Learning and Reward in a New Musical System

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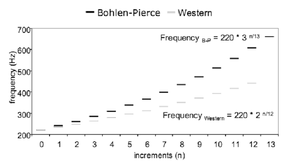
Introduction

- Music is considered a highly pleasurable stimulus, allowing researchers to use it to study reward mechanisms
- Previous research has shown that rewarding responses to music are related to measures of **uncertainty** and **surprise**[1]
- Engagement of the **nucleus accumbens (NAcc)** is involved in reward-related learning of music[2-3]
- However, the interaction between familiarity and musical predictability in learning-dependent reward network activity is unclear
- Our previous work shows that people can rapidly develop preferences for music in a novel and artificial musical system (**Bohlen-Pierce scale**)[4]
- How does musical uncertainty/surprise relate to liking as we learn a new musical system?
- What is the nature of striatal involvement when learning to like music that is devoid of prior associations?

Methods

Stimuli development and piloting

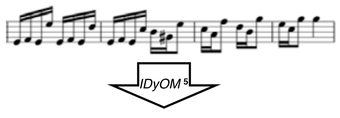
B-P vs. Western Tuning



12 B-P Melodies
(+ 12 modified versions)

B-P Melody 1 (exposure)	B-P Melody 1 (modified)
B-P Melody 2 (exposure)	B-P Melody 2 (modified)
B-P Melody 3 (test)	Western Melody

Information Dynamics of Stimuli



Surprise → Information Content (IC) = $-\log_2 p(x_i)$

Uncertainty → Shannon Entropy (H) = $1np(x_i)\log_2 p(x_i)$

Behavioral testing

N=47

Phase 1 (pre-ratings): Liking? Familiarity?

Phase 2 (exposure): Listen (x2,x4,x8,x16)

Phase 3 (testing): Liking? Familiarity?

fMRI Study

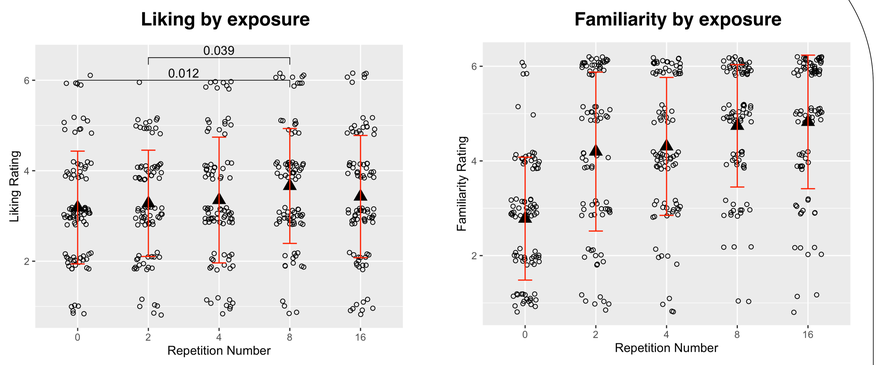
N=12 (current)

Scanning task: Like? Familiar? / Like? Familiar?

Contrasts

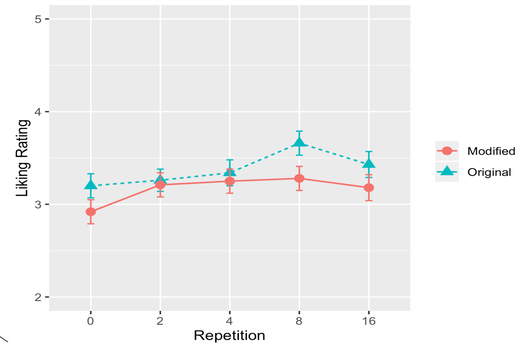
- Effect of melodic style: vs
- Effect of veridical prediction: vs.
- Effect of schematic prediction: vs
- Effect of item: vs.

Does liking increase with exposure to novel BP-melodies?



Liking ratings for novel B-P melodies peaked after 8 repetitions
Familiarity ratings continued to increase with repeated exposure

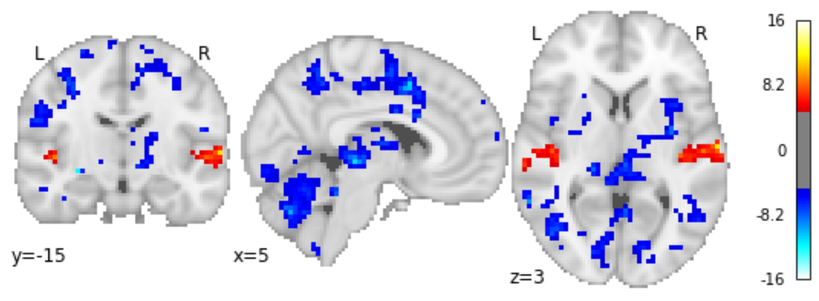
Do people learn to prefer B-P musical structure?



