Utah NeuroRobotics Lab:
Intuitive and Dexterous Control of Bionic Devices for Assistance and Rehabilitation

Presenter: Jacob A. George, Ph.D.
jacob.george@utah.edu

Brain-Computer Interfaces: from Invasive Neuroprostheses to Noninvasive Exoskeletons

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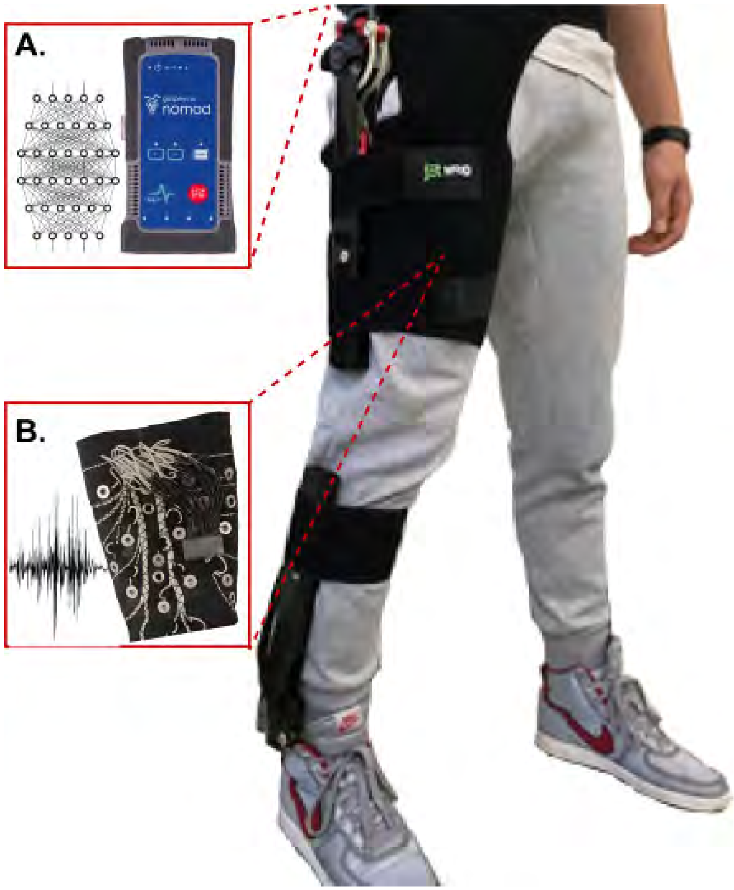
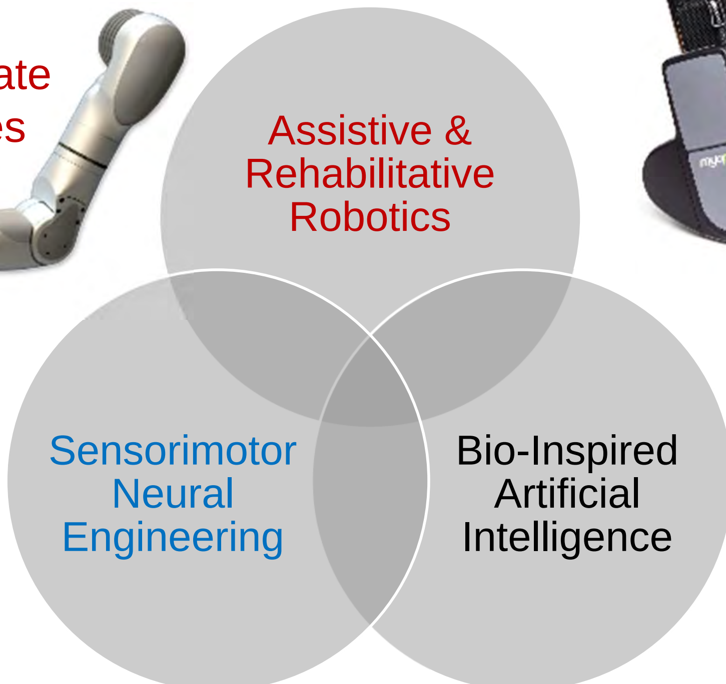


Craig H. Neilsen Rehab Hospital Serves the Largest Portion of the US by Landmass

Translational Research at the Intersection of Robotics, Brain-Computer Interfaces, and AI

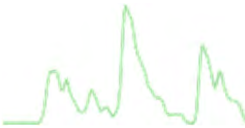
Adaptive Recreation

Multiarticulate Prostheses

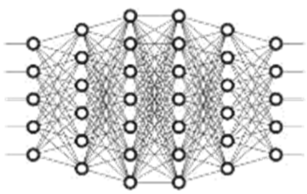


Powered Orthoses

Biomimetic Models

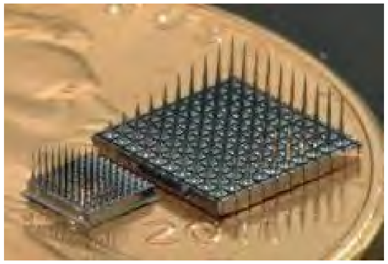


Deep Learning



Wearables

Implants



My Lab Was Established in Fall 2020 through the NIH Directors Award

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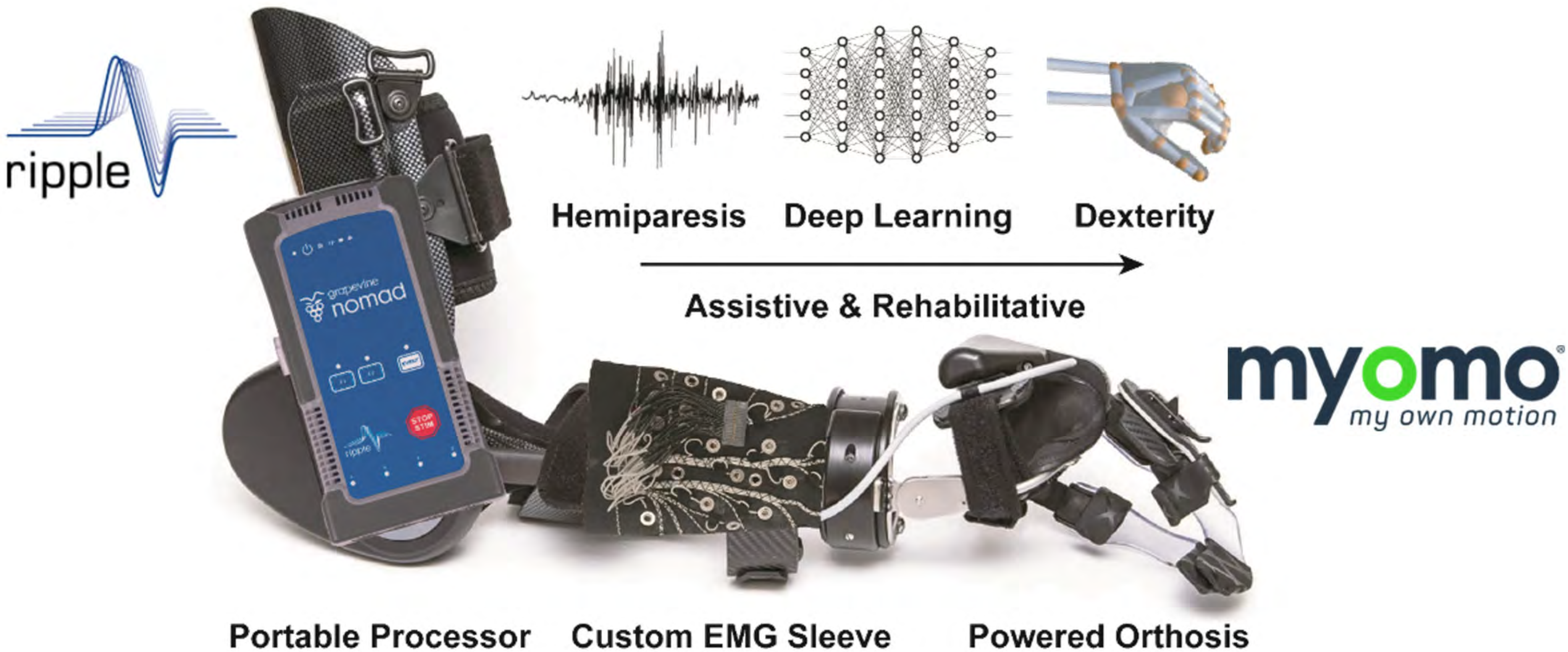
NIH

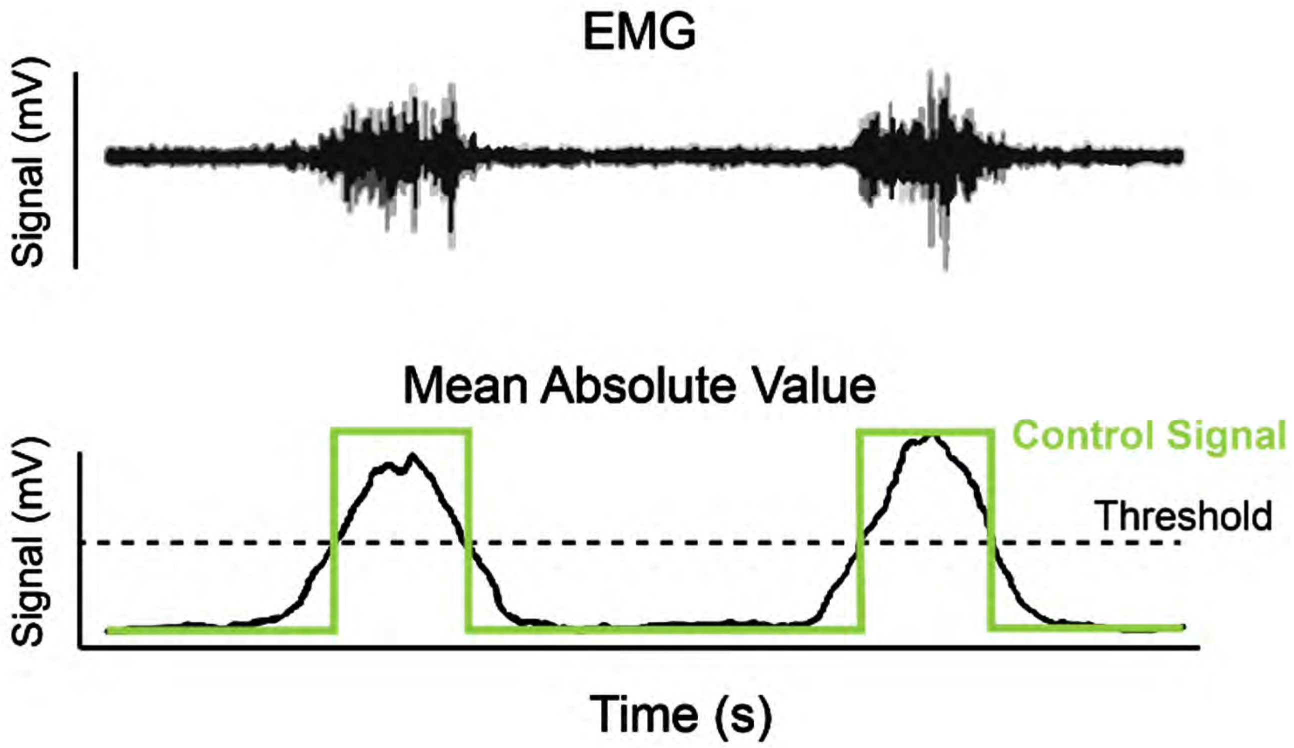
NIH DIRECTOR'S
EARLY
INDEPENDENCE
AWARD

Patient-Centered Rehabilitation through Dexterous & Adaptive Assistive Bionic Devices

