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Sound Waves For Brain Waves

BY Willie D. Jones // January 2009

When most people hear the word ultrasound, they think of the diagnostic tool used to look inside the womb and steal glimpses at a fetus. But researchers at Arizona State University at Tempe have developed a new use for it: to control brain activity from outside the skull.

William J. Tyler, one of the technique's developers and an assistant professor at ASU, says ultrasound will someday allow physicians to substitute neural implants with external devices. "We're trying to develop the technology to the point where we can do away with the electrodes that are used in vagus nerve stimulation and deep brain stimulation," says Tyler.

Vagus nerve stimulation is used to treat epilepsy and severe depression; deep brain stimulation treats Parkinson's disease and, experimentally, other neural and psychiatric ailments. Both rely on pacemaker-like systems surgically implanted in a patient's chest, with electrodes running either to nerves or the brain. Eliminating the risks of surgery could make neurostimulation more widely available.

In October, Tyler and his colleagues reported that they had used low-power, low-frequency ultrasound to stimulate activity in thin slices of brain tissue preserved on slides; by early November, the team had performed an experiment on a live mouse in which they induced involuntary movement by stimulating certain regions of the mouse's brain from outside its head. In both cases, they used bursts of ultrasound at frequencies between 0.44 and 0.67 megahertz—much lower than the frequencies used in imaging. The device delivers 23 milliwatts per square centimeter of brain—a fraction of the roughly 180 mW/cm2 upper limit established by the U.S. Food and Drug Administration (FDA) for womb-scanning sonograms.

This combination of low frequencies and low power represents a sweet spot where the sound readily penetrates the skull and affects brain cells. The sound waves temporarily knock open the cells' voltage-gated sodium channels, special proteins that allow sodium ions to pass through the cells' membranes. The result is a localized change in a cell's polarity from negative to positive. The polarity change can be strong enough to cause the cell to release chemical neurotransmitters and thereby induce similar voltage changes in other neurons to which they are linked, resulting in movement or other behaviors.

Expectant mothers needn't worry that ultrasound imaging would harm fetal brains, says Tyler. His group has shown that at the higher frequencies and power ratings used for imaging, ultrasound's bone-penetrating and brain-modulating potential is greatly diminished.

Tyler reports that he and his colleagues are also investigating low-power, low-frequency ultrasound's use in another device: instead of triggering precisely controlled brain activity in a focused area, it would lower the metabolic rate across the entire brain. One application for this is the prevention of secondary damage that occurs in the minutes or hours after a head injury—when a trauma-induced slowdown of blood flow and a cascade of biochemical reactions result in cell death.

"Imagine an infantryman rocked by an explosion or a football player knocked to the ground by a helmet-to-helmet hit," says Tyler. "Some sensor would detect that there was enough force generated for it to be a concussive event. Then an array of ultrasound transducers mounted in the helmet would automatically turn on, modulating neuroprotective pathways in the brain that would slow the brain's metabolic rate, [limit the destructive chemical cascade], and prevent cell death."

The low frequencies used can travel some distance through the air. So could you be zapped with a mood-altering blast from across a room? Probably not, Tyler says. In theory, the ultrasound technique could work from up to about a meter away, he says. "The farthest we've tried so far has been roughly 50 millimeters." It will take at least five years for any version of remote ultrasound brain control to make it through development, clinical trials, and FDA approval, Tyler estimates. He says he is establishing a spin-off company that will do the further research required to get a device to market. "I feel like I have the social responsibility to try to develop this as much as possible," he says.