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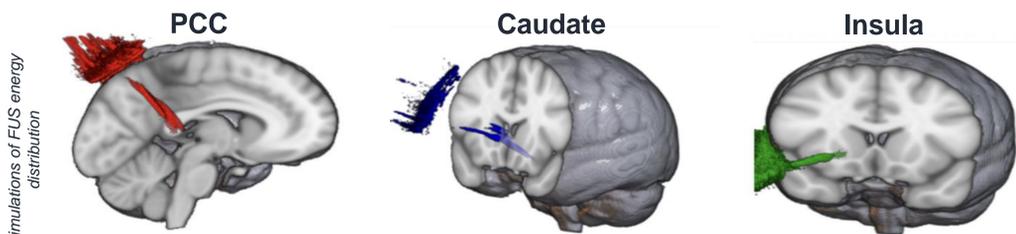
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SHORT ON TIME? HERE'S THE SUMMARY

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 Caudate FUS appears 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**.



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 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.

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.

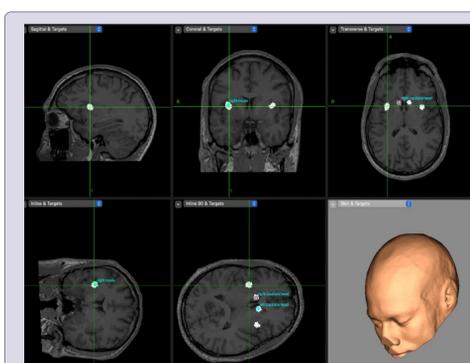
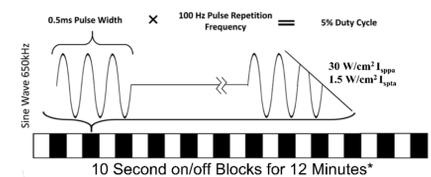
Does FUS disruption of the PCC, Insula, or Caudate result in changes in meditative depth, intensity, physiology, or subjective quality during a 1-hour meditation in expert meditators?

We predict:

- Increase in depth** in PCC and Caudate condition compared to sham
- Decrease in depth** in Insula condition compared to sham
- Increase in subjective intensity** (any change in subjectivity) in all stimulation conditions compared to sham

METHODS

Expert Vipassana meditators ($n=6$; 10+ years experience 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



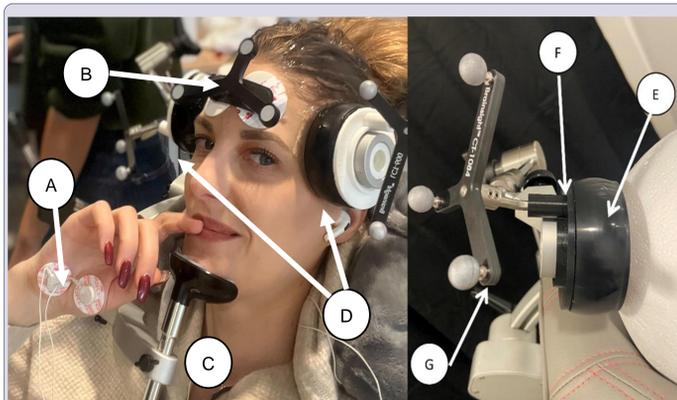
Brainsight Neuronavigation: Infrared (IR) camera detects real-time position of transducer in relation to subject MR image

"Online" (During Meditation/FUS) Variables:

- Self-reported meditative "depth" and subjective "intensity" (probed every ~4 minutes)
- Physiological changes (GSR, EMG, HR, RR)