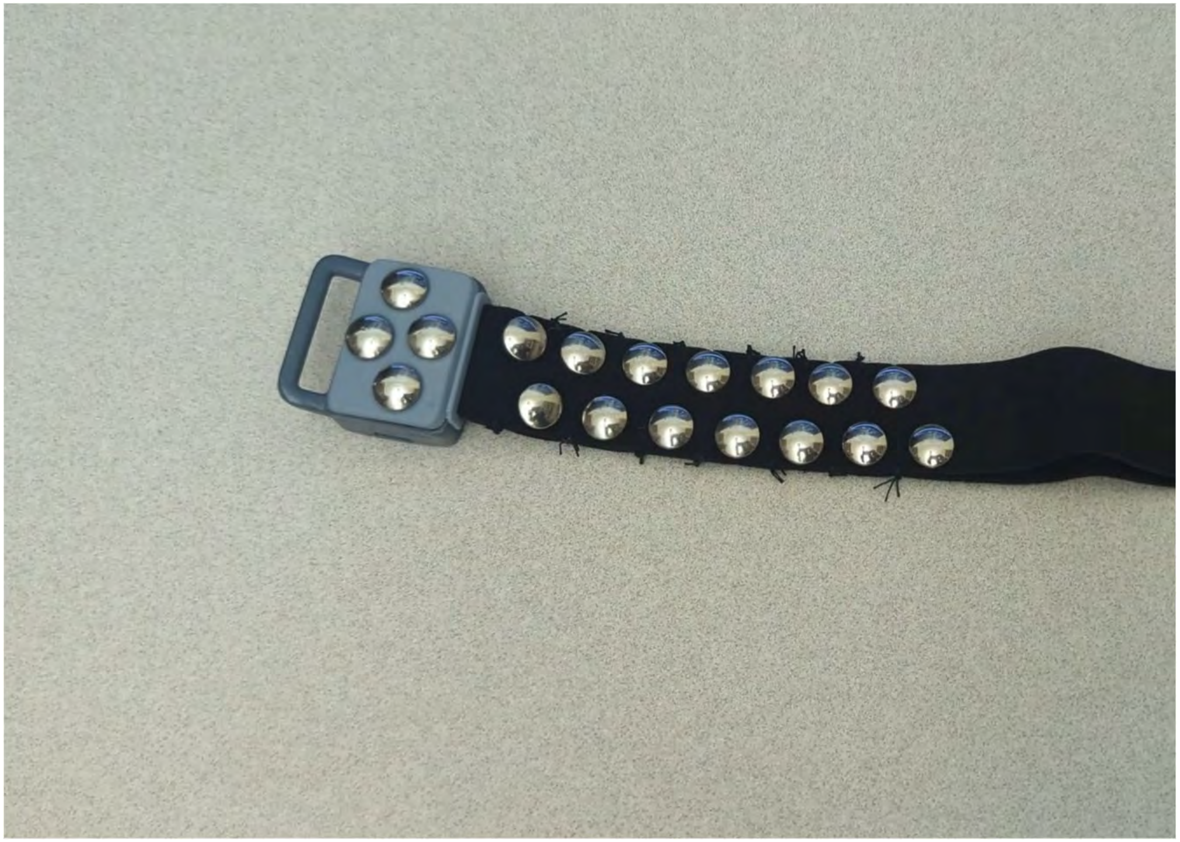


Clinical Exoskeletons Provide Binary (open-close) Control of Two Movements

Current Control Strategies Apply a Binary Threshold to Rectified EMG



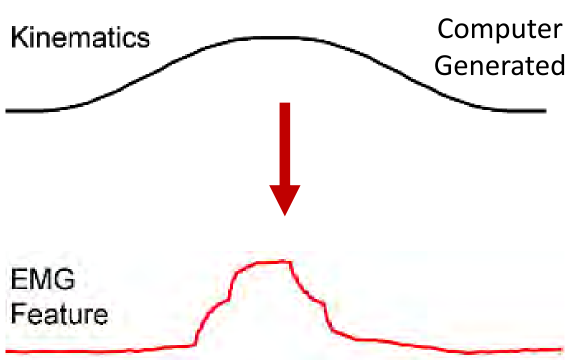
High Density EMG in a Common Wearable Formfactor

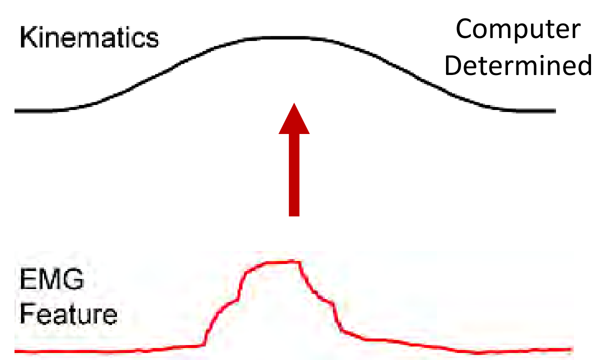


Three-Stage Approach to Restoring Intuitive and Dexterous Control

Generate Training Data → **Algorithm Training** → **Run-Time Performance**

User Mimics Computer | Computer Learns | Computer Predicts User Intent



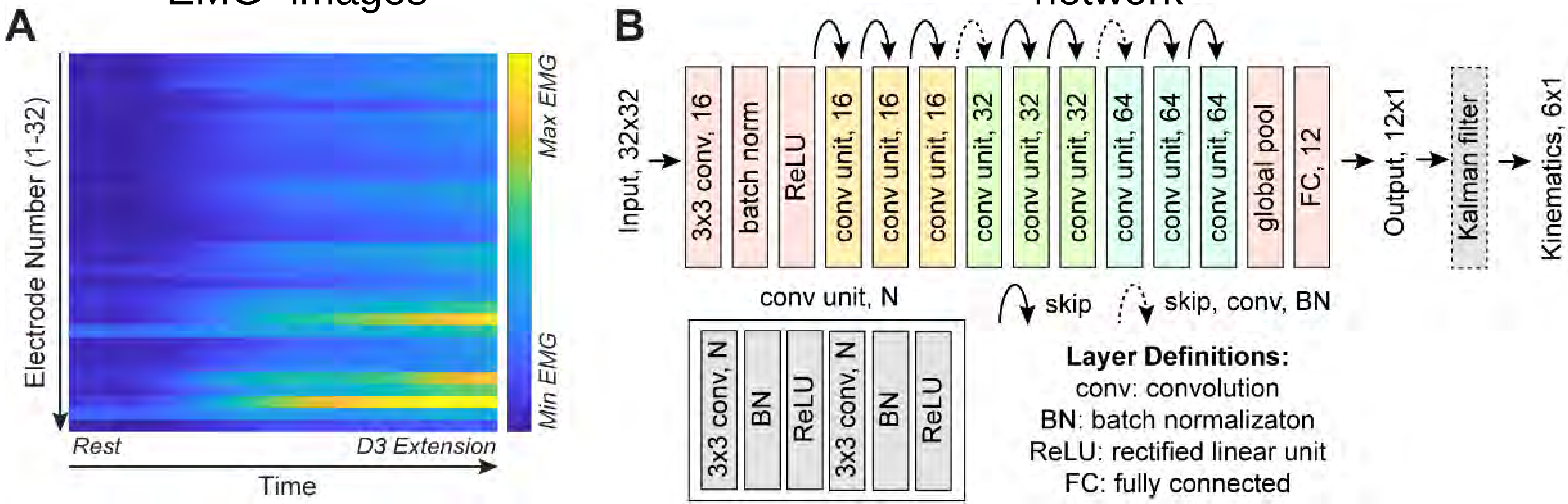


George et al., *J. Neurosci. Meth.*, 2019

Spatiotemporal Analyses of Muscle Activity for Accurate & Robust Control

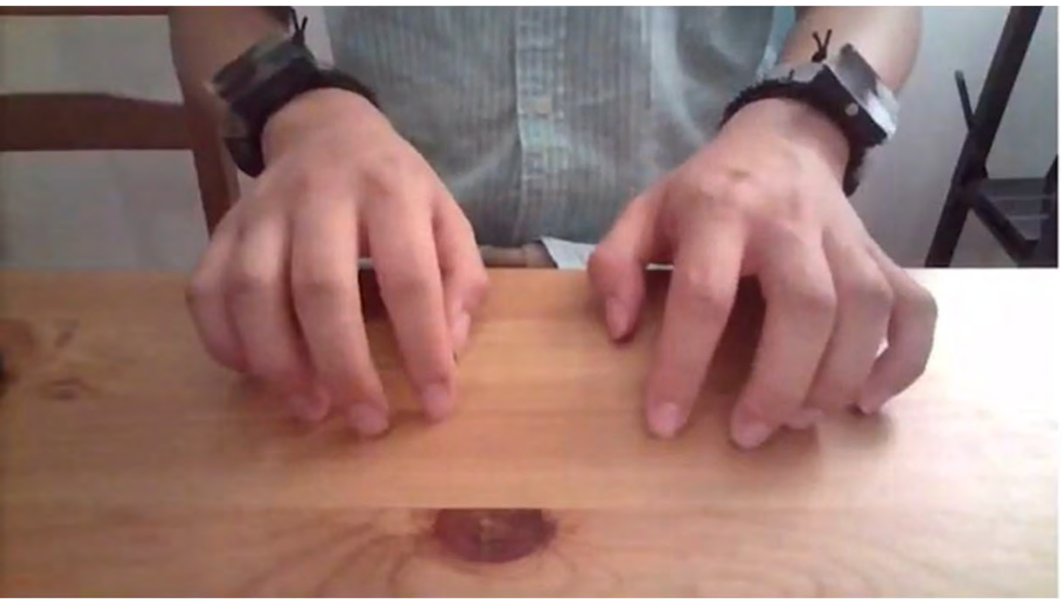
Spatiotemporal EMG "images"

74-layer deep neural network

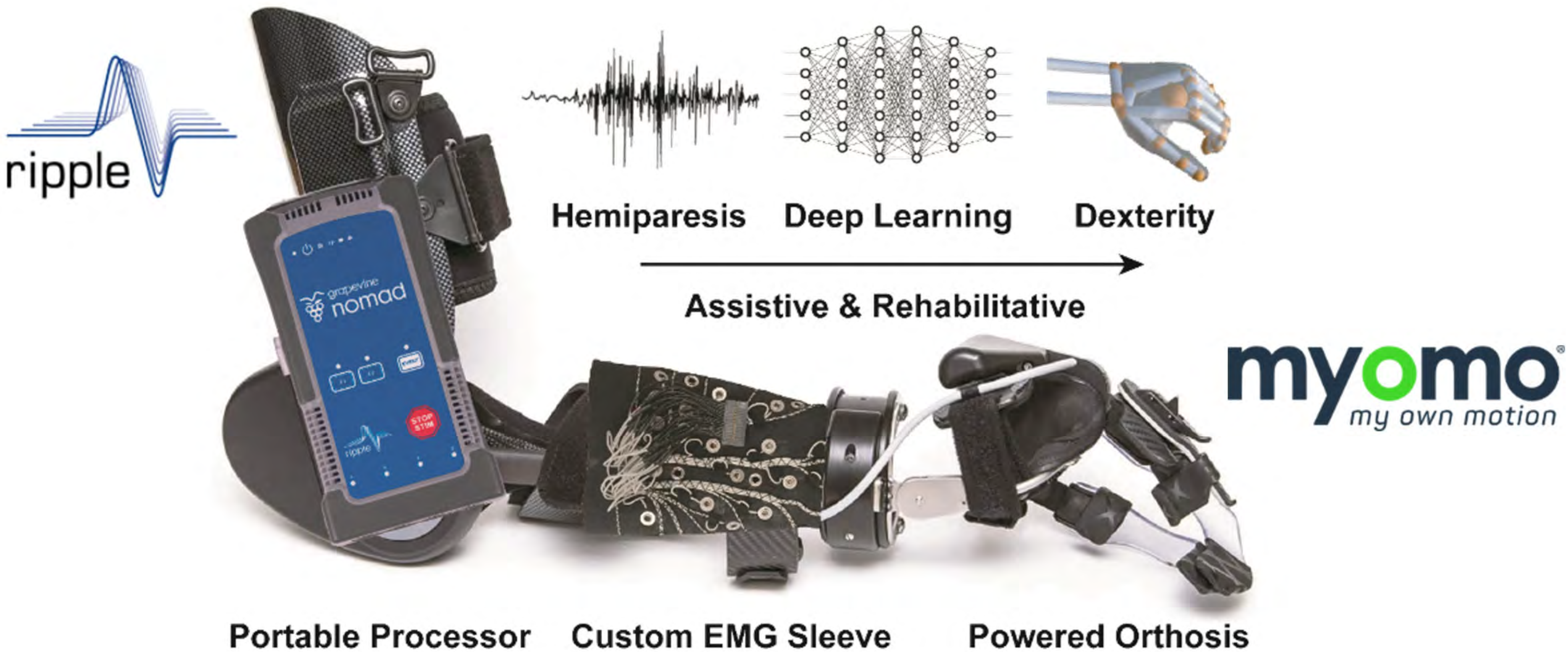


George et al., *Myoelectric Controls,* 2020

Deep Learning + EMG Provides A Powerful Estimate of Motor Intent



Deep Learning + EMG to Assist and Rehabilitate Stroke Patients



Intuitive and Dexterous Control of Bionic Devices for Assistance and Rehabilitation

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1. Paretic EMG is Weak & Spastic

