Temporal attention in multipart music

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Introduction

Evidence suggests that rhythmically structured sound patterns, such as music, can entrain attention in listeners, such that perception is enhanced at temporally salient moments (Large & Jones, 1999). A model that uses resonators to estimate a stimulus' metric structure (Tomic & Janata, 2008) holds promise in its potential for predicting temporal perceptual salience. However, this potential has not been tested. We address this question by developing a musically oriented psychophysical paradigm to test predictions of Tomic and Janata's model with multi-timbral rhythmic stimuli.

Methods

Participants: *N* = 28; 13 females; age range 18-43, mean 21.7 ± 4.7; all normal hearing; mixed levels of musical training

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: two time points associated with high levels of predicted perceptual salience, and two time points associated with low levels of predicted perceptual salience, as predicted by Tomic and Janata's (2008) resonator model (Figure 2).

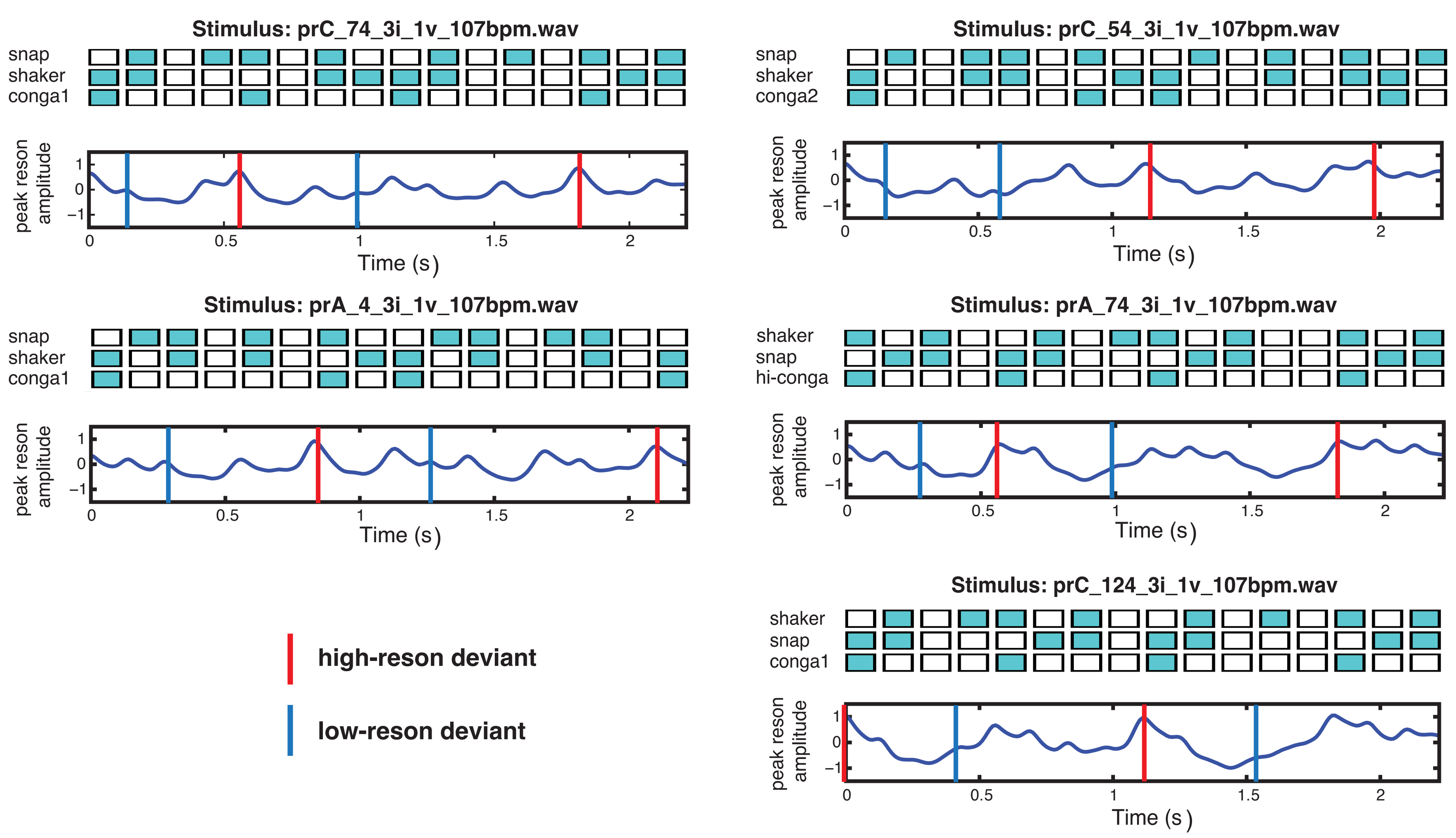

Figure 1. Top rows: stimulus rhythmic patterns in note matrix representation (16th note timing resolution). Bottom rows: deviant probe positions as a function of perceptual salience, as predicted by resonator amplitude.

Procedure:
- During each of 5 runs (one for each stimulus), 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 a resonator model developed by Tomic and Janata (2008).

