A Video-Based Behavioral Test Platform to Evaluate the Long-term Safety and Effectiveness of Neural Interface Technology

Stanley Huang, *Member, IEEE,* Eugene F. Civillico, David Y. Xing, Seong J. Park, Gretchen L. Knaack, Victor Krauthamer, and Cristin G.Welle

Current intracortical neuroprosthetic systems hold promise in translating neural activities into command signals to control prosthetic devices. However, chronically implanted intracortical interfaces lose their ability to record neural signals over time in both humans and animals, and gradually reduce neuroprosthetic control[1-3]. Complex tissue responses in the brain and physical degradation of the intracortical recording electrodes might contribute to the decline of neural signal[4, 5]. Signal decline is often quantified on the basis of single unit action potential amplitude, or the number of identified units. However, the correlation between neural signal characteristics in motor cortex and motor output behavior may serve as an additional metric of neural implant reliability.

To determine the longitudinal behavioral relevance of neural signals recorded by multi-electrode arrays, we implanted commercially-available electrode arrays (NeuroNexus, Blackrock Microsystems) in the caudal forelimb area of motor cortex of the mouse and recorded biweekly over time scales of 1 to 12 months post-implantation. In order to rule out an overall decline in the animals' movement and locomotion as an explanation for any observed decline in motor-related neural signals, we also monitor the animals' awake and freely-moving behaviors.

We implemented a video-based behavioral system (HomeCageScan, Clever Sys Inc.) to automatically classify spontaneous rodent behaviors into forelimb and non-forelimb movements. First, we characterized the error rate of the classification through comparison with human observation of behavioral activity. We then validated the system's temporal precision and synchronized the video stream with neural activity. During neural recording sessions, video recordings were simultaneously acquired as the animal explored freely. Neural firing rates for forelimb-relevant behavioral epochs were calculated across recording sessions. Behavior-locked longitudinal electrophysiological recordings were evaluated for changes in functional relevance.

An automated behavioral classification system allows for the characterization of naturalistic behaviors in the freely moving animal. Concurrent electrophysiological recording from the motor cortex can be analyzed on the basis of the animal's behavioral state. Combined behavioral and electrophysiological monitoring of neural implant devices may potentially be utilized as a test platform to evaluate safety and efficacy issues related to invasive neurological devices.

Disclaimer

The mention of commercial products, their sources, or their use in connection with material reported herein is not to be construed as either an actual or implied endorsement of such products by the Department of Health and Human Services.

References

[1] C.A. Chestek, V. Gilja, P. Nuyujukian, J.D. Foster, J.M. Fan, M.T. Kaufman, M.M. Churchland, Z. Rivera-Alvidrez, J.P. Cunningham, S.I. Ryu, and K.V. Shenoy, "Long-term stability of neural prosthetic control signals from silicon cortical arrays in rhesus macaque motor cortex," *Journal of Neural Engineering*, vol. 8, (no. 4), pp. 045005, 2011.

[2] S.-P. Kim, J.D. Simeral, L.R. Hochberg, J.P. Donoghue, and M.J. Black, "Neural control of computer cursor velocity by decoding motor cortical spiking activity in humans with tetraplegia," *Journal of Neural Engineering*, vol. 5, (no. 4), pp. 455, 2008.

[3] P.J. Rousche and R.A. Normann, "Chronic recording capability of the Utah Intracortical Electrode Array in cat sensory cortex," *Journal of neuroscience methods*, vol. 82, (no. 1), pp. 1-15, 1998.

[4] V.S. Polikov, P.A. Tresco, and W.M. Reichert, "Response of brain tissue to chronically implanted neural electrodes," *Journal of neuroscience methods*, vol. 148, (no. 1), pp. 1-18, 2005.

[5] A. Prasad, Q.-S. Xue, V. Sankar, T. Nishida, G. Shaw, W.J. Streit, and J.C. Sanchez, "Comprehensive characterization and failure modes of tungsten microwire arrays in chronic neural implants," *Journal of Neural Engineering*, vol. 9, (no. 5), pp. 056015, 2012.

This work was supported in part by the Defense Advanced Research Projects Agency, Microsystems Technology Office (DARPA, MTO) Reliable Neural Interface Program through an Interagency Agreement with the U.S. Food and Drug Administration (FDA-DARPA 224-10-6006).

S. Huang, E. F. Civillico, V.Krauthamer and C. G. Welle are with the U.S. Food and Drug Administration, Center for Devices and Radiological Health, Office of Science and Engineering Laboratories, Silver Spring, MD 20903 (phone: 301-796-2731; fax:301-796-9927; e-mail: stanley.huang@fda.hhs.gov, eugene.civillico@fda.hhs.gov, victor.krauthamer@fda.hhs.gov, cristin.welle@fda.hhs.gov).

D. Y. Xing is with Columbia University, Biomedical Engineering, New York, NY10027 (e-mail: dyx2001@columbia.edu).

S. J. Park is with Columbia University, Computer Science, New York, NY 10027 (e-mail: sjp2172@columbia.edu).

G. L. Knaack is with George Mason University, Neuroscience, Fairfax, VA 22030 (email: gknaack@masonlive.gmu.edu).