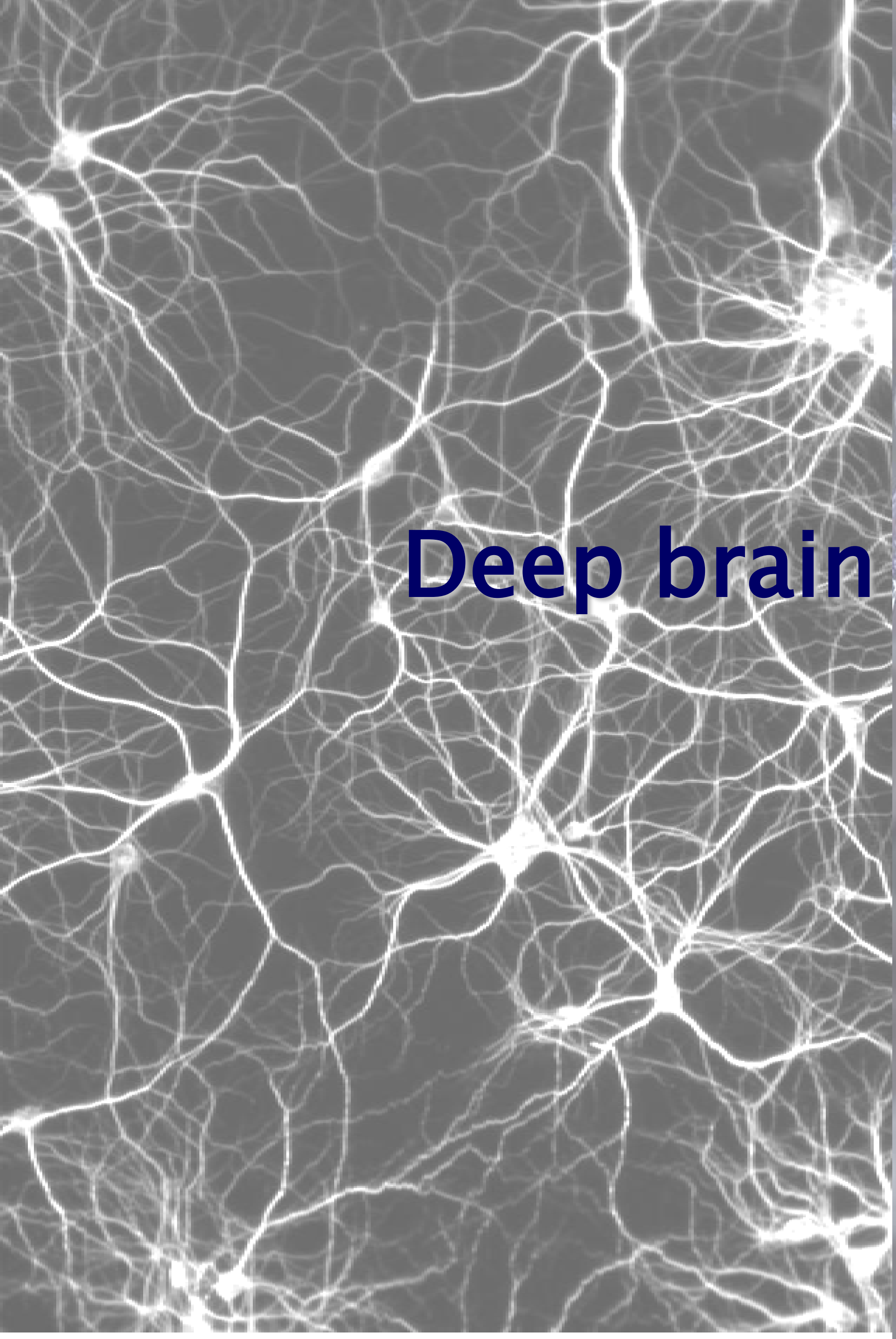
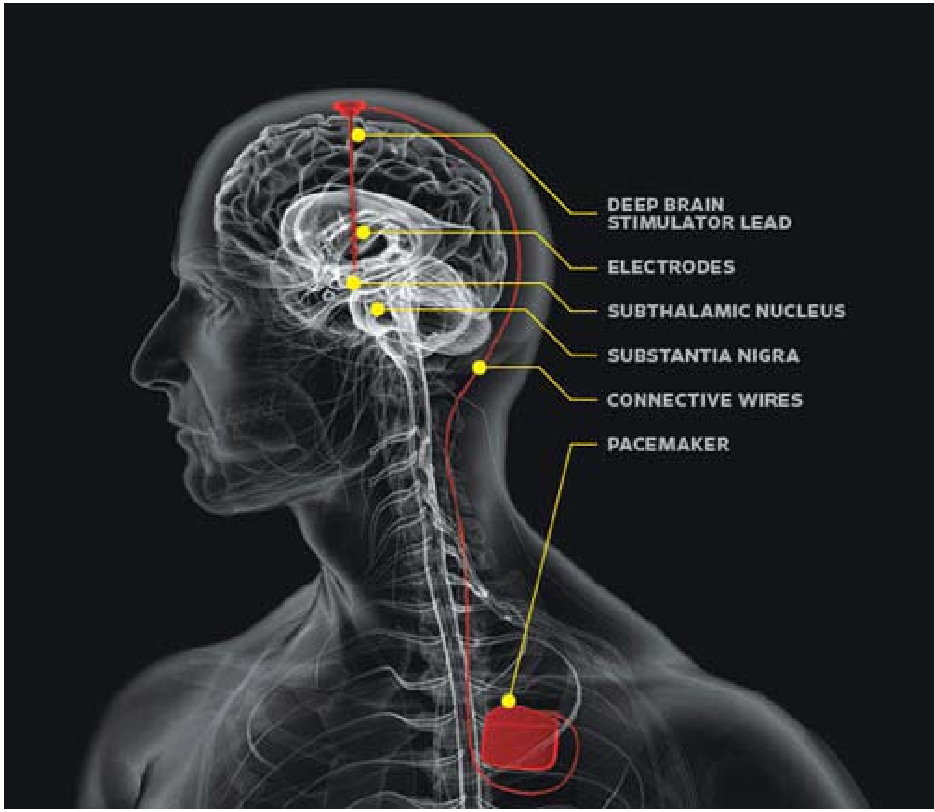
Deep brain stimulation



