Closed-loop adaptation of brain-machine interfaces using error-related potentials and reinforcement learning

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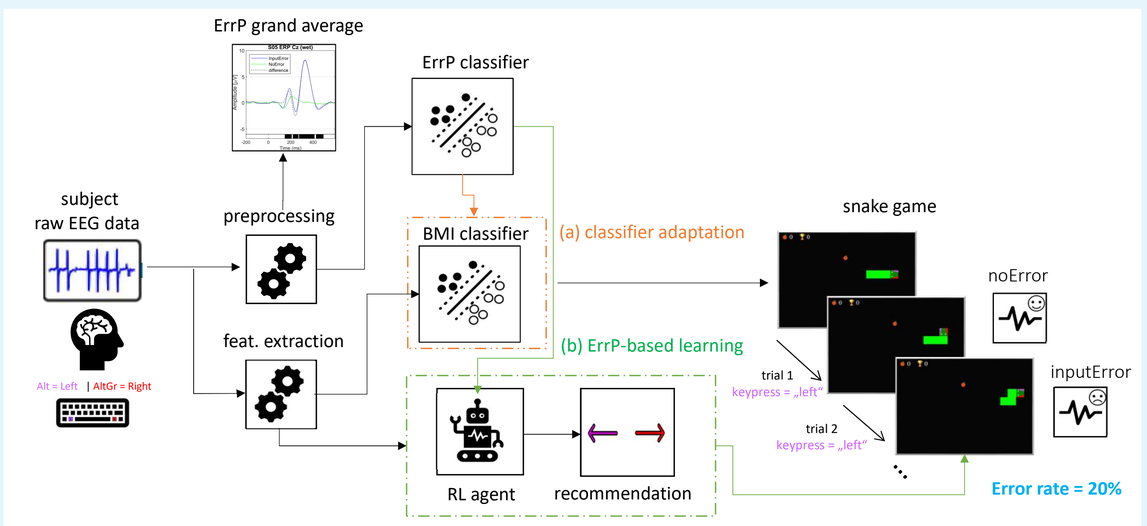
Motivation

Neurorehabilitation devices can be used to help patients restore the lost mobility of upper-body limbs caused, e.g., by a spinal cord injury or a stroke. Given the long calibration sessions and decrease in decoding performance, the development of systems that adapt to the individual patient's needs is of particular relevance. Error-related potentials (ErrPs) are elicited in the human brain as a consequence of both self-made and external system errors [1]. Different experimental paradigms can be used to generate such signals, and the ErrPs provide a convenient source of feedback to improve brain-machine interfaces (BMIs) with no extra workload for the subject [2]. However, their effective use depends on their accurate detection, which is a limitation in current ErrP-based BMIs.

Experimental Setup

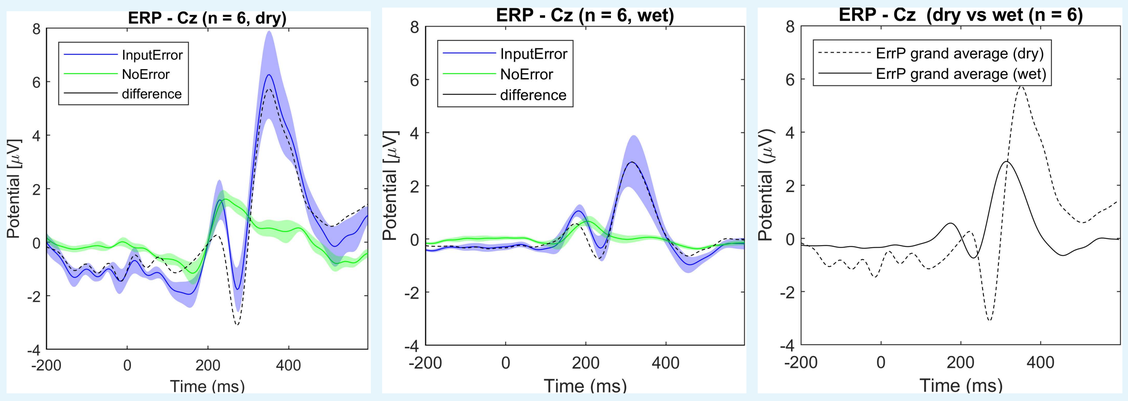


- **EEG devices:** Brain Products Xpress Twist: **32** active dry channels | Neuroelectrics Enobio: **8** gel-based channels
- **Subjects:** **6** participants (**3** male, $\mathbf{30.2 \pm 4.6}$)
- **Datasets:** **2** sessions of **10** runs with **120** trials each

