Title: Dynamic analysis of naïve adaptive brain-machine interfaces

Author Affiliation:

Kevin C. Kowalski[1,2], Bryan D. He[1,2], and Lakshminarayan Srinivasan[1]

[1] Neural Signal Processing Laboratory
Department of Radiology
University of California Los Angeles
Los Angeles, CA 90095-7437

[2] Department of Computer Science
California Institute of Technology
Pasadena, CA 91125

CORRESPONDING AUTHOR: LAKSHMINARAYAN SRINIVASAN, MD, PHD (LS2 AT NSPLAB.ORG)

ABSTRACT

The closed-loop operation of brain-machine interfaces (BMI) provides a context to discover foundational principles behind human-computer interaction, with emerging clinical applications to stroke, neuromuscular diseases, and trauma. In the canonical brain-machine interface (BMI), a user controls a prosthetic limb through neural signals that are recorded by electrodes and processed by a decoder into limb movements. In laboratory demonstrations with able-bodied test subjects, parameters of the decoder are commonly tuned using training data that includes neural signals and corresponding overt arm movements. In the application of BMI to paralysis or amputation, arm movements are not feasible and imagined movements create weaker, partially unrelated, patterns of neural activity. BMI training must begin naïve, without access to these prototypical methods for parameter initialization used in most laboratory BMI demonstrations.

Naïve adaptive BMI refer to a class of methods recently introduced to address this problem. We first identify the basic elements of existing approaches based on adaptive filtering and define a decoder, ReFIT-PPF to represent these existing approaches. We then present Joint RSE, a novel approach that logically extends prior approaches. Using recently developed human- and synthetic-subjects closed-loop BMI simulation platforms, we show that Joint RSE significantly outperforms ReFIT-PPF and non-adaptive (static) decoders. Control experiments demonstrate the critical role of jointly estimating neural parameters and user intent. Additionally, we show that non-zero sensorimotor delay in the user significantly degrades ReFIT-PPF but not Joint RSE, owing to differences in the prior on intended velocity. Paradoxically, substantial differences in the nature of sensory feedback between these methods do not contribute to differences in performance between Joint RSE and ReFIT-PPF. Instead, BMI performance improvement is driven by machine learning, which outpaces rates of human learning in the human-subjects simulation platform. In this regime, nuances of error-related feedback to the human user are less relevant to rapid BMI mastery.

KEYWORDS: SENSORIMOTOR LEARNING, NAÏVE ADAPTIVE BMI, CLOSED-LOOP BMI SIMULATION, PARALYSIS

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