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A New Human-Computer Interface Technique

Two-Dimensional Cursor-to-Target Control Based on Single Muscle Contractions

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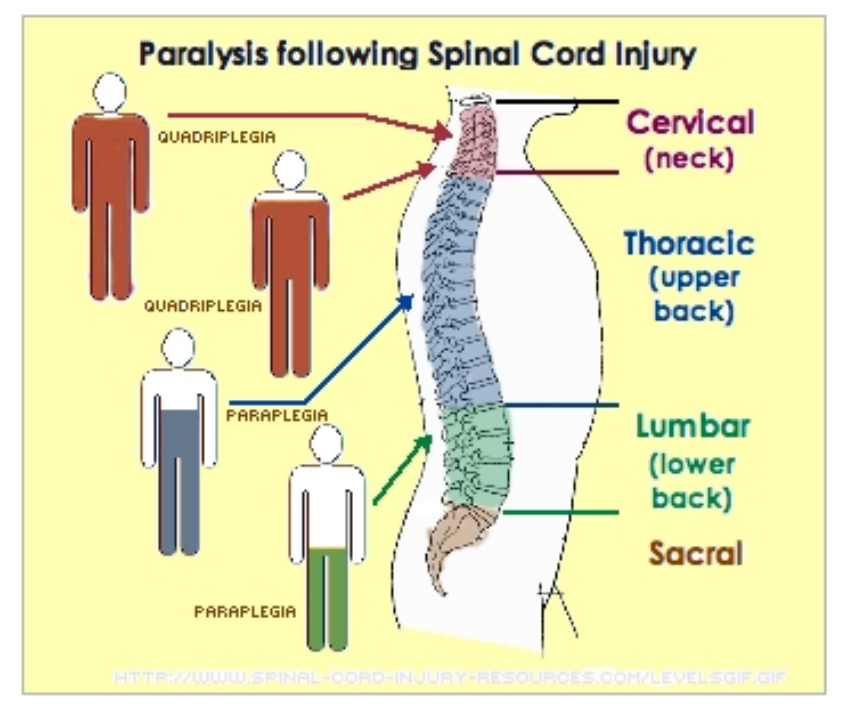
Motivation

Helping Disabled Persons to Interact with their Environment

- Several conditions may cause severe paralysis including high SCI, muscular dystrophy, multiple sclerosis, and severe stroke
- These persons require constant supervision for health and safety, and (without the aid of an assistive device) for routine environmental functions such as turning on/off lights, television operation, fans, etc.
- Our goal is to restore some level of independent functioning, even while support-personnel assist in most functions (e.g. environmental control, computer operation, and/or mobility)
- Many useful and creative human-machine interfaces currently exist- our aim is to provide another option

Target Populations: High SCI and Otherwise Paralyzed Persons



- Our target populations are those with severe paralysis, but who can still voluntarily control some muscles
- E.g., even those with high SCI can access head and face muscles
- Persons who have complete loss of voluntary muscle control can not use out system (e.g. advanced ALS persons who are “locked in”)

