An AI/ML-ready closed loop BCI simulation framework

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Communication brain-computer interface systems (cBCIs), as stated in the parent award R01DC009834, must be personalized for end-users with severe speech and physical impairments to make them as effective as possible for potential in-home use. If individuals are going to express themselves by typing with brainwaves (specifically, the RSVP Keyboard and P300 event-related potential for intent selection), systems must be reliable, efficient, and accurate. Most cBCI systems currently lack the ability to adapt to the user's changing needs and skills over time, leading to reduced accuracy and effectiveness. This incapacity to adapt to the end-user's internal states, preferences, and context is a driving motivation for enhancing system infrastructure and adaptive modeling to facilitate AI/ML readiness. The proposed enhancements and simulation framework will make the system more robust, and permit researchers to share labeled EEG datasets driven by FAIR standards. Current cBCIs do not have the capabilities of testing models for typing, nor do they have guardrails in place that are necessary for AI implementation. This supplement proposes improving infrastructure by adding meta-parameters to the BciPy open-source platform with our existing datasets and building a flexible task simulator for other cBCI research and development teams. Integrating AI and adaptive modeling into cBCIs will help overcome current limitations by including finer-grained controls that open up opportunities for online optimization, simulation, and user preference. Two specific aims are proposed: SA1. Build a closed-loop BCI-controlled task simulation framework, with two sub-aims: SA1a. Construct a task simulator for rapid model prototyping; SA1b. Optimize the closed-loop decision process for end-user intent inference. As products, we will provide the resulting data and simulator codes through public version control platforms and data repositories. SA2. Develop infrastructure to support integrating adaptive models and AI in a multimodal environment. An Orchestration entity will be created with fusion, decision, and weighting parameters available for updating across evidence and processing pipelines. The final labeled data will be stored in a separate file (.fif) with a text export of the artifact annotations for use outside MNE and BciPy. The semi-automatic artifact pipeline will be publicly available at our GitHub repo: https://github.com/CAMBI-tech. The BciPy Development Team (under the direction of Mr. Memmott) and the Signal Processing & Machine Learning Team (under the direction of Drs. Erdogmus and Imbiriba), with guidance from the Clinical Team (Dr. Fried-Oken) have been collaborating since the parent award was first funded in 2009. Their successful outputs will be further refined in this project. Creating a closed-loop task simulator and exposing meta-parameters for adaptive modeling will significantly speed up model comparisons, reduce costs of model exploration and prototyping, enhance customization for an end-user's fluctuating skills and needs, and increase data accessibility for broader BCI communities.