h2.o
new minds, new bodies, new identities

A One-Day Symposium
May 9, 2007
at MIT’s Kresge Auditorium
8:30 am - 4:30 pm

MIT Media Lab
Neural Interfaces

CONFLICT OF INTEREST:
Co-founder Cyberkinetics Neurotechnology Systems, Inc. JD is a consultant, stockholder and director of CKI, makers of BrainGate technology to be discussed.

John Donoghue
Brown University, Providence, RI, USA
NINDS Javits Investigator
Age of Neurotechnology

• *Neural Interfaces*: Devices coupled to the nervous systems to *diagnose* and *treat* nervous system disorders and to *restore lost function*: paralysis, blindness, deafness…
   .....epilepsy, depression…..
Neurotechnology
Current and Developing Neural Interfaces

**Electrical stimulation**
- Restore lost sensory function
- Therapy

**Sensing**
- Restore movement
- Evaluation (diagnosis)
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Available Neurotechnology: Stimulation
>80,000 Cochlear Implants to Restore Hearing

Stimulating electrode
Retinal Vision Implant (N~6)

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Deep Brain Stimulation (DBS) for Movement Disorders

>30,000
Neurotechnology
Neural Interfaces to ‘read out’ brain electrical signals

Out

Neural Sensing (what’s going on in there?)
Neural Interface System: Sensing

He-man

Movie/game thanks to M. Serruya, A. Caplan, D. Morris
Neural Interface System

\[ \text{Brain} \xrightarrow{\text{Muscular dystrophy}} \text{Muscles} \xrightarrow{\text{Action}} \]

\[ = \begin{cases} 
\text{Brain Computer Interface (BCI)} \\
\text{Brain Machine Interface (BMI)} \\
\text{Neuromotor Prosthesis (NMP)} 
\end{cases} \]

- Computer
- Assistive technology
- Robot
- Artificial Limb
- Muscles

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Neural Interface System

Field Potentials (FP, state)
Action Potentials (AP, 'spikes' code)

Neural electrical potentials

Brain
Muscles
Action

Sensor
Decoder
User interface

FP (macro)
AP (micro)
BrainGate Human Neural Interface System

IDE pilot trial: 4 tetraplegic humans (2 SCI, 1 Brainstem Stroke, 1 ALS)

- Sensor Implant

100 microelectrode array
4 x 4 mm  1-1.5 mm long

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BrainGate Neural Interface System

- Signals remain in Motor Cortex years after Injury
- Modulated by intention to move the arm (no learning)
BrainGate User Interface: Functionality

Early Test of Control
S1 Spinal Cord
1 year post injury

Control Now:
Point and click decoding
Black, Kim, Simeral et al., Brown U.
S3 > 9 years post stroke

See: Hochberg et al., (2006)

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User Interface: Demonstrations

TV Remote (S3)

Point and Click Typing
User Interface: Physical Devices

- Motorized Prosthetic hand courtesy of Liberating Technologies, Inc.
- Computer Interface courtesy of RollTalk, Inc.

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Neural Interface System: Advances Towards a Fully Implantable Device

Today

Next Steps

Wireless/ Fully implanted/ Automated

Implantable neural sensor Prototype (Nurmikko/Brown University)

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Next Steps: Moving Paralyzed Limbs
Coupling Functional Electrical Stimulation (FES) and BrainGate

NICHD/NCMRR
Kirsch / Peckham Case Western/ Cleveland FES Center
http://feswww.fes.cwru.edu/
From: Chadwick, Cornwell. Taylor, Branner, Caplan Peterson S3
‘Smart’ Neural Interface Platform: Applications

Sensing

- BrainGate – Communication
- BrainGate – FES

Stimulating

- Vision
- Hearing
- Neural Repair
- Neural Driven Drug Delivery
- Incontinence
- Sexual Dysfunction

From: Ron Emerson, MD
Columbia Univ/CKI

Brain Injury

Depression

Epilepsy

Pain

Plus: Unprecedented access to normal/abnormal human brain function at the neuron level

May 9, 2007
Thank You
MIT Media Lab

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Age of Neurotechnology

IN (Stimulation)

• Cochlear Implants > 50,000
• Deep Brain Stimulators > 30,000
• Retinal Vision Prosthesis ~6

OUT (Sensing)

1950 N=1

1960

NOW

1950 N=1

http://www.medtronic.com/corporate/
Donoghue Abstract Hot Topics AAN

Developments in Neural Interfaces to Restore Lost Functions in Tetraplegia.