but we can still predict…

2. Multiple Movements & Gestures

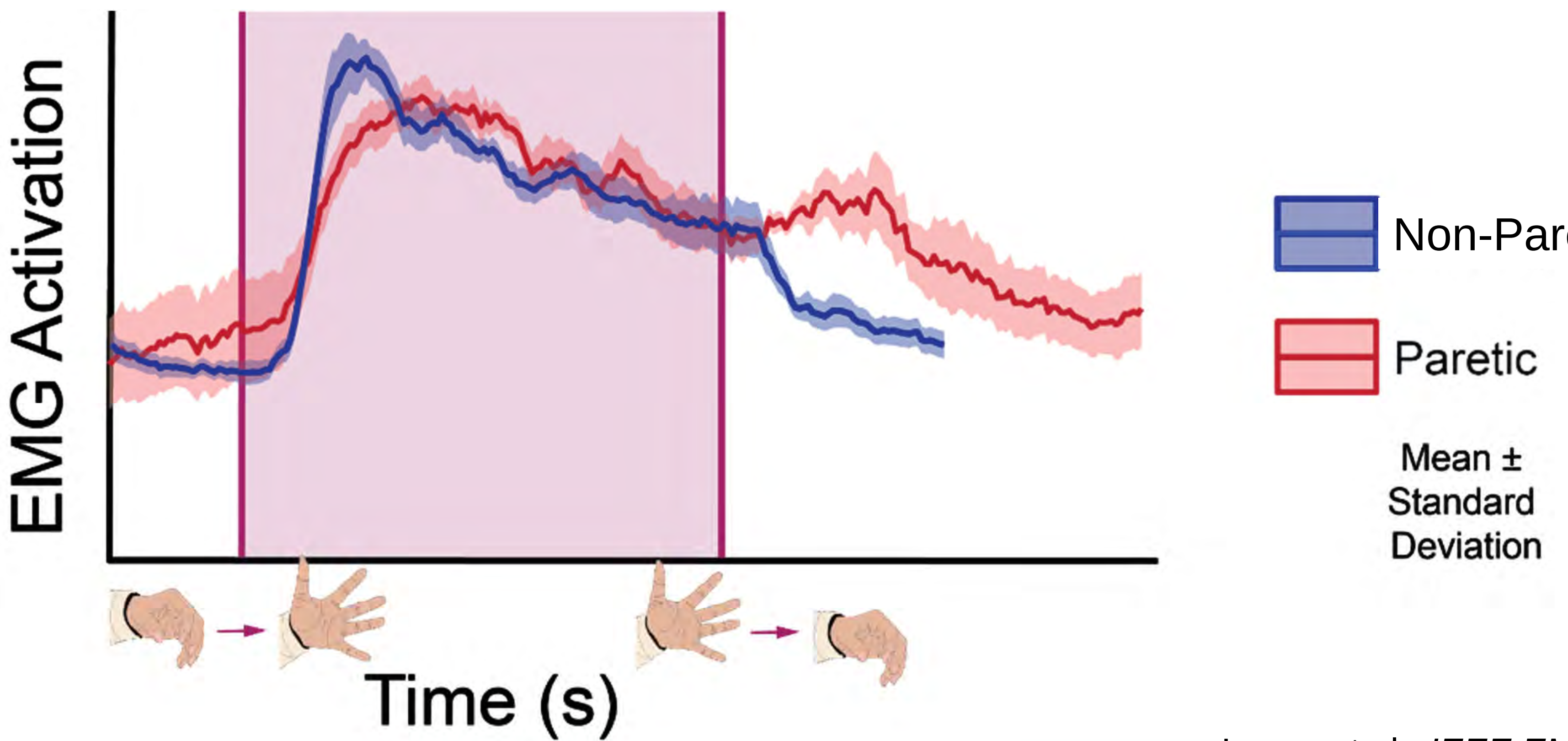
and provide…

3. Fine Force Regulation

enabled through…

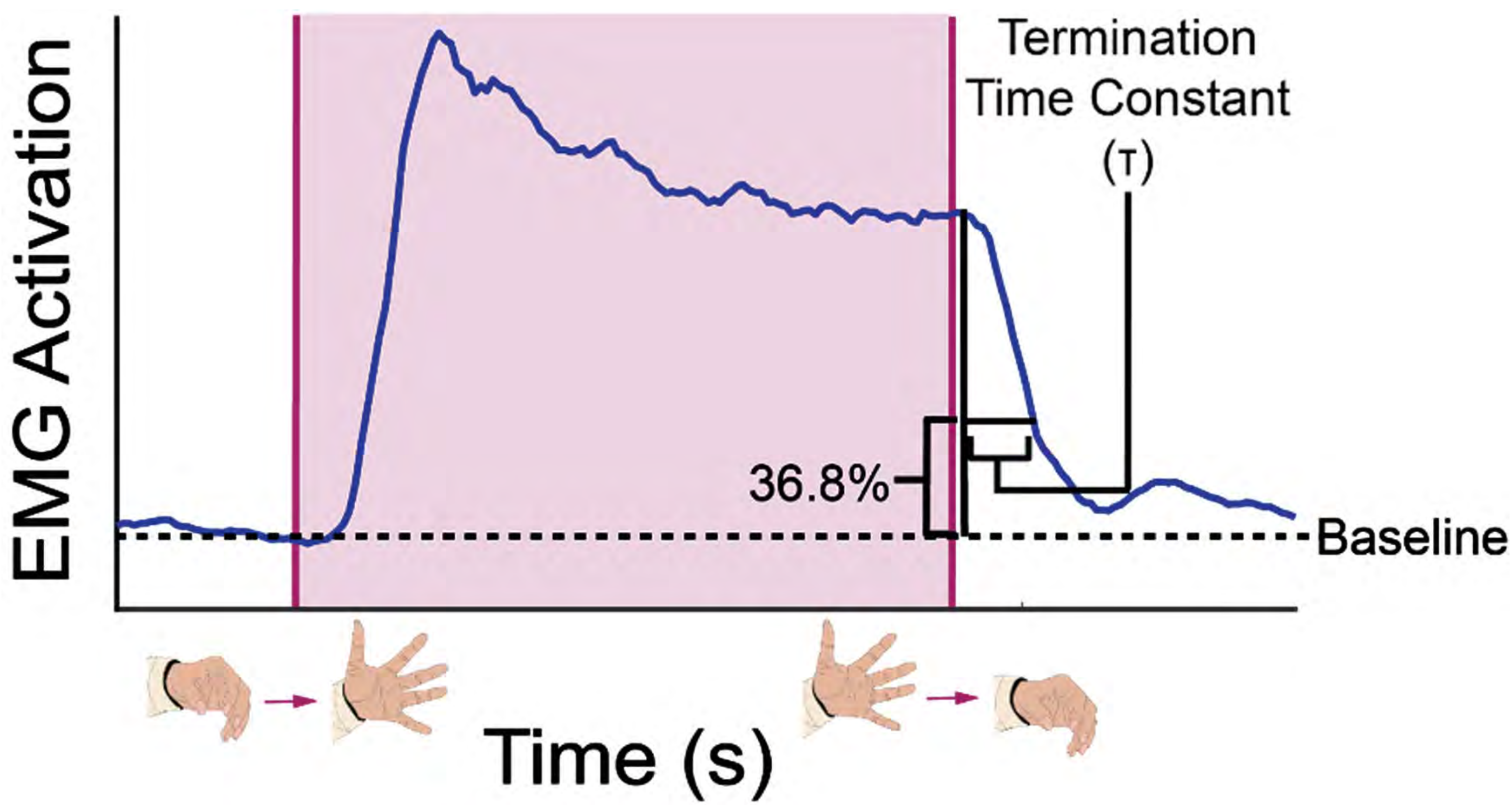
4. Co-Adaptive Learning

Example of Spastic EMG Activity During Hand Opening



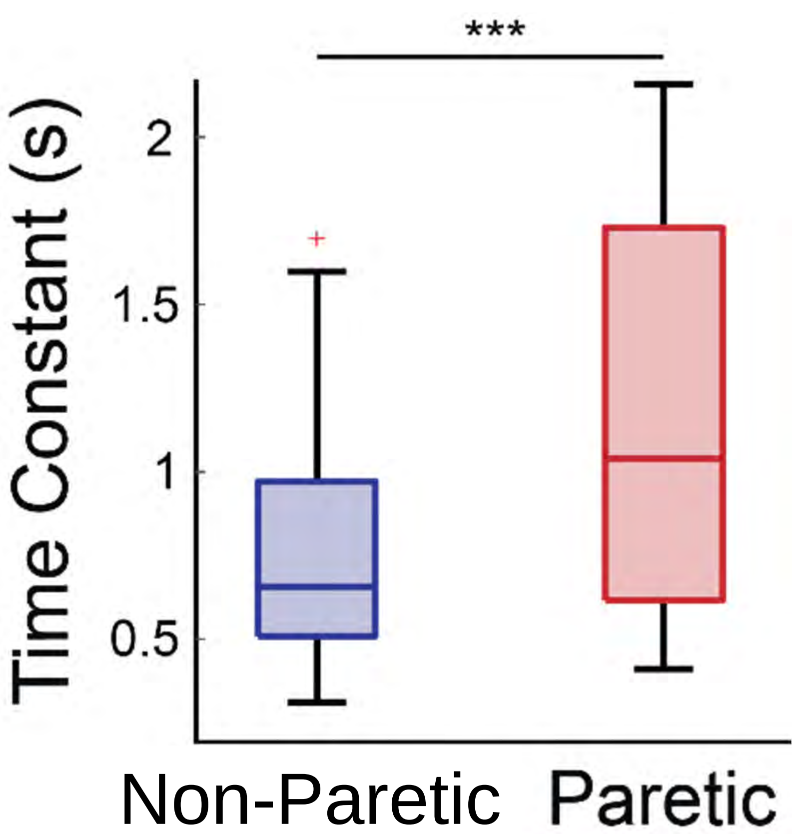
Lopez et al., *IEEE EMBC*, 2023

Time Constant of EMG Relaxation as a Measure of Spasticity Over Time



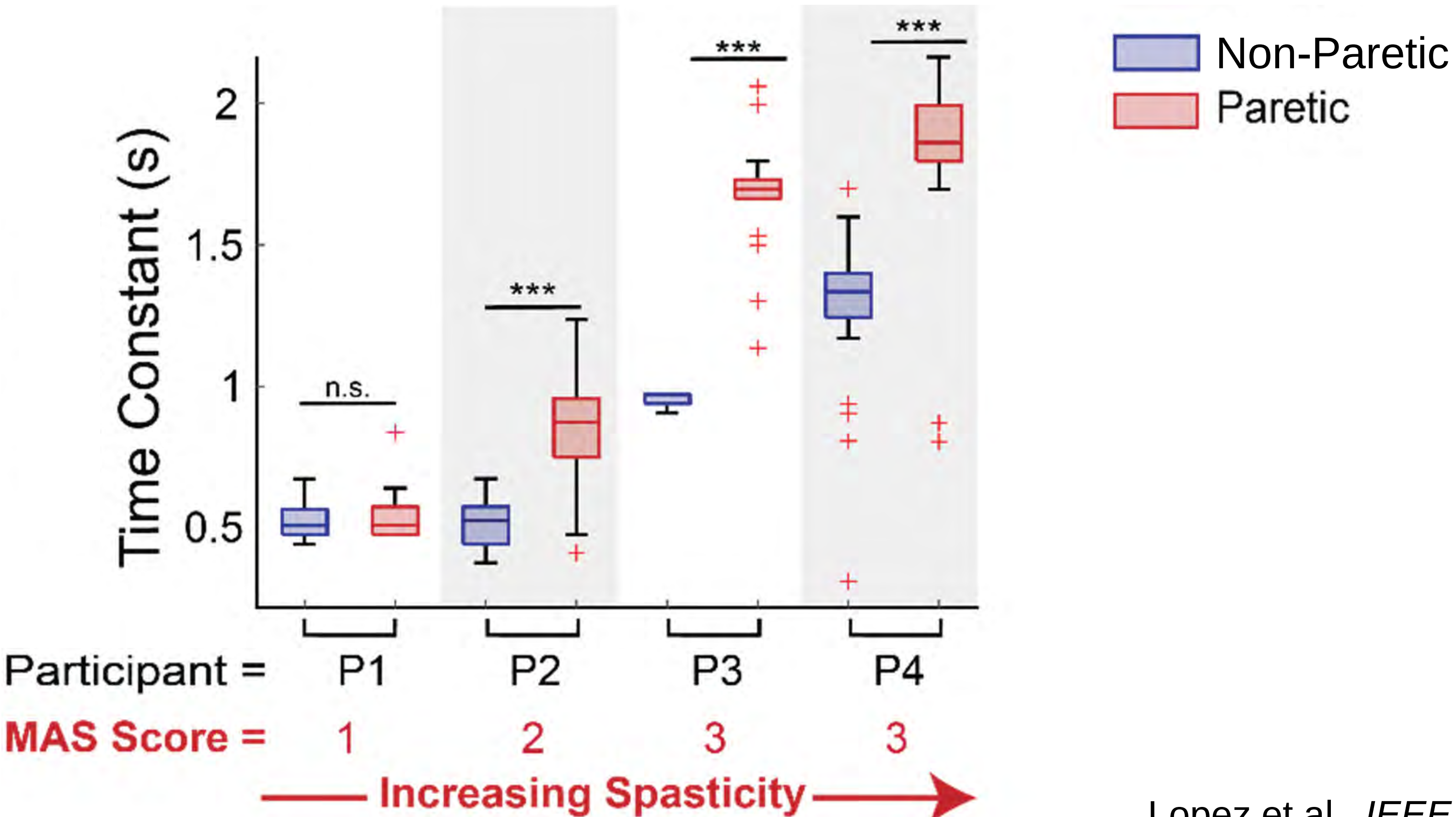
Lopez et al., *IEEE EMBC,* 2023

Paretic Arms Take Longer to Relax EMG



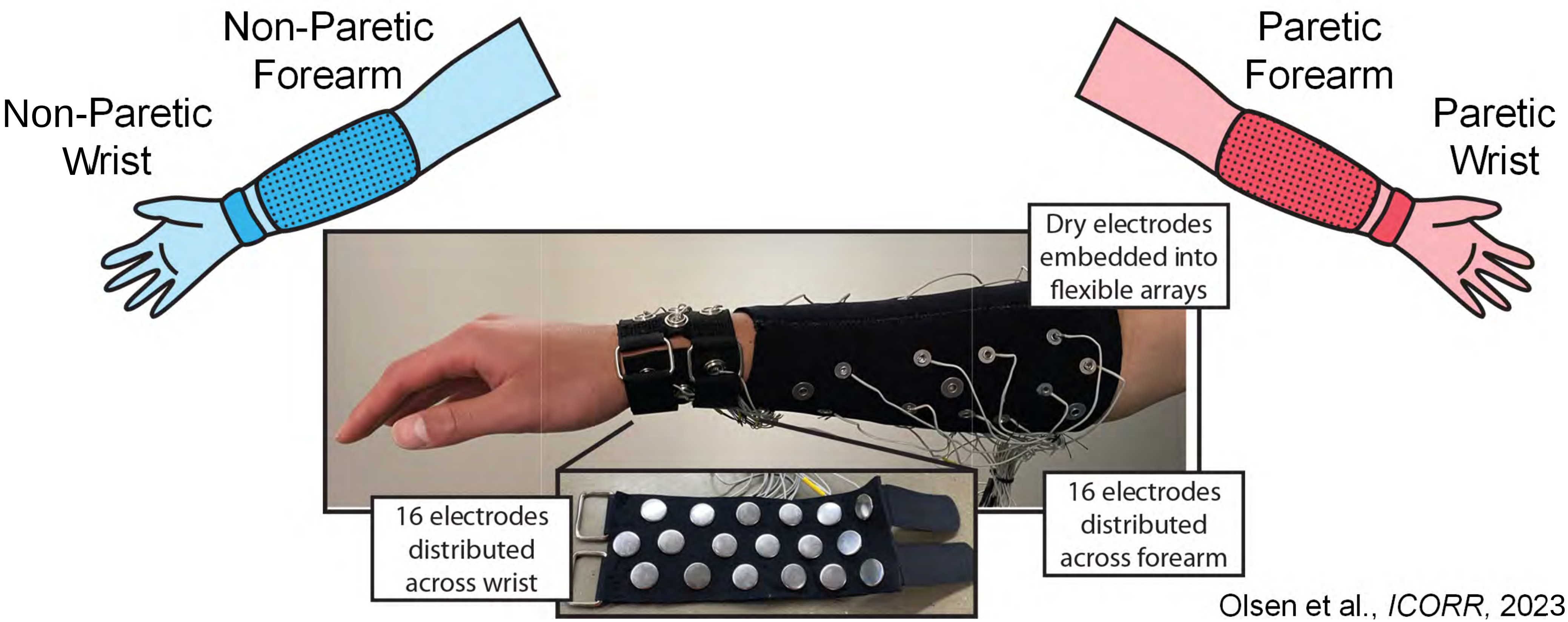
Lopez et al., *IEEE EMBC*, 2023

Time Constant Increases Bilaterally with Increasing MAS



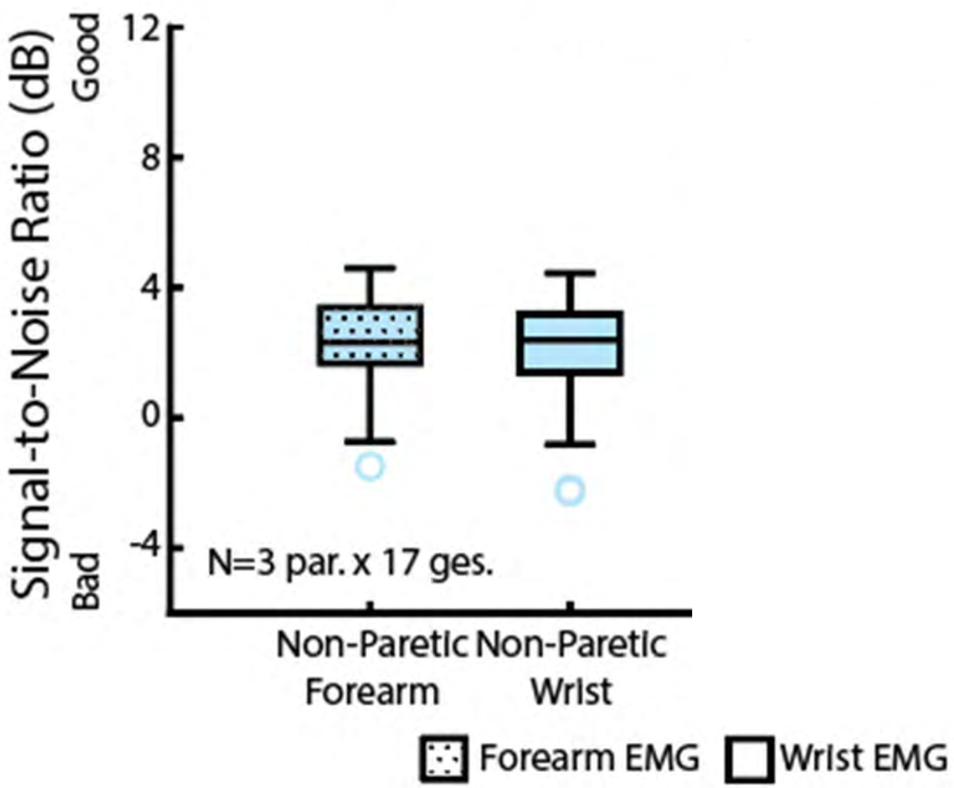
Lopez et al., *IEEE EMBC*, 2023

EMG Recordings From Forearm and Wrist During Bilateral Gestures



Olsen et al., *ICORR*, 2023

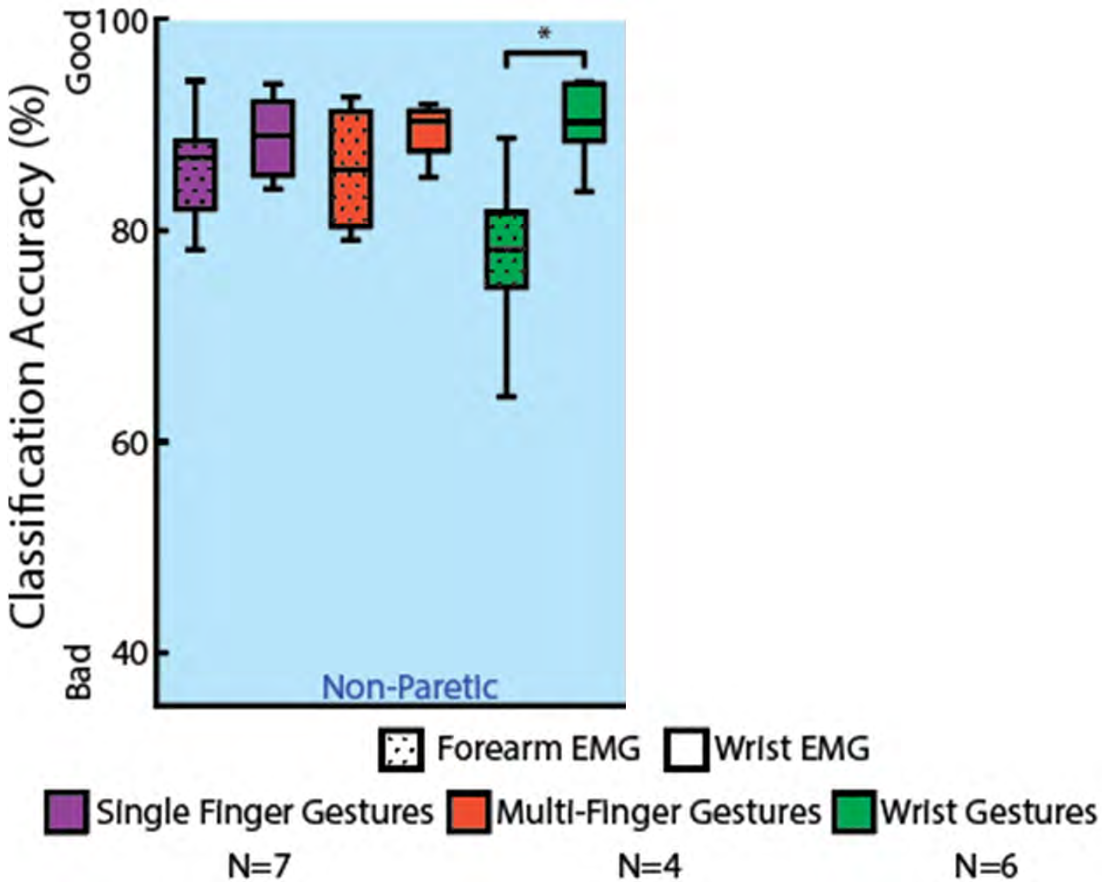
