Carnegie Mellon University

Sensing and stimulating the brain to restore neurological function

SEPTEMBER 23, 2024

Doug Weber, PhD
Akhtar and Bhutta Professor
Department of Mechanical Engineering
Neuroscience Institute

Disclosures

Dr. Weber declares a financial conflict of interest with the following companies:

- Iota Biosciences, Inc.
- NeuroOne Medical Technologies, Inc.
- NeuronOff, Inc.
- Panther Life Sciences, Inc.
- Reach Neuro, Inc.

Visitors are always welcome!

NeuroMechatronics Lab

Co-directors: Darcy Griffin & Doug Weber

Drew Beauchamp
Ernesto Bedoy
Luigi Borda
Nikole Chetty
Dailyn Despradel
Alpaslan Ersoz
Ariel Feldman
Emma Heinle
Ruitong Jiang
Kriti Kacker
Max Murphy
Lauren Parola
Omar Refy
Jonathan Shulgach
Sandhya Sridhar
Howard Wu
Nikhil Verma
Prakarsh Yadav
Jehan Yang

Recent alumni:
Dr. Jordyn Ting, Dr. Dev Sarma, Sharon Park, Kent Shibata, Dr. Ashley Dalrymple, Tom Hyatt, Rifeng Jin, Dr. Mehrdrad Javidi, Dr Monica Liu, Julian Low, Charli Hooper

Carnegie Mellon University

Research in the NeuroMechatronics Lab (NML)

Integration of neuroscience and engineering principles to develop technology that communicates directly with the nervous system to restore or enhance human abilities

Restore sensation

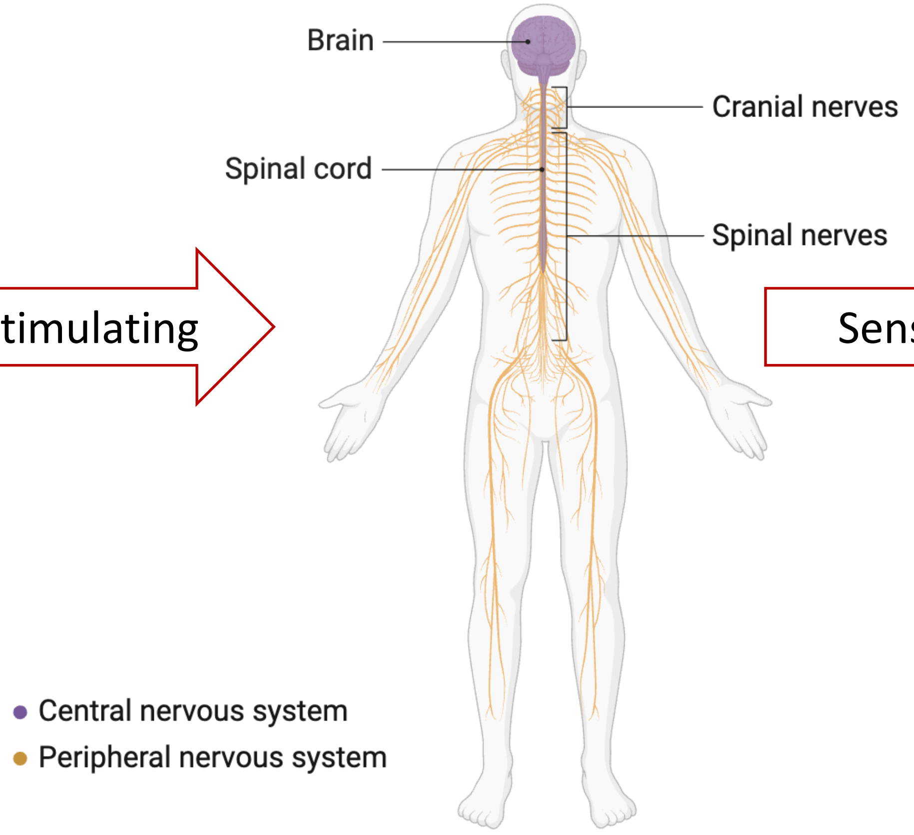
Reduce pain

Increase arousal

Reanimate paralyzed limbs

REACH NEURO

Stimulating



Sensing

Implanted Brain-Computer Interfaces

synchron

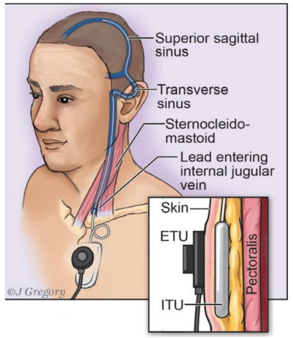
Wearable myoelectric interfaces

Meta

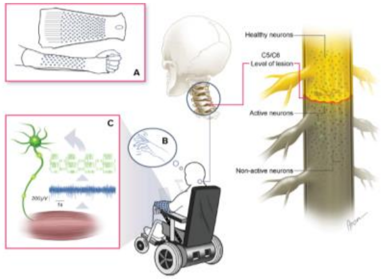
Topics

Sensing and interpreting motor signals for human-computer interaction

Brain-computer interfaces

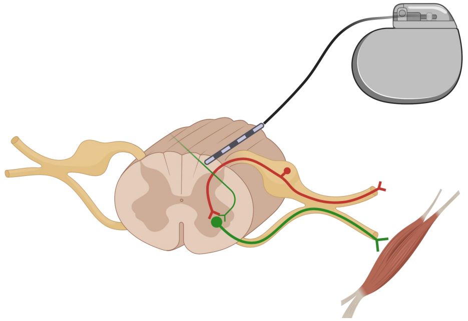


Muscle-computer interfaces



Stimulating motor function after paralysis

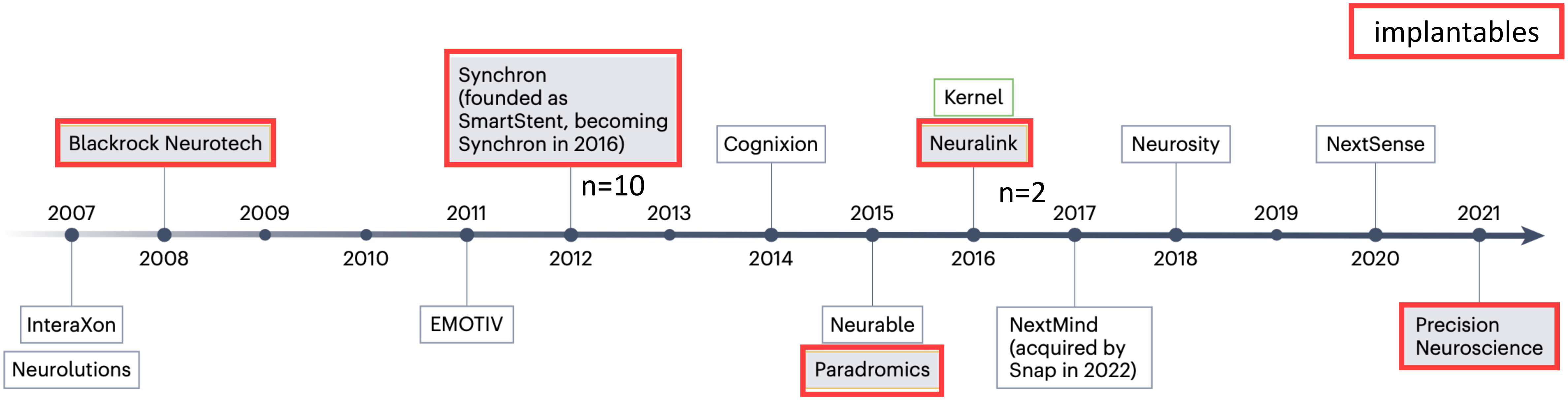
Spinal Dorsal Rootlet Stimulation after Stroke



