

TMS and Imaging

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Neuropsychiatry: Disorders of Connectivity

The diagram illustrates a multi-level model of neuropsychiatry. On the left is a 3D visualization of neural connectivity. On the right, a vertical stack of boxes represents levels of organization: genes, molecules, cells, synapses, brain areas, circuits/systems, organ, behavior/cognition/emotion, clinical syndromes, population dynamics, and cultural/religious. External influences are shown as arrows pointing to these levels: Medications to genes/molecules, Brain Stim to circuits/systems, and Behavioral Rx to behavior/cognition/emotion.

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Functional Neuroimaging Methods

Electrophysiologic: EEG/MEG

Metabolic and/or Vascular

- PET/SPECT
- fMRI
- NIRS

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2 Axis of Resolution... or 3?

This 3D plot shows the trade-off between temporal resolution (y-axis, from milliseconds to years), spatial resolution (x-axis, from molecular to whole brain), and cost (z-axis). Techniques are plotted as blocks: CT/MRI (high spatial, low temporal, high cost), PET/SPECT (high spatial, low temporal, high cost), fMRI (high spatial, low temporal, low cost), EEG/MEG (low spatial, high temporal, low cost), and Single-cell recording (low spatial, high temporal, high cost). Other methods like Microstimulation and Inference are also indicated.

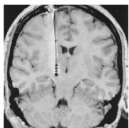


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3rd Axis: Causality

The first diagram shows a causal model where A and X are parents of B (A → B, X → B). The second diagram shows a causal model where A causes X (A → X), and B is an epiphenomenon of X (X → B), labeled as 'Epiphenomenon!!'.

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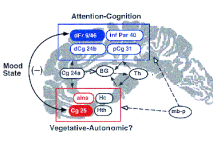

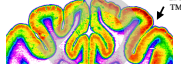
Brain Stimulation - Neuromodulation

| | | |
|--|--|---|
| <p>Invasive</p> <p>Deep Brain Stimulation (DBS) Vagal Nerve Stimulation (VNS) Epidural Stimulation (ES)</p>  | <p>Convulsive</p> <p>Electroconvulsive Therapy (ECT) Magnetic Seizure Therapy (MST)</p>  | <p>Noninvasive</p> <p>Transcranial Magnetic Stimulation (TMS) Transcranial Direct Current Stimulation (tDCS)</p>  |
|--|--|---|

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Neuromodulation: Need to know...

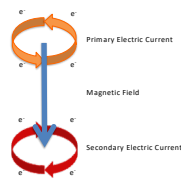

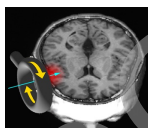
| | | |
|--|--|---|
| <p>The circuit(s)</p>  <p>Mayberg et al., 2010</p> | <p>The target(s)</p>  <p>Koenigs et al., 2009</p> | <p>Direction of modulation</p>  <p>20 Hz TMS Valero-Cabré et al., 2008</p> |
|--|--|---|

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Transcranial Magnetic Stimulation

1831 Faraday's Electromagnetic Induction Anthony Barker 1984

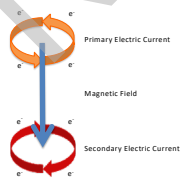

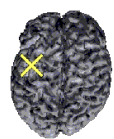
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Transcranial Magnetic Stimulation

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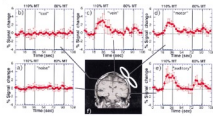
TMS Applications

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| <p>Clinical: Diagnostics (motor system disorders) (pre-surgical mapping)</p> | <p>Measure brain activity</p> <p>Change brain activity</p> | <p>Clinical: Therapeutics (circuit-based pathologies)</p> <p>MDD Acute Migraines OCD Smoking Cessation</p> |
|--|--|--|

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TMS limitations

- Where to stimulate? 
- What does TMS do to the Brain? Only behavioral measures? Beyond the black box approach. 

