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Development of an iBCI System for Control of a Soft Robotic Glove

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Introduction: Intracortical brain-computer interfaces (iBCIs) use signals recorded directly from the brain to help individuals with paralysis to control assistive devices such as computer cursors or robotic arms. For people with tetraplegia, an opportunity for iBCI systems is to provide for the intuitive reanimation of one's own limb and incorporating, for some users, residual proprioceptive feedback. In addition to ongoing work with functional electrical stimulation systems, the recent emergence of soft robotic technology has enabled the development of soft, wearable exoskeletons that, when paired with a reliable control signal, could be used to restore movement in people with severe motor impairment. In this study, we demonstrated the successful use of an iBCI system to provide basic movement of the hand via a soft robotic glove (SRG). We have also begun to investigate the effects of somatosensation and its effects on motor cortex-enabled, SRG-assisted hand control.

Materials, Methods, and Results: Experimental sessions were performed by participant T11, a 38-year-old, right-handed man with a spinal cord injury (C4 AIS-B). T11 had two 96-electrode arrays implanted in his left precentral gyrus as part of the BrainGate Clinical Trial. A fabric-based, pneumatically actuated glove and controller system were manufactured and programmed to provide 4 functionally relevant grip states: power grip, pinch grip, open hand, and relax. As part of our investigation, we recorded neural responses in the motor cortex when T11 attempted or passively observed the SRG perform grips on his own hand vs. a mannequin hand. Although significant neural modulation occurred during visual or somatosensory feedback alone, sensory feedback did not produce significant effects on offline or online decoding of attempted hand grips (LDA-HMM). We also investigated the performance of two robotic control strategies: a "Continuous" controller where SRG postures reflect continuously decoded estimates of intended grip type, and a "Toggle" controller where transient gesture attempts are used to *toggle* between SRG end postures. Both controllers performed well in assessments of grip-switching speed and object transfers, but the Toggle controller allowed T11 to hold grip postures for longer periods of time and was preferred by the participant.

Discussion: The lack of interference of SRG-induced sensory input in decoding of intended grip in this individual is an encouraging sign that existing iBCI strategies for operating external robots could translate well to control of soft robotic exoskeletons. T11's preference for the more robot-like "Toggle" controller raises interesting questions about how to balance the promise of restoring intuitive control of one's own hand with the functional performance of such a system. These questions will be important to ask across individuals with different degrees of sensorimotor impairment and different etiologies of paralysis.

Significance: Soft robotic exoskeletons hold extraordinary promise as avenues for restoration of movement in people with tetraplegia. Here we demonstrate the viability of using iBCI control to operate a soft robotic glove, laying the foundation for future research combining iBCIs with this exciting new class of effectors.

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