Implantable sensors for brain-computer interfaces (BCI)

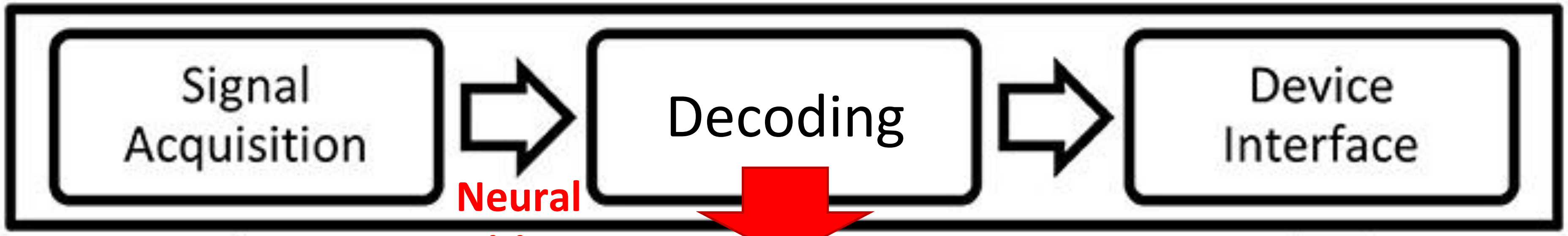
The BCI *industrial revolution*

Early innovators: Neural Signals, Inc. (1987) and Cyberkinetics (~2002)



Drew, L., 2023, "Decoding the Business of Brain–computer Interfaces," Nature Electronics, **6**(2), pp. 90–95.

BCI Concept



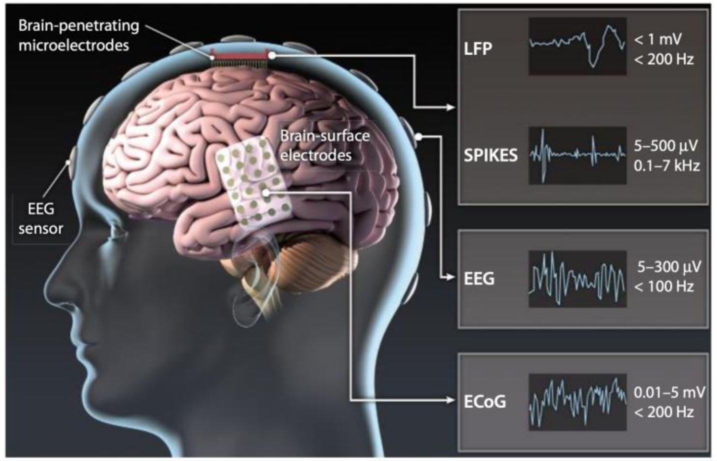
Microelectronics

Neural Firing Rates

MEMS Sensors

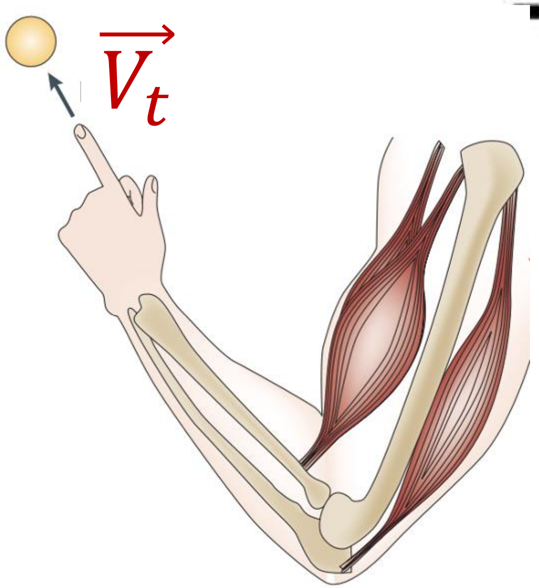
action = f(neural signals)

example: $\overrightarrow{V_t} = \sum_{i=1}^{N} w^i * FiringRate_t^i$



SYSTEMATIC REVIEW article

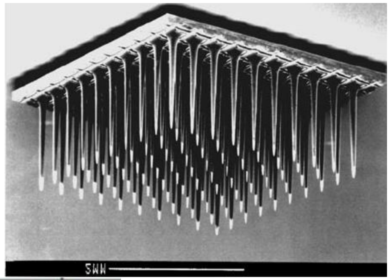
Front. Hum. Neurosci., 14 July 2021
Sec. Brain-Computer Interfaces
Volume 15 - 2021 | https://doi.org/10.3389/fnhum.2021.643294

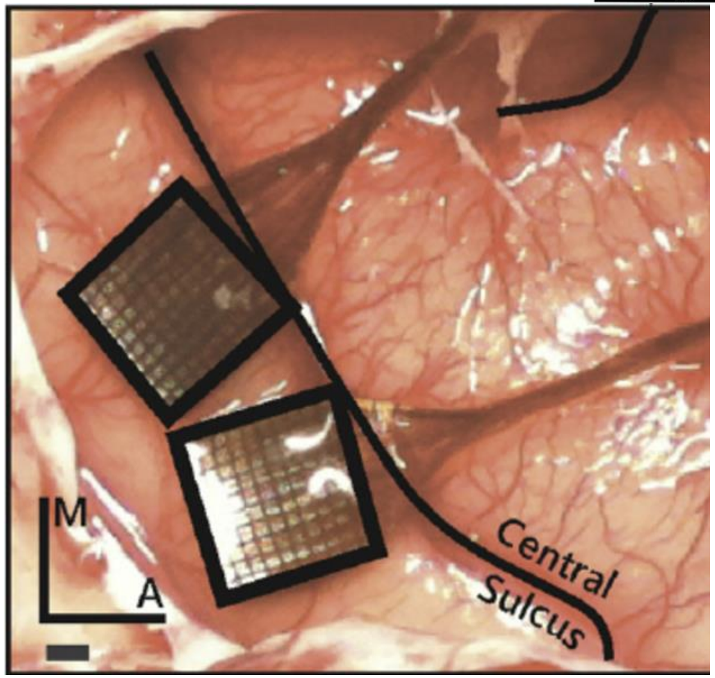


Assistive Device

Example: sensing and decoding brain signals to control a robotic arm

Sensor Technology:
Silicon microelectrode arrays
(n=100 electrodes)