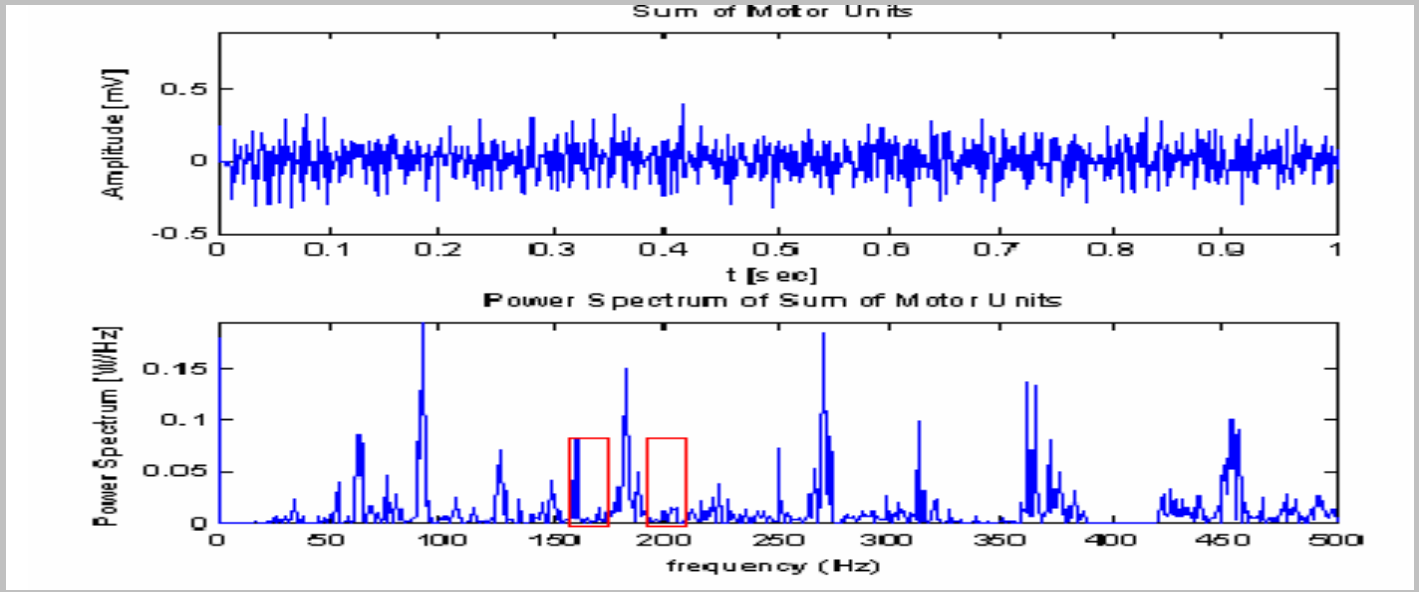
Possible Advantages of Single Muscle System for Target Population

- Non-invasive and localized to small area on scalp
- Does not interfere with other head functions
- sEMG signal is relatively robust and can be measured with standard electrodes
- Completely portable hardware that relies on “off-the-shelf” components
- Use of system does not rely on specific head, eye, or tongue orientations

Hypothesis and Underlying Technique

Our Hypothesis

Humans can be trained to create sEMG signals that simultaneously have two specific power levels in two specific bands of frequencies.



