Ultrasound neuromodulation

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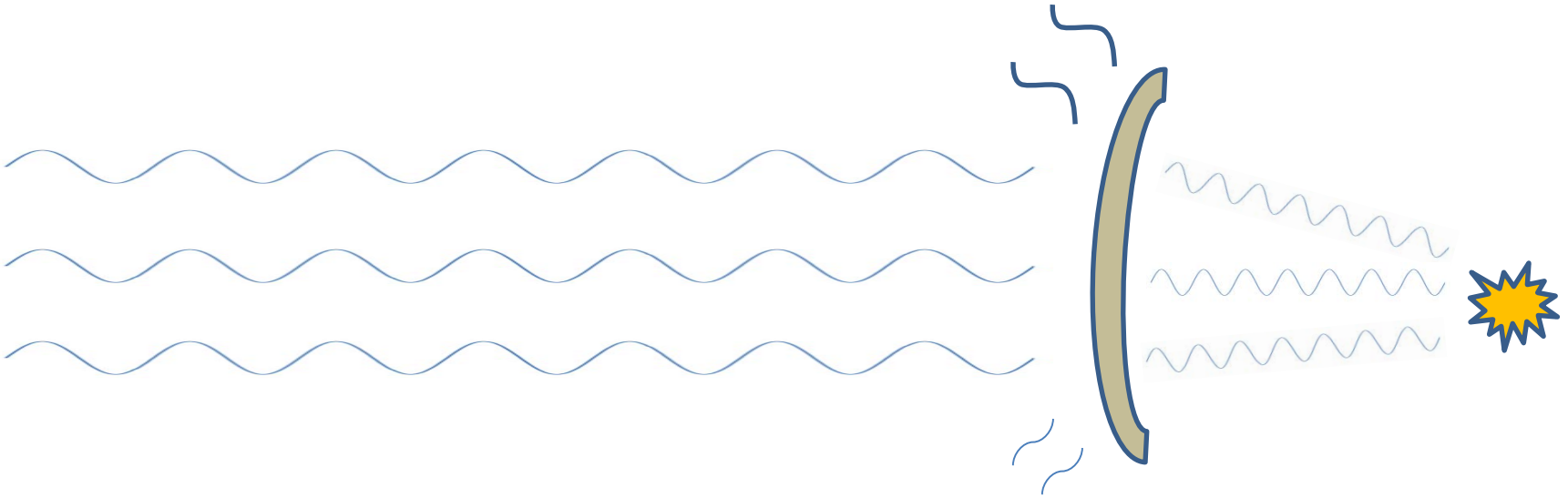
Disclosures

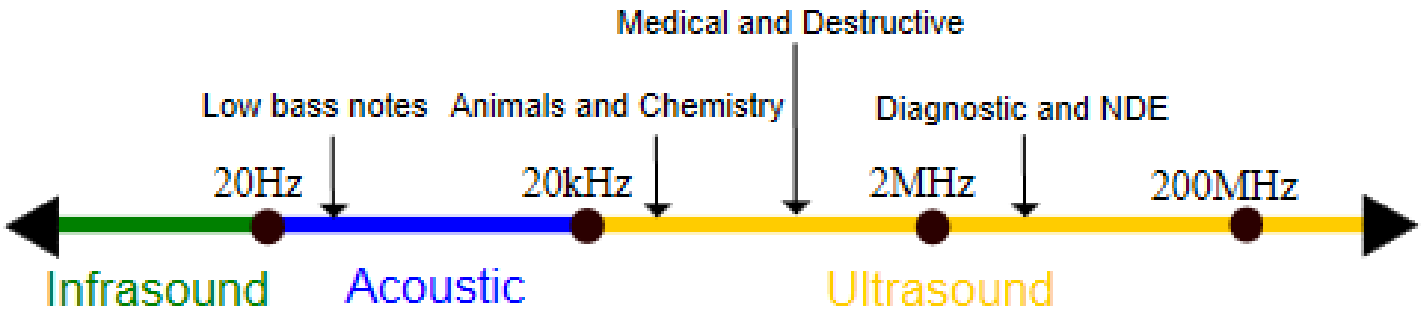
- FUS for brain : Investigational in U.S.