EMG SNR Is Worse on the Paretic Side, and Worst at the Paretic Wrist



Olsen et al., *ICORR*, 2023

Wrist EMG Provides Better Gesture Classification, Even on the Paretic Side

Single Finger Gestures
Thumb Flexion
Index Flexion
Middle Flexion
Ring Flexion
Pinky Flexion
Thumb Extension
Index Extension



Multi-Finger Gestures
Precision Pinch
Tripod Pinch
Power Grasp
Hand Open

Wrist Gestures
Flexion
Extension
Radial Deviation
Ulnar Deviation
Pronation
Supination

Olsen et al., *ICORR*, 2023

Wrist EMG Provides Better Gesture Classification, Even on the Paretic Side

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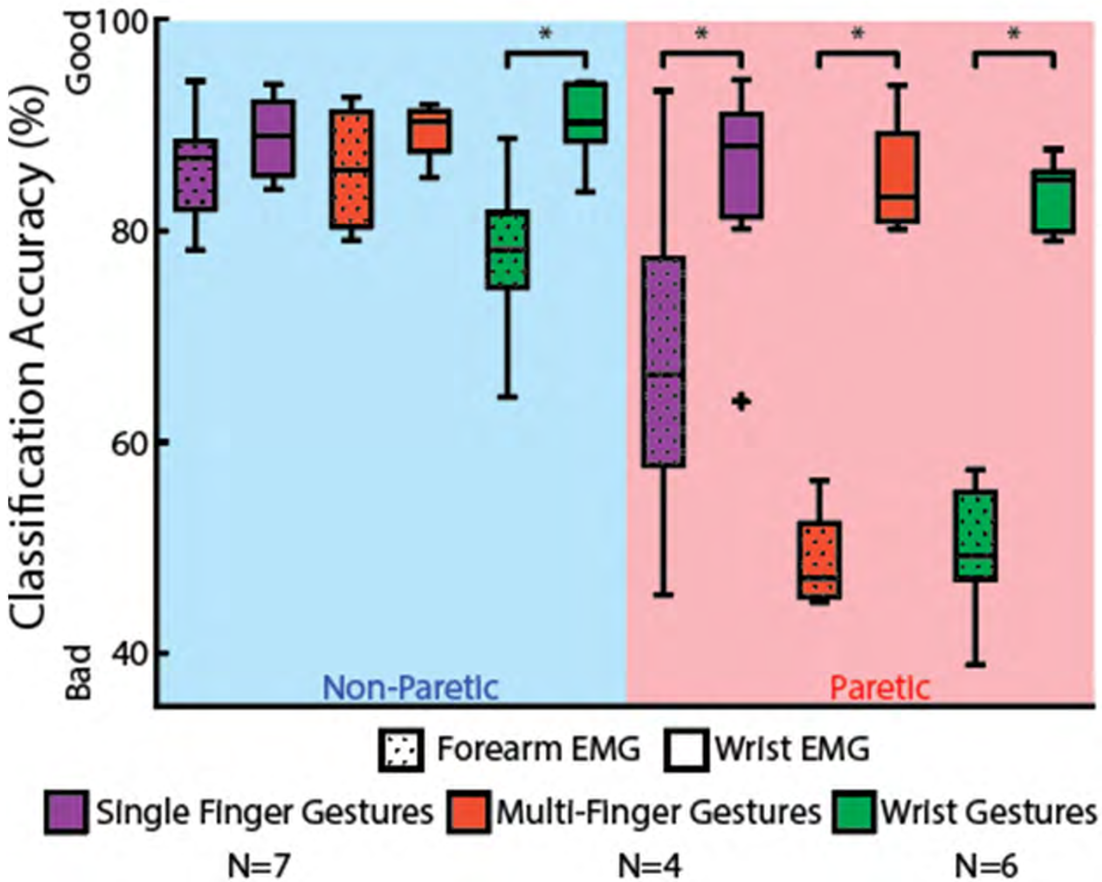

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Flexion
Extension
Radial Deviation
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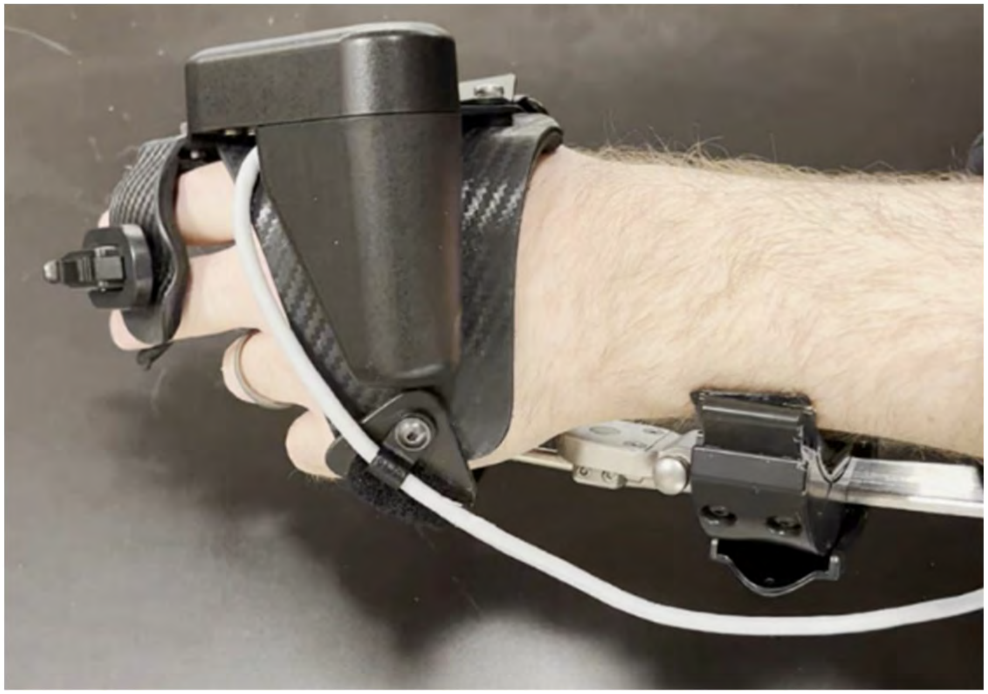
Pronation
Supination

