Human Sensorimotor Dynamics During the Onset and Offset of Touch, With and Without Visual and Tactile Feedback

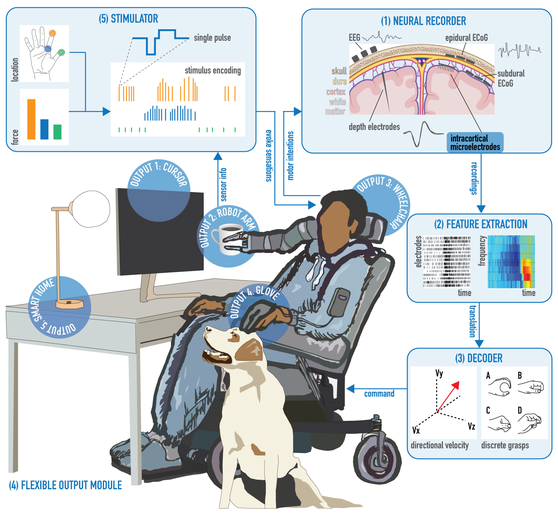
Mrigank "Mk" Maharana[1,2,3], Bradley Lega[2,3,4,5], Ceci Verbaarschot[2,3,6]

[1]Department of Bioengineering, The University of Texas at Dallas

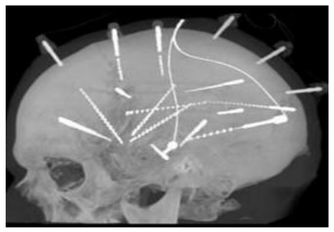
[2]Peter J. O'Donnell Jr. Brain Institute, The University of Texas Southwestern Medical Center

Departments of [3]Neurological Surgery, [4]Neurology, [5]Psychiatry, [6]Biomedical Engineering, The University of Texas Southwestern Medical Center

Introduction



Bi-directional brain machine interfaces (BMIs) can restore movement and sensation in people living with severe paralysis, but optimal device calibration and function requires a better understanding of the neural sensorimotor dynamics underlying skilled movement.



A. Campbell & C. Wu, 2019, Epilepsia

Stereo-electroencephalography (sEEG) is used in patients with drug-resistant epilepsy to localize seizure locations via implanted depth electrodes across cortical and subcortical brain regions. Unlike other implant populations — where patients typically have paralysis and absent hand function — sEEG patients retain fully intact motor abilities. This offers a unique opportunity to record high-resolution neural activity during dexterous movement and tactile processing, capturing distributed sensorimotor dynamics, that would otherwise be inaccessible noninvasively.

Hypotheses

I. Sensorimotor dynamics underlying finger movement onset, offset, and identity will be decodable from sulcal, white matter, and subcortical sEEG sites: Pre-motor Cortex, Supplementary Motor Area, and the Thalamus.

II. Error-related neural responses will be detectable in Precentral, Frontal, and Medial Frontal sEEG sites: Anterior Cingulate Cortex, Insula, Hippocampus. With real-time decoding possible predicting erroneous responses.

III. Modulating the presence and content of visual and tactile feedback while learning a skilled movement task will produce measurable changes in learning dynamics such as reaction time and accuracy.

Typing-Blind Examines The Significance of Visual and/or Tactile Feedback during Skilled Movement

Experimental Conditions		
Tactile Feedback	Visual Feedback	Response Pad
Yes	Yes	
No	Yes	
Yes	No	
No	No	

A V Incorrect Outcome Feedback V V

Non-Target Letter Cued	Target Letter Cued	Correct Outcome Feedback	Target Letter Cue Ends	
0.00s – 1.25s	1.25s – 2.50s	2.50s – 2.60s	2.60s – 2.70s	+0.0s – 0.5s Jitter to Next Cue

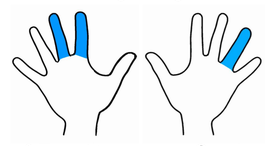
Participants responded to target letters by moving the assigned finger from the response-pad center to a target zone while visual and tactile feedback cues varied across blocks, then received outcome feedback.



