Control of Somatosensory Cortex via Optogenetic Stimulation of Motor and Thalamic Pathways

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**Abstract**—Loss of somatosensation has been shown to impair motor control. We have proposed subcortical stimulation as a means of restoring afferent somatosensory feedback in motor impaired subjects. In this study, we examined the response of somatosensory cortex (S1) to thalamic and motor cortex optogenetic stimulation. We generally observed frequency-dependent nonstationary S1 discharge dynamics. Evoked response caused by motor cortex stimulation exhibited slower dynamics than those evoked by thalamic stimulation. Strategies for delivering sensory information may therefore need to account for the complex interaction between bottom-up and top-down processing of somatosensory responses that seem to operate across multiple time scales.

I. INTRODUCTION

Visual and somatosensory feedbacks are indispensable for seamless motor control and have been shown to improve performance in cortically controlled brain-machine interface (BMI) experiments [1,2]. Artificial stimulation of the thalamus has been proposed as a means to deliver somatosensory feedback in spinal cord injured or paralyzed patients [3,4]. An ideal somatosensory prosthesis that restores both tactile and proprioceptive feedbacks would need to transmit continuous information about the limb state over the entire movement duration.

In this preliminary study, we characterized the response of primary somatosensory cortex (S1) to thalamic optogenetic stimulation over the course of minutes to assess stability of these responses to long-term stimulation. We found time-varying, frequency-dependent S1 responses to excitatory thalamic drive. In contrast, evoked S1 responses to motor cortex (M1) stimulation showed nonstationary characteristics at much slower time scales. These results suggest that M1 exerts modulatory state dependent changes in S1 compared to fast thalamic recruitment of S1 neurons.

II. METHODS

Excitatory neurons were transfected with Channelrhodopsin (ChR2) via injection of 1.0 μL of rAAV2/CamKIIΔ-cH2R(H134R)-mcherry into rat M1 or the ventroposterior medial nucleus (VPm) of the thalamus. Animals were given at least four weeks for expression to manifest prior to recording. One-millisecond optical stimulation pulses were delivered via a 200-μm diameter optical fiber positioned at the site of injection, and stimulation frequencies were varied between 5 and 20 Hz over 9-minute trials. Simultaneous unit and local field potential (LFP) responses were recorded.

III. RESULTS AND DISCUSSION

Both unit activity and Local Field Potential (LFP) responses to optical stimuli varied over the course of thalamic stimulation. LFPs showed a strong frequency component matching that of the stimulation frequency. This component was time varying over multiple intervals of varying lengths. Each interval was defined by the LFP response power at the frequency of stimulation. Single unit responses tended to correlate with these intervals, with some exhibiting specific time locking preference to each of these intervals. A nonstationary pattern was also observed in S1-evoked responses to M1 stimulation, but at considerably smaller time intervals. There was an initial gradual increase in LFP response magnitude for a few seconds, followed by a gradual decline until stimulation was discontinued. In comparison to thalamic stimulation, M1 stimulation resulted in a more steady-state response in S1.

Nonstationary and potentially nonlinear interaction between thalamic and motor drives may have strong implications for a somatosensory prosthesis design, particularly when somatosensory feedback is continuously delivered to indicate limb state. Accounting for these characteristics is needed to optimize stimulation patterns in real time [5] and may provide significant advantages over current open loop stimulation designs [3].

**REFERENCES**


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