Ultrasound shown to exert remote control of brain circuits

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In a twist on nontraditional uses of ultrasound, a group of neuroscientists at Arizona State University has developed pulsed ultrasound techniques that can remotely stimulate brain circuit activity. Their findings, published in the Oct. 29 issue of the journal ***Public Library of Science (PLoS) One***, provide insights into how low-power ultrasound can be harnessed for the noninvasive neurostimulation of brain circuits and offers the potential for new treatments of brain disorders and disease.

While it might be hard to imagine the day where doctors could treat post traumatic stress disorders, traumatic brain injury and even Alzheimer's disease with the flip of a switch, most of us have in fact experienced some of ultrasound's numerous applications in our daily lives. For example, ultrasound has been used in fetal and other diagnostic medical imaging, ultrasonic teeth cleaning, physiotherapies, or surgical ablation. Ultrasound also provides a multitude of other non-medical uses, including pharmaceutical manufacturing, food processing, nondestructive materials testing, sonar, communications, oceanography and acoustic mapping.

"Studies of ultrasound and its interactions with biological tissues have a rich history dating back to the late 1920s," lead investigator William "Jamie" Tyler points out. "Several research groups have, for more than a half-century, demonstrated that ultrasound can produce changes in excitable tissues, such as nerve and/or muscle, but detailed studies in neurons at the cellular level have been lacking."

"We were able to unravel how ultrasound can stimulate the electrical activity of neurons by optically monitoring the activity of neuronal circuits, while we simultaneously propagated low-intensity, low-frequency ultrasound through brain tissues," says Tyler, assistant professor of neurobiology and bioimaging in the School of Life Sciences in the College of Liberal Arts and Sciences.

Led by Tyler, the ASU research group discovered that remotely delivered low intensity, low frequency ultrasound (LILFU) increased the activity of voltage-gated sodium and calcium channels in a manner sufficient to trigger action potentials and the release of neurotransmitter from synapses. Since these processes are fundamental to the transfer of information among neurons, the authors pose that this type of ultrasound provides a powerful new tool for modulating the activity of neural circuits.

"Many of the stimulation methods used by neuroscientists require the use and implantation of stimulating electrodes, requiring direct contact with nervous tissue or the introduction of exogenous proteins, such as those used for the light-activation of neurons," Tyler explains.

The search for new types of noninvasive neurostimulation methods led them to revisit ultrasound.

"We were quite surprised to find that ultrasound at power levels lower than those typically used in routine diagnostic medical imaging procedures could produce an increase in the activity of neurons while higher power levels produced very little effect on their activity," Tyler says.

Other neuroscientists and engineers have also been rapidly developing new neurostimulation methods for controlling nervous system activity and several approaches show promise for the treatment of a wide variety of nervous system disorders. For example, Deep Brain Stimulation (DBS) and Vagal Nerve Stimulation (VNS) have been shown to be effective in the management of psychiatric disorders such as depression, bipolar disorders, post-traumatic stress disorder, and drug addition, as well as for therapies of neurological diseases such as Parkinson's disease, Alzheimer's disease, Tourette Syndrome, epilepsy, dystonia, stuttering, tinnitus, recovery of cognitive and motor function following stroke, and chronic pain. Up until now, these two techniques have captured the attention of physicians and scientists; however, these therapies still pose risks to patients because they require the surgical implantation of stimulating electrodes. Thus, these types of therapies are often only available to patients presenting the worst of prognoses.

One prior stumbling block to using ultrasound noninvasively in the brain has been the skull. However, the acoustic frequencies utilized by Tyler and his colleagues to construct their pulsed ultrasound waveforms, overlap with a frequency range where optimal energy gains are achieved between transcranial transmission and brain absorption of ultrasound – which allows the ultrasound to penetrate bone and yet prevent damage to the soft tissues. Their findings are supported by other studies examining the potential of high-intensity focused ultrasound for ablating brain tissues, where it was shown that low-frequency ultrasound could be focused through human skulls.

When asked about the potential of using his groups' methods to remotely control brain activity, Tyler says: "One might be able to envision potential applications ranging from medical interventions to use in video gaming or the creation of artificial memories along the lines of Arnold Schwarzenegger's character in 'Total Recall.' Imagine taking a vacation without actually going anywhere?

"Obviously, we need to conduct further research and development, but one of the most exhilarating prospects is that low intensity, low frequency ultrasound permit deep-brain stimulation procedures without requiring exogenous proteins or surgically implanted medical devices," he adds.

Tyler and the other ASU researchers will now focus on further characterization of the influence of ultrasound on intact brain circuits and translational research, taking low intensity ultrasound from the lab into pre-clinical trials and treatment of neurological diseases.

Source: Arizona State University

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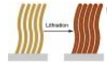

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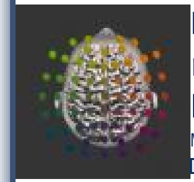

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