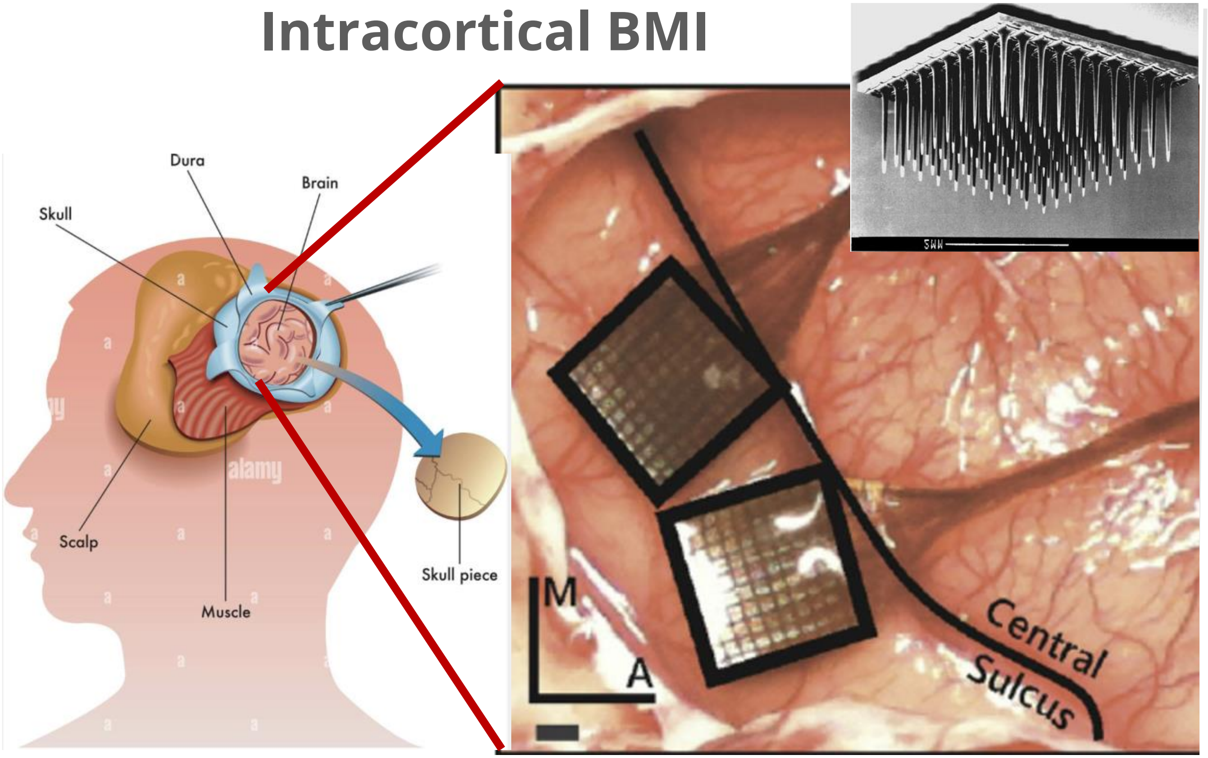
High-performance neuroprosthetic control by an individual with tetraplegia

Jennifer L Collinger, Brian Wodlinger, John E Downey, Wei Wang, Elizabeth C Tyler-Kabara, Douglas J Weber, Angus J C McMorland, Meel Velliste, Michael L Boninger, Andrew B Schwartz

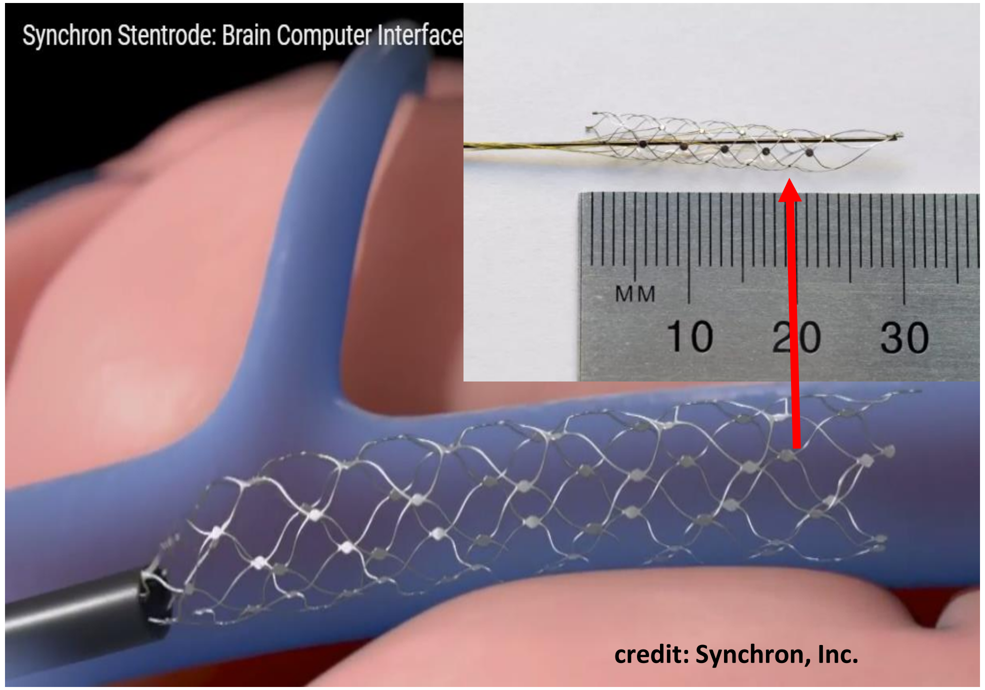
www.thelancet.com Vol 381 February 16, 2013

Emerging tech: “injectable” sensors for the brain

Intracortical BMI



Endovascular BMI

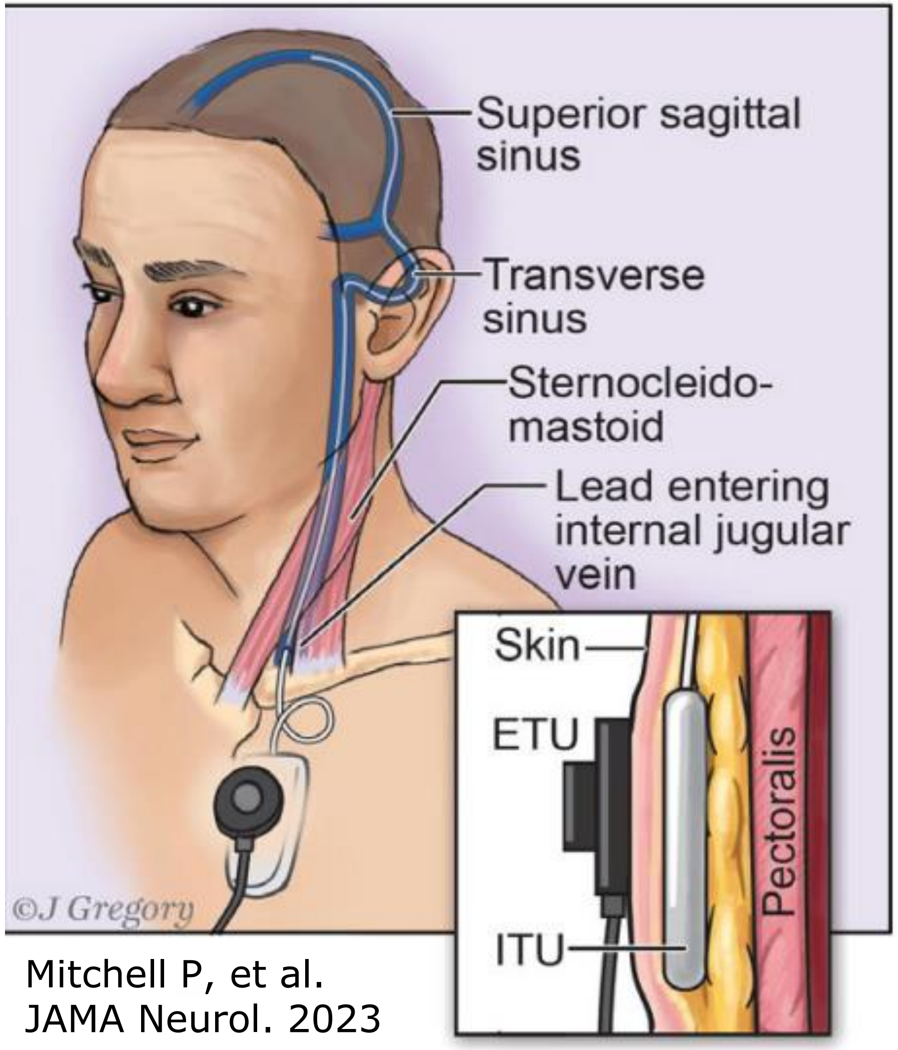


credit: Synchron, Inc.

