Optimizing BCI-FIT: Brain Computer Interface Functional Implementation Toolkit

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Many of the estimated four million adults in the U.S. with severe speech and physical impairments (SSPI) resulting from neurodevelopmental or neurodegenerative diseases cannot rely on current assistive technologies (AT) for communication. During a single day, or as their disease progresses, they may transition from one access technology to another due to fatigue, medications, changing physical status, or progressive motor dysfunction. There are currently no clinical or AT solutions that adapt to the multiple, dynamic access needs of these individuals, leaving many people poorly served. This competitive renewal, called BCI-FIT (Brain Computer Interface-Functional Implementation Toolkit) adds to our innovative multidisciplinary translational research conducted over the past 11 years for the advancement of science related to non-invasive BCIs for communication for these clinical populations. BCI-FIT relies on active inference and transfer learning to customize a completely adaptive intent estimation classifier to each user's multiple modality signals in real-time. The BCI-FIT acronym has many implications: our BCI fits to each user's brain signals; to the environment, offering relevant personal language; to the user's internal states, adjusting signals based on drowsiness, medications, physical and cognitive abilities; and to users' learning patterns from BCI introduction to expert use.

Three specific aims are proposed: (1) Develop and evaluate methods for optimizing system and user performance with on-line, robust adaptation of multi-modal signal models. (2) Develop and evaluate methods for efficient user intent inference through active querying. (3) Integrate language interaction and letter/word supplementation as input modalities in real-time BCI use. A single case experimental research design is proposed for each aim to evaluate both user performance and technology performance for functional communication with 15 healthy controls and 45 participants with SSPI in the community. The same dependent variables will be tested in all experiments: typing accuracy (correct character selections divided by total character selections), information transfer rate (ITR), typing speed (correct characters/minute), and user experience (UX) questionnaire responses about comfort, workload, and satisfaction. Our goal is to establish individualized recommendations for each user based on a combination of clinical and machine expertise. The clinical expertise plus user feedback added to active sensor fusion and reinforcement learning for intent inference will produce optimized multi-modal BCIs for each end user that can adjust to short- and long-term fluctuating function. Our research is conducted by four sub-teams who have collaborated successfully to implement translational science: Electrical/computer engineering; Neurophysiology and systems science; Natural language processing; and Clinical rehabilitation. The project is grounded in solid machine learning approaches with models of participatory action research and AAC participation. This project will improve technologies and BCI technical capabilities, demonstrate BCI implementation paradigms and clinical guidelines for people with severe disabilities.