Olsen et al., *ICORR*, 2023

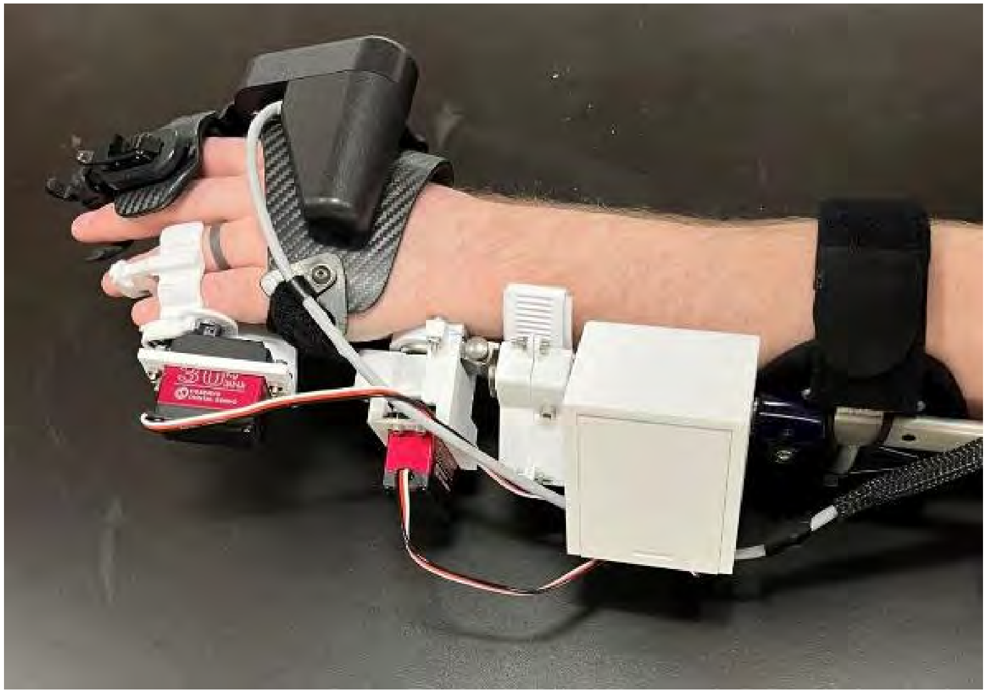
Enabling More Movements and Gestures

Enabling More Movements and Gestures

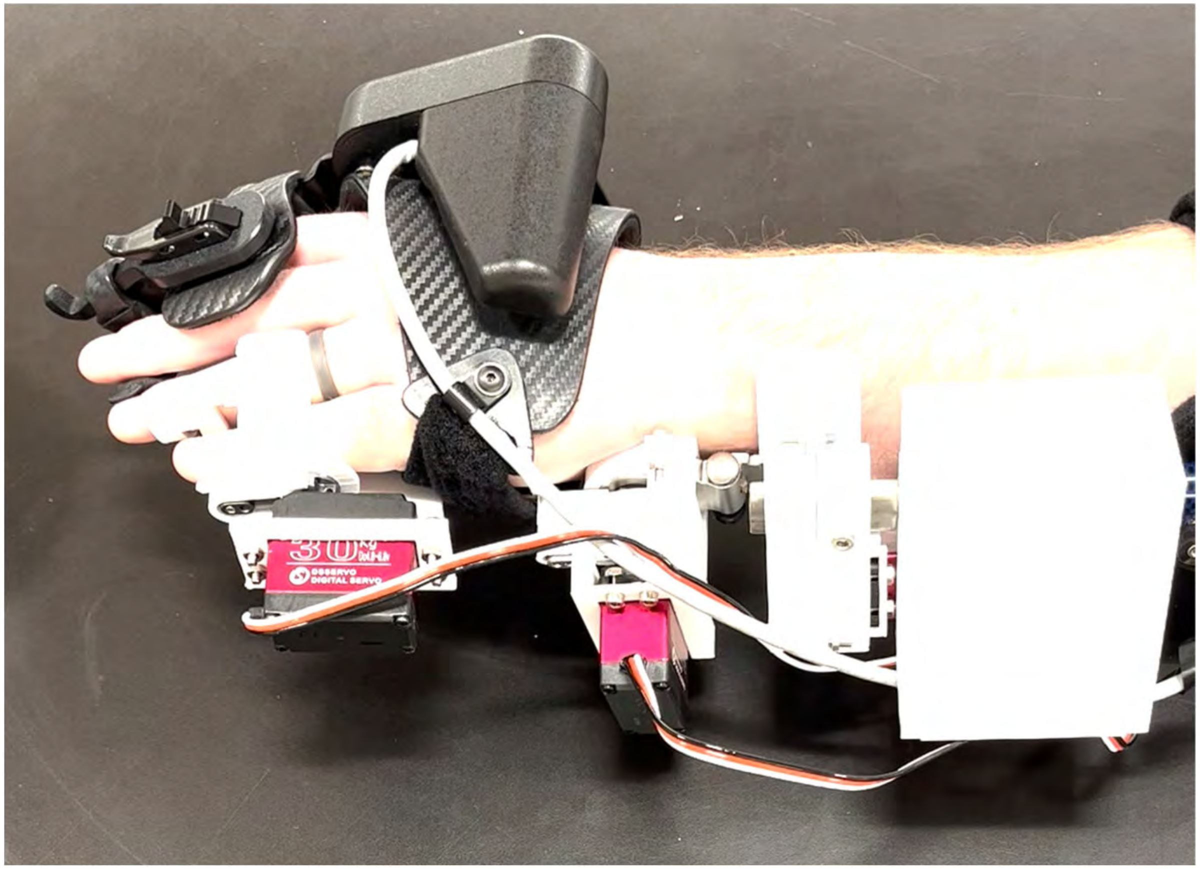
Original:
Tripod Pinch



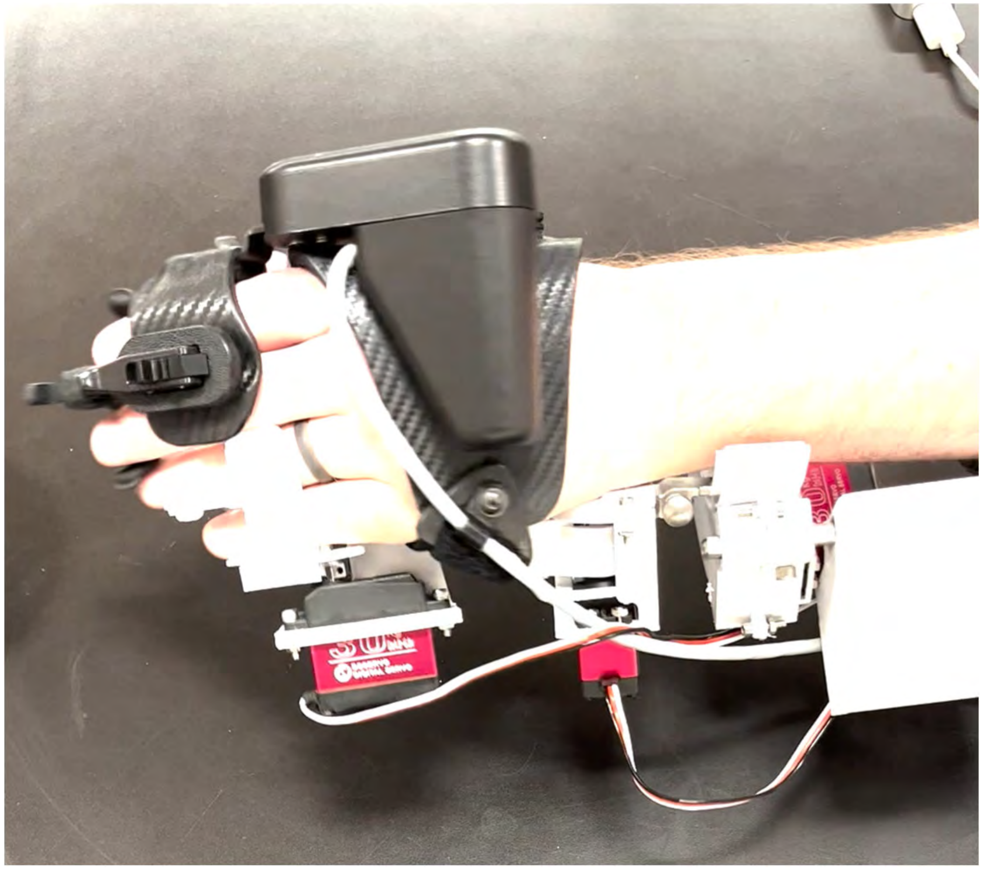
Upgrade:
Tripod Pinch + Power Grasp



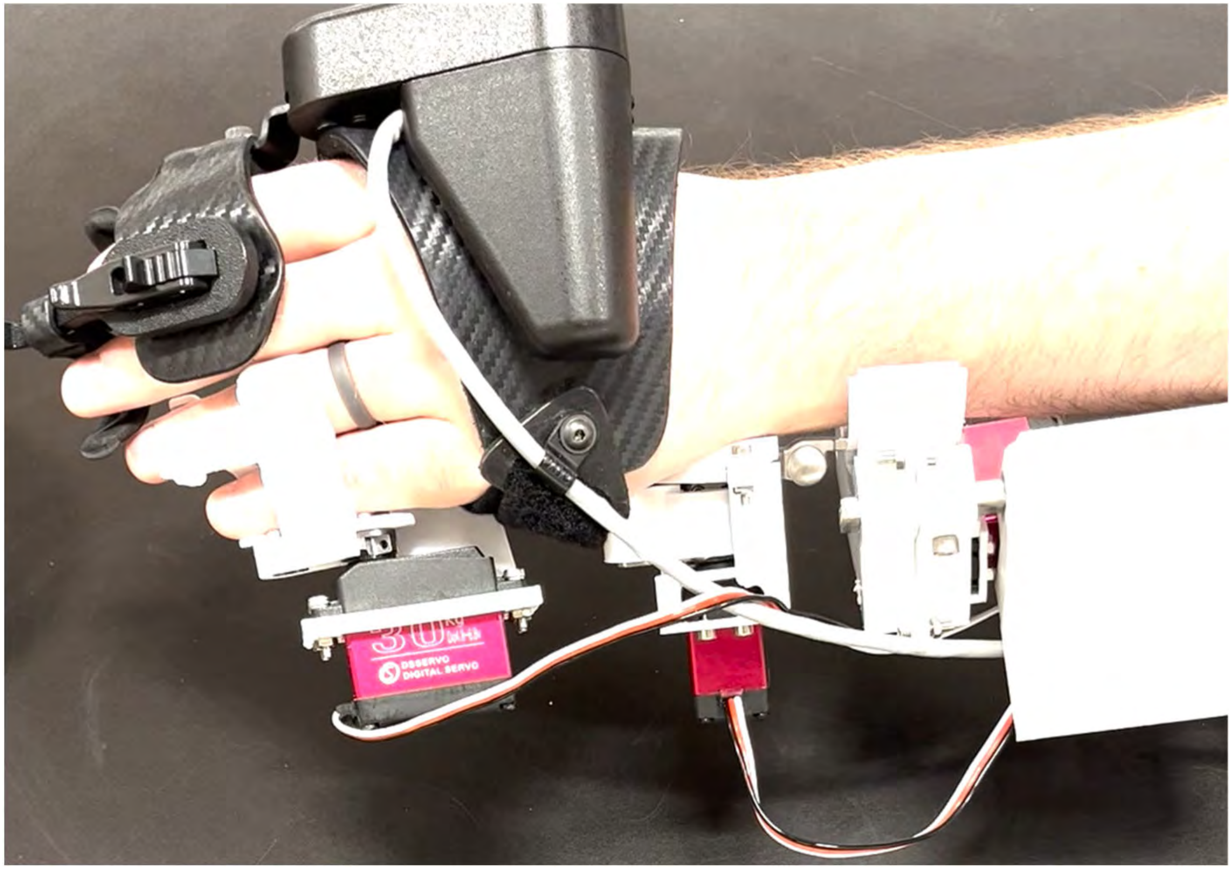
Can Now Perform:
Power Grasp



Can Now Perform:
Wrist Flexion/Extension



Can Now Perform: *Wrist Rotation*



Intuitive and Dexterous Control of Bionic Devices for Assistance and Rehabilitation

