Effects of Repetitive Transcranial Magnetic Stimulation on the Human Brain Revealed by Intracranial Electrocorticography

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Introduction

Repetitive transcranial magnetic stimulation (rTMS) is a noninvasive technique for modulating the regional excitability of the brain. The remote effects of rTMS across brain networks are poorly understood due to limited spatiotemporal resolution of currently available tools.

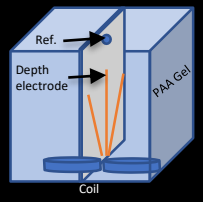
Here, we evaluate the safety of simultaneous rTMS-electrocorticography (ECoG) experiments using a gel-based phantom brain. Next we present rTMS experiment results in human subjects with intracranial electrodes.

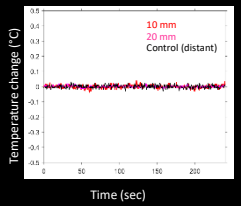
We hypothesize 1) rTMS will have focal effects at remote sites as opposed to global effects, and 2) rTMS will induce frequency specific changes.

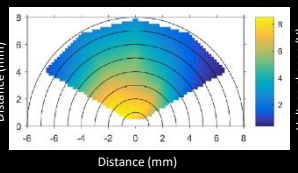
Methods

Safety Testing

Gel-based phantom experiments were performed prior to human testing to evaluate safety of TMS on intracranial electrodes.







1. Temperature change was < 0.1° C at 10 mm from the coil surface
2. No displacement of saline suspended electrode occurred 5 mm from coil at 100% intensity
3. Induced voltage at 100% output is below safety threshold[1,2]

Based on this safety data the TMS-ECoG protocol was approved by the University of Iowa Institutional Review Board

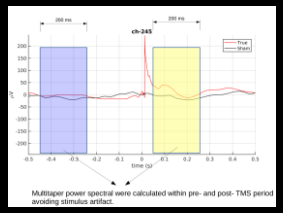
Functional connectivity-guided stimulation targets

Anatomical reconstructions of electrode locations were performed. Here, the hippocampus depth electrode location was used as a seed ROI to derive a connectivity map using a pre-implantation resting state scan, which was overlaid onto the cortical surface in Brainsight[3] and used to set a TMS target.

ECoG Processing

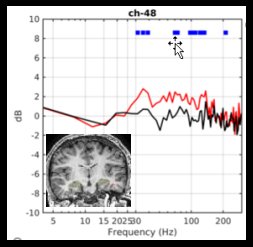
The brief period of TMS-induced artifact was excluded from analyses

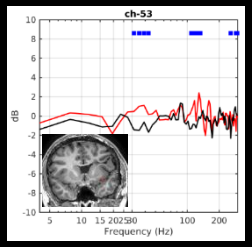
ECoG responses in active and sham conditions were compared at each stimulation site.



Results

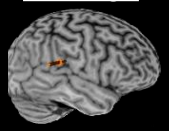
6 patients underwent rTMS-ECoG with no adverse events



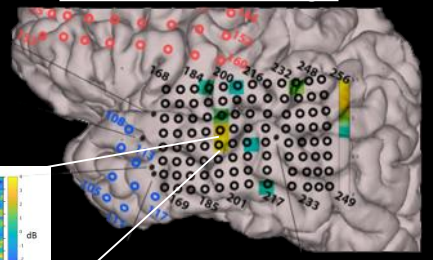


Hypothesis 1: rTMS produced focal responses at remote sites. For example, 2 of 170 electrodes showed a significant elevation in high gamma after parietal stimulation shown in the methods, within 1 cm of the hippocampal target

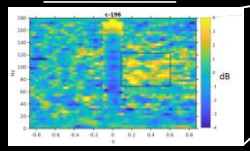
rTMS target



rTMS-induced ECoG changes



Active - Sham



Low frequency rTMS over right superior temporal gyrus caused focal high gamma (>40 Hz) activity in the contralateral hemisphere.

Hypothesis 2: Induced ECoG changes did not vary with rTMS stimulation frequency. rTMS induced high gamma (>40Hz) activity at remote sites in active, but not sham, conditions at both low (0.5 Hz) and high (10 Hz) frequencies

Discussion

Simultaneous rTMS-ECoG is safe in humans with intracranial electrodes.

We observed spatially-specific ECoG changes at remote sites, where ECoG changes were characterized by elevated high gamma (>40 Hz) activity in both low (0.5 Hz) and high (10 Hz) frequency rTMS conditions as opposed to frequency-specific change. Ongoing efforts are focused on removing TMS-induced artifacts from the ECoG signal.

rTMS-ECOG provides a novel tool for evaluating the remote effects of TMS that may lead to more effective therapies.

References

1. Greenlee JD, Oya H, Kawasaki H, et al. A functional connection between inferior frontal gyrus and orofacial motor cortex in human. J Neurophysiol. 2004;92(2):1153-64.
2. Matsumoto R, Nair DR, Lapresto E, Bingaman W, Shibasaki H, Lüders HO. Functional connectivity in human cortical motor system: a cortico-cortical evoked potential study. Brain. 2007;130(Pt 1):181-97
3. Brainsight® TMS, Rogue Research Inc., Montreal, QC Canada.