The Effect of Proprioceptive Feedback on BCI Control

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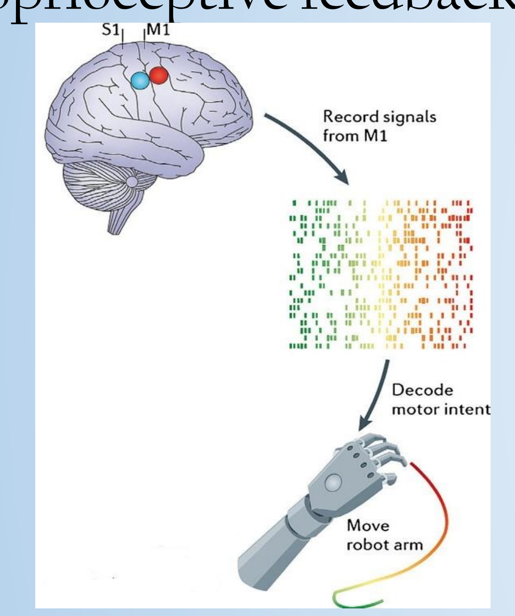
Background

Sensory feedback is necessary to guide and correct movement

Neurons in M1 respond to visual and proprioceptive input during visually guided reaching

Brain-computer-interfaces (BCIs) are typically implemented with visual feedback alone, but may function differently when proprioceptive feedback is provided

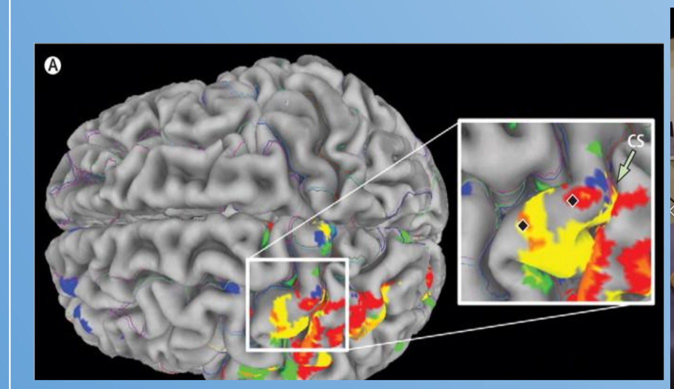


Experimental Details

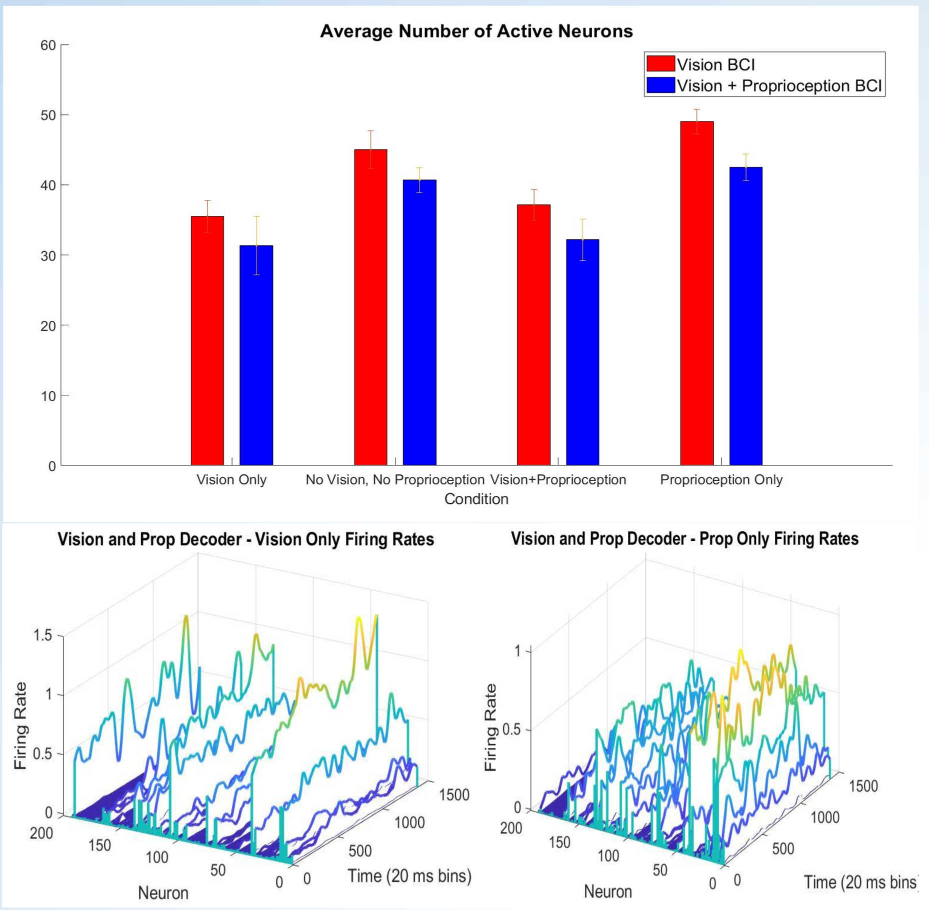
Two 96-channel multielectrode arrays were implanted in primary motor cortex (M1) of a person with tetraplegia to create a BCI for driving a robotic arm