Data Preprocessing

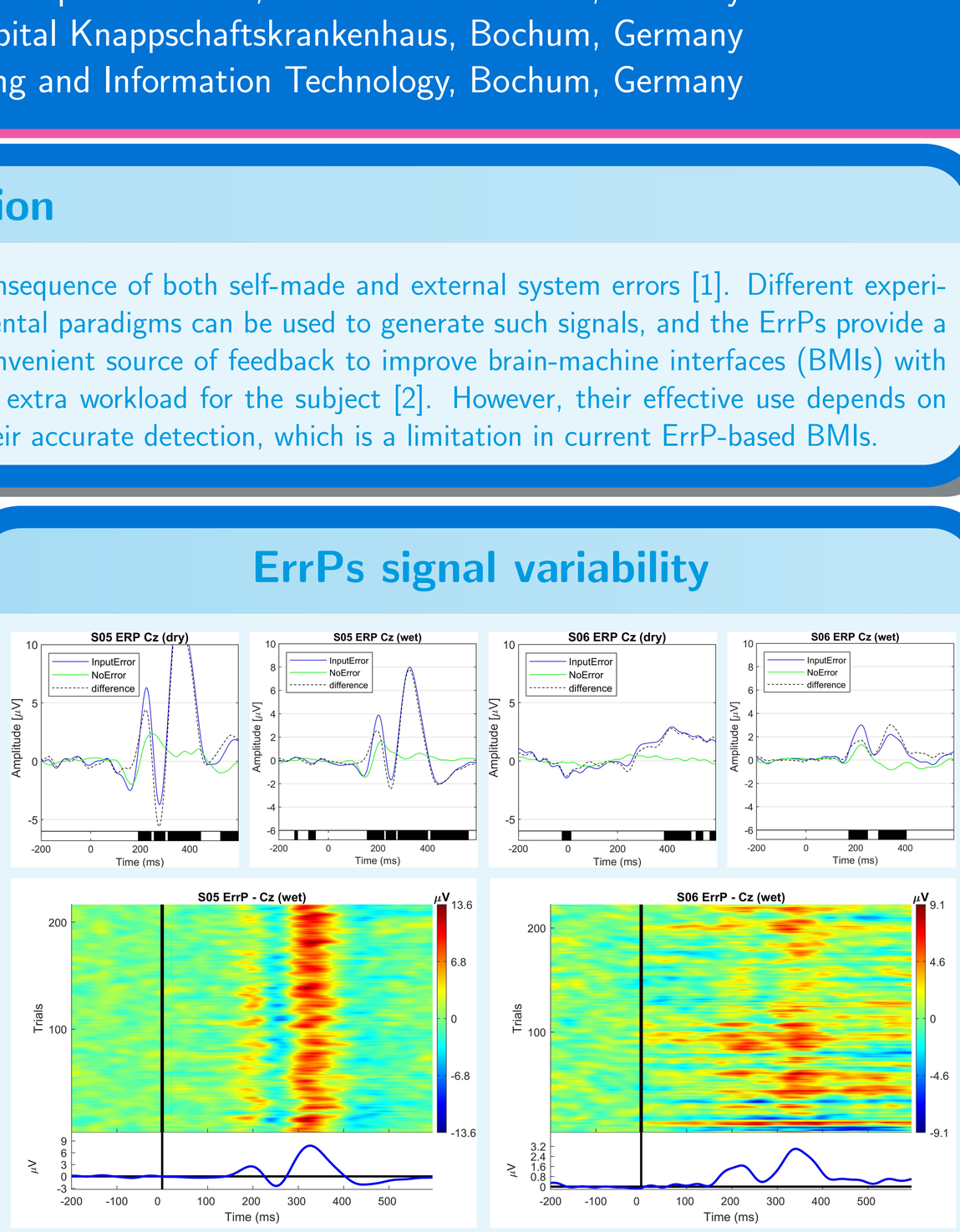
1. Artifact rejection (continuous data)
2. Downsampling to **250** Hz
3. Notch and [**1**-**20**] Hz bandpass FIR filters
4. Automatic artifact rejection: bad channels and eyes blinks
5. Common-average re-referencing
6. Baseline correction [**-0.2**-**0**]s

Results



Overall grand averages at Cz: dry (left) and wet (right). ErrPs difference (error minus correct) grand averages at Cz combined (right). Measured ErrPs present waveshapes consistent with other studies [3].

ErrPs signal variability



Single-trial analysis of the measured ErrPs highlights both within- and inter-subjects variability in the signal.

Outlook

The specified protocol can be used to elicit a prominent interaction ErrPs but variability among subjects is still present. Factors affecting the occurrence of a significant ErrP signal have to be better understood, as well as the influence in the adaptation framework.

References

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[2] S. K. Kim *et al.*, "Flexible online adaptation of learning strategy using EEG-based reinforcement signals in real-world robotic applications," in *2020 IEEE International Conference on Robotics and Automation (ICRA)*, Paris, France

[3] P. W. Ferrez and J. d. R. Millán, "Error-Related EEG Potentials Generated During Simulated Brain–Computer Interaction," *IEEE Transactions on Biomedical Engineering*, vol. 55, no. 3, Mar. 2008

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