InSightec
Bringing therapy into focus

FOCUSED ULTRASOUND SURGERY FOUNDATION

Ultrasound

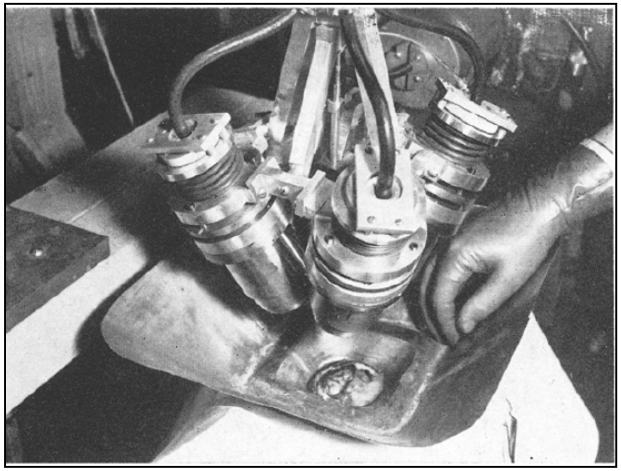



Medical and Destructive
Low bass notes
Animals and Chemistry
Diagnostic and NDE
20Hz
20kHz
2MHz
200MHz
Infrasound
Acoustic
Ultrasound


