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Self-Correcting Multi-Command Brain-Computer Interfaces based on Error-Related Potentials

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Introduction: Electroencephalogram (EEG)-based Brain-Computer Interfaces (BCIs) are often hindered by high error rates, limiting their effectiveness. In previous work we developed a self-correcting BCI, based on classification, rather than just detection, of error-related potentials (ErrPs), which are evoked when users observe erroneous BCI actions. The error classifier (EC) had three outputs: (1) correct movement, (2) failure to remain idle (i.e., performing a movement when none was intended), and (3) erroneous movement (i.e., performing one movement when another was intended). This approach was successfully demonstrated on a three-command BCI that adjusted the pose of the right hand, left hand, or neither hand, achieving an average accuracy improvement of 6.6±3.8% (n=11) [1]. However, scaling this methodology to BCIs with more commands introduces new challenges, as detecting an "erroneous movement" does not resolve which of the remaining movements should be executed.

Methods and Results: We present the development and evaluation of a novel self-correcting BCI designed to handle five commands. The system integrates a basic Movement Classifier (bMC) and an enhanced Movement Classifier (eMC), as illustrated in Figure 1. The eMC incorporates an EC followed by a novel combined classifier (CC) that determines the final command. Various CC configurations were evaluated, leveraging different features and scores derived from the convolutional neural networks (CNNs, [2]) used to implement the bMC and EC. All CC configurations demonstrated significant performance improvement, with the best configuration achieving an average accuracy improvement of 10.1±4.8%, resulting in average accuracy of 79.0±10.4% (n=18).

Conclusions: This study demonstrates that ErrPs encode valuable information about the type of error that elicit them and can be leveraged to enhance self-correcting BCIs capable of handling multiple commands. These findings represent a critical advancement in the development of more accurate, reliable, and user-adaptive non-invasive BCIs.

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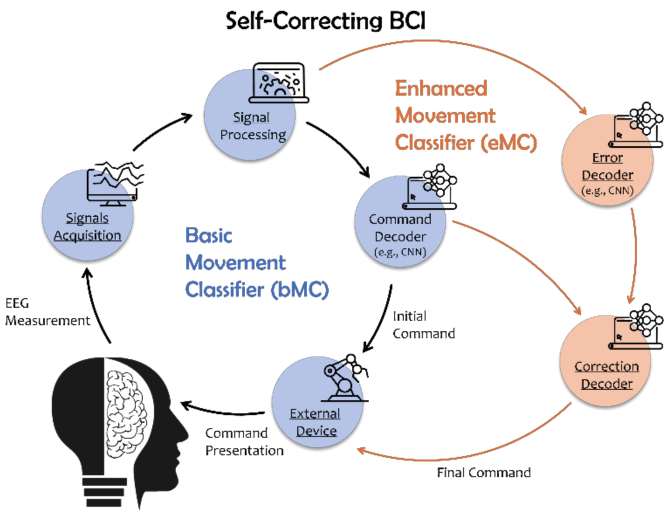

Figure 1: Architecture of self-correcting brain-computer interface.

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