Stentrode Endovascular BCI

credit: Synchron

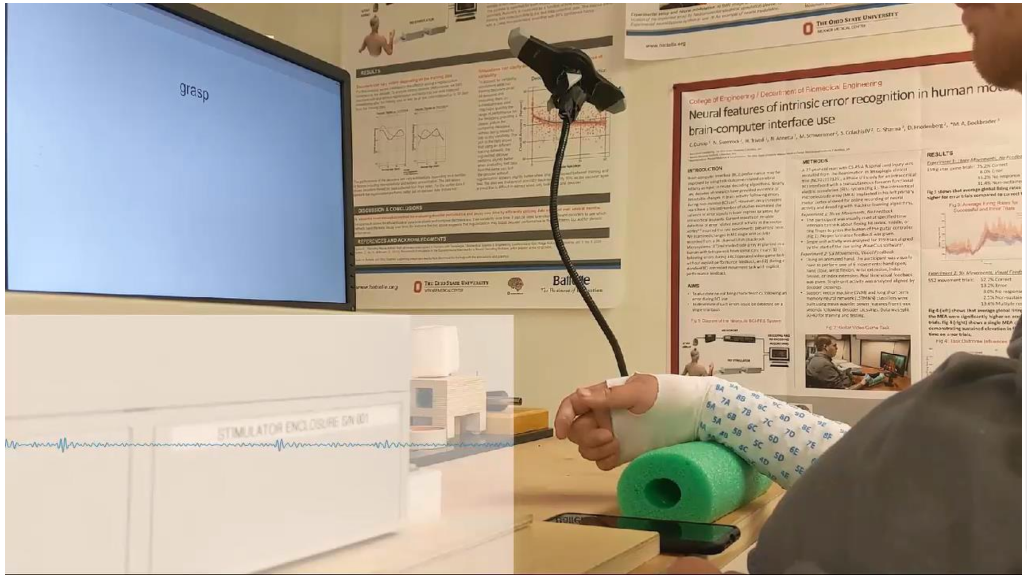
- Nitinol stent scaffold
- 16 x 500 μm diameter platinum electrodes
- Inserted via catheter through jugular vein to the superior sagittal sinus adjacent to motor cortex

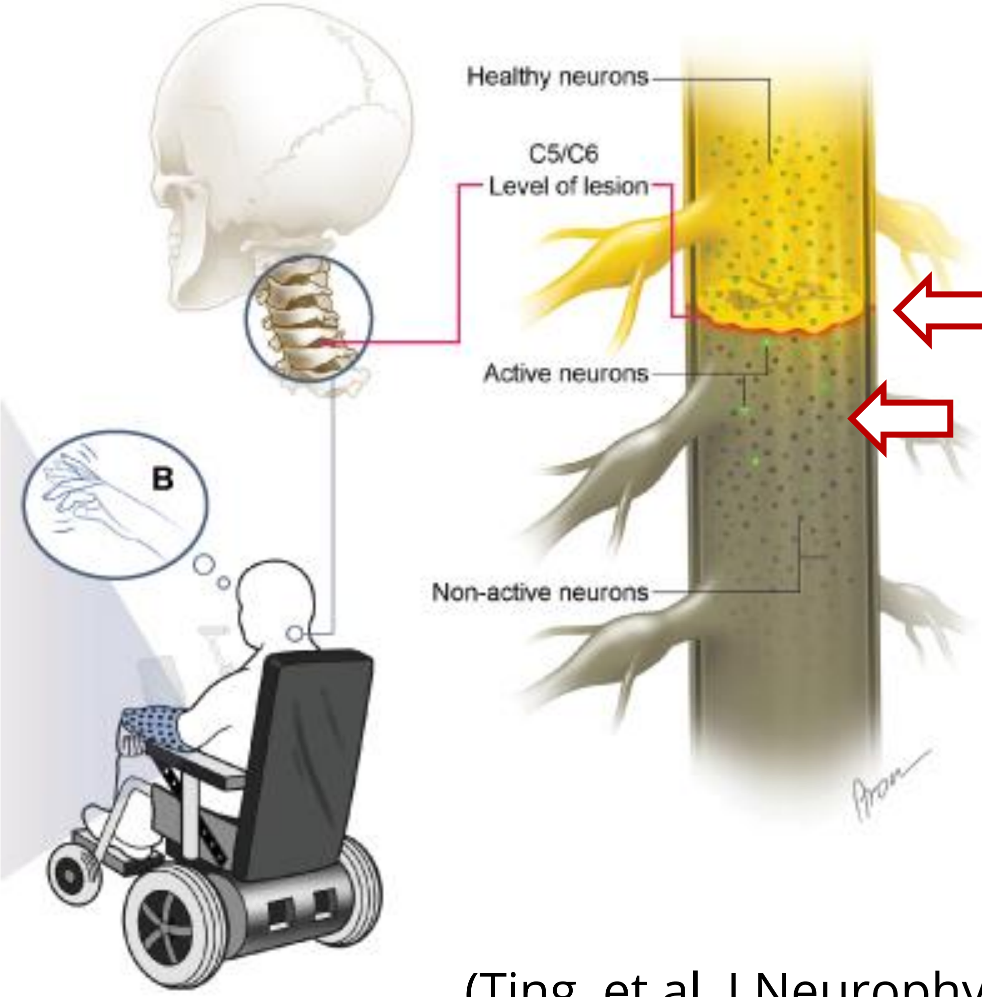


Mitchell P, et al.
JAMA Neurol. 2023

Wearable sensors for detecting motor signals

An estimated 80% of people with “complete” SCI retain some myoelectric function below level of injury (Sherwood et al, 1992)



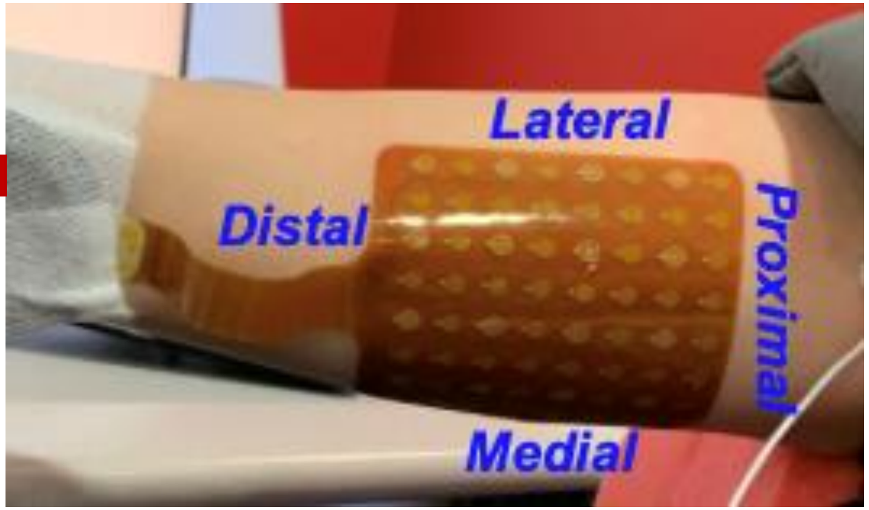


Injury site in spinal cord

”Spared” motor neurons

(Ting, et al, J Neurophys, 2021)