TWIN A

Production of reversible changes in the central nervous system by ultrasound

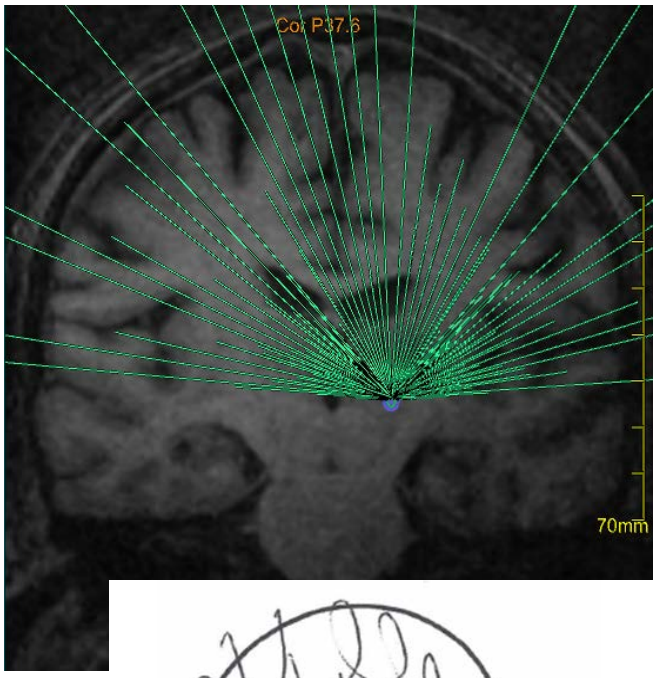
- WJ Fry. Science 1958

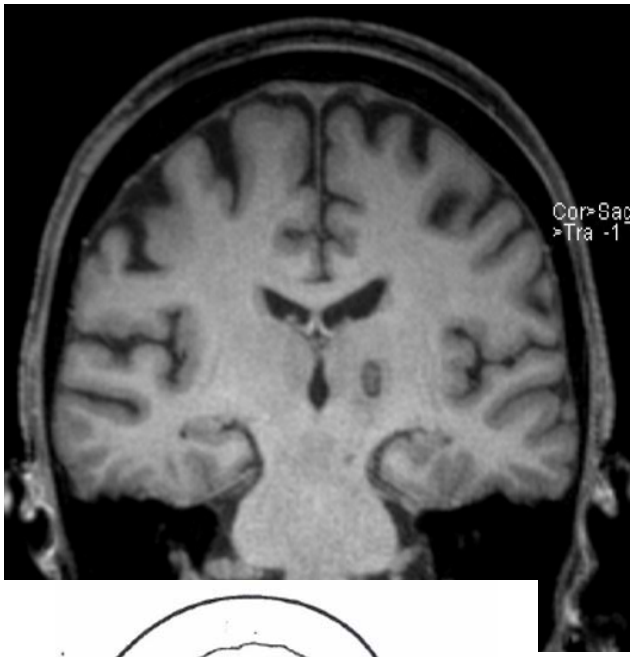


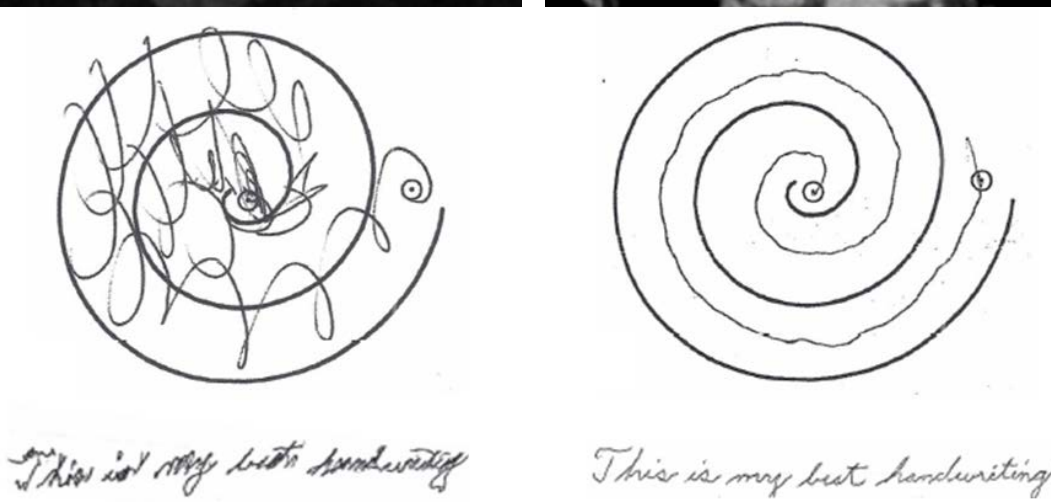
The possibility, already realized in animals, of making reversible lesions, the effects of which will pass off in 5-10 minutes while the patient is being observed … it will be relatively simple matter to change the parameters and buzz the site for the production of an enduring lesion. It should be possible for us to report on the first human cases at the next meeting of this society.

