Motor contributions to rhythm perception: a TMS-EEG Study

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Motivation:

The human capacity for beat-based timing perception relies on auditory and motor predictive mechanisms [1,2,3,4]. The dorsal auditory stream, an auditory-motor network routed through parietal cortex, may be causally involved in making these sensory predictions (see Action Simulation for Auditory Prediction, ASAP)[5]. Additionally, the supplementary motor area (SMA) is consistently active during musical and rhythmic tasks[6] and is proposed to support timekeeping during beat anticipation (alongside subcortical structures)[4]. Humans show stronger auditory-motor connectivity compared to non-human primates, which may explain better performance on behavioral beat-based timing tasks[7].

EEG experiments shed light on the neural mechanisms underlying rhythm perception that might not be apparent in behavioral tests. These studies have revealed event-related potentials (ERPs) relating to prediction errors as a result of rhythmic deviations in musical stimuli [8, 9, 2]. Two ERPs, the mismatched negativity (MMN) and P3a, are responses to temporal deviations in patterned stimuli that have been shown to differ between Rhesus macaques and humans when presented with on- or off-beat deviants in isochronous or jittered rhythmic stimuli[10, 11]. However, this EEG paradigm cannot isolate the *causal* role of specific neural structures involved. We seek to manipulate auditory-motor connectivity in human participants to reduce predictive timing and probe the causal role of parietal cortex (dorsal auditory stream), and SMA (motor planning outside the dorsal auditory stream) in beat-based timing.

Methods/Implications:

Participants listen to patterned rhythmic stimuli (following Bouwer et al 2016[10] and Honing et al 2018[11]) before and after downregulatory TMS[12] to parietal cortex, SMA, or sham stimulation. It is expected that the MMN and P3a ERPs will be attenuated after downregulatory TMS to parietal cortex or to SMA. Results will reveal insight into the neural mechanisms underlying human beat-based timing perception, and which differ between human and non-human primates.

References

1. Balasubramaniam, R., Haegens, S., Jazayeri, M., Merchant, H., Sternad, D., & Song, J.-H. (2021). Neural Encoding and Representation of Time for Sensorimotor Control and Learning. *The Journal of Neuroscience*, *41*(5), 866–872. https://doi.org/10.1523/JNEUROSCI.1652-20.2020
2. Koelsch, S., Vuust, P., & Friston, K. (2019). Predictive Processes and the Peculiar Case of Music. *Trends in Cognitive Sciences*, *23*(1), 63–77. https://doi.org/10.1016/j.tics.2018.10.006
3. Proksch, S., Comstock, D. C., Médé, B., Pabst, A., & Balasubramaniam, R. (2020). Motor and Predictive Processes in Auditory Beat and Rhythm Perception. *Frontiers in Human Neuroscience*, *14*, 578546. https://doi.org/10.3389/fnhum.2020.578546
4. Cannon, J. J., Patel, A. D. (2021) How Beat Perception Co-opts Motor Neurophysiology. *Trends in Cognitive Science, 2,* 137–150. https://doi.org/10.1016/j.tics.2020.11.002
5. 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*. https://doi.org/10.3389/fnsys.2014.00057
6. Gordon, C. L., Cobb, P. R., & Balasubramaniam, R. (2018). Recruitment of the motor system during music listening: An ALE meta-analysis of fMRI data. *PLOS ONE*, *13*(11), e0207213. https://doi.org/10.1371/journal.pone.0207213
7. Merchant, H., & Honing, H. (2014). Are non-human primates capable of rhythmic entrainment? Evidence for the gradual audiomotor evolution hypothesis. *Frontiers in Neuroscience*, *7*. https://doi.org/10.3389/fnins.2013.00274
8. Lumaca, M., Trusbak Haumann, N., Brattico, E., Grube, M., & Vuust, P. (2019). Weighting of neural prediction error by rhythmic complexity: A predictive coding account using mismatch negativity. *European Journal of Neuroscience*, *49*(12), 1597–1609. https://doi.org/10.1111/ejn.14329
9. Vuust, P., Ostergaard, L., Pallesen, K. J., Bailey, C., & Roepstorff, A. (2009). Predictive coding of music – Brain responses to rhythmic incongruity. *Cortex*, *45*(1), 80–92. https://doi.org/10.1016/j.cortex.2008.05.014
10. Bouwer, F. L., Werner, C. M., Knetemann, M., & Honing, H. (2016). Disentangling beat perception from sequential learning and examining the influence of attention and musical abilities on ERP responses to rhythm. *Neuropsychologia*, *85*, 80–90. https://doi.org/10.1016/j.neuropsychologia.2016.02.018
11. Honing, H., Bouwer, F. L., Prado, L., & Merchant, H. (2018). Rhesus Monkeys (Macaca mulatta) Sense Isochrony in Rhythm, but Not the Beat: Additional Support for the Gradual Audiomotor Evolution Hypothesis. *Frontiers in Neuroscience*, *12*, 475. https://doi.org/10.3389/fnins.2018.00475
12. Huang, Y.-Z., Edwards, M. J., Rounis, E., Bhatia, K. P., & Rothwell, J. C. (2005). Theta Burst Stimulation of the Human Motor Cortex. *Neuron*, *45*(2), 201–206. https://doi.org/10.1016/j.neuron.2004.12.033