Brain ultrasound improves mood

May 16 2013

Dr. Patick Boyle administers TUS to Dr. Stuart Hameroff whose skull and brain cortical surface are visible on the image screen of the GE LOGIQe ultrasound machine. Credit: Biomedical Communications University of Arizona Medical Center

Non-invasive brain stimulation techniques aimed at mental and neurological conditions include transcranial magnetic stimulation (TMS) for depression, and transcranial direct current (electrical) stimulation (tDCS), shown to improve memory. Transcranial ultrasound stimulation (TUS) has also shown promise.

Ultrasound consists of mechanical vibrations, like sound, but with

frequencies far greater than the upper limit of human hearing, around 20 thousand to 20 million cycles per second (20 kilohertz to 20 megahertz). Ultrasound vibrations penetrate bodily tissue including bone, and are widely used to image anatomical structures via echo effects, e.g. visualizing unborn babies in mothers' wombs, and organs, blood vessels, nerves and other structures in medical procedures. Virtually every part of the body, including the brain, has been safely imaged with low to moderate intensity ultrasound.

High intensity, focused ultrasound can damage tissue by heating and cavitation, and has been used to ablate tumors and other lesions. 'Sub-thermal' ultrasound can safely stimulate neural tissue. In 2002 a UCLA group led by Alexander Bystritsky noticed beneficial side effects in psychiatric patients whose brains were imaged by TUS. A team led by Virginia Tech's W. Jamie Tyler has shown TUS-induced behavioral and electrophysiological changes in animals. A Harvard group led by S-S Yoo has used focused ultrasound aimed at mouse motor cortex to wag the mouse's tail. But clinical trials of TUS aimed at human mental states have been lacking.

Now, in an article in the journal *Brain Stimulation*, a group from the Departments of Anesthesiology and Radiology at the University of Arizona Medical Center in Tucson, Arizona has investigated TUS for modulating mental states in a pilot study in human volunteers suffering from chronic pain. A clinical ultrasound imaging device (General Electric LOGIQe) was used, with the ultrasound probe applied at the scalp overlying the brain's temporal and frontal cortex (visible on the imaging screen). In random order, each subject received two 15 second exposures: sham/placebo, and 8 megahertz ultrasound (undetectable to subjects). Following exposure, subjects reported (by visual analog scales) significant improvement in mood both 10 minutes and 40 minutes after TUS, but not after sham/placebo. In a followup study (led by University of Arizona psychologists Jay Sanguineti and John JB Allen) preliminary

results suggest 2 megahertz TUS (which traverses skull more readily) may be more effective in mood enhancement than 8 megahertz TUS.

The mechanism by which TUS can affect mental states is unknown (as is the mechanism by which the brain produces mental states). Tyler proposed TUS acts by vibrational stretching of neuronal membranes and/or extracellular matrix, but two recent papers from the group of Anirban Bandyopadhyay at National Institute of Material Sciences (NIMS) in Tsukuba, Japan (Sahu et al. [2013] Appl. Phys. Letts. 102, 123701; Sahu et al [2013] Biosensors and Bioelectronics 47:141) have suggested another possibility. The NIMS group used nanotechnology to study conductive properties of individual microtubules, protein polymers of tubulin (the brain's most prevalent protein). Major components of the neuronal cytoskeleton, microtubules grow and extend neurons, form and regulate synapses, are disrupted in Alzheimer's disease, and theoretically linked to information processing, memory encoding and mental states. Bandyopadhyay's NIMS group found that microtubules have remarkable electronic conductive properties when excited at certain specific resonant frequencies, e.g. in the low megahertz, precisely the range of TUS.

Dr. Stuart Hameroff, lead author on the new TUS study, said: "This suggests TUS may stimulate natural megahertz resonances in brain microtubules, enhancing not only mood and conscious mental states, but perhaps also microtubule functions in synaptic plasticity, nerve growth and repair. We plan further studies of TUS on traumatic brain injury, Alzheimer's disease and post-traumatic stress disorders. 'Tuning the tubules' may help a variety of mental states and cognitive disorders."

More information: Hameroff, S. et al. (2013) Transcranial ultrasound (TUS) effects on mental states: A pilot study. *Brain Stimulation* 6: 409-415.
dx.doi.org/10.1016/j.brs.2012.05.002

Provided by University of Arizona