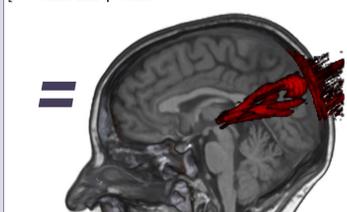
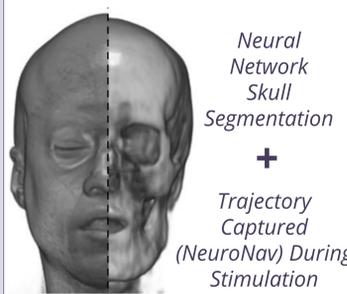
"Offline" (After Meditation/FUS) Variables:

- Pre- and post-meditation questionnaire to assess altered subjectivity induced by stimulation



- A: Physiological Sensors** – measures heart rate, respiration, GSR, EMG
- B: Subject Tracker** – allows for real-time tracking of subject head/brain position
- D/E: Brainsonix Transducer (source of ultrasound)** – Emits ultrasound in a cone that tapers to a focal point of high energy over a target region
- F: 3D printed custom-made attachment** – Integrates Brainsight with FUS
- G: Transducer-tracking fiducial** – Used to position center of ultrasound transducer over target region inside the brain

Computational Modelling with Real Subject Skull and Transducer Location/Trajectory

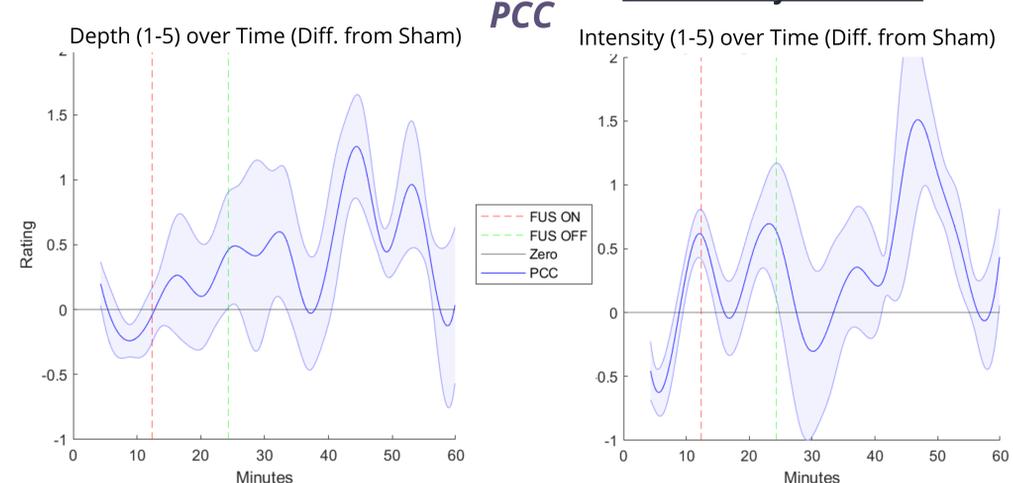


A First: Accurate Maps of FUS in-brain during Stim.

RESULTS

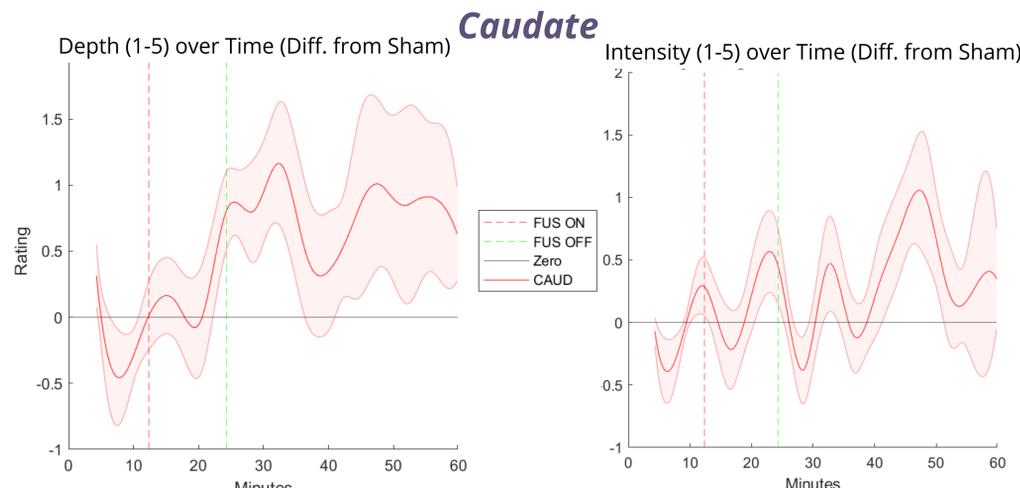
(Preliminary $n = 6$)