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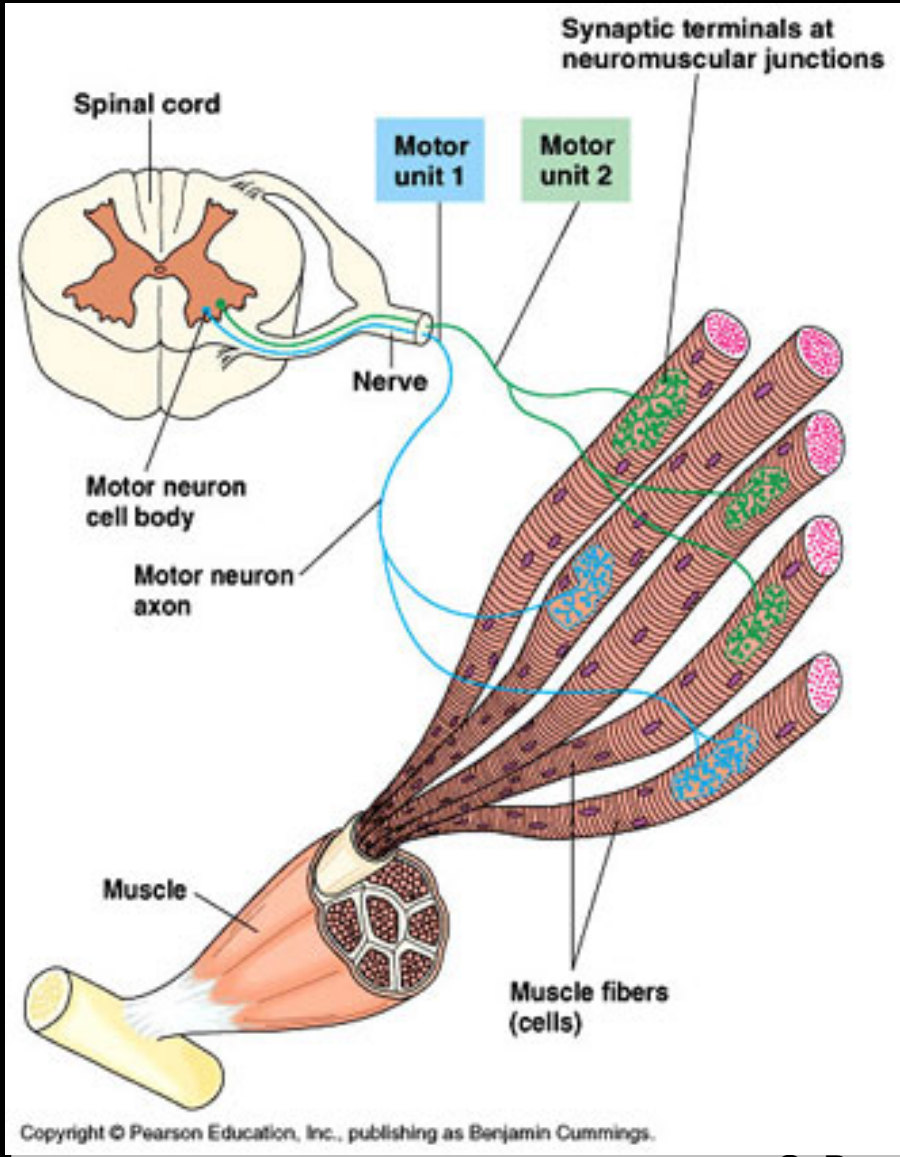