Neural firing rates were transformed into an end-point velocity control signal using an optimal linear estimator

The subject moved the robotic arm left and right over a centerline as many times as possible in one minute and was provided with either visual feedback, proprioceptive feedback, or neither

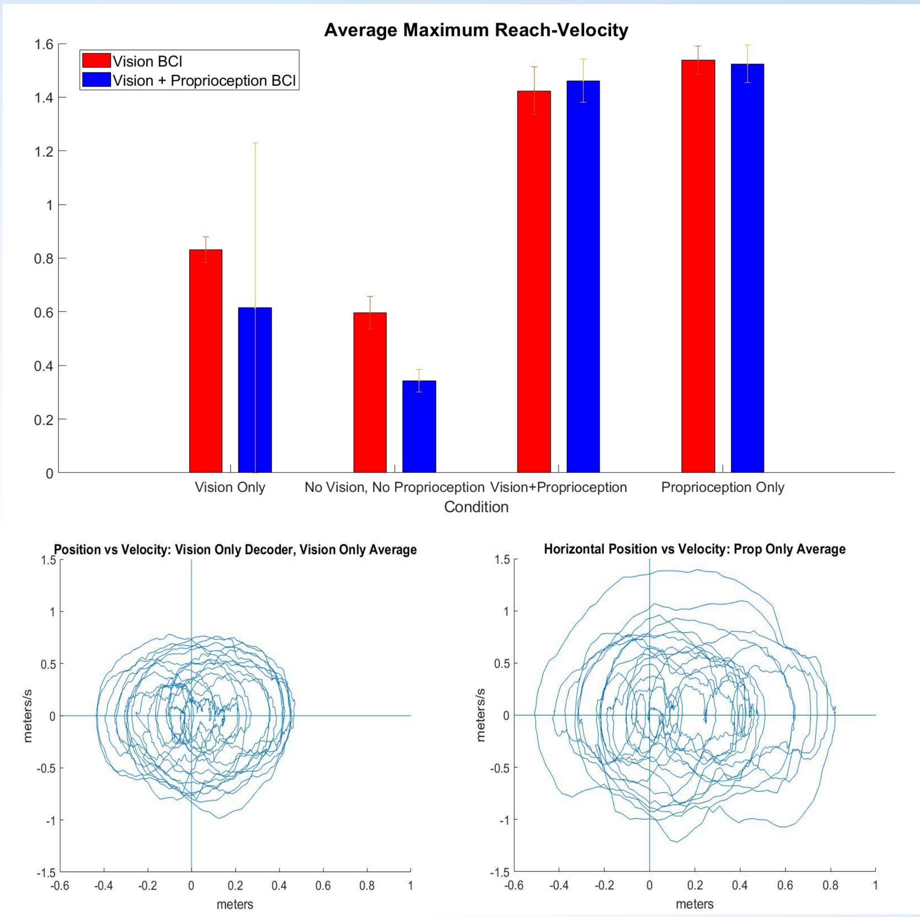


Proprioceptive Feedback Increases M1 Firing Rates and Reach-Velocity



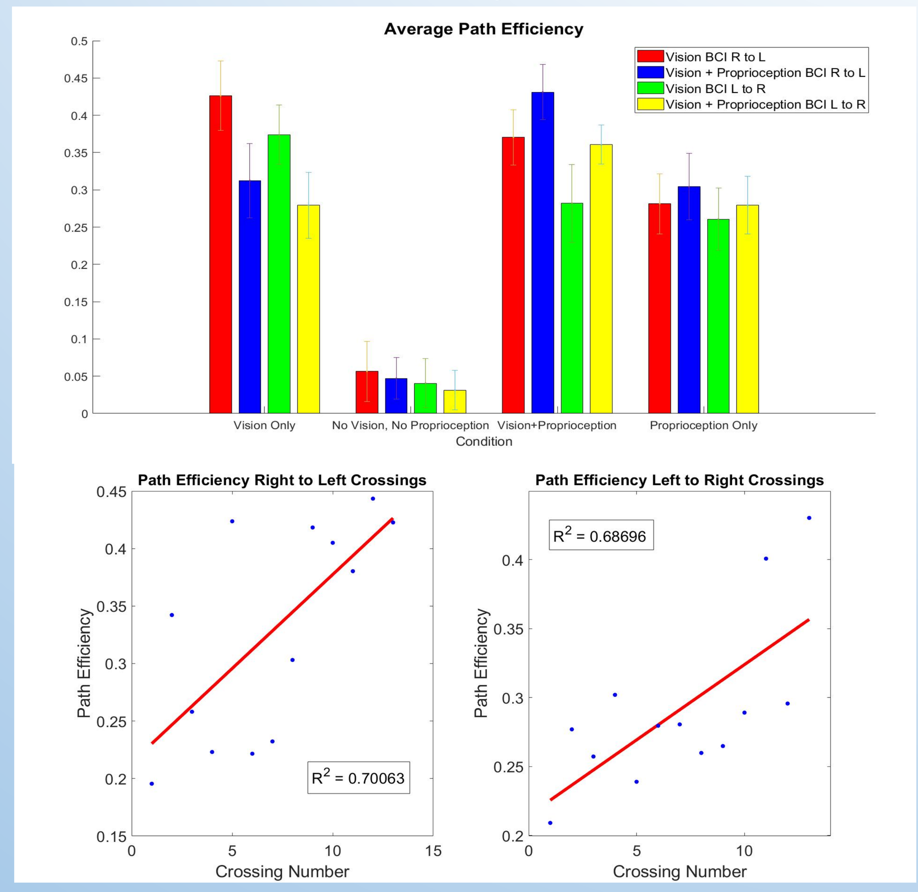
Average number of active neurons for decoder trained on vision only (red) and decoder trained on vision + proprioception (blue); firing rate slope plots for decoder trained on vision + proprioception for vision only condition (left) and proprioception only condition (right)

Number of active neurons is greatest in proprioception only condition; number of active neurons is greatest with decoder trained on vision only



Average maximum reach-velocity for decoder trained on vision only (red) and decoder trained on vision + proprioception (blue); position versus velocity plots for decoder trained on vision only for vision only condition (left) and proprioception only condition (right)