NOTE: Report scale is from 1-5 and subtracted from sham!



- Increase in Depth esp. 20-30 min after FUS (~50% increase)**
- Felt change in Subjectivity 20-30 min after FUS**

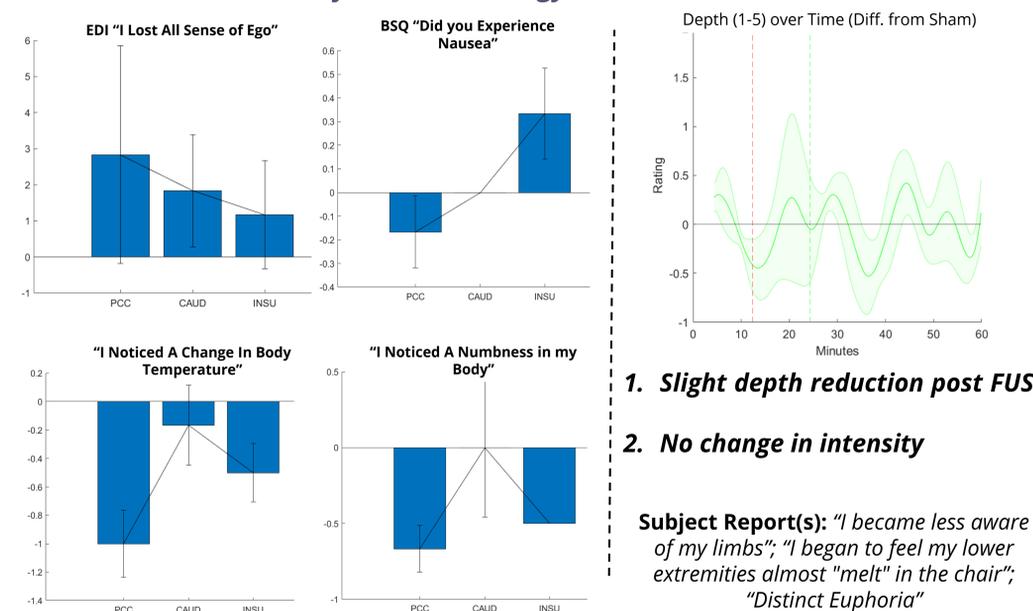
Subject Report: "Distinct Enhancement of Meditation. There was a certain effect compared to other trials. Some ego dissolution and subtle, but noticeable, lessening of bodily boundaries"



- Increase in Depth throughout period after FUS**
- Change in subjectivity 20-30 min after FUS**

Subject Report: "This was it! After about 5 minutes of stimulation, I felt like I was just in the meditative state and I didn't even need to try. I didn't even have thoughts that I needed to ward off in order to get a glimpse of the nothingness experience. I just was."

Post-Assessment of Phenomenology



Subject Report(s): "I became less aware of my limbs"; "I began to feel my lower extremities almost "melt" in the chair"; "Distinct Euphoria"

CONCLUSION

- Average increases in "Intensity", confident subject free response, and trends in phenomenology assessment results are **consistent with effects on subjectivity from FUS**.
- Average increases in reported "Depth" during Caudate and PCC stimulation compared to a sham control is consistent with the **potential of FUS as a method for inducing deep states of mindfulness**.

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