DOI: 10.3217/978-3-99161-050-2-005

A Speech Neuroprosthesis for Decoding High Frequency Activity in Anterior Cingulate and Orbitofrontal Cortices and Hippocampus for Phonemes Articulation

A. Tankus[1,4,5*], E. Stern[1,4], G. Klein[5,6], N. Kaptzon[5,6], L. Nash[5,6], T. Marziano[7], O. Shamia[7], G. Gurevitch[2,8], L. Bergman[1], L. Goldstein[3], F. Fahoum[3,4], I. Strauss[1,4]

[1]Functional Neurosurgery Unit, [2]Sagol Brain Institute, [3]Department of Neurology, Tel Aviv Sourasky Medical Center, Tel Aviv, Israel.
[4]Department of Neurology and Neurosurgery, Faculty of Medicine, [5]Sagol School of Neuroscience, [6]Blavatnik School of Computer Science, [7]School of Electrical Engineering, [8]Department of physiology and pharmacology, Faculty of Medicine Tel Aviv University, Tel Aviv, Israel.

*Functional Neurosurgery Unit, Tel Aviv Sourasky Medical Center, Tel Aviv 6423906, Israel. E-mail: arielta@gmail.com

Introduction: Speech is a main form of communication for humans. Its loss due to injury or disease is terrible. Here, we report a novel speech neuroprosthesis that artificially articulates building blocks of speech based on the high frequency activity, that includes single neuron activity, in the anterior cingulate and orbitofrontal cortices, and hippocampus. These brain areas were never harnessed for a neuroprosthesis before. However, our earlier studies found neuronal populations in these [1] and other [2-5] brain areas that encode these building blocks and demonstrated high accuracy decoding.

Material, Methods and Results: A 37-year-old neurosurgical epilepsy patient with intact speech, was implanted with depth electrodes solely for clinical reasons. He gained control over the neuroprosthesis almost immediately and silently produced two vowel sounds voluntarily [6]. During the first set of trials, the participant made the neuroprosthesis produce the different vowel sounds artificially with 85% accuracy. Performance improved consistently as more trials were conducted. This may be attributed to neuroplasticity, as the decoder remained the same along the experiment. The decoder was trained on overt speech data, but was utilized for silent control over the closed-loop speech neuroprosthesis.

Conclusion: The ability of a neuroprosthesis trained on overt speech data to be controlled silently may open the way for a novel strategy of neuroprosthesis implantation. In ALS patients, for example, the neuroprosthesis may be implanted at early stages of the disease, while speech is still intact, for improved training of the decoder, and be utilized at later stages for silent control. The results demonstrate clinical feasibility of direct decoding of high frequency activity, including spiking activity, in the aforementioned areas for silent production of phonemes that may serve as a part of a neuroprosthesis for replacing lost speech control pathways.

Acknowledgments and Disclosures: This research was supported by Israel Ministry of Innovation, Science and Technology (Grants 17630 and 1818105) and Alrov Research Fund. The authors wish to thank the study participant for his devotion; Shy Shoham of NYU; Genela Morris, Efrat Rabstein, Malki Langerman, Esther Tadesse, Snejana Vaiberman, and Geula Levy for technical assistance.

References:

[1] Tankus A, Fried I, Shoham S. Structured neuronal encoding and decoding of human speech features. *Nature Communications*, 3:1015, 2012.

[2] Tankus A, Fried I. Degradation of neuronal encoding of speech in the subthalamic nucleus in Parkinson's disease. *Neurosurgery*, 84(2):378–387, 2019.

[3] Tankus A, Solomon L, Aharony Y, Faust-Socher A, Strauss I. Machine Learning Algorithm for Decoding Multiple Subthalamic Spike Trains for Speech Brain-Machine Interfaces. *Journal of Neural Engineering*, 18:066021, 2021.

[4] Tankus A, Lustig Y, Gurevitch G, Faust-Socher A, Strauss I. Neuronal Encoding of Speech Features in the Human Thalamus in Parkinson's Disease and Essential Tremor Patients. *Neurosurgery*, 94(2):307-316, 2024.

[5] Tankus A, Rosenberg N, Ben-Hamo O, Stern E, Strauss I. Machine Learning Decoding of Single Neurons in the Thalamus for Speech Brain-Machine Interfaces. *Journal of Neural Engineering*, 21(3):036009, 2024.

[6] Tankus A, Stern E, Klein G, Kaptzon N, Nash L, Marziano T, Shamia O, Gurevitch G, Bergman L, Goldstein L, Fahoum F, Strauss I. A speech neuroprosthesis in the frontal lobe and hippocampus: decoding high frequency activity into phonemes. *Neurosurgery*, 2024.

Published by Verlag der Technischen Universität Graz