Resonator model. Reson filters are driven by stimulus onsets recurring at the periodicities to which the filters are tuned (Figure 2A). The model applies a windowed root-mean-square calculation to each reson filter's output, resulting in Periodicity Surfaces (Figure 2B), which are time-frequency representations of resonator energy. Periodicity surfaces are averaged together to produce an Average Periodicity Surface (APS) (Figure 2C). Averaging the APS across time results in a mean periodicity profile (MPP), which depicts prominent periodicity frequencies as an energy spectrum.

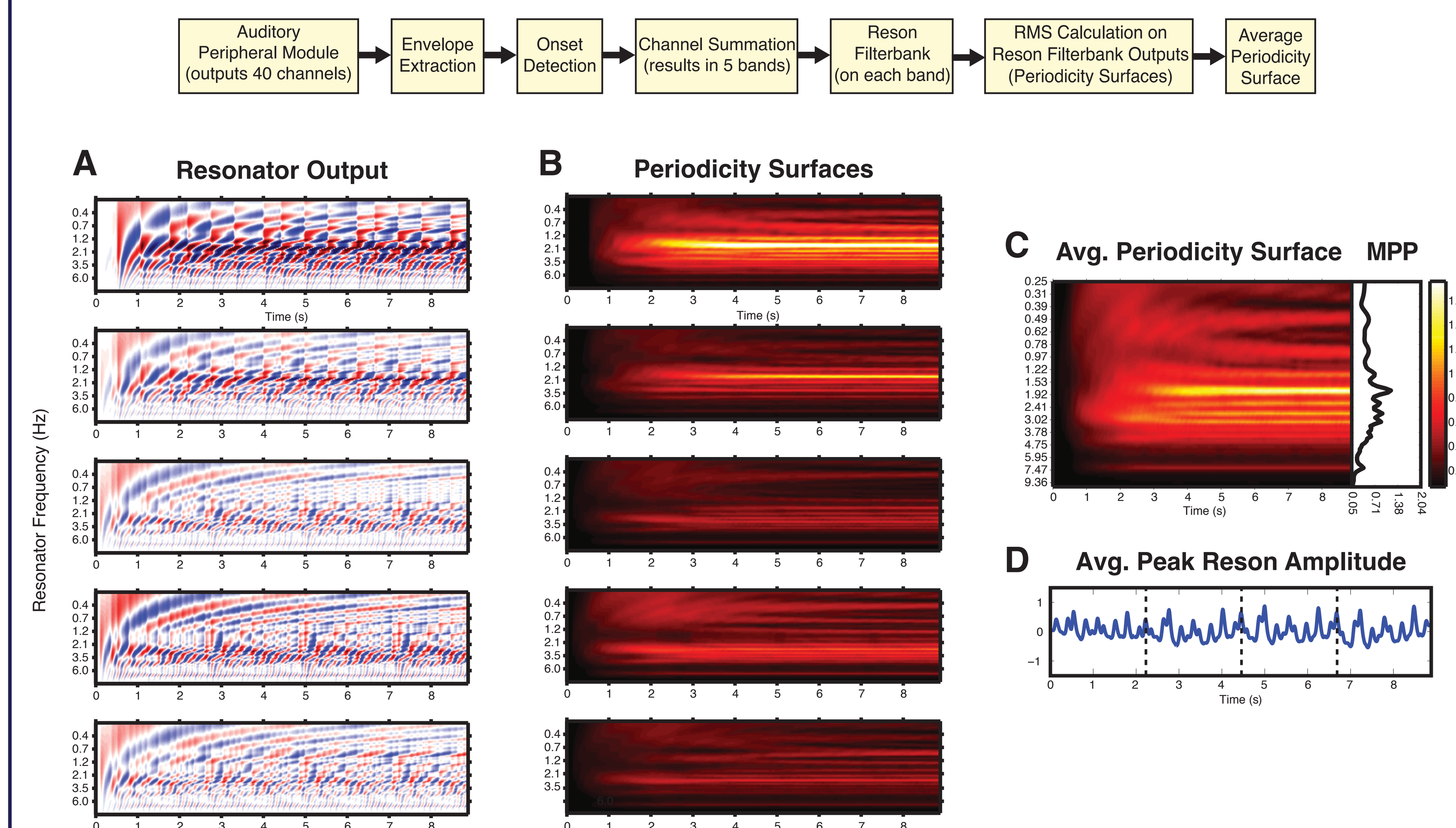

Figure 2. Representation steps of Tomic and Janata's (2008) resonator model, as utilized to estimate temporal salience.

Model metric for temporal salience. For each time point, we averaged the amplitude of output from reson filters tuned to metrically related periodicities (i.e., frequencies corresponding to MPP peaks). This yielded a time series of Peak Reson Amplitude (Figure 2D), which can be interpreted as a time course of modeled temporal perceptual salience. We used this metric to select deviant probe time points associated with moments of high and low temporal salience in stimuli (see Figure 1).

