ERROR-RELATED POTENTIALS

FOR ADAPTIVE DECODING AND VOLITIONAL CONTROL

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ABSTRACT

Locked-in syndrome (LIS) is a condition characterized by total or near-total paralysis with preserved cognitive and somatosensory function. For the locked-in, brain-machine interfaces (BMI) provide a level of restored communication and interaction with the world, though this technology has not reached its fullest potential. Several streams of research explore improving BMI performance but very little attention has been given to the paradigms implemented and the resulting constraints imposed on the users. Learning new mental tasks, constant use of external stimuli, and high attentional and cognitive processing loads are common demands imposed by BMI. These paradigm constraints negatively affect BMI performance by locked-in patients. In an effort to develop simpler and more reliable BMI for those suffering from LIS, this dissertation explores using error-related potentials, the neural correlates of error awareness, as an access pathway for adaptive decoding and direct volitional control.

In the first part of this thesis we characterize error-related local field potentials (eLFP) and implement a real-time decoder error detection (DED) system using eLFP while non-human primates controlled a saccade BMI. Our results show specific traits in the eLFP that bridge current knowledge of non-BMI evoked error-related potentials with

error-potentials evoked during BMI control. Moreover, we successfully perform real-time DED via, to our knowledge, the first real-time LFP-based DED system integrated into an invasive BMI, demonstrating that error-based adaptive decoding can become a standard feature in BMI design.

In the second part of this thesis, we focus on employing electroencephalography error-related potentials (ErrP) for direct volitional control. These signals were employed as an indicator of the user's intentions under a closed-loop binary-choice robot reaching task. Although this approach is technically challenging, our results demonstrate that ErrP can be used for direct control via binary selection and, given the appropriate levels of task engagement and agency, single-trial closed-loop ErrP decoding is possible.

Taken together, this work contributes to a deeper understanding of error-related potentials evoked during BMI control and opens new avenues of research for employing ErrP as a direct control signal for BMI. For the locked-in community, these advancements could foster the development of real-time intuitive brain-machine control.