Effects of Learning on Neural Representations of Rhythm and Beat

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Background

- Humans spontaneously synchronize to the beat in rhythms.[1]
- Strong-beat rhythms elicit increased activity in the basal ganglia and SMA.[1]
- Activity for non-beat rhythms likely related to general temporal encoding.

Experiment 1 – Neural Representations of Rhythm and Beat (MVPA):
Do SMA and basal ganglia encode individual rhythms, or beat strength?
Hypothesis
Beat-sensitive areas encode the beat via spatial activity patterns, with highest dissimilarity between patterns with the largest difference in beat strength.

- Multivariate analyses reveal whether *fine-grained spatial activity patterns* are 'tuned' to beat strength.
- We hear music daily; beat responses may actually reflect ↑ exposure to rhythm.

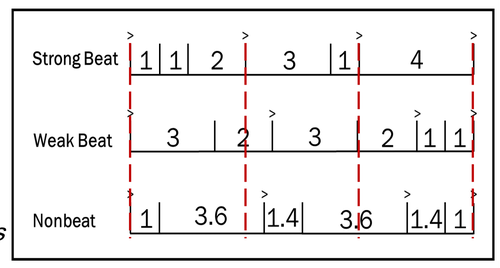
Experiment 2 (to be conducted) – Effects of Learning on Rhythm Representation:
What influence does exposure have on neural rhythm and beat encoding?
Hypothesis
Training will cause any exposure-sensitive regions to reduce in dissimilarity between beat strength conditions when all rhythms are learned.

Exp. 1 Neural Representations of Rhythm and Beat Methods

Stimuli

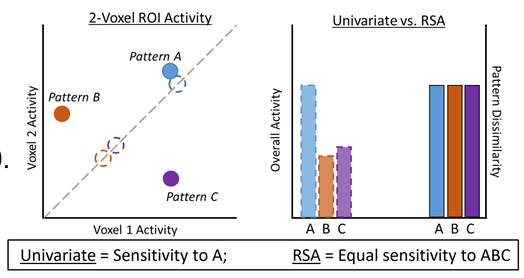
- 12 filled-tone rhythms
  - 4 Strong-beat
  - 4 Weak-beat
  - 4 Non-beat

1 = 230, 250, or 270 ms.
> = Perceptual accents[2]
Theoretical beat locations



Analysis

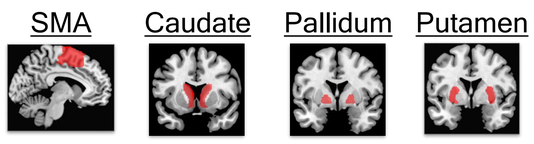
- Representational Similarity Analysis.
- Crossnobis distance estimate.[3]
  - Larger distances = more dissimilar patterns.
  - Cross-validation allows testing against meaningful 0.



Univariate = Sensitivity to A; RSA = Equal sensitivity to ABC

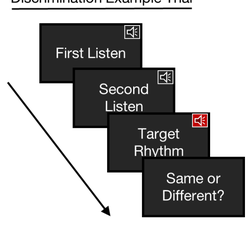
Regions

- Anatomically-defined regions of interest.
- Whole-brain searchlight.



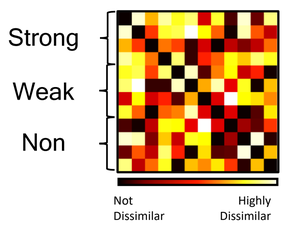
Procedure

- Rhythm Discrimination Task.
- 8 Blocks of 24 trials each.
- 7T MRI Scanning.
- Analyze activity during 'Listen' stages



Read the preprint here:

Representational Model Fitting

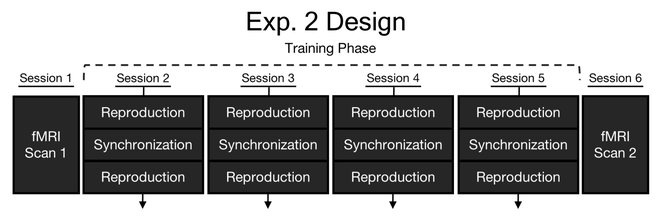


Basic Features	Condition	Beat Strength
# of Onsets	Strong-beat > All	Equal
# intervals	Weak-beat > All	Hierarchy
Tempo	Non-beat > All	Counterevidence[2]

Exp. 2 (to be conducted) Effects of Learning Methods:

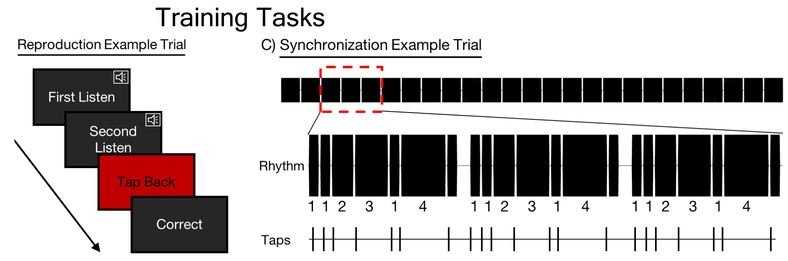
Procedure

- Pre & post-training fMRI scans *(conducted as in Exp. 1)*.
- 4 behavioral training sessions.
- Learn to reproduce the rhythms.