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Functional Neuroimaging vs. TMS

| Neuroimaging | TMS |
|---|-------------------------------------|
| Correlational (cannot establish causality) | Interventional (and thus causal) |
| Measures whole-brain activity | Measures behavioral outcomes |

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Why Combine TMS and Neuroimaging?

- Plan, guide and document localization of TMS → Neuroimaging BEFORE TMS
- Develop circuit predictor biomarkers → Neuroimaging DURING TMS
- Measure neurobiological effects of TMS, beyond cognitive and behavioral outcomes → Neuroimaging AFTER TMS

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TMS-fMRI vs PET/EEG

- Vs. TMS-PET
 - MRI: better spatio-temporal resolution
 - MRI: no need of radioligands (better potential for repeated measures)
 - PET: neurotransmitter dynamic or more complex biological process
- Vs. TMS-EEG
 - MRI: better spatial resolution
 - EEG: better temporal resolution
 - MRI: ability to measure subcortical structures with greater detail (anatomy)
 - EEG: diversity of physiological measures in frequency and time domain

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Anatomy: Therapeutic Targets

OCD Target: DMPFC/pre-SMA

MDD Target: DLPFC

Smoking Cessation: VLPFC/Insula

Migraine Target: Occipital pole

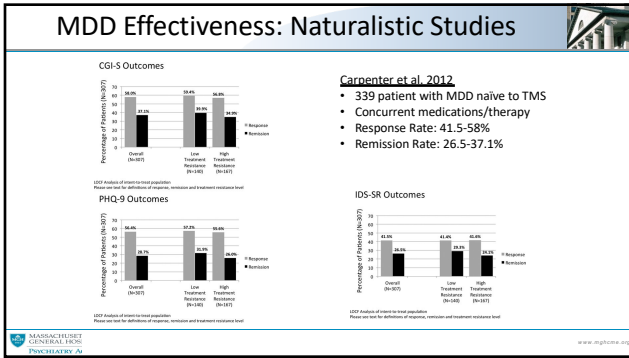
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Localization: Stereotactic Neuronavigation