Tactile Feedback Aids

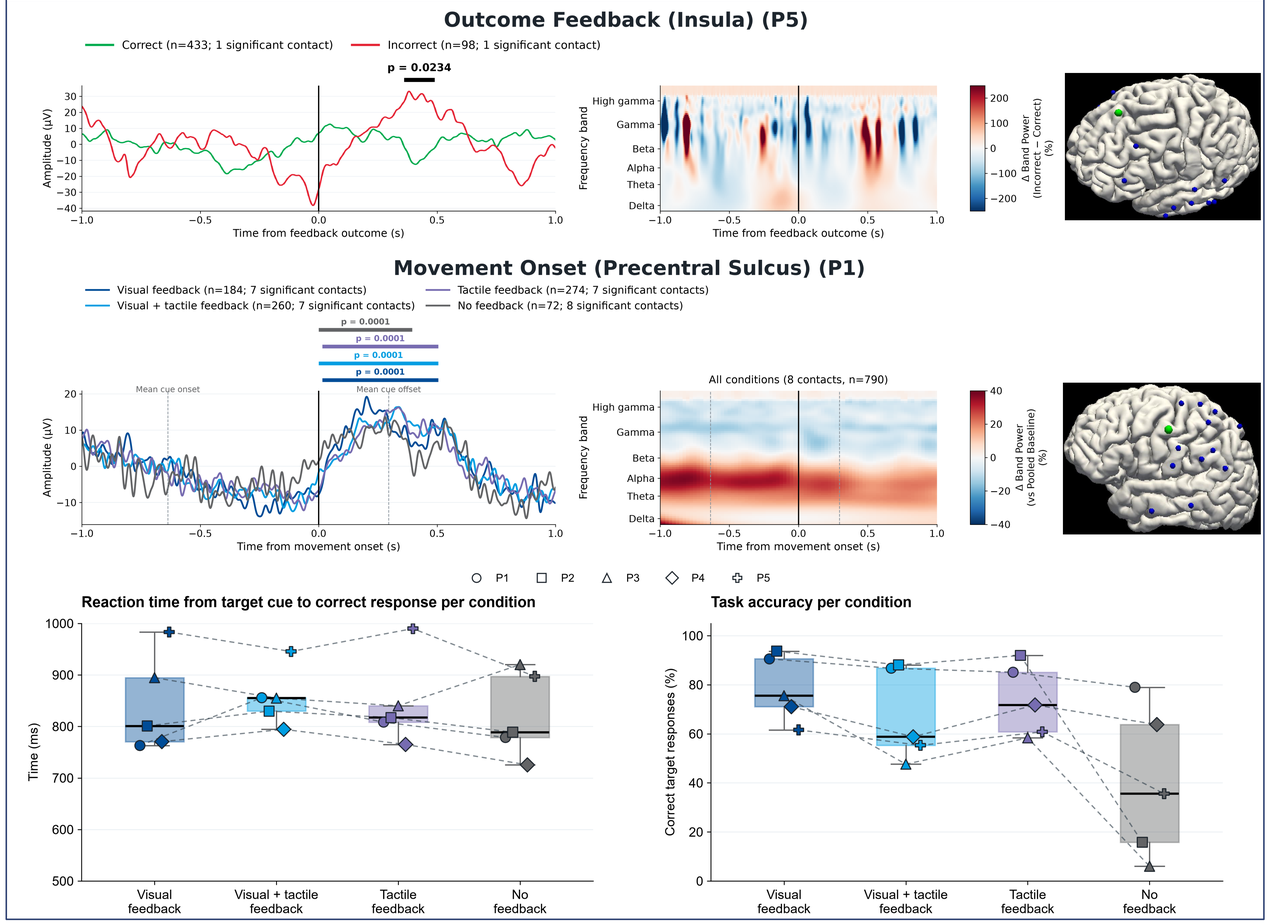


Keyboard Mapping for Target Fingers



3 Target Fingers per Session

Preliminary Results: sEEG can detect Significant Error- and Movement-Related Activity



Conclusions

I. sEEG recordings show significant movement-related neural activity in the Precentral Sulcus, supporting the feasibility of detecting neural correlates of movement onset in real-time. Preliminary findings support further investigation of neural activity associated with movement offset and identity.

II. Distinct neural responses associated with correct and incorrect movement outcomes were observed in the Insula. These findings suggest that error-related neural activity may provide useful features for future real-time decoding of action accuracy.

III. Reaction time and target accuracy varied across visual and tactile feedback conditions. Preliminary behavioral findings suggest that the availability of sensory feedback enhances skilled motor performance.

Future Directions

I. Characterize neural activity associated with movement onset, offset, and identity across additional sEEG recording sites. Develop decoding models to classify movement-related events from neural activity.

II. Characterize error-related neural activity across Precentral, Frontal, and Medial Frontal regions, including the Anterior Cingulate Cortex, as well as the Insula and Hippocampus. Evaluate the feasibility of real-time error detection and pre-response error prediction.

III. Quantify the effects of visual and tactile feedback on reaction time and target accuracy using statistical comparisons. Investigate how feedback conditions modulate neural activity and motor performance to inform adaptive, closed-loop BMIs.

Acknowledgments and Contact Information

This research was funded by the Peter J. O'Donnell Jr. Brain Institute, Department of Neurological Surgery, and the Cain Scholarship in Mobility Disorders at The University of Texas Southwestern Medical Center.

Presenter's Email:
Mrigank.Maharana@UTSouthwestern.edu

Principal Investigator's Email:
Cecile.Verbaarschot@UTSouthwestern.edu

Mind to Motion Lab Website