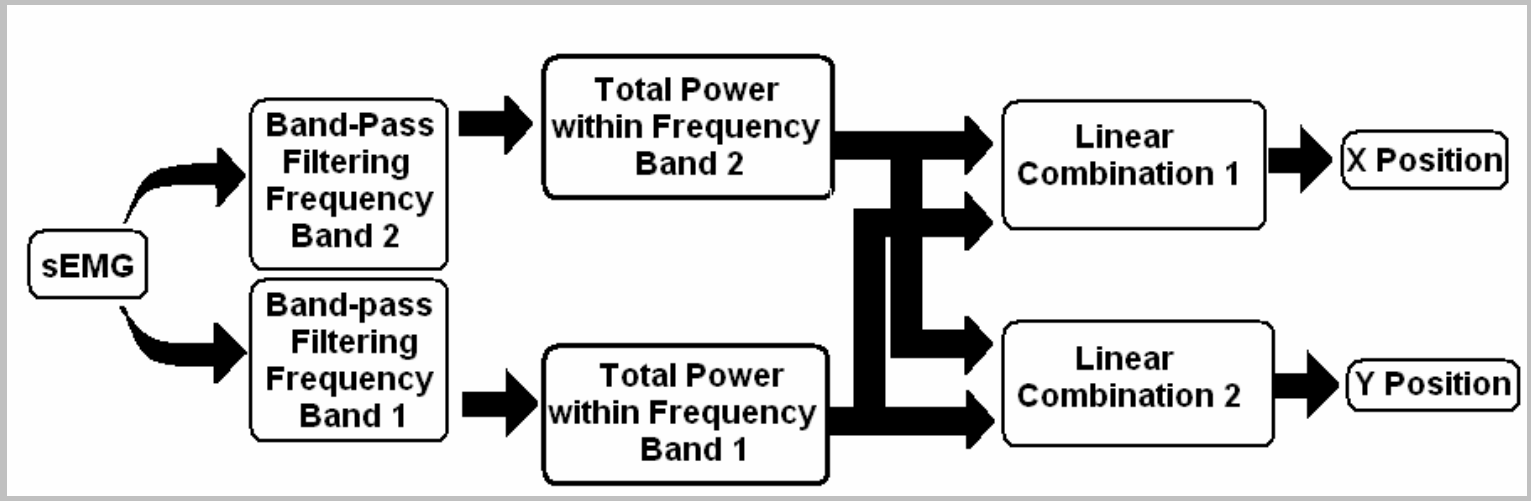
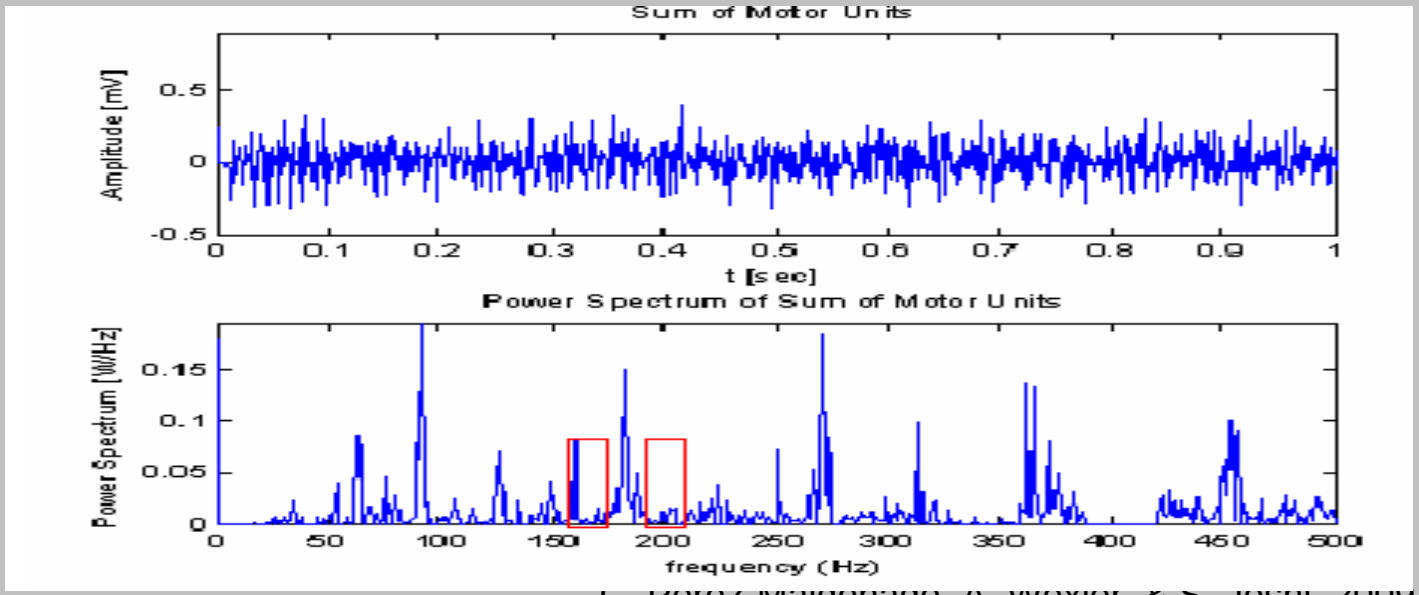
Muscle Physiology