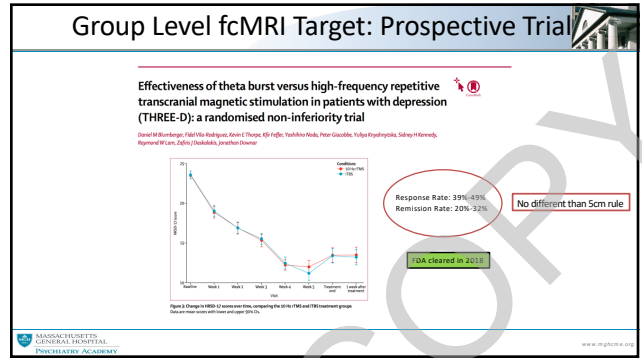
Task fMRI

fcMRI

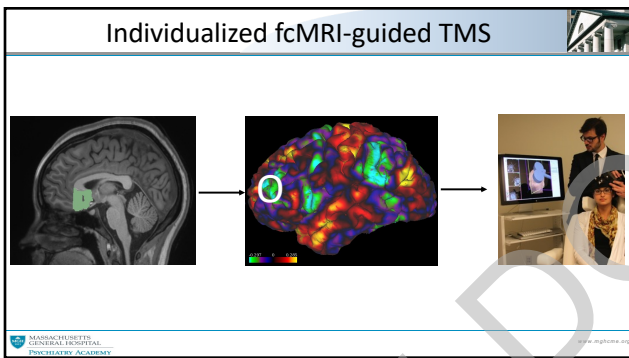
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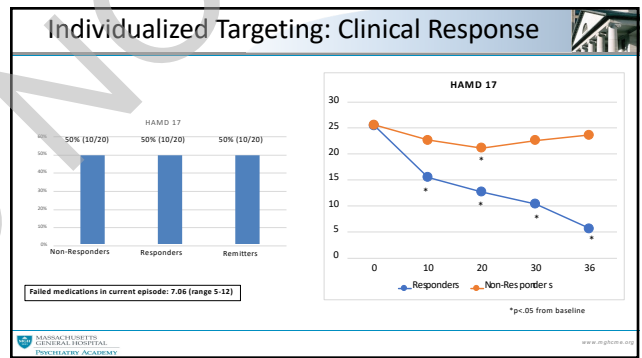
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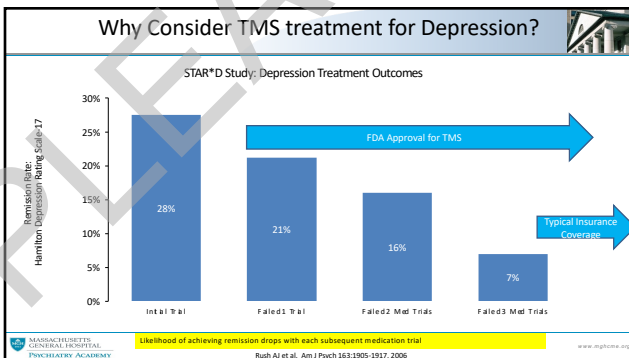
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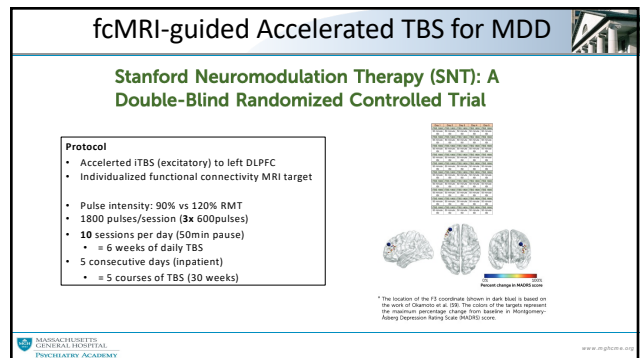
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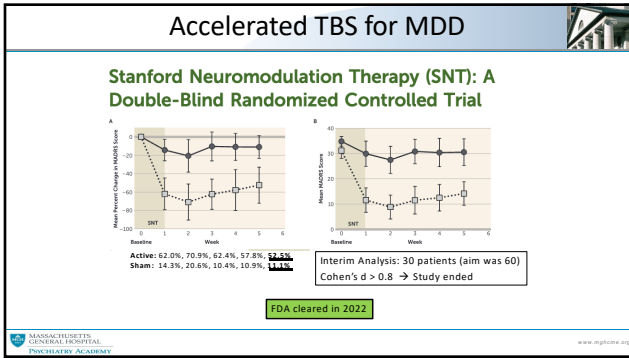
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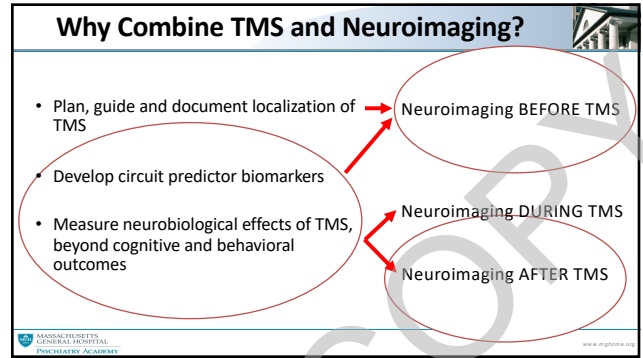