Deep Brain Stimulation

- Surgical treatment involving the implantation of a medical device called a “brain pacemaker”, which sends electrical impulses to specific parts of the brain.

- Treatment for essential tremor, dystonia, and Parkinson's disease. DBS may also alleviate symptoms in treatment-resistant clinical depression.



History of Deep Brain Stimulation

- A.D. 46 - Ancient medicine
  Scribonius Largus suggested applying the live ray to the head of a patient suffering from a headache. This remedy was later used for hemorrhoids, gout, depression, and epilepsy.

- 18c – Electric fish were used for pain control

- 1870 - G. Fritsch and E. Hitzig
  bodily movements by electrical currents on cerebral tissue (motor cortex)
  → possibility that neurological disorders affecting volitional movement could be treated with electrical stimulation.

- 1960s - Cardiac pacemaker was introduced
  → Technological advances made possible the implantation of a comparable device for the focal stimulation of brain.

- 1960 Hassler et al., stimulation of the ventrolateral thalamus for tremor

- 1973 Hosobuuchi et al., for pain

Electric Ray

THE
FARADIC
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ONE of the MOST MARVELLOUS INVENTIONS OF THE CENTURY! An electric appliance which, while worn on the body, gives a genuine Faradic current of electricity, which can be constantly felt, and can be made as strong or weak as desired. Don't confound this with so-called magnetic and galvanic appliances that have been sold in this city.