Data Analysis

Adaptive threshold. We assessed participants' performance on the task using an adaptive threshold procedure: Zippy Estimation by Sequential Testing (ZEST) (Marvitet al., 2003). ZEST uses Bayes Theorem to adjust stimulus intensity and converge on a threshold based on the participant's performance. We tracked multiple thresholds concurrently, such that separate thresholds could be estimated 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).

Results

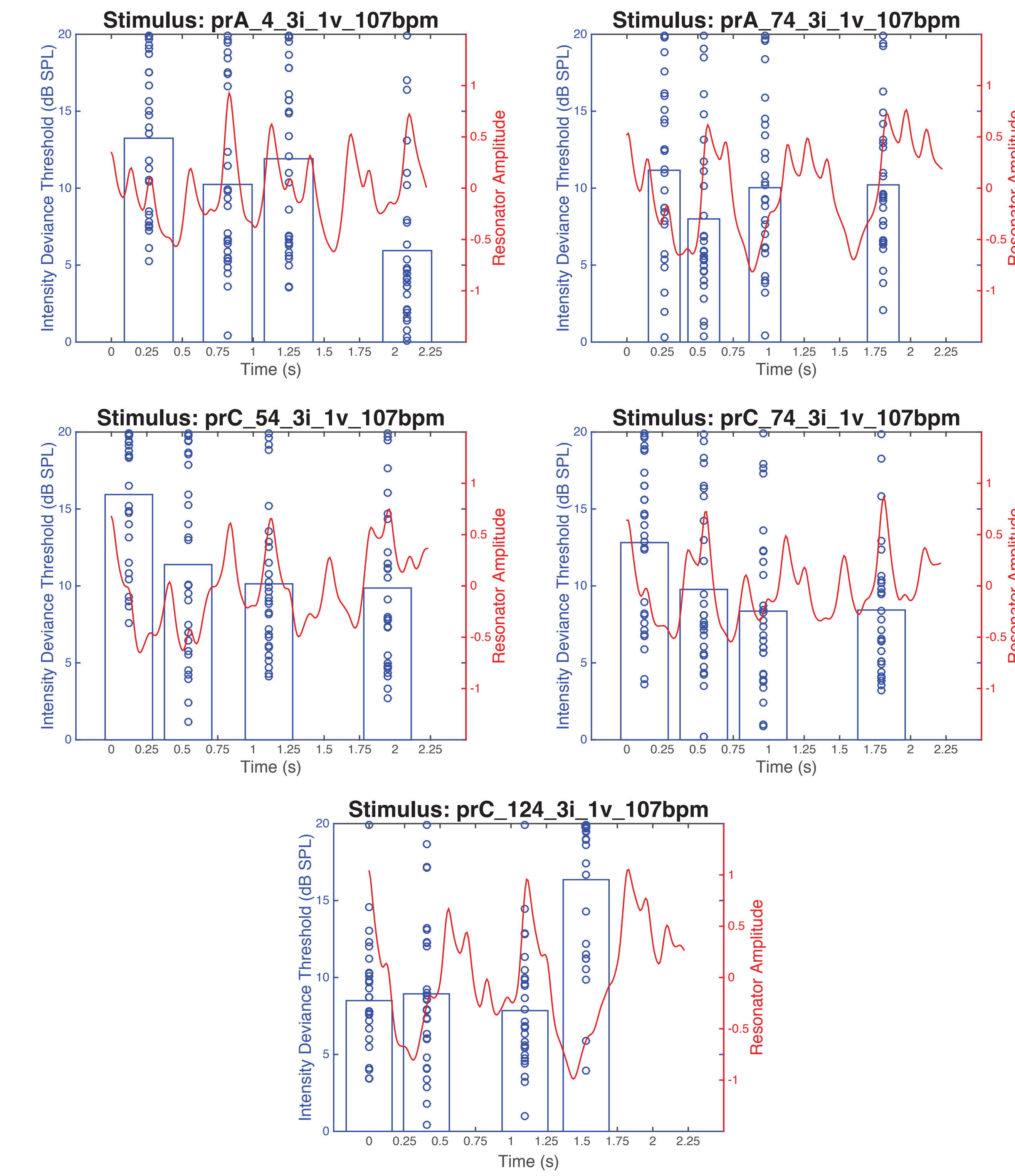

Figure 3. Deviant detection thresholds (blue; bars = mean threshold; circles = individual subject thresholds) and peak reson amplitude (red) for each stimulus.

Parameter	Est.	SE	p-value
Intercept	10.61	1.20	< .0001
Resonator amplitude	**-2.88**	**0.53**	**< .0001**
Musicianship	0.41	1.56	.80
Musicianship*Resonator level	0.44	0.68	.52

Conclusion

These results offer intial evidence that resonator output from Tomic and Janata's (2008) model can predict temporal attending behavior in complex, multi-timbral rhythmic patterns.

Upcoming experiments will test the current paradigm with other deviant types (e.g., intensity reduction, temporal onset perturbation) to examine whether deviant type influences the estimation of listeners' perceptual sensitivity to points in time. Moreover, future experiments are needed to examine attentional interactions between timing and timbre.

References

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