High-density electromyography (HDEMG) sensors



Motor unit
decomposition

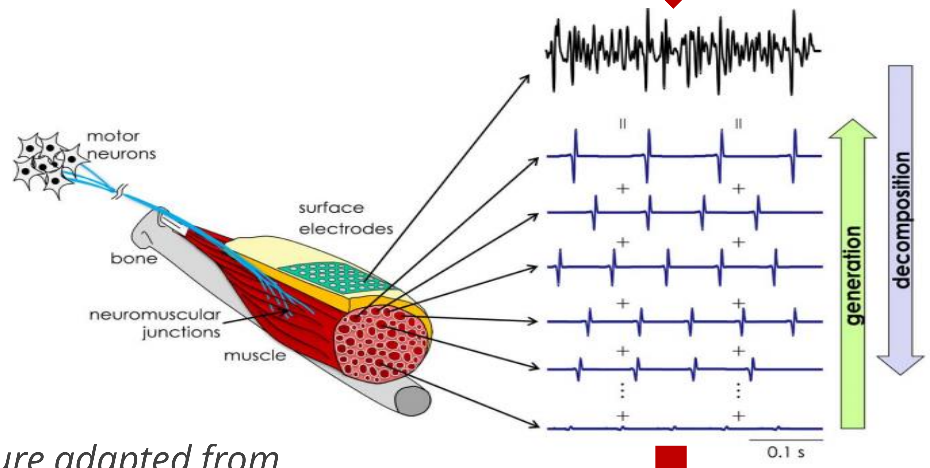
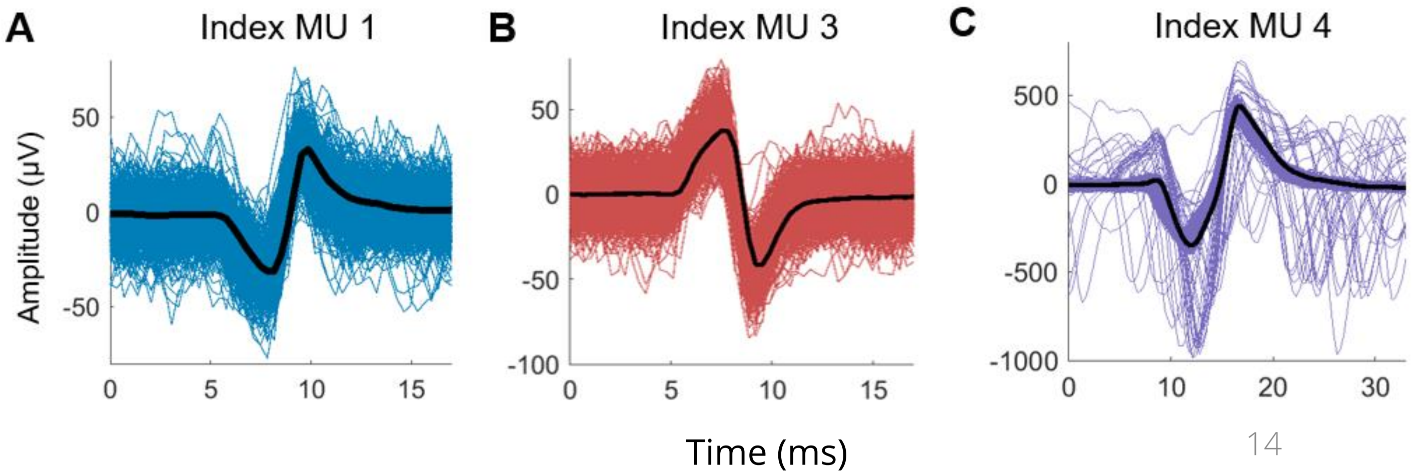
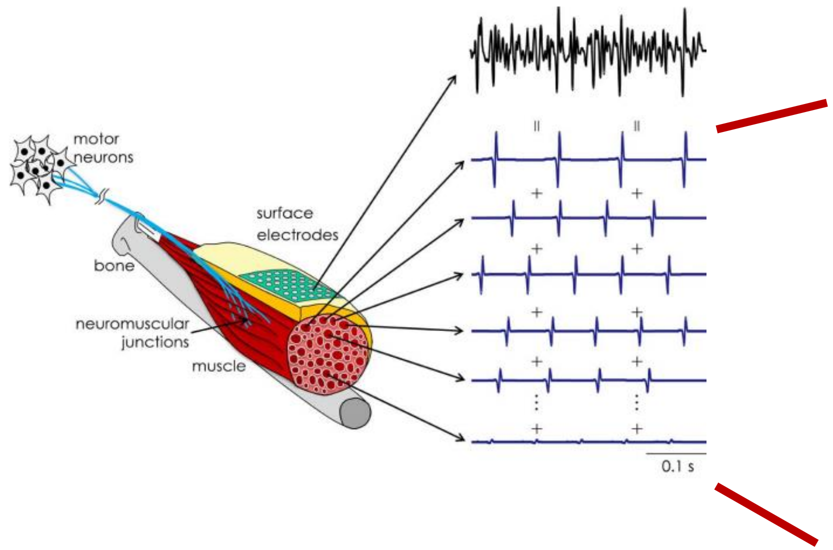


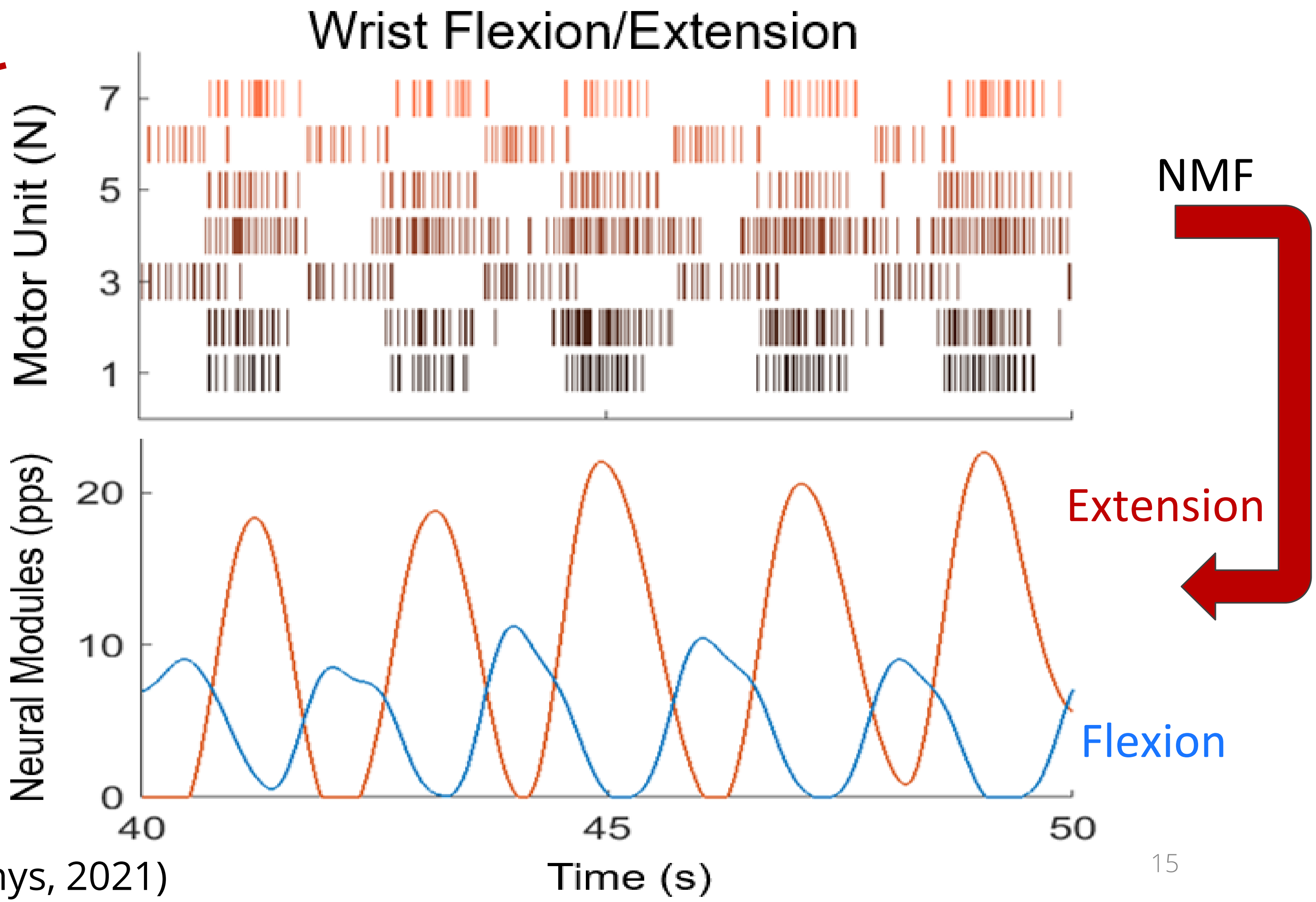
Figure adapted from
Farina & Holobar, 2016