-- Russell Meyers at the Harvey Cushing Society, 1957

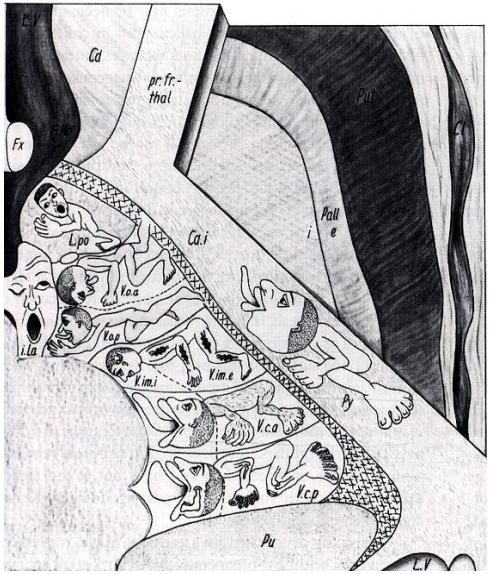
Focused Ultrasound

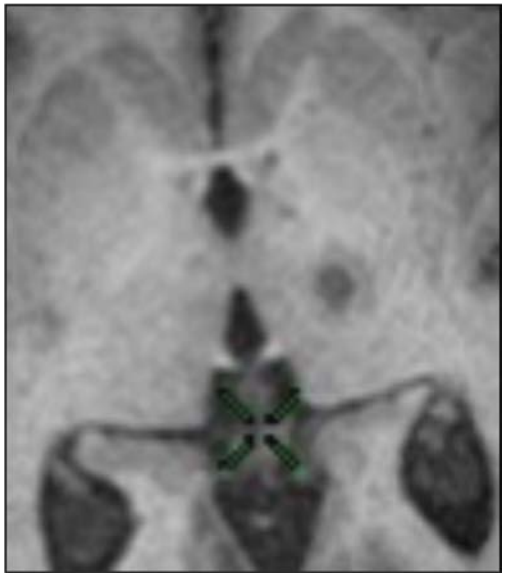






HIFU Neuromodulation





Subject	Sonication	Intraop paresthesia	Adjustment (mm)
1	8	50°	1.5
3	11	~50°	1.4
6	9	54°	1.0
8	16	46°	2.1, 1.0
14	5	46°	1.0

Acoustic effects at the focus

1. Thermal
   - Frictional energy btwn molecules ~ pressure/frequency of US pulse
   - Tissue ablation
2. Mechanical
   - Sustained cavitation – microbubbles oscillate (*BBB disruption*)
   - Inertial cavitation - microbubbles burst (*Sonothrombolysis*)
   - Neuromodulation

- HIFU > 1000 W/cm^2
  - can induce coagulative necrosis and cavitation
- LIFU: pulsed at 30-500 mW/cm^2
  - Nonthermal, mechanical

LIFU Neuromodulation, cortex

Neuron
Neurotechnique

Transcranial Pulsed Ultrasound Stimulates Intact Brain Circuits

Yusuf Tufail,[1] Alexei Matyushov,[1] Nathan Baldwin,[2] Monica L. Tauchmann,[1] Joseph Georges,[1] Anna Yoshihiro,[1] Stephen I. Helms Tillery,[2,3,4] and William J. Tyler[1,2,*]
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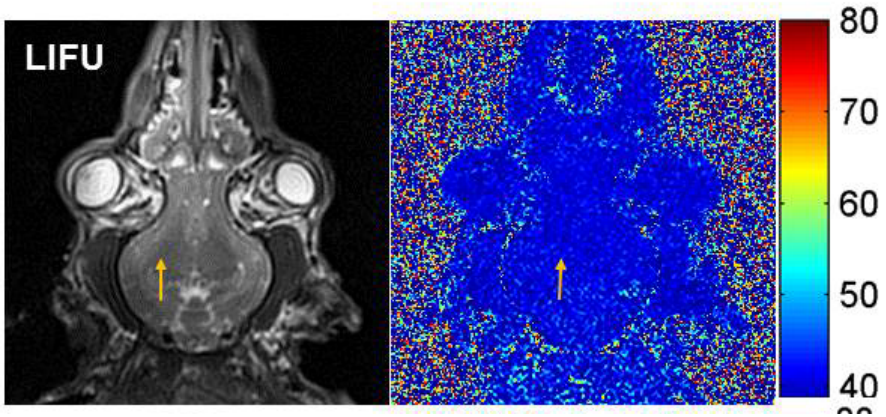
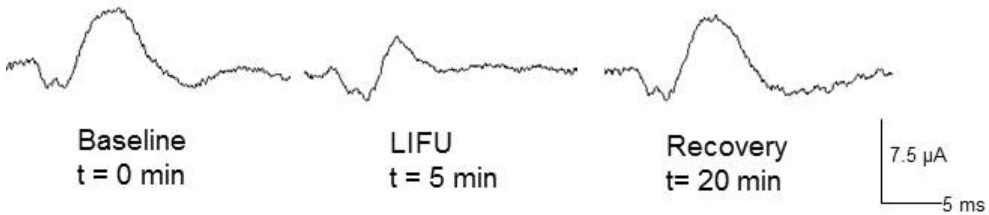
DOI 10.1016/j.neuron.2010.05.008

