Transcranial Ultrasound for Brain Stimulation: Effects on Mood

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Summary

1929: Ultrasound stimulates excitable tissue [1].

1950's-1970's: ultrasound can reversibly suppress or excite neuronal activity in animals; replicated recently with more sophisticated methods [2].

2000's: Ultrasound penetrates the human skull. Low-intensity transcranial ultrasound can reach deep brain structures and can be focused for high spatial resolution without damaging bioeffects [3].

Recently: Hameroff et. al [4] reported that transcranial ultrasound (TUS) affected pain and mood in chronic pain patients. This was the first use of low-intensity transcranial ultrasound in humans.

Here, the first demonstration that transcranial ultrasound affects mental states in healthy human participants is reported.

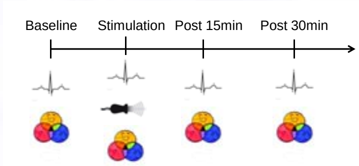
TUS delivered to the right frontal cortex increased positive affect, replicating effects in the transcranial magnetic stimulation (TMS) literature in healthy controls [5].

Methods

Experiment 1

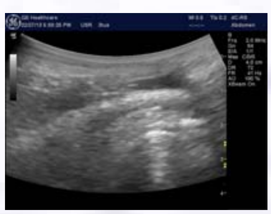
- Aim: Determine optimal parameters
- 2 MHz vs 8 MHz; 15 seconds stimulation
- General Electric LOGIQe ultrasound
- Right frontal cortex, F8 (10-20 system)
- Between subjects, non-blind, n = 29
- Measured mood (VAMS and PANAS)
- Measured EKG (RSA, HR)
- Thermal index (TI) and mechanical index (MI) were monitored. Maximum acoustic output was 152 mW/cm^2 (20% of FDA limit)

- Four sessions
- EKG at each session
- Mood scales (faces in figure) at each session



Experiment 2

- Aim: Rule out expectation (placebo)
- 2 MHz vs Sham, 30 seconds stimulation
- General Electric LOGIQe ultrasound
- Right frontal cortex, F8 in 10-20 system
- Between subjects, double blind, n = 33
- Measured good (VAMS and PANAS)
- Measured EKG (RSA, HR)

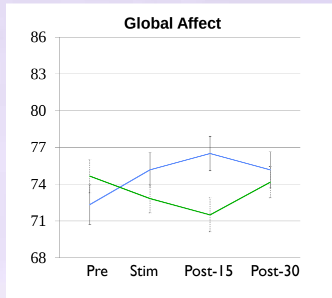


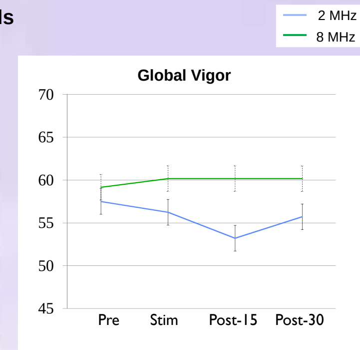
An ultrasound image from the right frontal cortex. Skull can be seen towards the top as a thick horizontal line. Brain tissue can be seen in the image, showing that the skull was penetrated with ultrasound.

Administering ultrasound to the right frontal cortex with the GE LOGIQe transducer.

Results

Experiment 1: 2 MHz vs 8 Mhz – 15 seconds

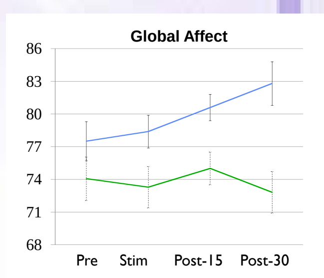


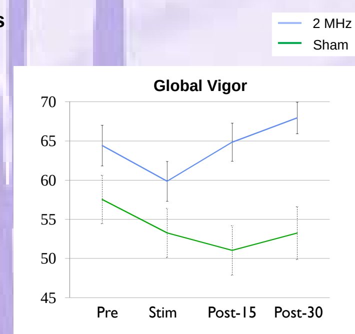


- A significant interaction for Probe Type by Session. There was a significant increase for 2 Mhz relative to baseline and a significant decrease for 8 MHz, suggesting 2 Mhz is optimal for stimulation.
- 5/14 participants reported positive mood effects in post-questioning; 2/15 reported positive effects in 8 Mhz condition.

- No significant interaction for Probe Type by Session.
- No effects with PANAS or EKG measures (resting HR, RSA) for either Global Affect or Global Vigor.

Experiment 2: 2Mhz vs Sham – 30 Seconds





- A significant interaction for Probe by Session. There was a significant increase for 2 Mhz relative to baseline at Post-15 and Post-30; no change for Sham.
- 7/17 participants reported positive mood effects in post-questioning in 2Mhz; 0/16 in placebo reported a positive change; 1/16 in placebo reported a negative change.

- A significant interaction for Probe by Session. Relative to baseline, there was a significant increase at Post-30 for 2 Mhz. Post-15 and Post-30 were significantly below baseline for Sham. This shows that 2 Mhz to right frontal cortex increase vigor after 30 minutes.
- No effects with PANAS or EKG measures (resting HR, RSA) for GA or GV.

Discussion

Transcranial ultrasound (TUS) delivered to the right frontal cortex in healthy controls has positive effects on mood.

Replicated previous findings [4], showing that ultrasound can modulate mood, and also replicates TMS stimulation to the same area [5].

Our findings suggest that low-intensity TUS could be a safe, non-invasive brain stimulation method alongside TMS and tDCS.

TUS offers advantages over established methods. It can be focused for high spatial resolution, reach deep brain structures, and does not cause sensations on the skin

References

[1] Harvey. (1929) *Am J Physiol*, 91(1):284-90

[2] Tyler (2010) *The Neuroscientist,* 17(1):25-36

[3] Clement & Hynynen (2002) *Phys Med Biol*, 47(8):1219-36

[4] Hameroff et al., (2012). *Brain Stim*, 6(3):409-415

[5] Pascual-Leone et al (1996) *Neurology*, *46*(2), 499-502.

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