Decoding the intensity and frequency of TMS: A concurrent TMS-fMRI study

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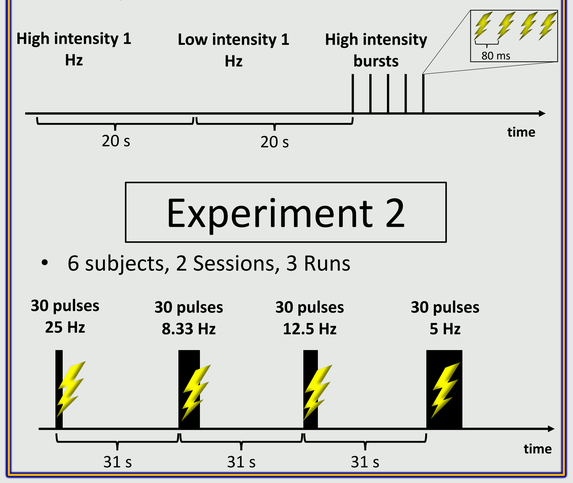
Introduction

- Transcranial magnetic stimulation (TMS) is neuromodulatory technique that can be used to examine the causal role of specific regions in perceptual, motor and cognitive processes.
- However, the mechanism of action by which TMS affects the neural dynamics is still unclear.
- One way to elucidate the changes of brain activity evoked by TMS is to measure the blood-oxygenation level-dependent (BOLD) signal using fMRI.
- In this study, our goal is to examine the changes in activation patterns in regions immediately under the stimulation spot, using multi-voxel pattern analysis (MVPA).

Experiment 1

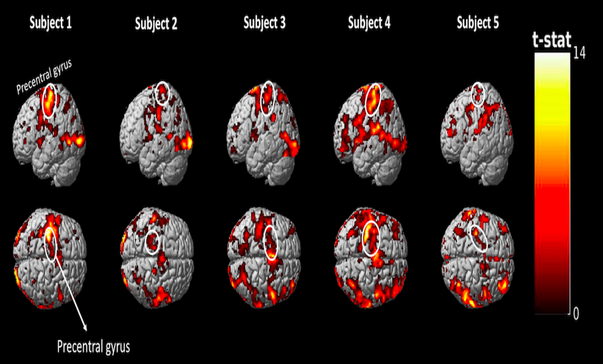
- 5 subjects, 1 Session, 3 Runs



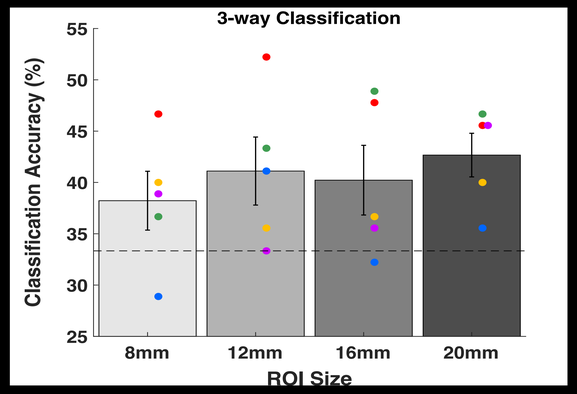
Experiment 2

- 6 subjects, 2 Sessions, 3 Runs

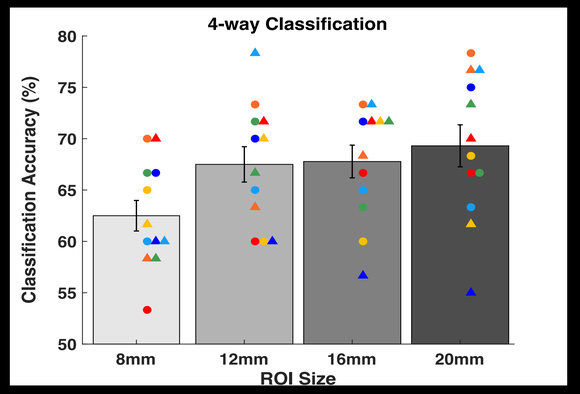
Setup Validation



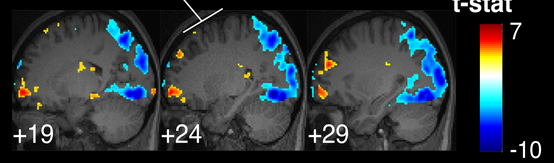
Experiment 1 Results



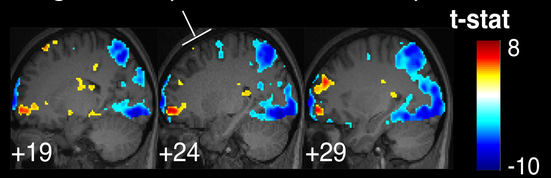
Experiment 2 Results



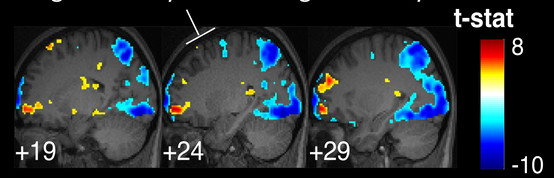
High intensity 1 Hz > Low Intensity 1 Hz