Motor unit
spikes



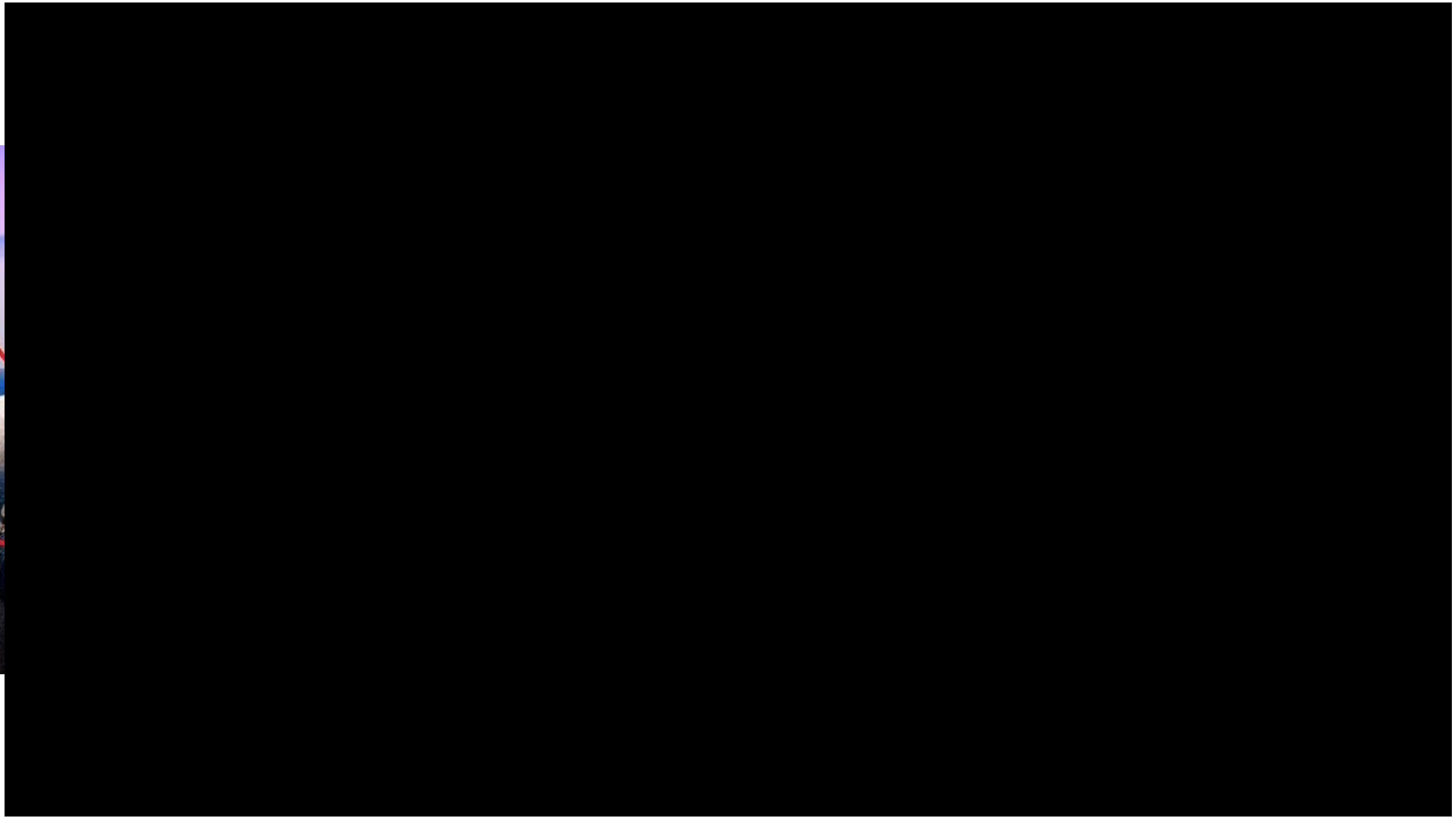
Motor neuron "spikes" encode attempted action





(Ting, et al, J Neurophys, 2021)

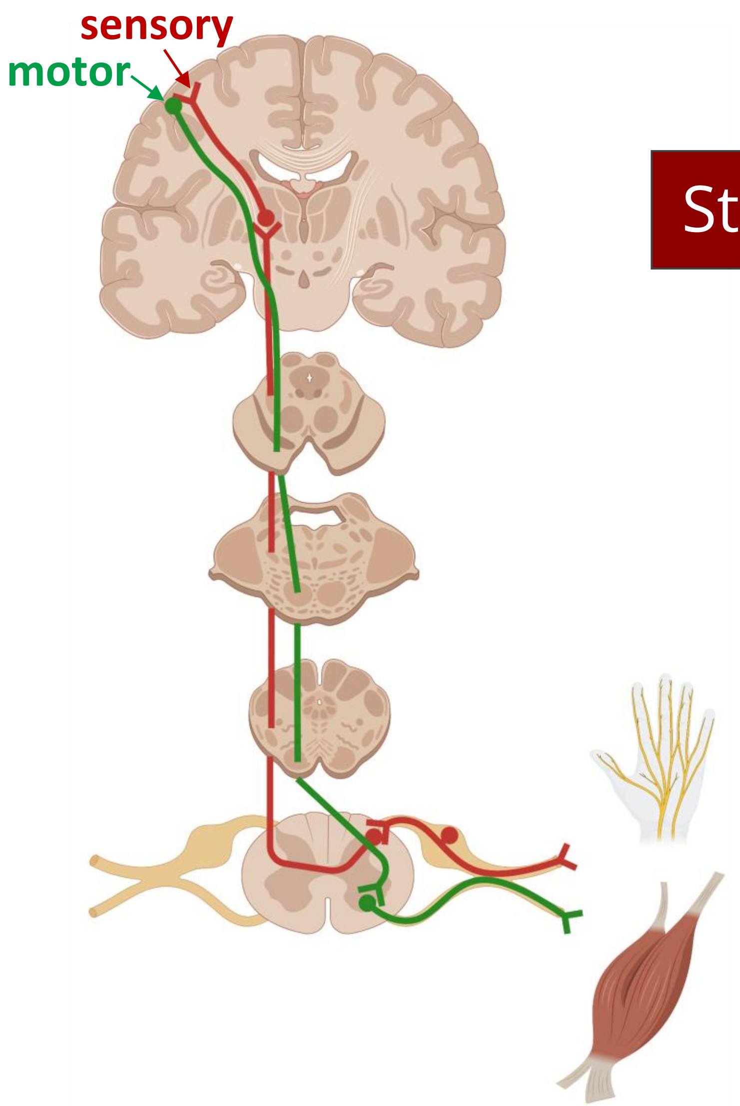
Muscle Biopotential Signals as Input Controllers (Collaboration with Meta Reality Labs)