LIFU Neuromodulation

Reference	Species	Target	Response	Frequency	Intensity
Tufail et al	Rat	Somatomotor cortex	Tail flick, whisker and limb contraction	350 kHz	36.2 mW/cm2
Yoo et al	Rabbit	Somatomotor cortex	Limb contraction	690 kHz	6.3 W/cm2
King et al	Mouse	Somatomotor cortex	Tail flick, neck and hind limb extension	500 kHz	0.1-100 W/cm2
Younan et al	Rat	Somatomotor cortex	Limb contraction	320 kHz	7.5-17.5 W/cm2

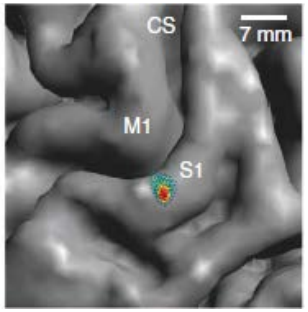
LIFU sonication targeting the right VL thalamus

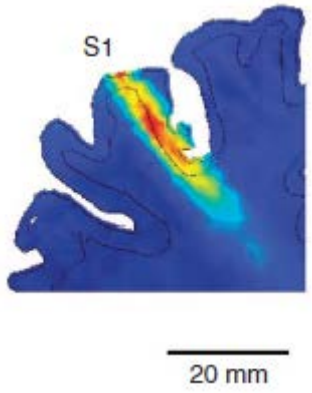


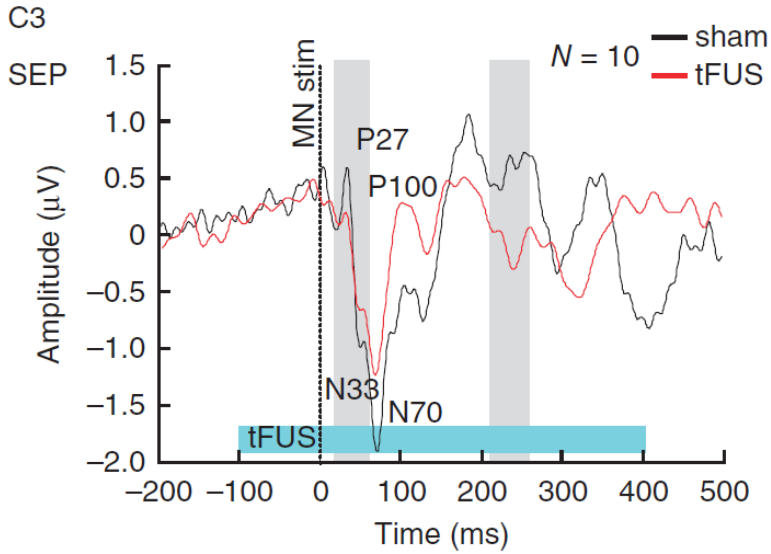


US neuromodulation, *humans*

--Tyler, Nature Neuroscience 2014







US Neuromodulation

Advantages

- Transcranial
- Noninvasive
- Deep targets
- Spatial resolution ~ mm
- MRI compatible
- Safe (MI/TI within FDA)

Disadvantages

- Early stage
  - Investigational
  - Not optimized
- Unknowns
  - Mechanism
  - Cortical/subcortical
  - Focused/Unfocused

US neuromodulation:
Future indications

1. Refining stereotactic procedures
2. Brain mapping
    1. New targets
    2. Define deep circuits
3. Acute therapy: seizure/status epilepticus (requires 'nonfocal' treatment)
4. Chronic therapy: depression (requires long term effects)

Thank you