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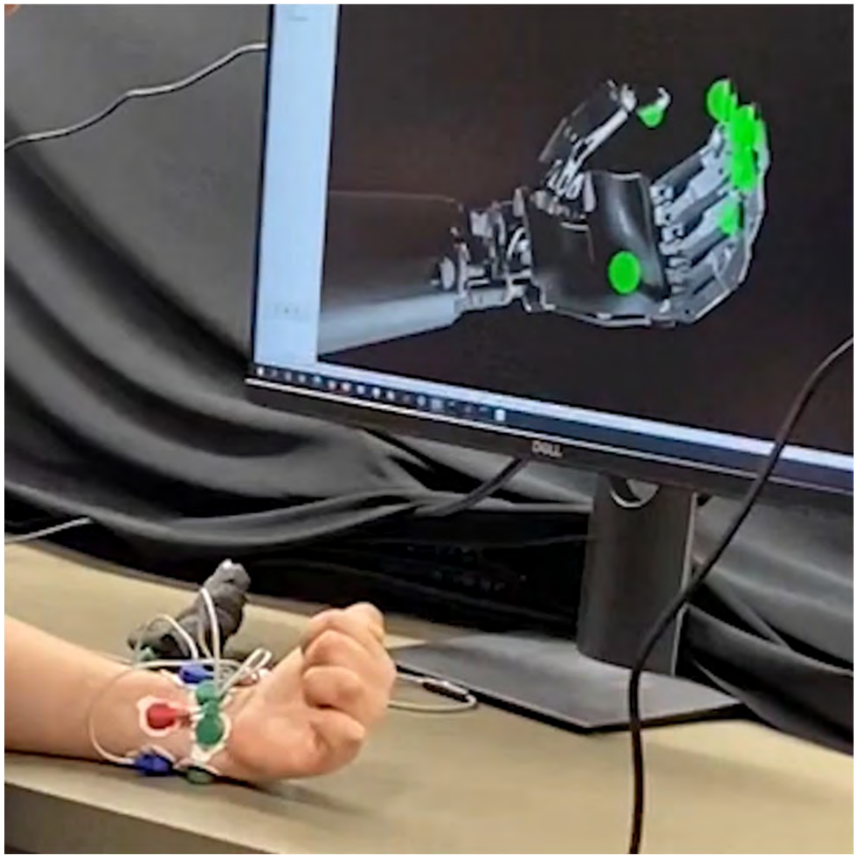
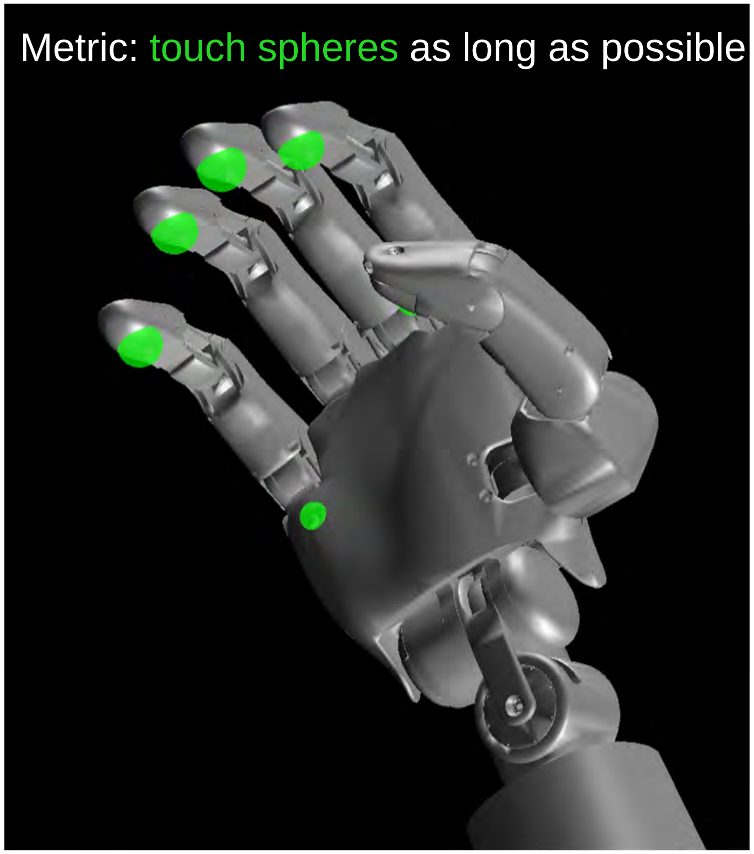
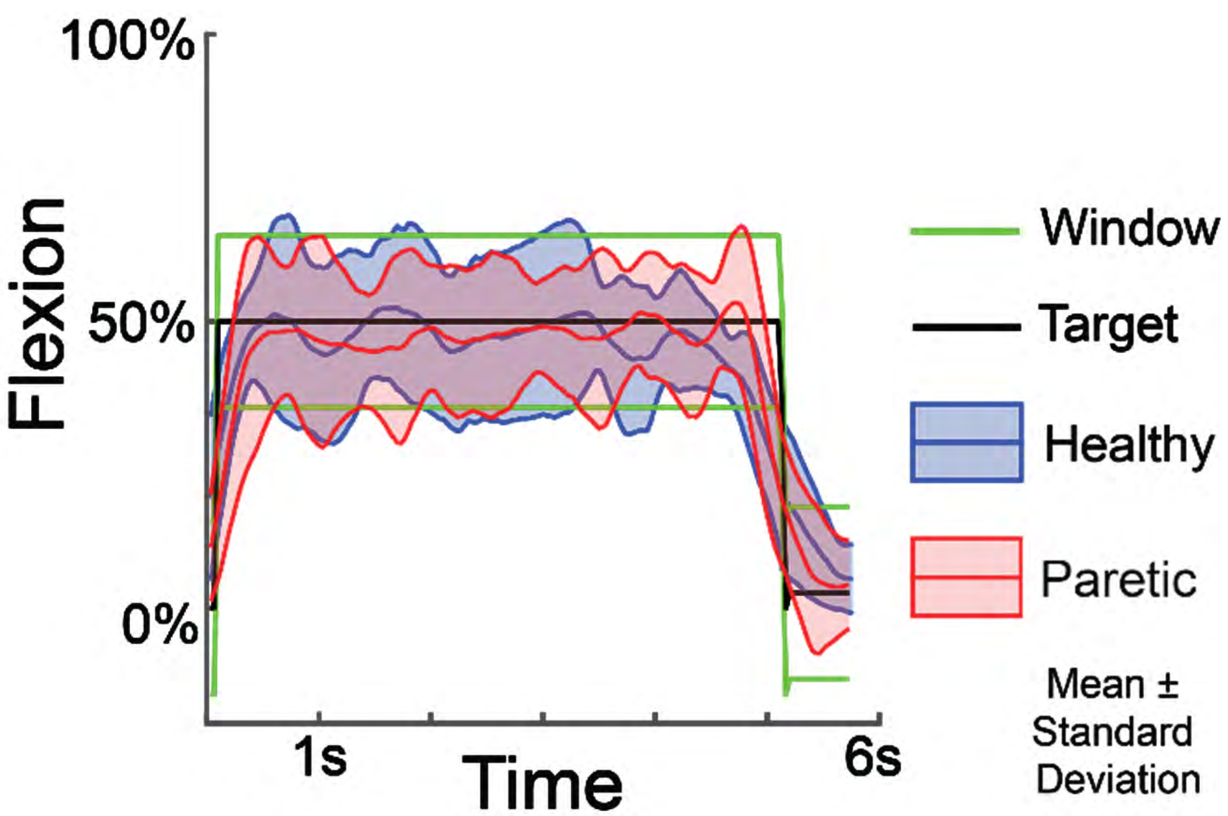
Participants Can Control a Virtual Bionic Arm Despite No Physical Movement



Similar Performance Between Healthy and Paretic Hand on Virtual Target-Touching Task





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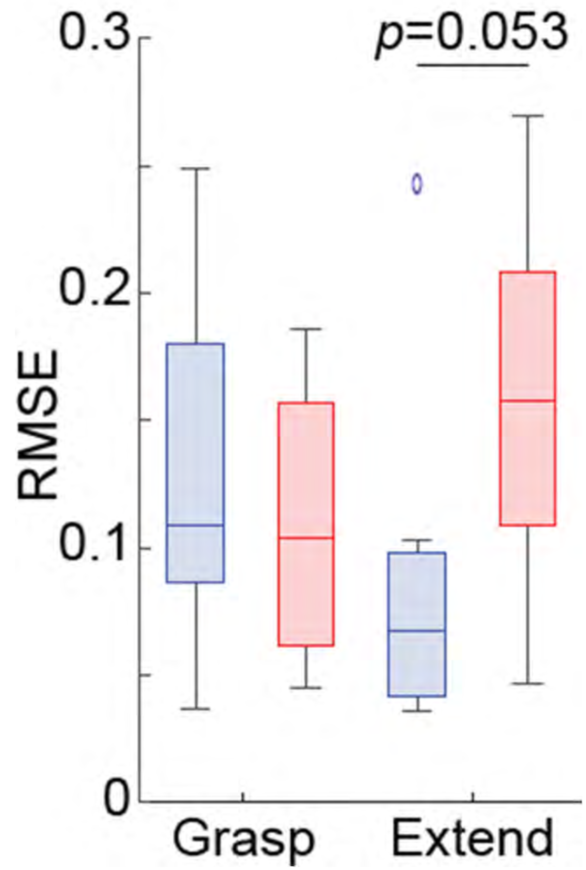

An Inclusive Metaverse for All, Regardless of Physical Disability

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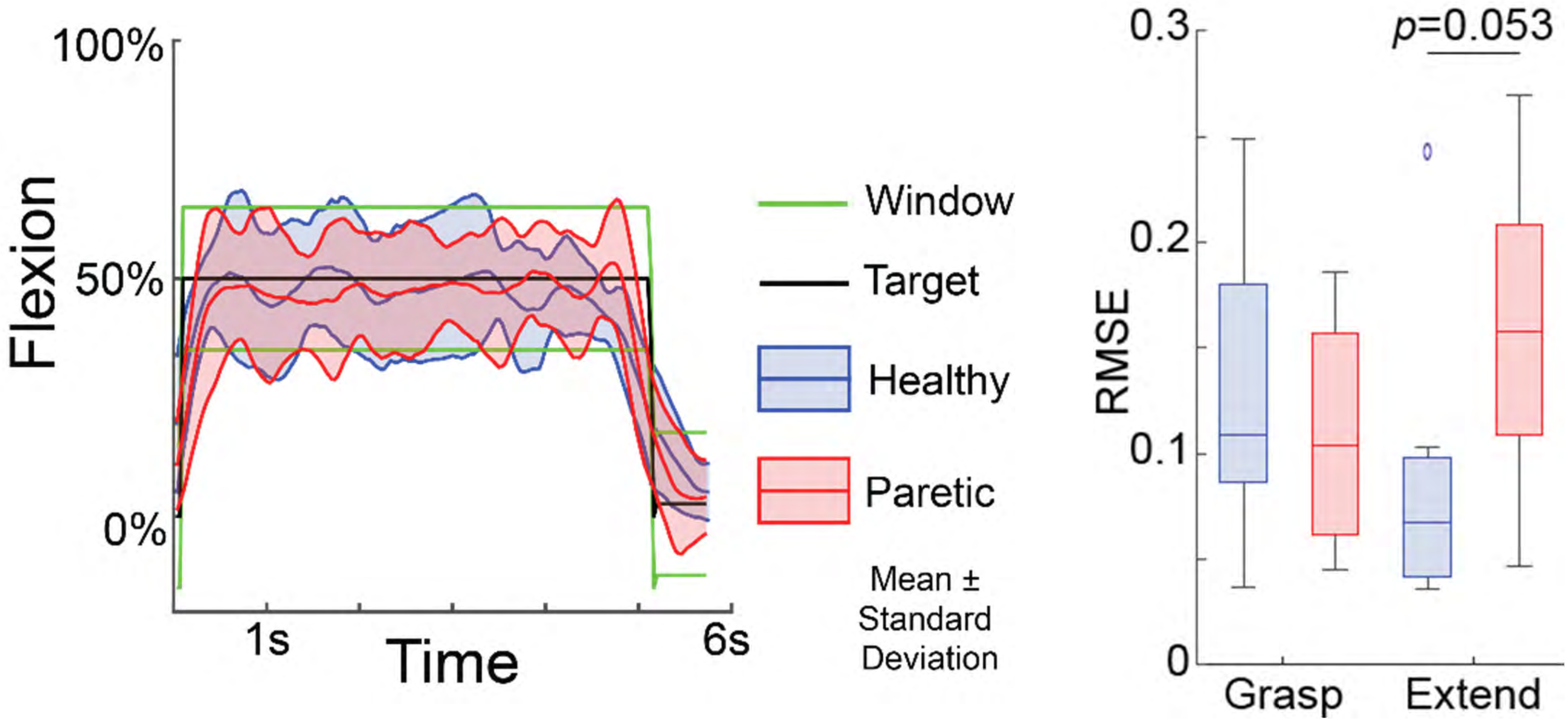
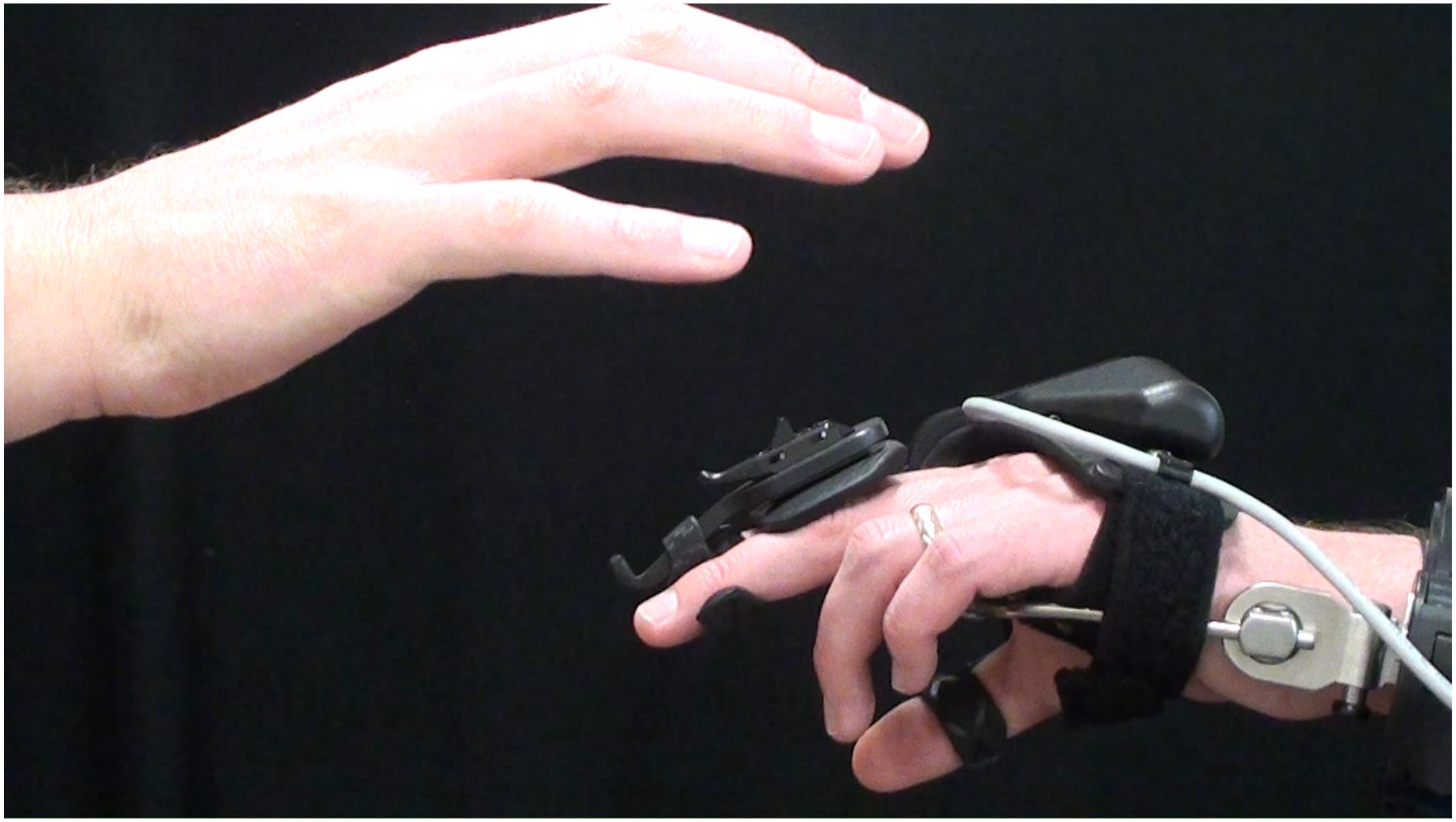
Meta

