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Closed-loop error damping in human BCI using endogenous modifications in motor cortex activity

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Introduction: The motor cortex is known to encode motor intents, carrying rich information about movement kinematics. Interestingly, motor cortex activity also includes an *error signal*, i.e. a neural correlate of erroneous motor control that does not align with the movement goal. This error signal could potentially be leveraged during real-time BCI control, to detect a discrepancy between the decoded movement and the user's intent and to perform on-the-fly error correction. Previous studies have been able to identify a neural correlate of such periods of erroneous motor control to perform on-the-fly detection of BCI control in monkeys [1]. However, whether this signal is sufficiently robust to be used in human applications, and can generalize across realistic tasks, is still unknown. Here, we train a classifier to detect periods of erroneous motor control based on intracortical recordings from motor cortex, and use it to perform real-time error detection and control signal modulation in different BCI tasks with human participants.

Material, Methods and Results: We obtained intracortical data from 3 human participants (C2, P2, and P4) who were asked to perform a BCI 2D cursor control center-out task. Participants provided informed consent prior to enrolling in a clinical trial of an intracortical sensorimotor BCI that was approved under an FDA Investigational Device Exemption (NCT01894802). We trained a classifier to detect periods of erroneous control using data collected while the participants performed the center-out task, where "error" was defined as an increasing distance between the cursor and the target. Crucially, neural features immediately preceding the onset of an error (and which represent endogenous activity rather than responses to visual feedback) are also included in the training set, allowing earlier error detection. Then, in subsequent testing blocks, whenever the detected error probability reached a defined threshold, the system performed error modulation by reducing the decoded velocity, hence preventing the cursor from moving further away from its target (Fig.1**A**). Error modulation significantly improved BCI performance on a variety of performance metrics (Fig.1**B**). In individual participants, we demonstrated improved performance when applying error modulation to a more realistic and multidimensional click and drag task (Fig.1**C**) and to the precision task from the recent Cybathlon BCI competition (Fig.1**D**), where stability is especially critical to performance.

Conclusion: Results show that motor cortex activity is significantly modified during erroneous control, and that this neural signature can be leveraged to minimize errors, hence improving BCI performance.

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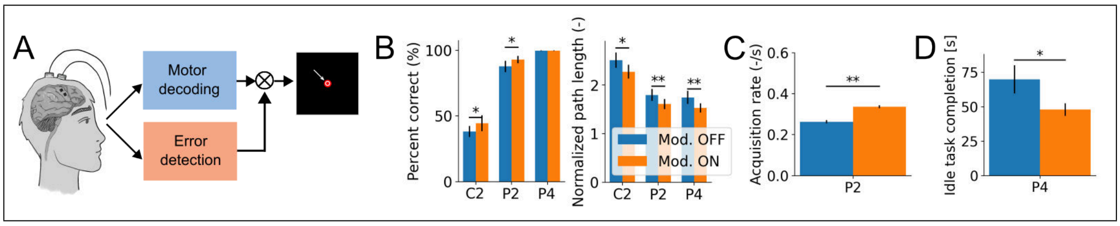

Figure 1: ***(A)*** *A BCI system is used to decode the motor intent and to move a cursor towards a target in a 2D control task. In parallel, a classifier detects the error signal and modulates the decoded velocity accordingly.* ***(B)*** *Trajectory accuracy metrics without (blue) and with (orange) error modulation.* ***(C)*** *Target acquisition rate without and with error modulation during a click-and-grasp task.* ***(D)*** *Completion time improvements with error modulation during the precision task from the BCI Cybathlon competition.*

References:

[1] Wallace, Dylan M., et al. "Error detection and correction in intracortical brain–machine interfaces controlling two finger groups." Journal of Neural Engineering 20.4 (2023): 046037.

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