Towards Enhancing Meditation with Focused Ultrasound Neuromodulation in Experts

Joshua A. Cain[1], Geena Wang[1] ,Tracy Brandmeyer[1], Ninette Simonian[1], Jay Sanguinetti[2], Shinzen Young[2], Matthew Sacchet[3], and Nicco Reggente[1]

[1] Institute for Advanced Consciousness Studies, Santa Monica, Los Angeles, USA , [2] Center for Consciousness Studies, University of Arizona, Tucson, USA, [3] Meditation Research Program, Department of Psychiatry, Harvard Medical School, Boston, MA USA

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SHORT ON TIME? HERE'S THE SUMMARY

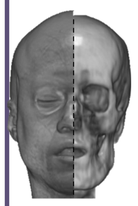
Our overarching goal is to reliably induce deep and beneficial states of meditation with neuromodulation. Here, we target three candidate regions of the brain: Posterior cingulate cortex (PCC), Caudate, and Insula via non-invasive focused ultrasound (FUS) neuromodulation while probing the quality of meditation in experts. PCC and, especially, Caudate FUS appear effective.

INTRODUCTION

Consistent meditation benefits those with affective disorders [1], however aspiring practitioners often struggle to maintain a regular practice [2]. **Focused ultrasound (FUS)** neuromodulation can be used to ***non-invasively*** target brain regions (e.g., those related to achieving mindfulness) with **unmatched [4] (millimeter scale) spatial precision [3] *anywhere in the brain***.

Individualized Skull Extraction and FUS simulations for each session/subject

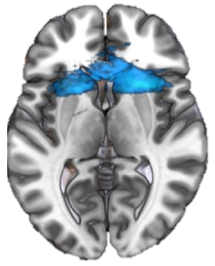
Simulations of FUS energy distribution



PCC

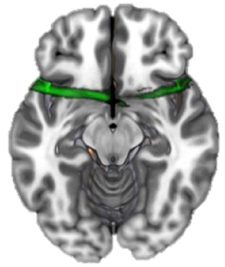
The ***Posterior Cingulate Cortex (PCC),*** a key component of the default mode network (DMN), is linked to self-referential thinking [5] and "effortless awareness" [6] . Its activity is reduced during mindful meditation [7].

Caudate



Caudate damage may result in "Athymhormia," a condition described as mental emptiness with loss of motor and affective motivation but without anxiety or pain [8]. There exist clear similarities between this and mindfulness.

Insula

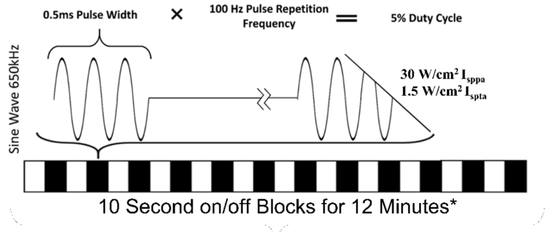


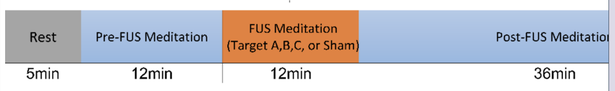
The ***Insula*** appears to mediate emotional regulation and interception [9] and may play a particular role in particular meditative techniques (e.g., body scanning)[10] .

Does FUS disruption of the PCC, Insula, or Caudate result in changes in meditative depth, intensity, physiology, or subjective quality during a 1-hour meditation in expert meditators?

METHODS

Expert Vipassana meditators (***n*=36 total** (15 shown here); **5+ years experienc**e including on retreats) participated in 4 total sessions to compare the effects of ultrasound stimulation applied (for 12 minutes) to **3 targets + 1 sham** (one site per session) during a **1-hour long vipassana meditation**



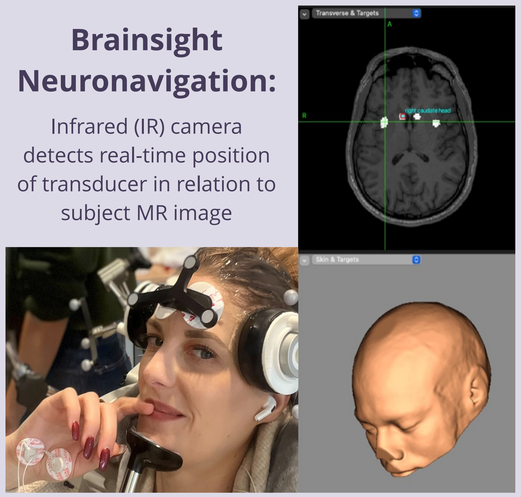


"Online" (During Meditation/FUS) Variables:
Self-reported meditative "depth" and subjective "intensity" (probed every ~4 minutes)
Physiological changes (GSR, EMG, HR, RR)