Read the Stage 1 Registered Report here:

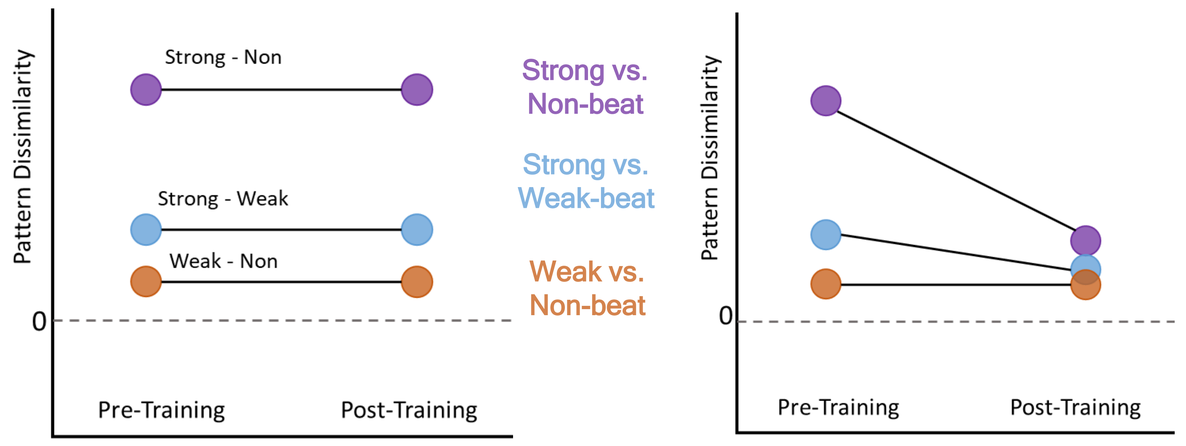
Training Tasks



Exp. 2 Planned Analysis

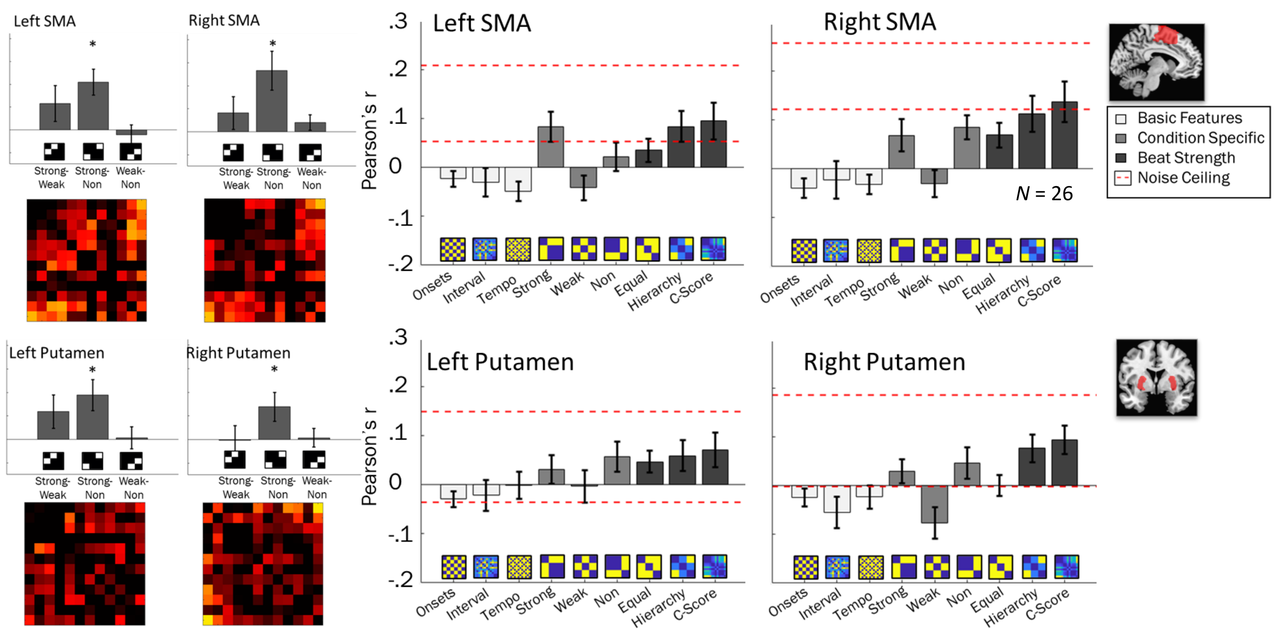
Prediction: Regions encoding beat strength will maintain dissimilarity between conditions from pre- to post-training.