- A **motor unit** is a motor neuron and the muscle fibers that it innervates.
- Whole skeletal muscles are comprised of groups of motor units.
- Motor units are activated as a whole when their motor neuron is activated.
- Groups of motor units work together to coordinate the contractions of a single muscle
- **Repetitive activations** (firing rates) of groups of motor units define muscle contraction characteristics
- Motor units differ in their size etc.

Methods: Two *Simultaneous* Control Channels





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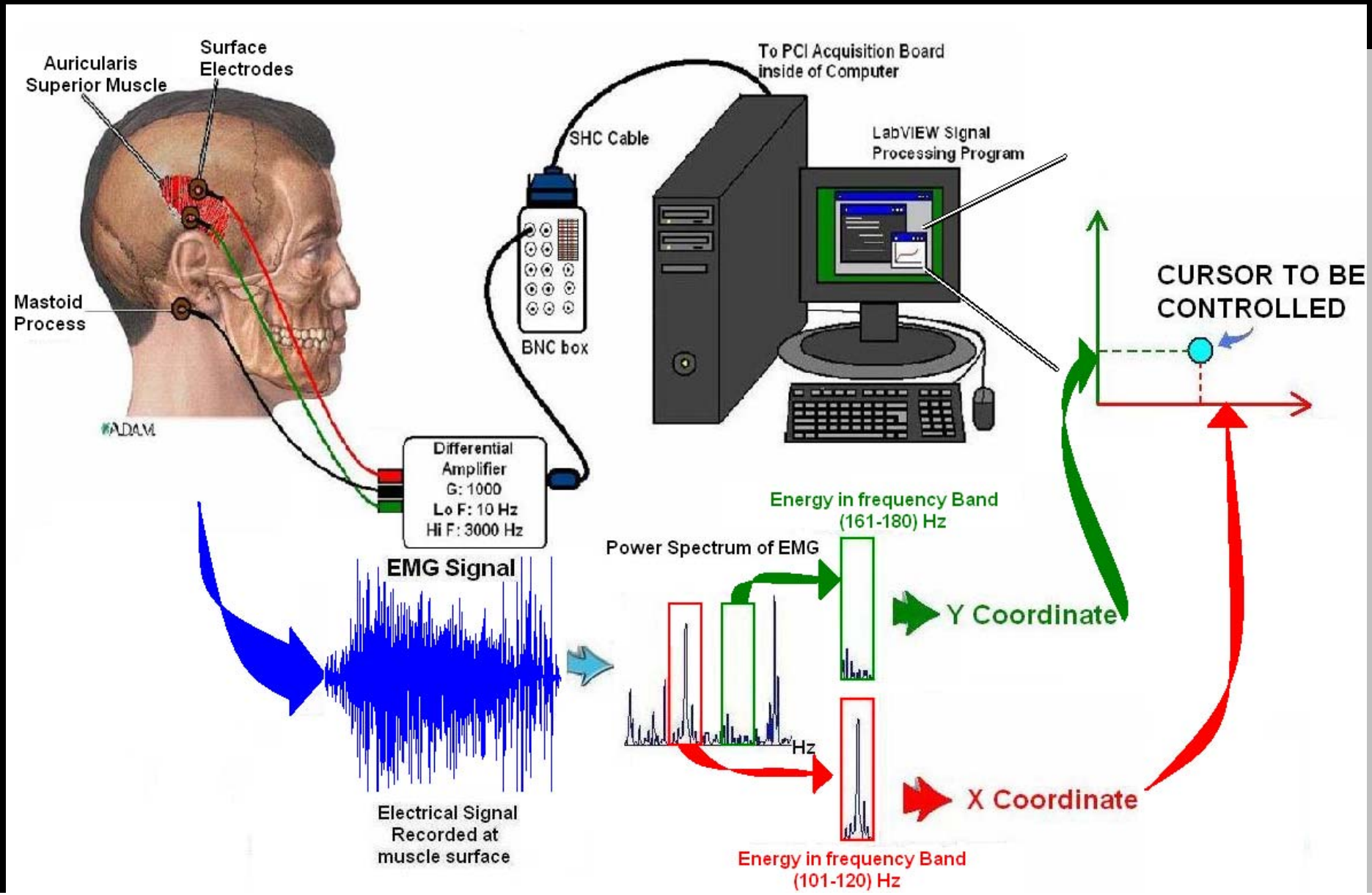
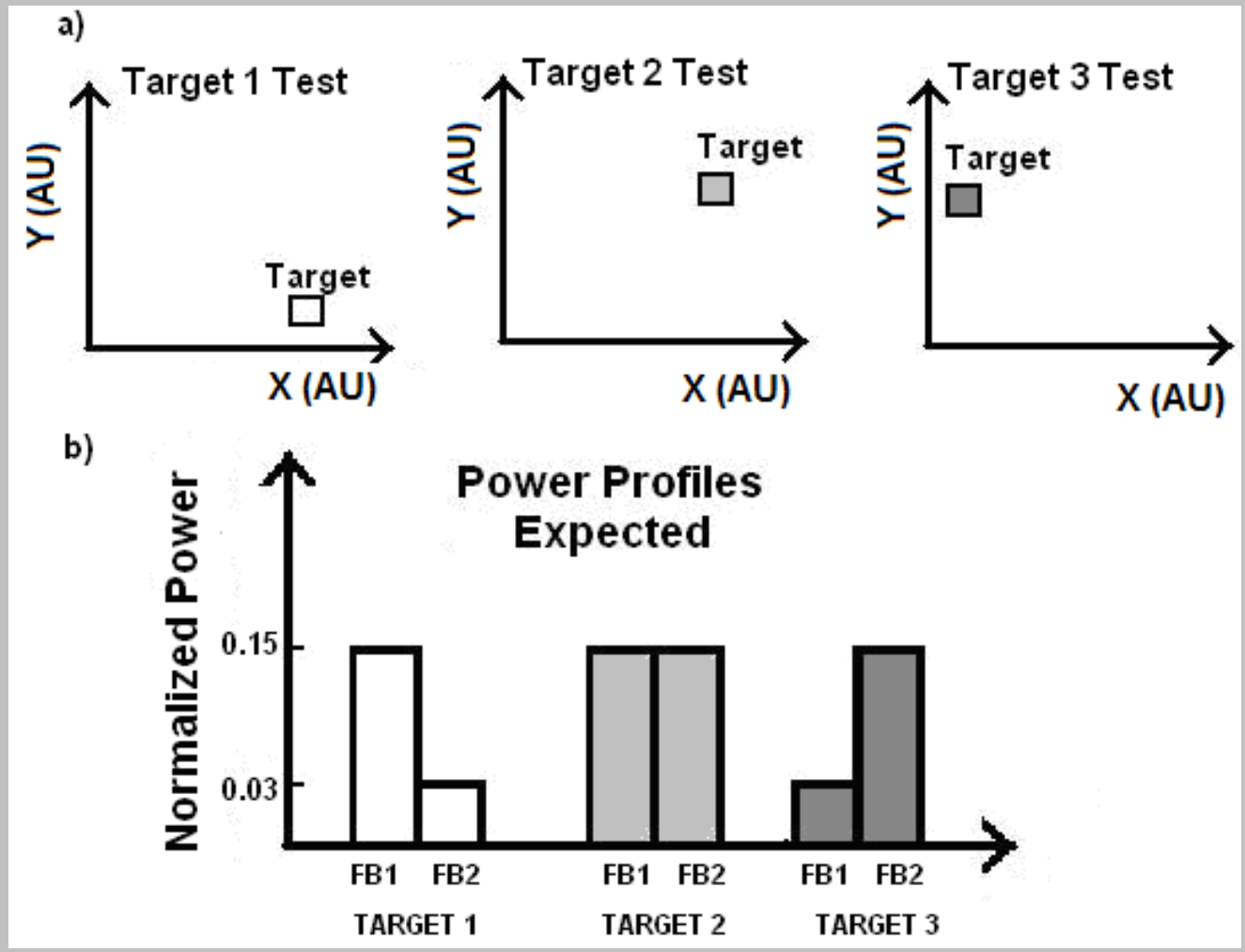
Big Picture: Muscle Used as Signal Generator!