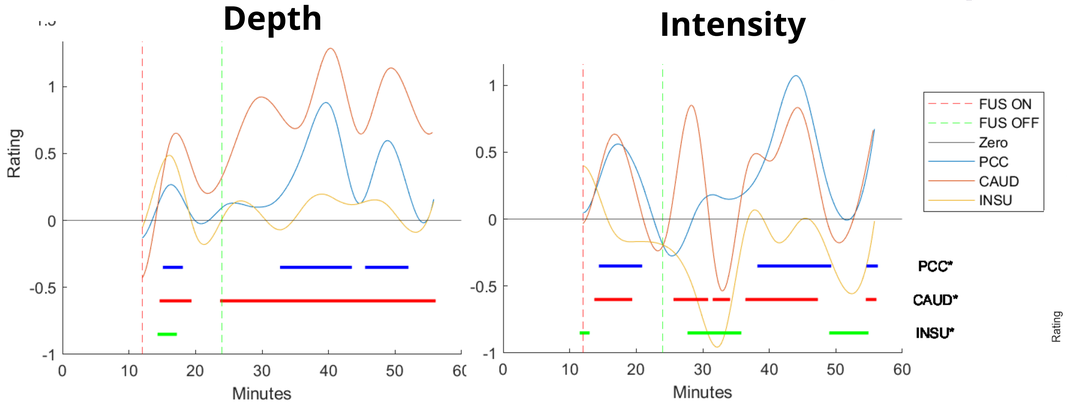
"Offline" (After Meditation/FUS) Variables:
Pre- and post-meditation questionnaire to assess altered subjectivity induced by stimulation

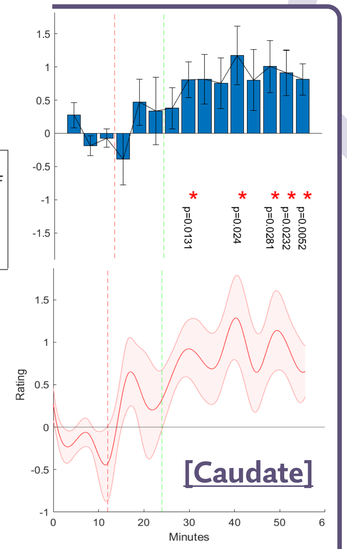
Brainsight Neuronavigation:

Infrared (IR) camera detects real-time position of transducer in relation to subject MR image

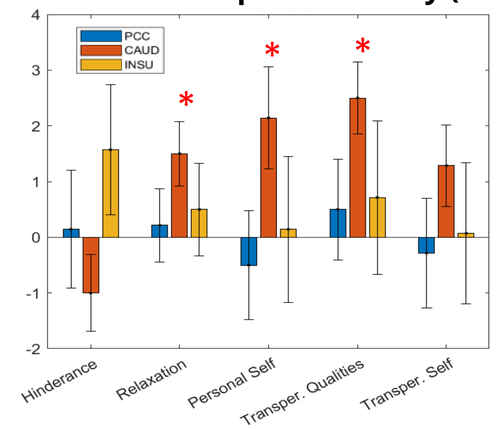


RESULTS (Difference from Sham; N=15)





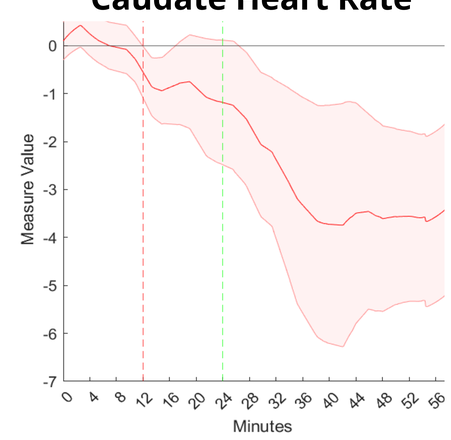
Meditation Depth Inventory (MEDI)



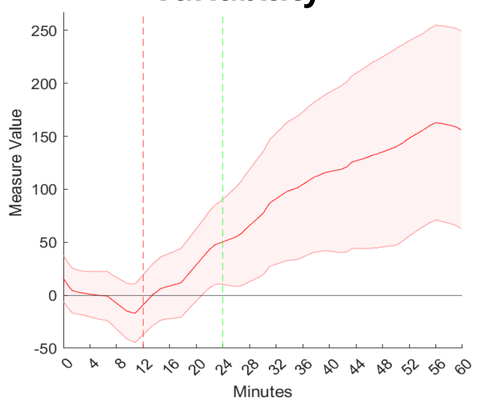
Other Interesting Findings in Post-Questionnaire

1. *"How likely was today Sham Stimulation?"*
   No Effect of Condition! p > 0.05
2. *"I Lost All Sense of Ego"*
   Increase in Caudate Condition, p = 0.0068
3. *"I Felt Love, Surrender, Connection."*
   Increase in Caudate Condition, p = 0.0081
4. *"Total Mood Disturbance" (Profile of Mood States)*
   Decrease in Caudate Condition, p = 0.011

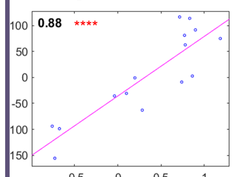
Caudate Heart Rate



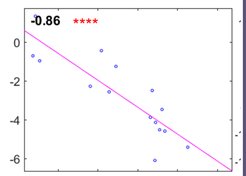
Caudate Heart Rate Variability



Physiology Correlates with Depth! [Caudate Specific]



HRV and Depth r = 0.88 p < 0.0001



HR and Depth r = -0.86 p < 0.0001