Prediction: Regions encoding learned predictions will decrease dissimilarity between conditions from pre- to post-training.

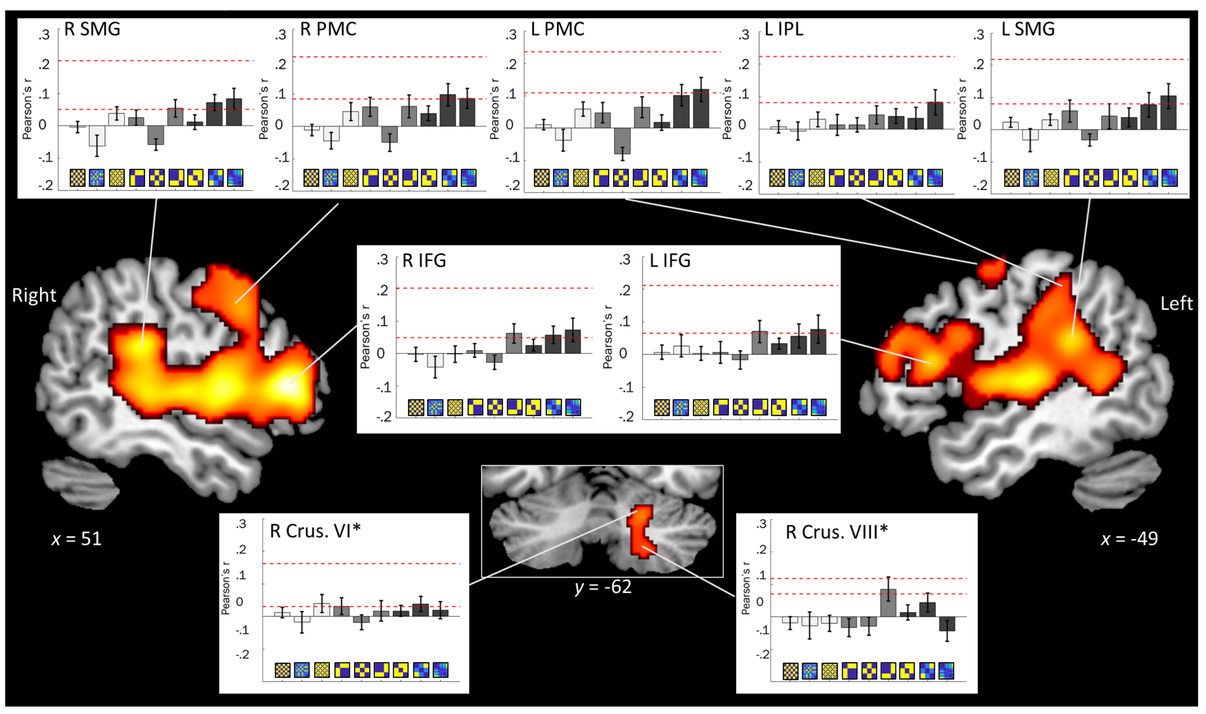


Exp. 1: Motor and Association Regions Encode the Beat

Activity patterns in SMA and putamen sensitive to beat strength.



Across the brain, beat strength encoded in frontal and parietal regions.



- Significant dissimilarity between strong- and non-beat activity patterns.
- Beat counter-evidence model most correlated with neural representations.

- Dissimilar between-condition patterns in frontal, premotor, parietal, and cerebellum.
- Beat strength models most correlated in cortical regions; tempo model in cerebellum.

Discussion

Exp. 1 – Neural Representations of Rhythm and Beat:

- Bilateral SMA and putamen are sensitive to beat strength, confirming previous findings.
- Beat strength encoded at the individual rhythm level.
  - **Greater differences in beat strength** = **more dissimilar** activity patterns.
- IFG and parietal regions appear to encode the beat.
- IFG may reflect attention allocation – greater attention with more irregularity.
- IPL may facilitate cross-talk between auditory and motor regions.[4]

Exp. 2 (to be conducted) – Effects of Learning on Rhythm Representation:

- Will reveal role of exposure in rhythm encoding.
- Additional questions:
  - Musicians (5+ yrs. music training) vs. non-musicians (0-2 yrs.).
  - Relationship between tapping accuracy and neural representations.
- Data collection ongoing.

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[2]Povel, D.J., & Essens, P. (1985). Perception of temporal patterns. *Music Perception, 2*(4), 411-440.
[3]Diedrichsen J, Zareamoghaddam H, Provost S. (2016). The distribution of cross-validated Mahalanobis distances. *ArXiv.*
[4]Patel, A. d., & Iversen, J. R. (2014). The evolutionary neuroscience of musical beat perception: the Action Simulation for Auditory Prediction (ASAP) hypothesis. *Frontiers in Systems Neuroscience, 8.* doi:10.3389/fnsys.2014.00057