1.5 kg

100 billion neurons \((10^{11})\)

1,000 trillion synapses \((10^{15})\)
Neural activity encodes movement intention. Movement control signal calculated from neural activity.

Brain Computer Interface

Feedback

Neural Signal Acquisition

Signal Processing and Feature Extraction

Neural activity encodes movement intention

Decoding Intent

Form Control Signal

Device Control

Movement control signal calculated from neural activity
Least Invasive >> EEG >> ECoG >> Microelectrodes >> Most Invasive
Utah/Blackrock Microelectrode Array

- 4x4 mm silicon substrate
- 100 machined and etched electrodes
- 1.5 mm long electrodes
- Platinum or Iridium Oxide tips
- Implanted in >20 people at 6+ centers in the US and Europe
Directional tuning in motor cortex

\[ f = b_0 + b_x v_x + b_y v_y \]

Neural activity represents a ‘weighted sum’ of desired movements.
Skilled movement and manipulation requires tactile sensation.
• 28 year old male, 10 years post injury
• C5 Motor, C6 Sensory spinal cord injury
• AIS B (motor complete, sensory incomplete)
• Study conducted under FDA IDE and IRB approvals
Projected field locations are stable

<table>
<thead>
<tr>
<th>Day</th>
<th>Medial Array</th>
<th>Lateral Array</th>
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<tbody>
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<td>1211</td>
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</table>
Neural Recording and Decoding for Motor Control

Sensor Encoding and Electrical Stimulation for Sensory Feedback


Image Credit: Kenzie Green
ARAT

Task phase identification and ICMS configuration

University of Pittsburgh
Highly practiced task

No blindfold

Without tactile sensations, a score of three was achieved only once during the 108 trials.

When tactile sensations were provided, a score of three was attained 15 times during the 108 trials.

ARAT

Fastest trial comparison for each object with and without ICMS feedback

University of Pittsburgh
Stimulation-induced tactile feedback improves performance

Median Times

Reach decrease: 27.8% (0.6 s)
Transport decrease: 22.3% (0.8 s)
Grasp decrease: 44.7% (9.0 s)

Flesher et al. BioRxiv, 2019

What’s next?

Fix our current problems
- Wireless
- Longevity
- Simple surgery
- Reliable and Independent
- Better Robots

Future BCI?
- Clinical adoption for paralysis
- Millions of contacts / massive scaling
- Ethics are critical
- Humans + machines = ?
- Performance enhancement
Summary

• Implanted BCIs and robotic prostheses can restore lost sensory and motor function.
• Only dozens to hundreds of neurons are required to restore meaningful function.
• Interdisciplinary research and development still needed to make this a clinical reality.
• Special thanks to our participants and to all collaborators!!

More information at: rnel.pitt.edu
President Obama: “This stuff is real science fiction!”

Nathan Copeland: “Now it’s just science!”