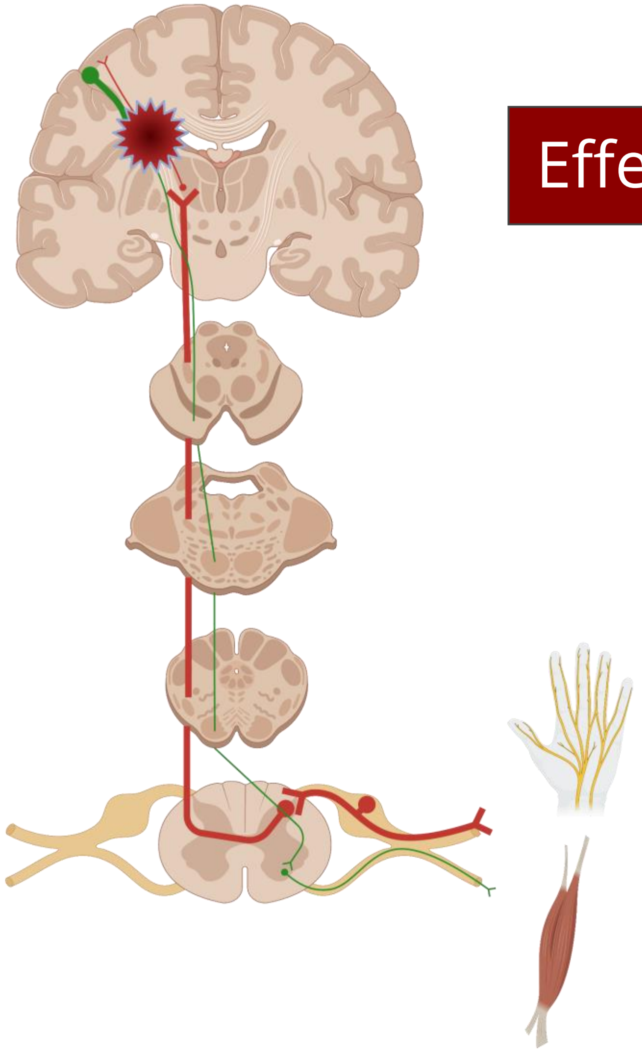
Meta

Amplifying Spared Motor Function using Spinal Cord Stimulation

Stroke Damages Motor and Sensory Neural Circuits



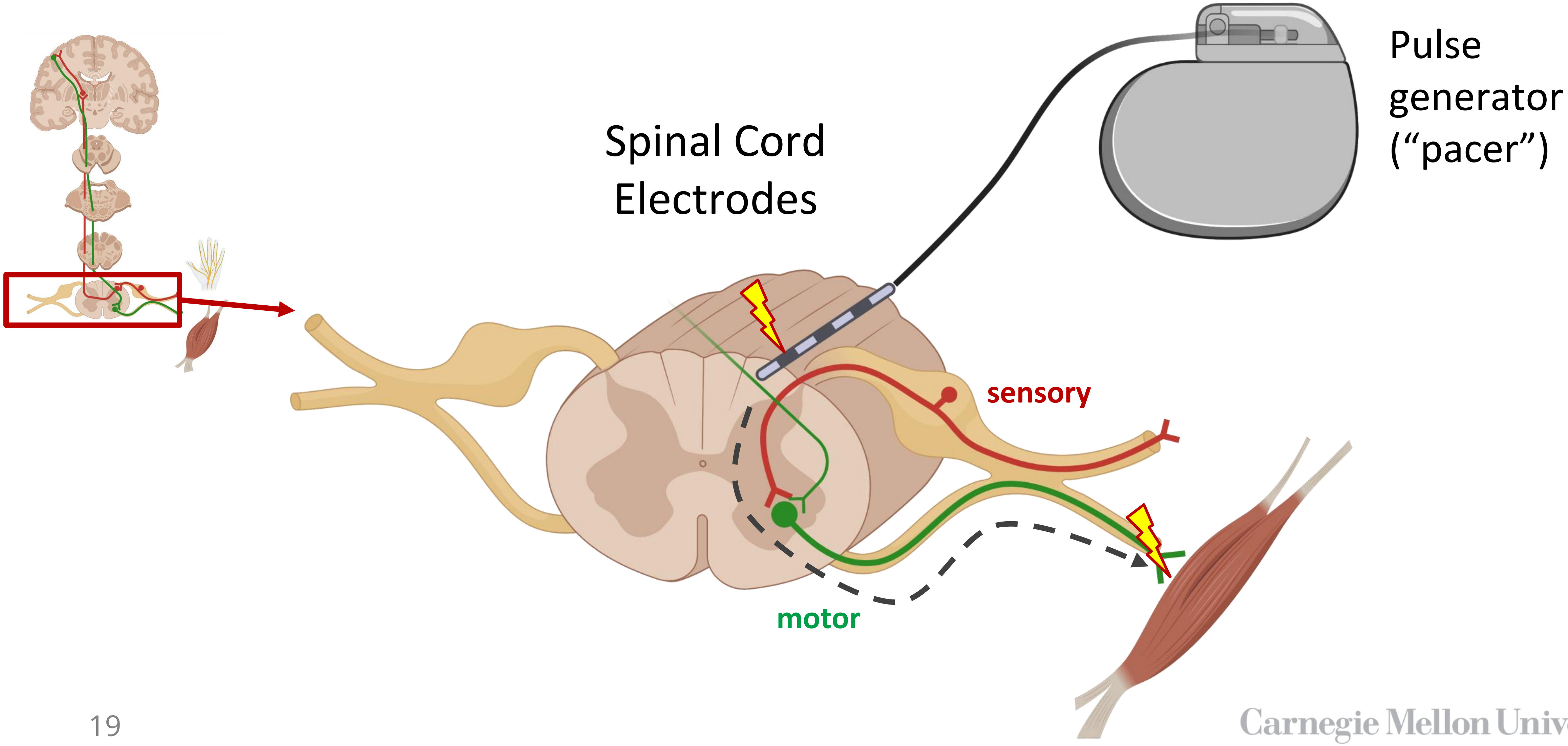
Stroke



Effects

- Muscle weakness throughout the limb
- Abnormal coordination
- Spasticity
- Impaired sensation

Electrical Stimulation Excites Motor Neurons by Targeting Sensorimotor Circuits in Spinal Cord