With proprioceptive feedback alone, maximum reach-velocity increases



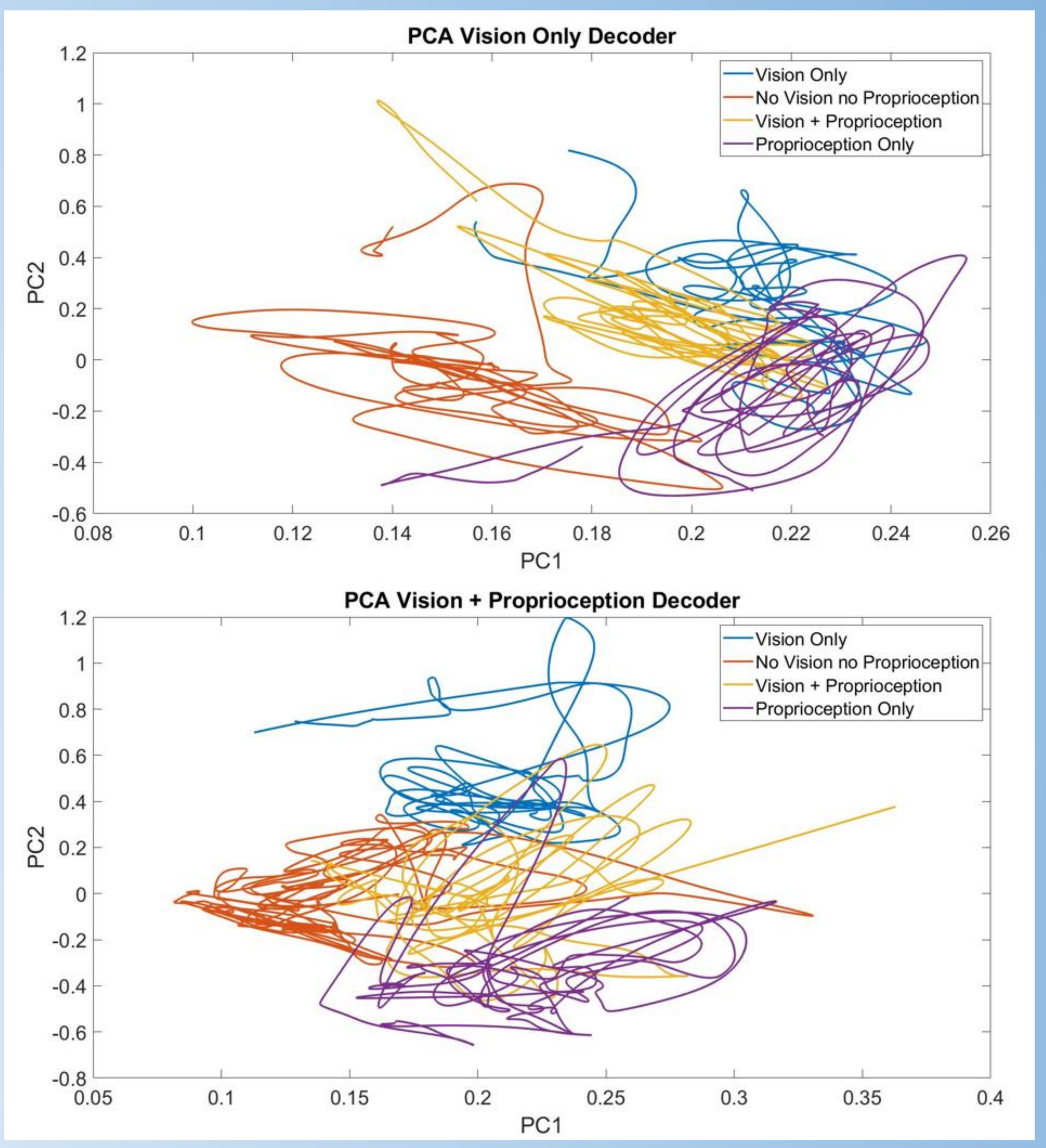
Path efficiency was calculated using ideal trajectories for horizontal and vertical position and velocity

Path efficiency averages of right to left crossings with vision decoder (red) and vision + proprioception decoder (blue) and left to right crossings with vision decoder (green) and vision + proprioception decoder (yellow);

Path efficiency of vision only decoder and vision only condition for individual crossings right to left (left) and left to right (right)

Path efficiency of individual crossings increases throughout each trial; right to left individual crossings are overall more efficient; most efficient groups are the vision only condition with the decoder trained on vision only and the vision + proprioception condition with the decoder trained on vision + proprioception

PCA of Neural Activity



First and second principle components of neural activity for decoder trained on vision only (top) and decoder trained on vision + proprioception (bottom); vision only (blue), proprioception only (purple), neither (red), vision + proprioception (yellow)

Neural response differs across conditions

Conclusions

There is a subset of neurons used for BCI decoding that are modulated by proprioception

Proprioceptive feedback, when presented while using a decoder trained on vision + proprioception, provides efficient control of the robotic limb

References

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