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A Functional Ultrasound Brain-Machine Interface: Real-Time Decoding of Direction and Task State

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Introduction: Brain-machine interfaces (BMIs) are transformative for people living with chronic paralysis, enabling them to control computers, robots, and more with only thought. However, state-of-the-art BMIs have shortcomings that limit user adoption. These include high invasiveness, small field of view, limited lifespan, and a need to calibrate daily. Functional ultrasound imaging (fUSI) is an emerging technique that can address these limitations[1,2].

Material, Methods, and Results: In this study, we demonstrate the first successful implementation of a closed-loop ultrasonic BMI (**Fig. 1A**). We streamed functional ultrasound data from the posterior parietal cortex of two rhesus macaque monkeys **(Fig. 1B**) while they performed memory-guided eye and hand movements. After a period of training, the monkeys were able to control up to eight independent movement directions using the BMI. We show that we can decode not only the intended movement direction, but also the current task state (fixation, movement planning, movement, and intertrial interval). We also present a method for pretraining ultrasonic BMIs using data from previous sessions (**Fig. 1C**). This enabled immediate and improved BMI control on subsequent days, even those that occurred months apart, without requiring extensive calibration. Finally, we have begun translating this ultrasonic BMI into non-invasive human applications taking advantage of a unique patient population with ultrasound-transparent skull replacements.

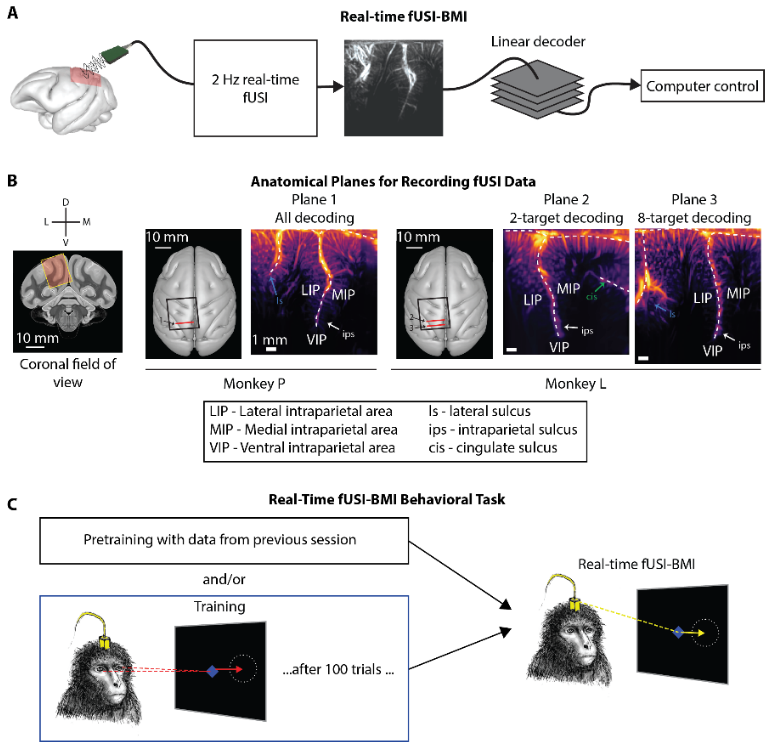

Figure 1: Overview of methods and results.

Discussion and significance: The contributions presented here demonstrate the first online, closed-loop ultrasonic BMI. It prepares for a next generation of BMIs that are less invasive, high-resolution, stable across time, and scalable to sense activity from large regions of the brain. These advances are a step toward fUS-BMI for a broader range of applications, including restoring function to patients suffering from debilitating neuropsychiatric disorders.

References

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