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Presentation Abstract

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Title:	A closed-loop human simulator for understanding feedback-control and its relevance for brain-machine interfaces
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Abstract:	By translating neural activity into control commands, brain-machine interfaces (BMI) seek to improve the lives of severely disabled people. There are many challenges in developing such a system, but all BMI share in common the need for a decode algorithm. Decode algorithms map recorded neural activity into physical commands. These algorithms are typically applied offline to neural activity previously gathered from a healthy animal, and the decoded arm reach is then compared to the true movement that corresponded to the recorded neural activity. However, this offline testing may neglect important features of a real BMI, most notably the critical role of feedback-control, which enables the user to adjust neural activity while using the BMI. We hypothesize that a full understanding of decoder design requires an experimental platform where the human learning machine (the brain and motor plant) is in closed-loop with the various candidate decode algorithms. It remains unexplored the extent to which the subject can, for a particular decode algorithm or parameter choice, engage feedback mechanisms, learning and adaptation, and other control strategies to

improve decode performance. Here we ask the previously unaddressed research question: can a healthy human subject, using a closed-loop BMI driven by synthetic neural activity, inform the choices made in prosthetic decode algorithms? We design this Online Prosthesis Simulator (OPS), we use it to ask a key algorithm design question, and we demonstrate a definitive answer. We use the OPS to optimize decode performance based on a key parameter of a current state-of-the-art decode algorithm - the bin width of a Kalman filter. First, we show that offline and online analyses do indeed suggest different parameter choices. Previous literature and offline analyses agree that neural activity should be analyzed in bins of roughly 200ms width. Our OPS analysis, which incorporates feedback-control, disagrees with these findings and suggests that much shorter bin widths (25-50ms) will yield higher decode performance. Second, we confirm this surprising finding with a real BMI system (animal experiments), which suggests that the OPS does provide an accurate proxy to real neural control. We hypothesize that this novel testing approach will allow rapid and lower-cost testing of many algorithmic choices and will be a better proxy to clinical use than offline data analyses. Providing further evidence of the importance of feedback-control and the OPS approach, this finding has critically enabled some of the significant performance gains in our related BMI experiments.

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