Similar Performance Between Healthy and Paretic Hand on Virtual Target-Touching Task



Proportional Control of MyoPro Exoskeleton



Patients Use the MyoPro Device Daily

Big Data & Deep Learning for Enhanced Assistive and Rehabilitative Devices

Generate Training Data → **Algorithm Training** → **Run-Time Performance**

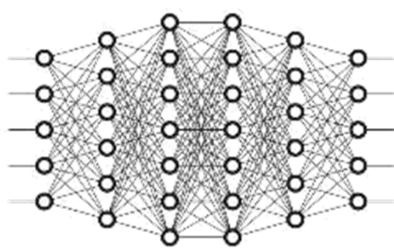
User Mimics Computer

Computer Learns

Computer Predicts User Intent

Recalibrate
(collect new data)

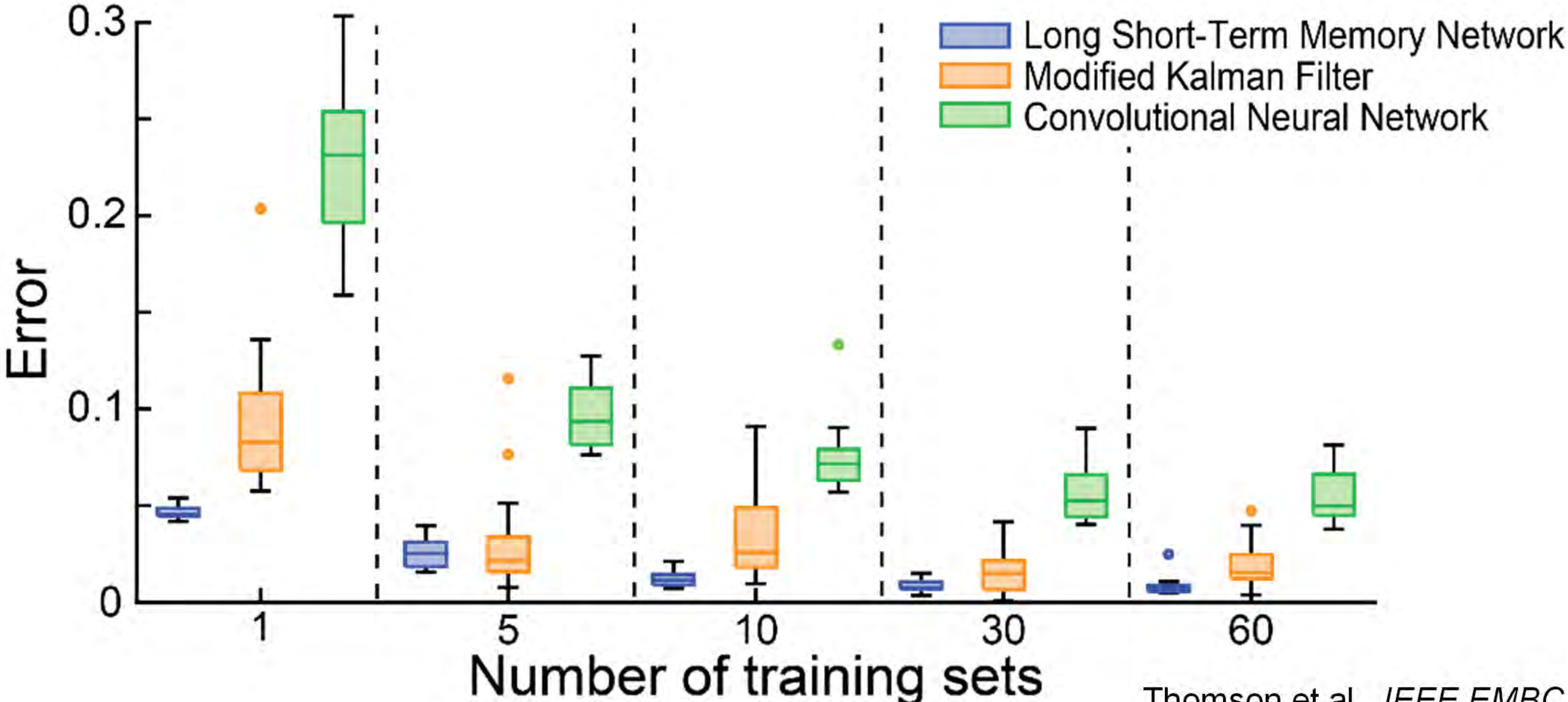
Improve?
(add new data?)



Big Data & Deep Learning

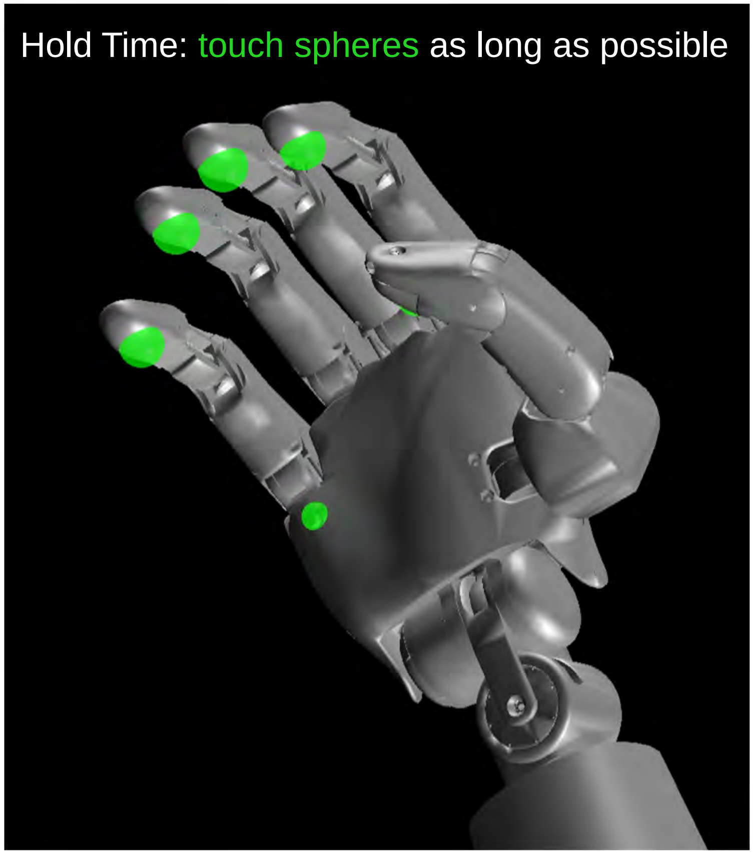
George et al., *Myoelectric Controls*, 2020

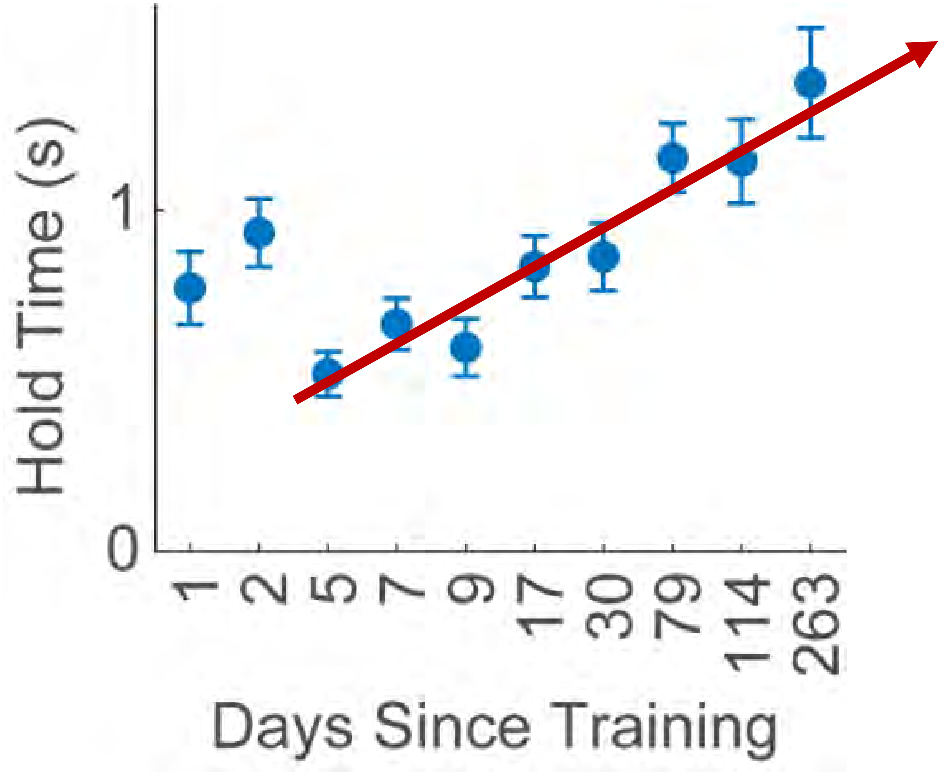
Algorithm Performance Improves with Increasing Data



