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Title: Functional Ultrasound Neuroimaging: a New Platform for Brain-Machine Interfaces

Abstract: Brain-machine interfaces (BMIs) detect and interpret neural activity, enabling users to communicate and control devices without physical movement. BMIs are already being used to restore function to people experiencing deficits from neurological injury or disease. Despite this technical success, BMI adoption has been slow. This is, in part, because high-performance BMIs use intracortical electrodes that require open-brain surgery, degrade over time, and are difficult to scale across multiple brain regions. To achieve widespread use, the next generation of BMIs must be less invasive, high-performing, and scalable. Functional ultrasound (fUS) is a recently developed and minimally invasive (epidural) neuroimaging technique that meets these criteria. It senses hemodynamics in the brain using ultrafast Doppler angiography. fUS provides excellent spatiotemporal resolution (<100 microns and 100 ms) and high sensitivity (~1 mm/s velocity) across a large field of view (several centimeters). In previous work[1], we used brain activity detected by fUS to predict upcoming movements in non-human primates (NHPs) as a precursor to BMI. We predicted movement timing, direction, and effector simultaneously. Now, we have expanded the behavioral repertoire predicted by the BMI and trained NHPs to use it in real-time. Finally, we have developed ultrasound-transparent skull replacements, enabling us to collect the first fUS images in awake adult human volunteers. Ongoing developments in high-speed volumetric imaging and chronic implantation of the ultrasound probe further promise to improve our understanding and treatment of neurological disorders and injuries.

[1]S. L. Norman et al., “Single-trial decoding of movement intentions using functional ultrasound neuroimaging,” Neuron, vol. 109, no. 9, pp. 1554-1566.e4, May 2021