Brain-Machine Interfaces: Adaptation and Learning of Sensorimotor systems

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Electrocorticographic (ECoG) Arrays

- Placed for ~7 days for surgical localization of epilepsy
- Platinum electrodes: 2mm exposed, 1cm spacing
- ~500,000 neurons beneath each electrode
Mu and beta suppress with movement
Functional mapping of human sensorimotor cortex with electrocorticographic spectral analysis
II. Event-related synchronization in the gamma band

Nathan E. Crone,1 Diana L. Miglioretti,3 Barry Gordon1,4,5 and Ronald P. Lesser1,2,5
Focal high-frequency changes
Back to the motor homunculus
Patient Population and Setup

- Patients implanted for localization of seizure
- Experiments at bedside in 7-10 days between surgeries

(photo courtesy Seattle Times)
Simple Feedback Task

\[ \dot{y}(t) = g\left( P(t) - P_0 \right) \]
Augmentation After Feedback

Movement: 0.55
Imagery: 0.47
Feedback: 0.78

HFB (76-100 Hz)

Activation Decrease | No Activation | Activation Increase

Relative Activation

Movement | Imagery | Feedback
Learning

Two-dimensional (Chance = 25%)

One-dimensional (Chance = 50%)
Imagery-based learning
BCI Learning is similar to Motor Skill Learning

Wander et al., *PNAS*, 2013
Experience changes the map

Reorganized

Face
Lips
Pharynx
Trunk
Foot
Genitals

Normal

Hand
Thumb
Face
Lips
Pharynx
Somatosensory Cortex
Trunk
Foot
Genitals
Static?
Assessing the controlling electrode (CE): Force-related signals
Changes in local activity (CE)?
Concurrent BCI and execution task

- 2D center-out movement of a cursor
- Horizontal movement = tapping arrow keys on a keyboard
- Vertical component=hand motor imagery of hand area: rest – down, imagined movement – up
- Activity generating the two components originates from the same location
With Mehring, Bashford – Univ of Freiburg
Center for Sensorimotor Neural Engineering

Arm/hand reanimation

Wireless sensing

Controller

Brain

Spinal Cord

ECoG Recording & Stimulation

FME stimulates nerve/spinal cord

Stroke

TBI

SCI

Nerve injury

Limb loss

Sensory feedback via sensors & stimulation

ACT Hand

Neurochip

FES
Cortical stimulation

- Amplitude (mA)
- Pulse width (microseconds)
- Pulse period (1/ frequency)
- Pulse train duration (milliseconds)
Sensory stimulation

- Spatial Discrimination

- Amplitude discrimination (about 0.3mA resolution)

- Frequency discrimination 100Hz > 75Hz > 50Hz
Can sensory stimulation be used as effective feedback?

**Methods**

**Parameter Sweep:**
- **Amplitude threshold:**
  - 2AFC - perceived? (yes/no)
- **Just Noticeable Difference (JND):**
  - 2AFC - more intense? (1\textsuperscript{st}/2\textsuperscript{nd} stim train)

**JND Setup:**
During JND trial one stimulation amplitude was held constant (static amplitude). Train order was randomized.

- Audio tone: 200 ms
- 2nd Stim train: 200 ms
- Inter-train Interval: 1000 ms
- Subject’s verbal response
Subject followed hand shape using sensory stimulation feedback.
Preserved evoked hand sensation in a patient with a history of arm amputation

Despite presumed changes in input, Body representation of lost areas preserved for decades
Rubber hand illusion

Ehrsson lab – Karolinska Institute, Stockholm
K. Collins, Neurosurgery PGY6, UW
Sensory stimulation can drive illusion
Endorsed the stimulation as ‘natural’ and professed a sense of ownership.

Timothy Brown, Philosophy UW
Summary

• High frequency ECoG is a rapid, flexible mapping tool
• ECoG can be a feedback/neuroprosthetic signal
• This novel motor task can be learned, using intrinsic learning networks
• This new task alters the motor network
• Sensory systems can also be engineered