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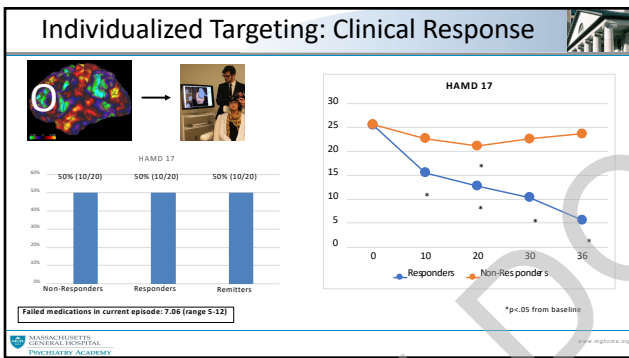
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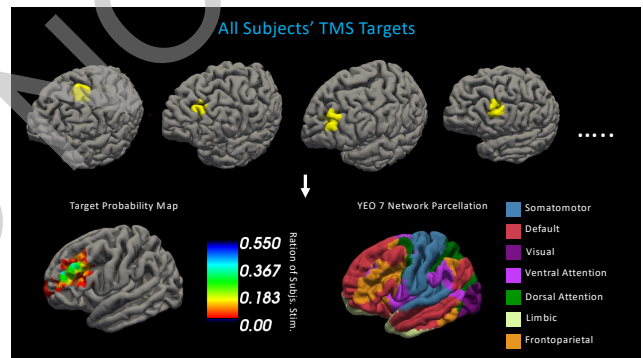
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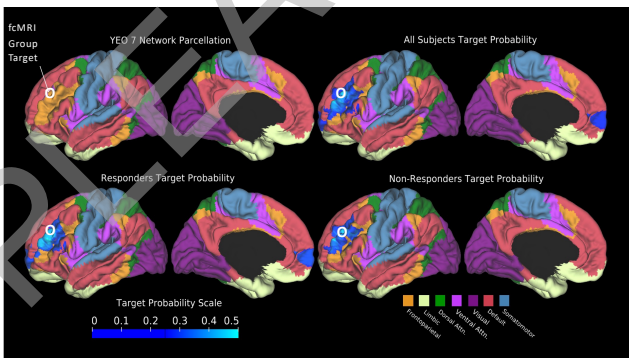
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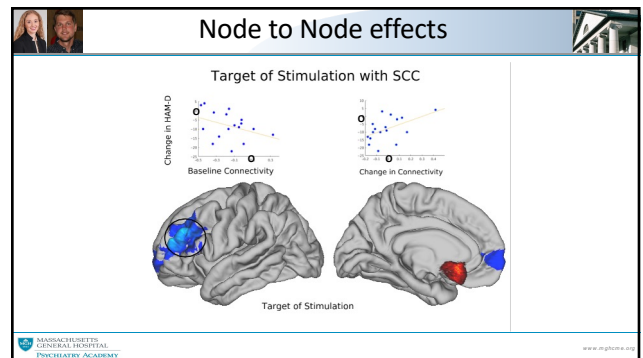
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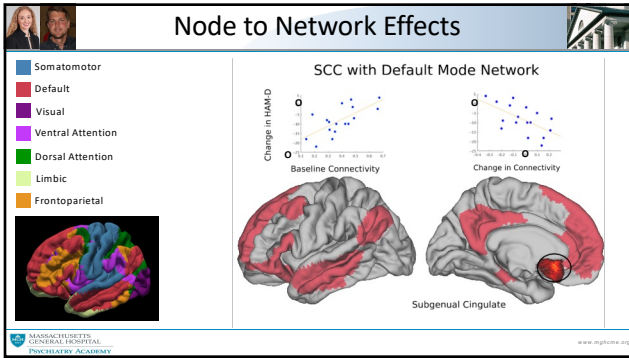
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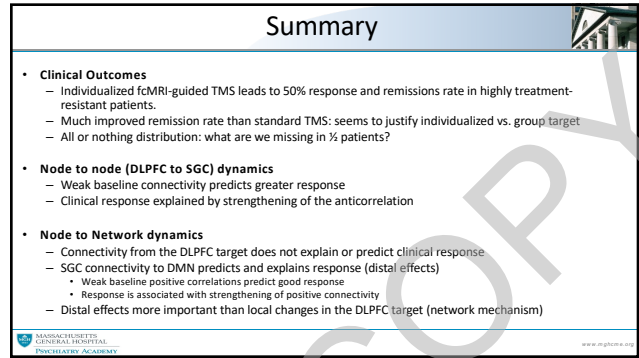
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