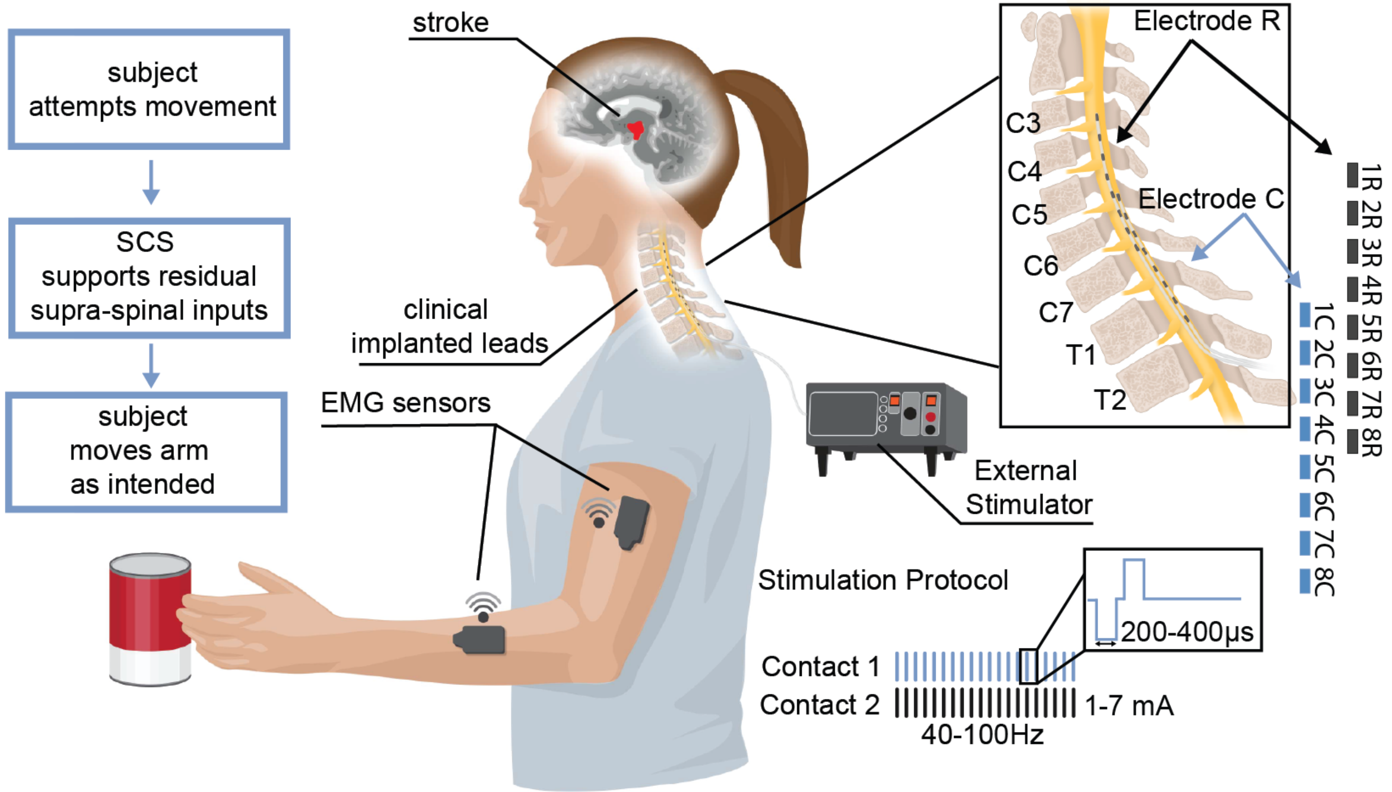
Pilot Clinical Trial:
Dorsal Rootlet Stimulation (DRS) for Stroke

n = 7 (so far) patients with chronic hemiplegia, 1+ years post-stroke

Impairment levels range from moderate to severe with mild to severe spasticity

2 x 8-channel linear arrays implanted percutaneously for 4 weeks and then removed

External stimulator with custom controller



Article | Published: 20 February 2023

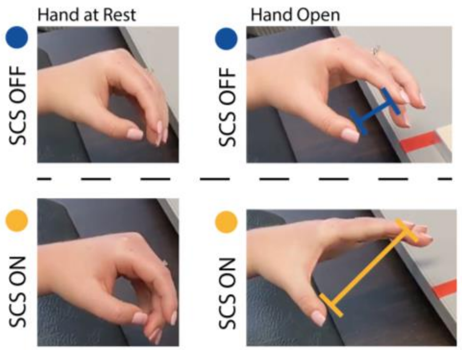
Epidural stimulation of the cervical spinal cord for post-stroke upper-limb paresis

Marc P. Powell, Nikhil Verma, Erynn Sorensen, Erick Carranza, Amy Boos, Daryl P. Fields, Souvik Roy, Scott Ensel, Beatrice Barra, Jeffrey Balzer, Jeff Goldsmith, Robert M. Friedlander, George F. Wittenberg, Lee E. Fisher, John W. Krakauer, Peter C. Gerszten, Elvira Pirondini, Douglas J. Weber & Marco Capogrosso

Nature Medicine **29**, 689–699 (2023) | Cite this article

DRS facilitates hand function (Day 1)

*"I have not been able to open my hand **in 9 years**"*
-SCS01

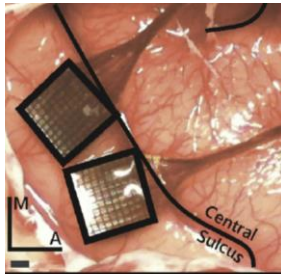


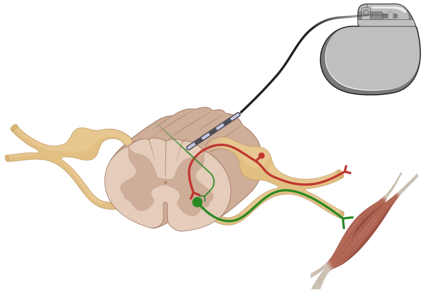
DRS Improves Function for Daily Activities

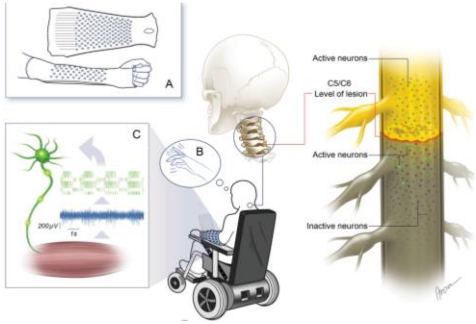
Summary

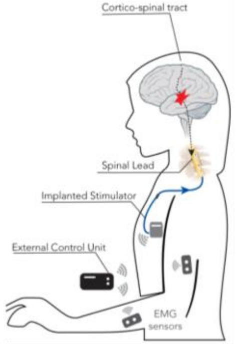
Implantable and wearable sensors can detect and interpret motor intent to restore independent motor function to people with severe paralysis.

Electrical stimulation of sensory neurons can amplify motor output and improve motor control in the arm and hand in people with chronic hemiplegia after stroke





Questions?

contact info:

dougweber@cmu.edu

@dougweberlab

@NeuroMechLabX

Funding

NIH National Institutes of Health

National Institute of Neurological Disorders and Stroke

NIH The BRAIN Initiative®

Meta

US Trial Milestones

July 2022
US first-in-human trial began
1st participant implanted - ALS

Sep. 2022
2nd participant implanted - ALS

Dec. 2022
3rd participant implanted - ALS

Apr. 2023
4th participant implanted- Brainstem stroke

June 2023
5th participant implanted - ALS

Aug. 2023
6th participant implanted - ALS

DRS Improves Manual Dexterity

University of Pittsburgh

A SPINAL NEURAL INTERFACE TO IMPROVE VOLUNTARY MOTOR CONTROL IN POST-STROKE UPPER-LIMB HEMIPARESIS

Carnegie Mellon University