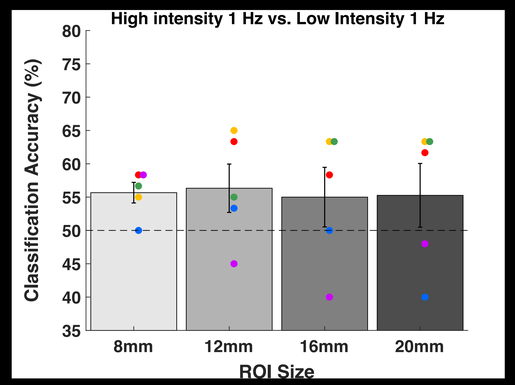


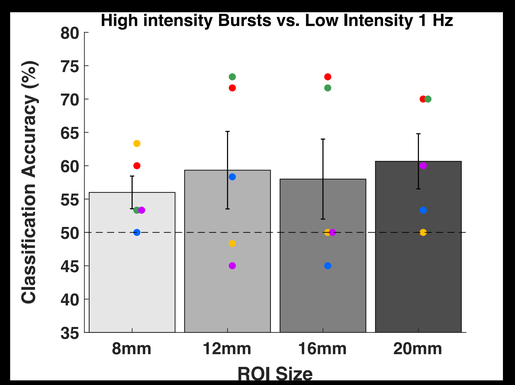
High intensity Bursts > Low Intensity 1 Hz

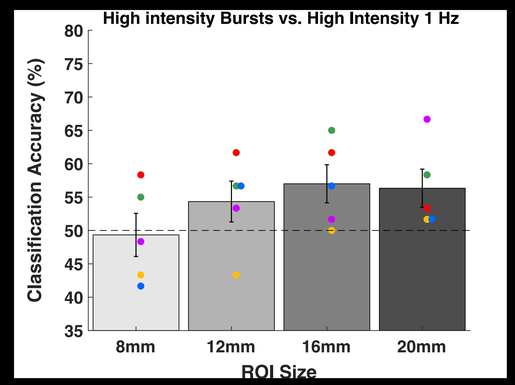


High intensity Bursts > High Intensity 1 Hz









Methods

- We defined spherical regions of interest (ROIs) in areas which are immediately under the coil and performed two types of analysis:
- **Univariate analysis:** Generate activation maps using general linear modeling (GLM) at $p < 0.001$, uncorrected error rate and measure BOLD signal change in defined ROIs.
- **Multivariate analysis:** Use the beta values estimated for each voxel inside the defined ROIs to decode the stimulation type. We used support vector machine (SVM) and Gaussian Naïve Bayes (BNB) classification with leave-one-run-out scheme implemented by The Decoding Toolbox (TDT).
- Mixed effects modeling used to pool the classifier performances from each subject

Conclusions

- In two experiments, we observed that TMS had no effect on overall BOLD activity underneath the coil even when bursts of up to 30 high-intensity pulses were employed.
- On the other hand, both the intensity and frequency of stimulation could be reliably decoded directly underneath the TMS coil.
- These findings suggest that TMS does influence BOLD activity even in the absence of a task but that the TMS effects may differ even for nearby neuronal populations thus producing a complex pattern of activations and deactivations.
- These results suggest that the effects of TMS on the underlying neural tissue may be more complex than previously appreciated but that decoding methods are sensitive to variations in both TMS intensity and frequency.

References

- Bestmann S, Ruff CC, Blankenburg F, Weiskopf N, Driver J, Rothwell JC (2008) Mapping causal interregional influences with concurrent TMS–fMRI. Exp Brain Res 191:383–402.
- Ruff CC, Driver J, Bestmann S (2009) Combining TMS and fMRI: From “virtual lesions” to functional-network accounts of cognition. Cortex 45:1043–1049 Available at: http://dx.doi.org/10.1016/j.cortex.2008.10.012.

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