loop at 107 beats per minute.

For each stimulus, transient (200 ms) intensity deviants were placed at four temporal positions, each associated with varying levels of predicted perceptual salience, as predicted by Tomic and Janata's (2008) resonator model (Figure 2).

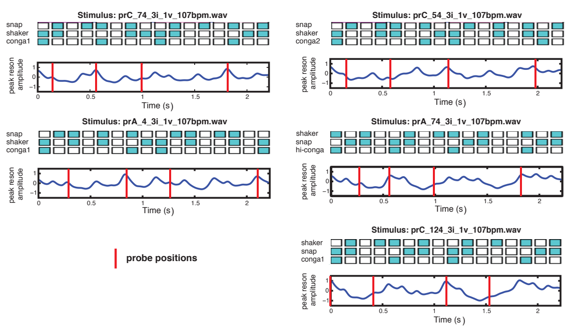


Figure 1. Top rows: stimulus rhythmic patterns in note matrix representation (16th note timing resolution). Bottom rows: deviant probe positions as a function of perceptual salience, as predicted by resonator amplitude.

Procedure:
- During each stimulus run, stimulus loop is continuously played back
- Participants probed with deviant amplitude increase once every 2 to 3 loop iterations
- Intensity of deviants varied adaptively, as governed by ongoing threshold estimation (tracked separately for each deviant position) -- see Adaptive Threshold section for details.
- Participants reported deviance detection with button press
- Run ends once all thresholds converge

Modeling Temporal Salience

We modeled stimulus periodicity structure and temporal salience using Tomic & Janata's (2008) resonator model.

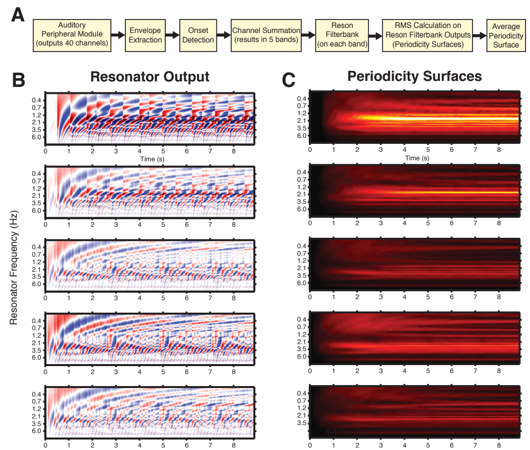
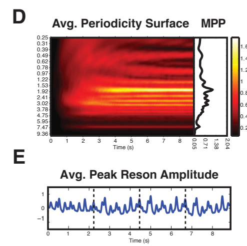


Figure 2. (A) Stages of the resonator model. (B) Output from reson filter banks. Resonators are driven by stimulus onsets recurring at the filter-tuned periodicities. (C) A windowed RMS is applied to resonator output, resulting in Periodicity Surfaces. (D) Periodicity surfaces are averaged together to produce an Average Periodicity Surface (APS). Averaging the APS across time yields a mean periodicity profile (MPP), which depicts prominent periodicities as an energy spectrum. (E) For each time point, we average the amplitude of peak periodicity-tuned resonator output. This yields a time series of Peak Reson Amplitude, which can be interpreted as a time course of modeled temporal perceptual salience.



Data Analysis

Adaptive threshold. Participants' deviance detection thresholds were estimated using Zippy Estimation by Sequential Testing (ZEST) (Marvit et al., 2003), which uses Bayes Theorem to adjust stimulus intensity and converge on a threshold based on the participant's ongoing performance. We estimated separate thresholds for each deviant probe position. Lower deviance detection thresholds imply greater perceptual sensitivity, whereas higher thresholds imply less perceptual sensitivity.

Statistical analyses. Statistical effects were examined using a linear mixed-effects model (dependent measure: deviant detection threshold; fixed effects: resonator level, musicianship; random intercept: participant).

Experiment 1 Results

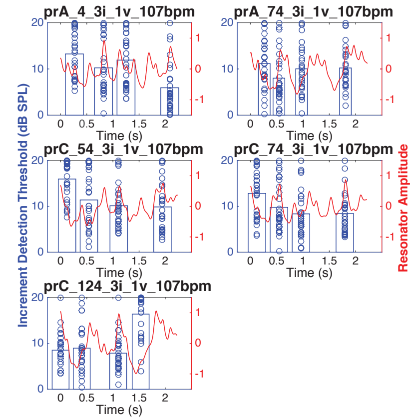


Figure 3. Intensity increment detection thresholds (blue; bars = mean threshold; circles = individual subjects' thresholds) for each probe. Each stimulus' peak reson amplitude time series (red) is superimposed over the threshold data.

Experiment 2 Results

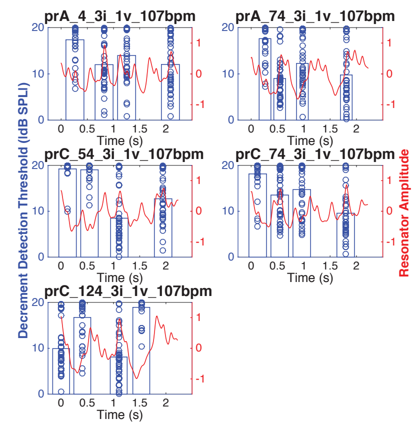


Figure 4. Intensity decrement detection thresholds (expressed in absolute value) and peak reson amplitude time series for each stimulus.

Musicianship

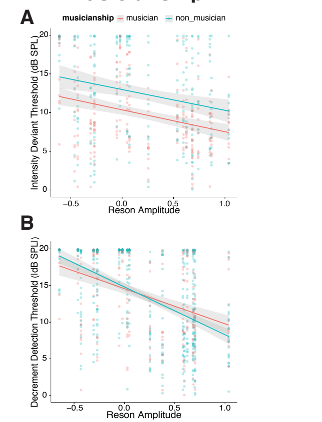


Figure 5. Relationship between model prediction and observed detection threshold for intensity deviants (A) and decrement deviants (absolute value) (B).

Experiment 1 (Increment Detection)			
Parameter	**Est.**	**SE**	**p-value**
Intercept	10.35	1.03	< .0001
Resonator amplitude	**-2.82**	**0.52**	**< .0001**
Musicianship	2.62	1.45	.09
Musicianship*Resonator amp.	0.14	0.76	.85
Experiment 2 (Decrement Detection)			
Parameter	**Est.**	**SE**	**p-value**
Intercept	14.58	0.84	< .0001
Resonator amplitude	**-4.80**	**0.59**	**< .0001**
Musicianship	0.23	1.06	.83
Musicianship*Resonator amp.	**-1.72**	**0.75**	**.02**

Conclusion

These results suggest that output from Tomic and Janata's (2008) resonator model can predict temporal attention in complex, multi-timbral rhythmic patterns. Ongoing experiments examine whether these effects hold for other deviant types (e.g., temporal purturbation), the nature in which temporal and streamwise attention interact in musical auditory scenes, and the effects of stimulus complexity and individual differences on the precision of model-behavior fit.

References

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