Experiments

2D cursor control

Experimental Studies: Cursor Control



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Training and Evaluation

- Subjects trained on 1 target at a time (15-16 total sessions, 120 contractions per session)
- For evaluation, targets presented randomly within each evaluation session (80 total contractions per session).
- Six evaluation sessions (EV1-EV6) conducted over multiple non-consecutive days (application and re-application of electrodes).

Experiment Details

- Subjects start with cursor at (0,0) and then contract until cursor reaches target (or they give up)
- Relaxation of muscle indicates end of attempt (hit or miss)
- Software gains and initial calibration restrict contractions to 15% of MVC, so as to help avoid fatigue
- Two frequency bands used in method are customized to each subject by initial correlation tests
- Width of frequency bands is 20 Hz for all subjects (determined by simulation experiments - not shown)
- Size of target: $1/625^{th}$ screen size

Results

- All four subjects were able to hit each target consistently, although some subjects had higher hit-rate and lower time-to-target than others
- Path from start position (0,0) to target position varies from contraction to contraction
- Size of target makes big difference in time-to-target

VIDEO

Conclusions

- Electrophysiological data recorded in our tests supported our underlying hypothesis that human subjects can voluntarily and simultaneously modify the spectral power of two different frequency bands in the sEMG signal of a single muscle
- This method can be used in a new class of human-computer interface in which a muscle is essentially used as an electrical signal generator to drive different devices
- Especially beneficial to high spinal cord injury patients and other paralyzed persons who can control head/face muscles, but may have few other means to interact with the world around them

Thank you!

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