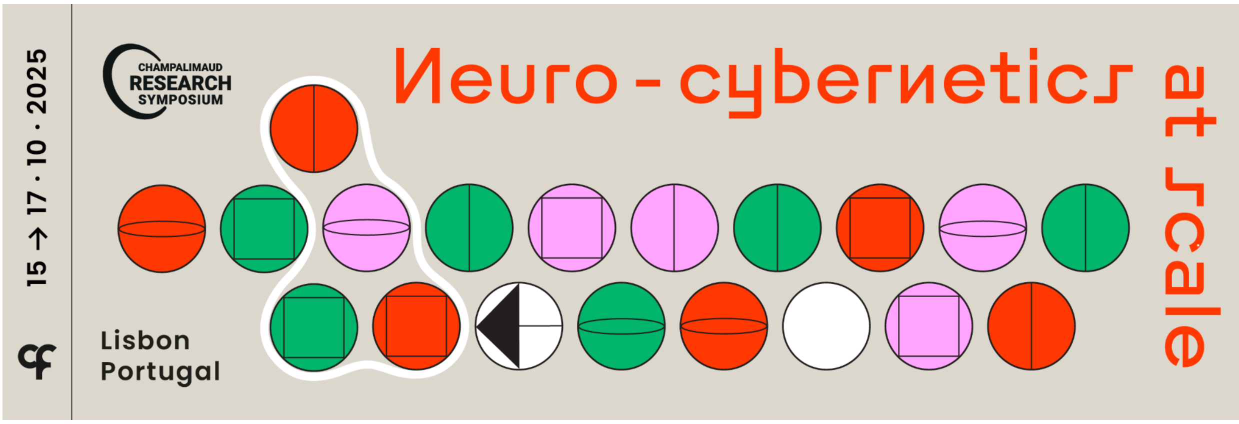

Addressing non-stationarities in neural population dynamics for long-term behavioral decoding

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Intracortical Brain-Computer Interfaces (iBCI) decode behavior from neural population dynamics to restore motor functions and communication abilities in individuals with motor impairments. A central challenge for long-term iBCI deployment is the nonstationarity of the recorded population activity, where electrode instability changes the composition and tuning of the recorded population across sessions. Existing approaches address this issue with explicit alignment techniques; however, they rely on fixed neural identities and require test-time labels and parameter updates, limiting their generalization across sessions and imposing extra computational burden during deployment. We introduce SPINT, a Spatial Permutation-Invariant Neural Transformer framework for behavioral decoding that operates directly on unordered sets of neural units. Our approach is centered on a novel context-dependent positional embedding that dynamically infers unit-specific identities, enabling flexible generalization across sessions. SPINT supports inference on variable-size populations and allows few-shot, gradient-free adaptation using only a small amount of unlabeled data from the test session. We evaluate our approach on three motor decoding tasks from the FALCON Benchmark, demonstrating robust cross-session generalization that outperforms existing zero-shot and few-shot unsupervised baselines while eliminating the need for test-time alignment and fine-tuning. Our work contributes an initial step toward a flexible and practical framework for robust, scalable neural decoding in long-term iBCI applications.

intracortical brain-computer interface