Liking ratings are higher for original B-P melodies after repetition, as compared to modified versions that violate learned expectations

What brain regions are involved in processing novel B-P melodies?

B-P listening (pre-learning) vs. rest (FWE-corrected, $p < 0.05$)



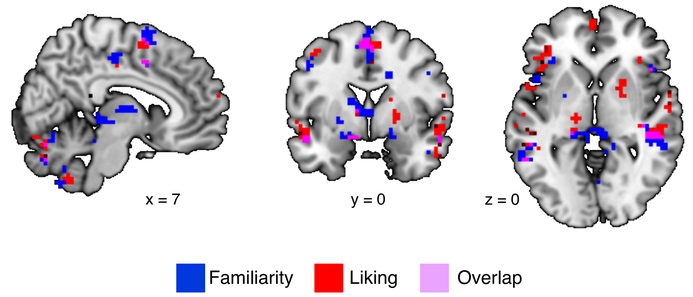
Novel B-P melodies were associated with wide-spread deactivation, particularly in the SMA/ ACC

References

[1] Koelsch, S., Vuust, P., & Friston, K. (2018). Predictive Processes and the Peculiar Case of Music. *Trends in Cognitive Sciences*, *23*(1), 63–77.
[2] Gold, B. P., Mas-Herrero, E., Zeighami, Y., Benovoy, M., Dagher, A., & Zatorre, R. J. (2019). Musical reward prediction errors engage the nucleus accumbens and motivate learning. *Proceedings of the National Academy of Sciences*, 1–6.
[3] Cheung, V. K. M., Harrison, P. M. C., Meyer, L., Pearce, M. T., Haynes, J.-D., & Koelsch, S. (2019). Uncertainty and Surprise Jointly Predict Musical Pleasure and Amygdala, Hippocampus, and Auditory Cortex Activity. *Current Biology*, *29*.
[4] Loui, P., Wessel, D. L., & Kam, C. L. H. (2010). Humans papidly learn grammatical structure in a new musical scale. *Music Perception*, *27*, 377–388.
[5] Pearce, M. T., & Wiggins, G. A. (2012). Auditory Expectation: The Information Dynamics of Music Perception and Cognition. *Topics in Cognitive Science*, *4*(4), 625–652.

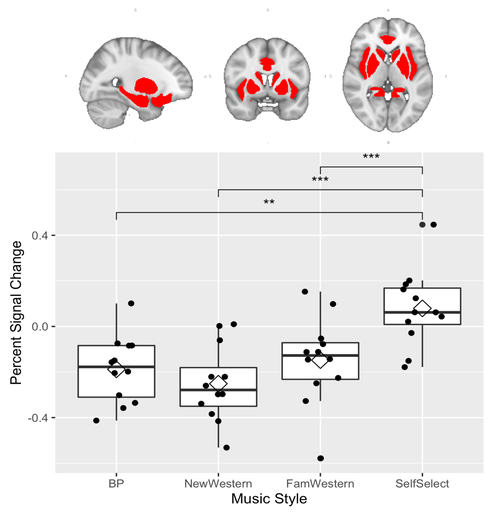
What brain regions become engaged with increased liking and familiarity?

Parametric contrast of on-line liking (red) and familiarity (blue)



Melodies that were liked are associated in the caudate, PCC, STS/MTG
Melodies that were more familiar are associated with activity in the PCC, SMA, STS/MTG.

What is the involvement of the reward network when listening to unheard BP-melodies vs. Western Music?



Before training, B-P melodies are associated with decreased signal change in the reward network, whereas self-selected Western music was associated with greater percent signal change in this network.

Discussion and next steps

- Rewarding responses to unfamiliar B-P melodies increases with repeated exposure and were greater than modified versions
- Before exposure, the reward-network (including NAcc) was deactivated during B-P music listening
- But, more familiar and more rewarding music did engage the reward-network, as well as the SMA and cingulate
- Forthcoming fMRI data after exposure will allow us to test for changes in striatal activity as a result of prediction types and compare these learning-dependent changes with **music anhedonics**