John P. Donoghue, Ph.D.
Department of Neuroscience Brown University, Cyberkinetics Neurotechnology Systems, Inc.

Neurotechnology is an emerging field that is beginning to provide a range of new devices to treat nervous system disorders. Tens of thousands of humans have already received neural interface technologies that stimulate the nervous system to treat symptoms of disorders such as epilepsy and Parkinson’s disease. Neural interface systems that sense neural signals are in early stages of development, but promise to provide a means to restore independence, communication, and potentially movement. Spinal cord injury, stroke and other paralyzing conditions, as well as motor neuron disorders such as ALS, prevent movement intentions from being realized. In these disorders, a neural interface system can provide a physical means to restore a new communication link from the brain to the body or to assistive technologies. Early-stage clinical trials of a pilot human neural interface system, called BrainGate (Cyberkinetics Neurotechnology Systems, Inc.), indicate that individuals with paralysis can use neural activity from the arm area of motor cortex as a control signal to operate a range of assistive technologies. The system is based upon a 4 x 4 mm intracortically implanted array of 100 microelectrodes that detects neural activity patterns. Signal processors located outside the body derive movement intent from the neural patterns to generate a command signal. This command signal can then be used to operate a range of assistive technologies, including a computer, robotic hand or a powered wheelchair. Studies to date have included four individuals with tetraplegia. Despite their inability to move, we found that neural activity in the motor cortex modulated with imagined actions in all participants, even though they had different, long-standing forms of CNS impairment. Participants were able to control cursors in point-to-point movements and operate a robotic arm and hand, but not as well as an able bodied person. Recent advances in decoding have demonstrated the ability to provide point and click control signals that may be effective command signals for a variety of prosthesis applications. By combining the neural sensor with muscle functional electrical stimulation it may be possible to reanimate muscles, returning them to voluntary control via physical connections. These early-stage developments suggest that neural interface systems have to potential to significantly modify the lives of individuals with paralysis from neurodegenerative diseases or CNS damage. The multi-electrode sensor itself also appears to provide a sensitive means to monitor neural function that could be useful in a range of other neurological conditions such as epilepsy or brain trauma.

Conflict of Interest: John Donoghue is a shareholder, director and Chief Scientific Officer of Cyberkinetics.
Neural Interface Systems: Advances- Muscle Control

Brain $\rightarrow$ Muscles $\rightarrow$ Action

Neuromotor prosthesis (NMP)

May 9, 2007
Where we are: Neurotechnology for Paralysis

• **Neural Interface Systems** (external and intracranial) hold great promise to help those with paralysis;

• Very active research area (signals (AP,FP); decoding, technology)

• Human Pilot trials. Initial proof of concept that intracortical interfaces function years after injury in
  • Spinal Cord Injury (2)
  • Brainstem Stroke (1)
  • ALS (1)

• Control includes computer interfaces, physical devices

• Potential to reanimate limb muscle

• Challenges include: engineering fully implantable, automated systems; efforts underway.

• New window on brain function and disease via implanted chronic sensor
For further details:

S37.004 Wednesday, May 2, 2007 ***4:30 PM***

Leigh R. Hochberg
Cortical Control of Assistive Devices by Persons with Tetraplegia
Neuroprosthetic System: Vision

Nurmikko Lab/Brown

BIC Sensor Assembly

Stimulus Array

Power and I/O Fiber

Fiber Optic “nerves”

Muscle Stimulator

Inductively/ Optically Coupled Power and I/O Pack

Abdominal Pack
- Lasers
- DSP
- Battery

Restore

Rehabilitate

Replace
Platform Presentation:

S37.004 Wednesday, May 2, 2007 ***4:30 PM***

Leigh R. Hochberg, MD PhD
Cortical Control of Assistive Devices by Persons with Tetraplegia

Nature WEBSITE:
http://www.nature.com/nature/journal/v442/n7099/index.html
The Need for Neural Interface Systems

- Many neurological disorders disrupt the ability to move or communicate, but leave cognition intact.
- 100,000s affect worldwide.
- Current assistive technology is limited.

spinal cord injury
- cerebral palsy
- cerebellar disorders
- locked-in syndrome
- stroke
- spinal muscular atrophies
- ALS
- muscular dystrophy
- limb loss
- multiple sclerosis