Thomson et al., *IEEE EMBC*, 2021

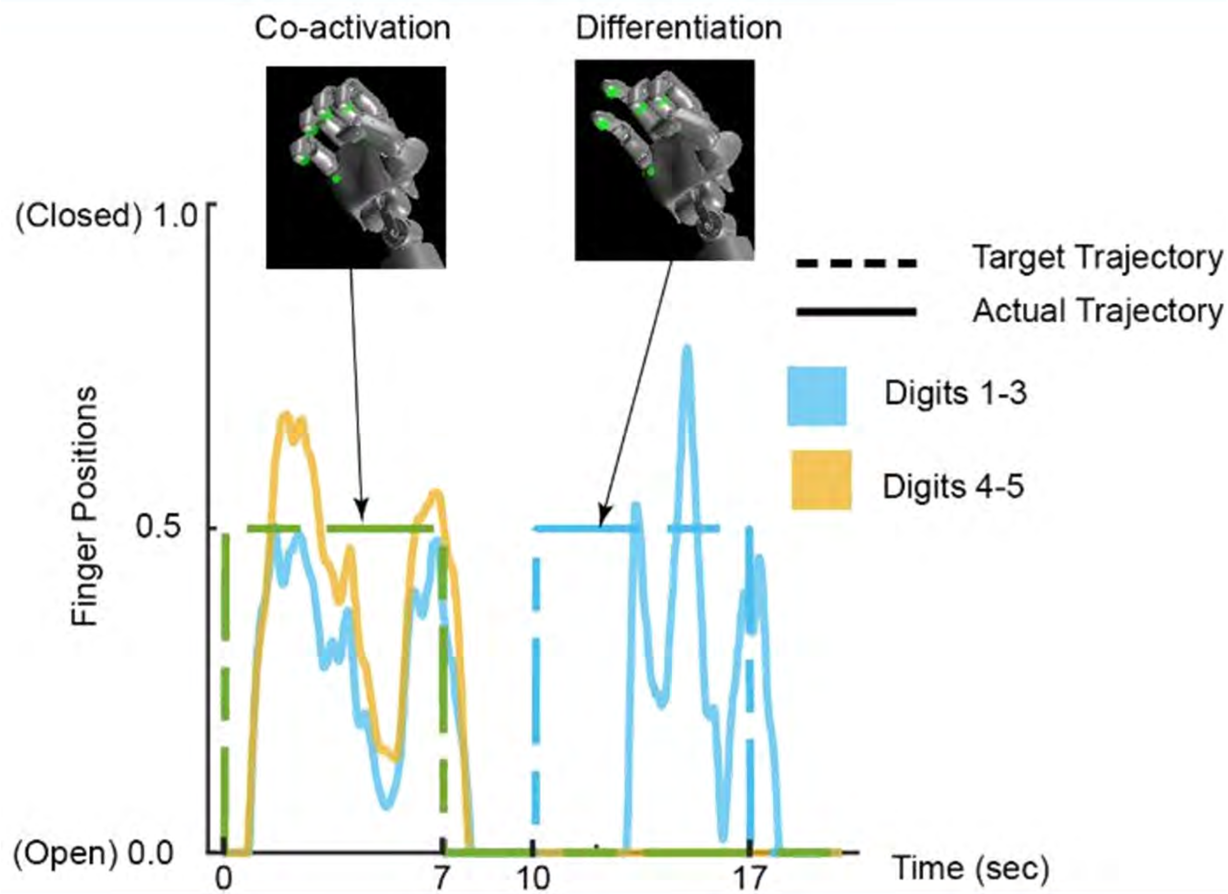
Human Performance Improves over Time

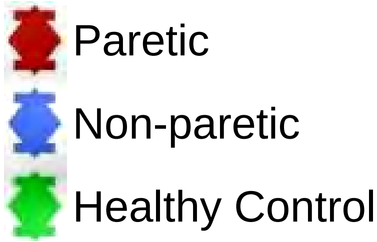




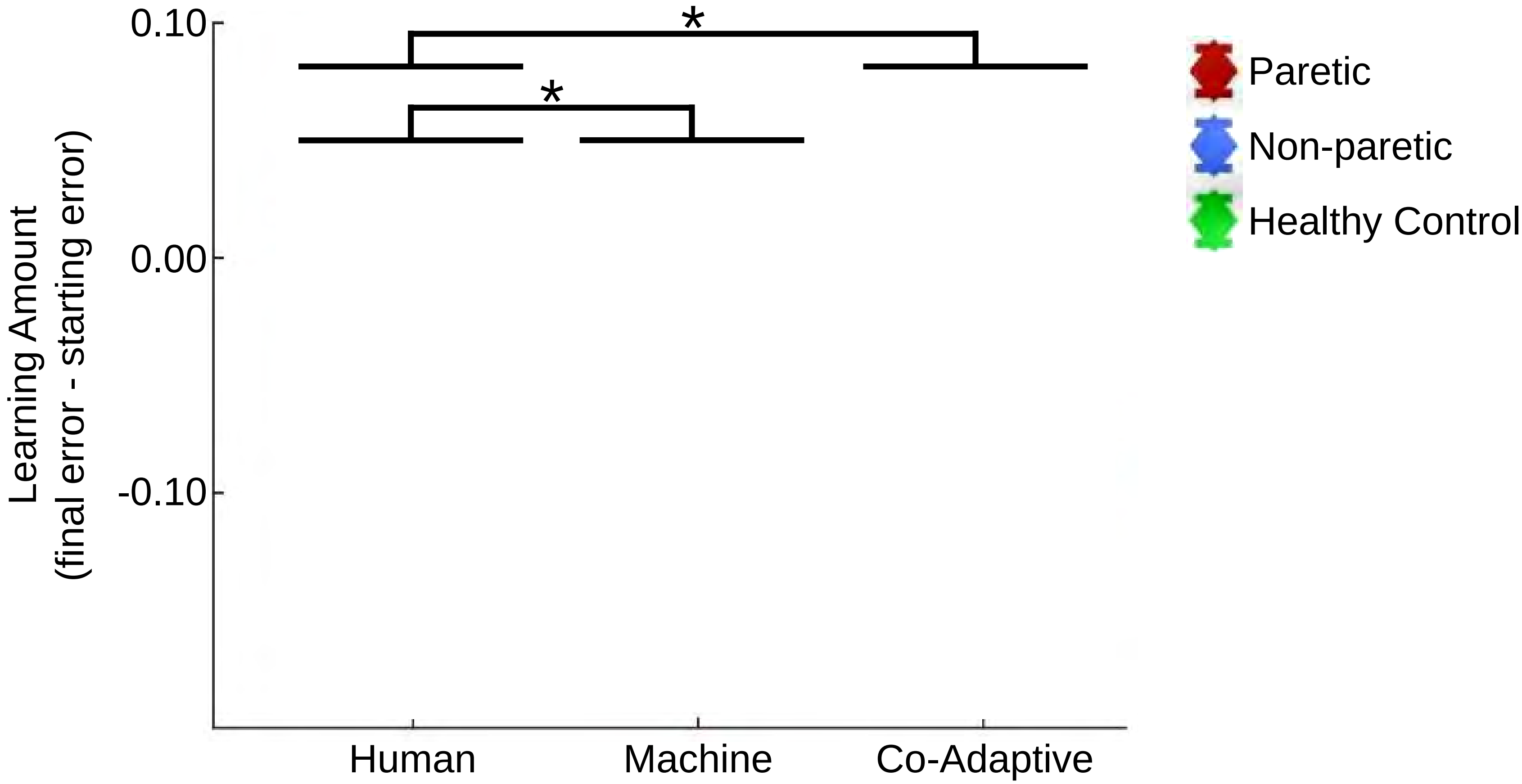
George et al., *Myoelectric Controls,* 2020

Quantifying Learning Under Human Alone, Machine Alone, and Co-Adaptive Models

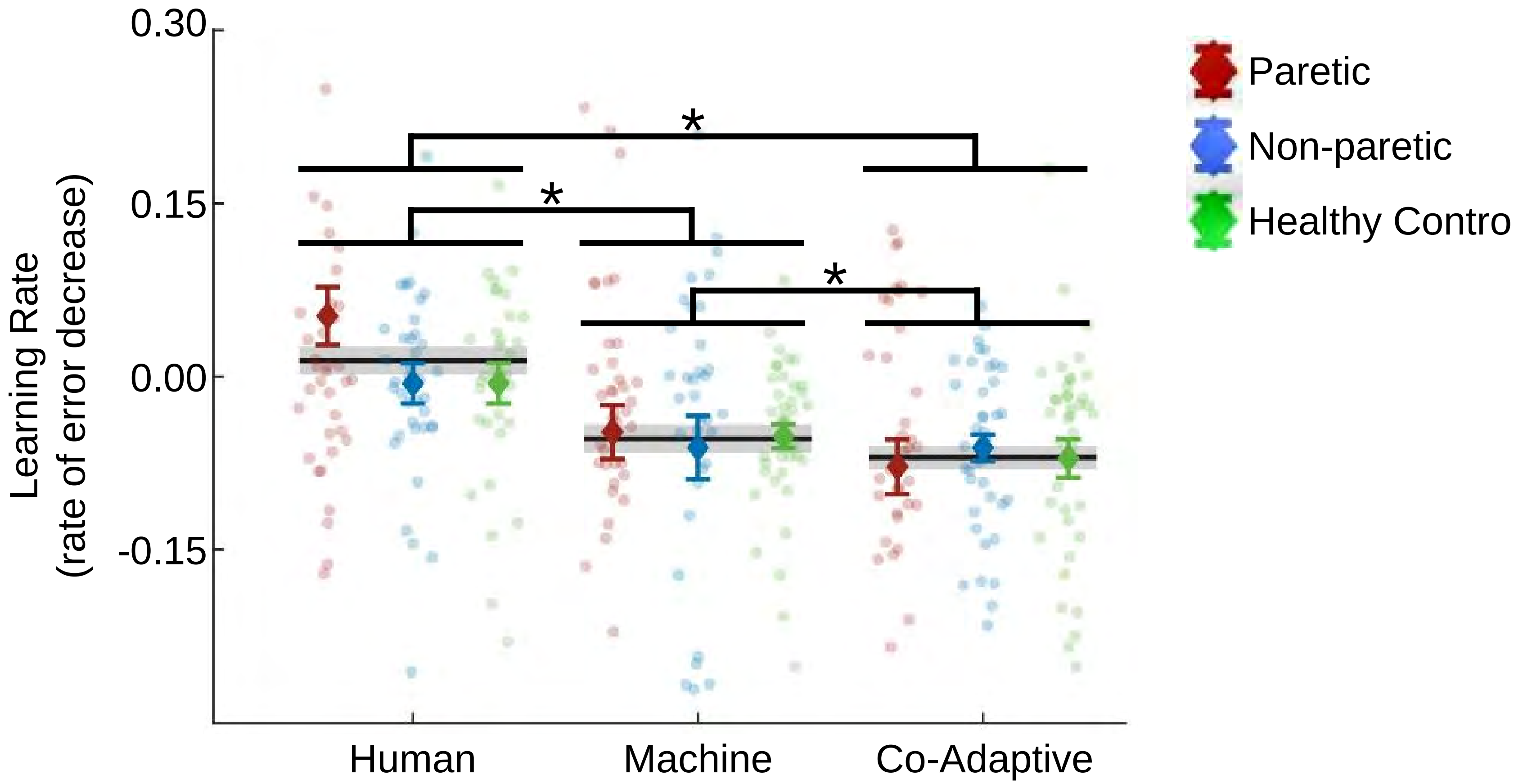




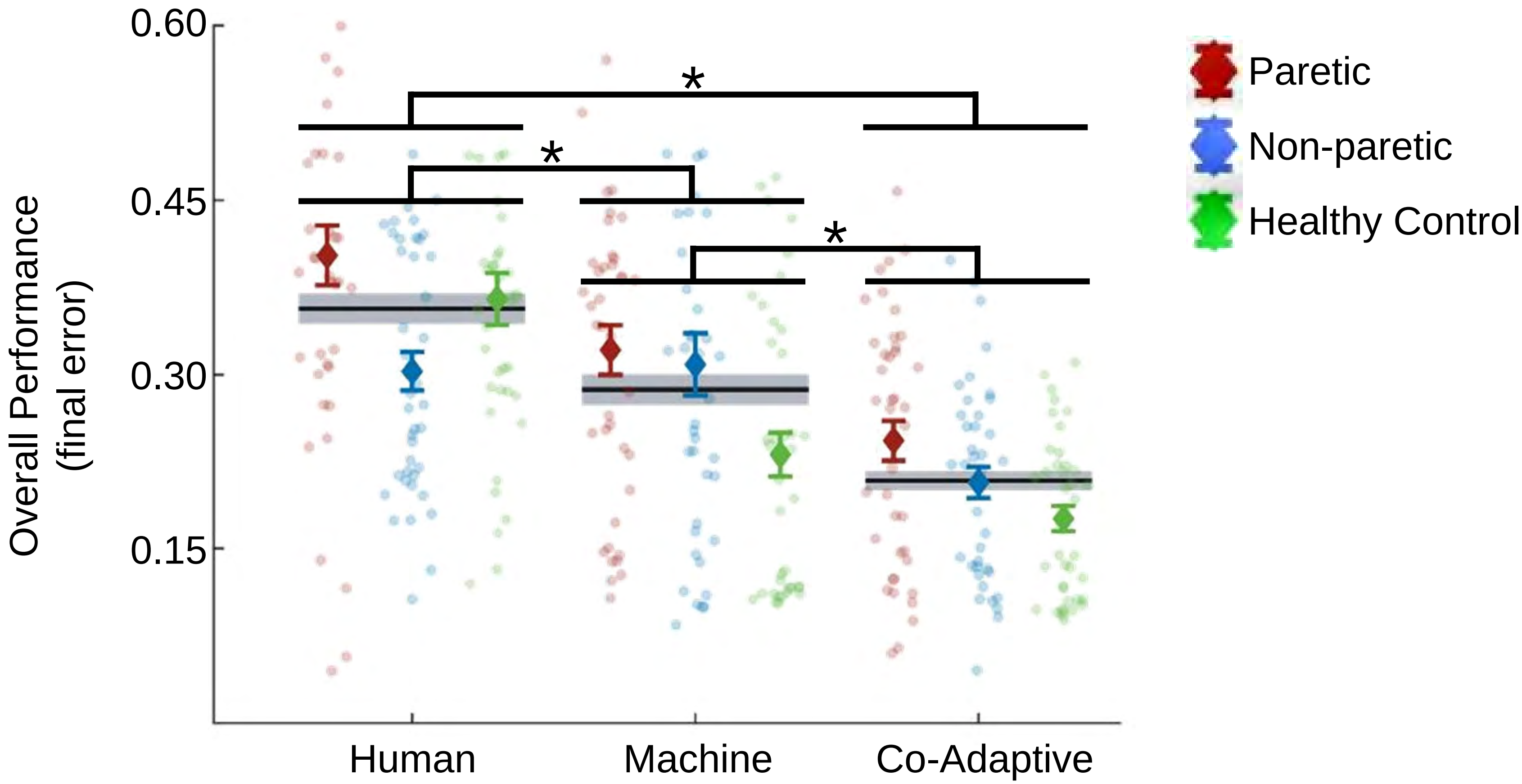
Co-Adaptive Learning



Co-Adaptive Learning



Co-Adaptive Learning



Intuitive and Dexterous Control of Bionic Devices for Assistance and Rehabilitation

1. Paretic EMG is Weak & Spastic → **Real-Time Monitoring** → **Quantitative Diagnostics**

but we can still predict…

2. Multiple Movements & Gestures → **Immediate Assistance** → **Increase Limb Usage**

and provide…

3. Fine Force Regulation → **Real-Time Feedback** → **Improve Motor Control**

enabled through…

4. Co-Adaptive Learning → **Balance Assistance & Rehabilitation**

Research Funding

- **NIH Directors Early Independence Award** DP5OD029571-01
- NIH UL1TR002538
- NIH TL1TR002540

Engineering Approaches to Responsible Neural Interface Design Research Award #2990450277899571

- DARPA BTO HAPTIX N66001-15-C-4017
- DARPA INI PO57482

- Institutional Startup
- Research Instrumentation Fund
- PIVOT Ascender Grant

- NSF CHS-1901236
- NSF CHS-1901492
- NSF NCS-FO-1533649
- NSF GRFP-1747505

- DOD W81XWH-16-1-0701
- **VA UU-2022-SAHAT-01**

Industry Partners

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