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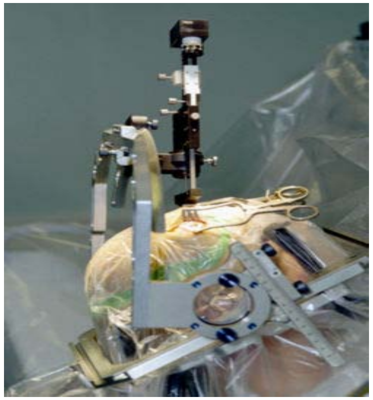
19 Tremont Row, Scollay Sq.

Advertisement for electrical stimulation in the *Boston Globe* from 1882

History of Deep Brain Stimulation

- 1983~1990 – Recordings in the basal ganglia of both normal and MPTP-treated monkeys helped to define the operational principles of basal ganglia-thalamocortical loops, and showed for the first time pronounce over-activity in a part of the basal ganglia called the sub thalamic nucleus (STN)



- 1990 – Lesions of STN in monkeys were shown to completely and permanently reverse the effects of MPTP

- 1993 – The first report from Benabid's clinic of the use of DBS in the STN to treat Parkinson's Disease. Benabid's group had first used DBS in the thalamus as early as sides of the brain, which is now the standard approach in PD patients

- 1997 - FDA approved DBS of the thalamus for PD and essential tremor

- 2002 – FDA approved DBS STN and GPi for symptoms of PD

Neurological Movement Disorder

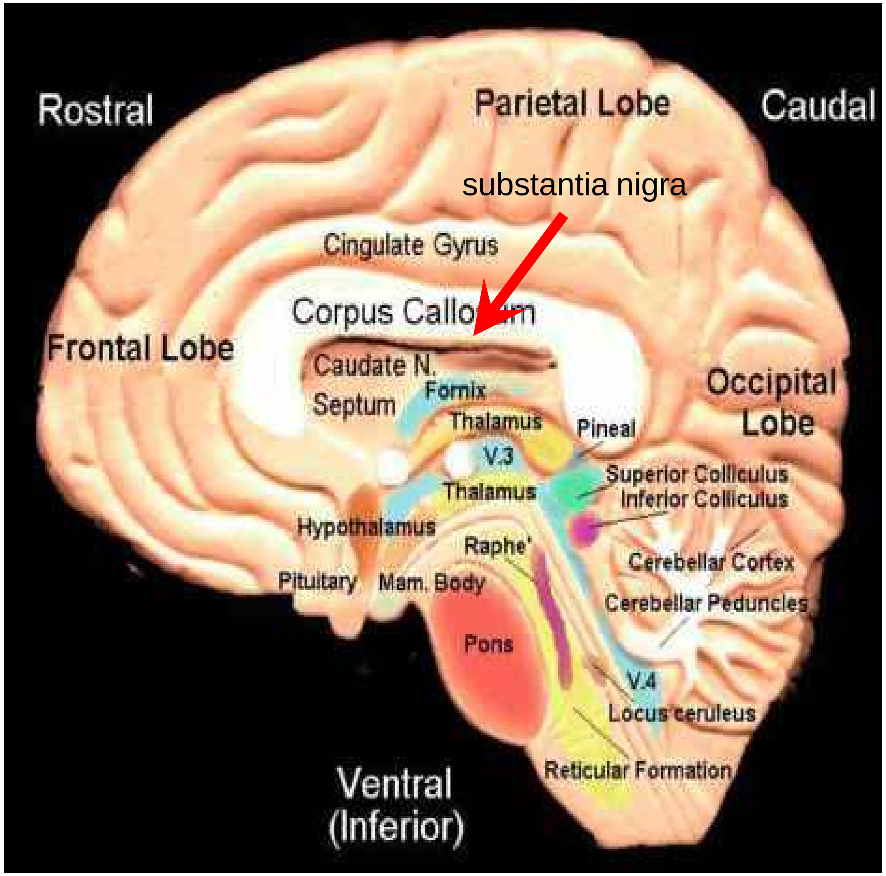
발병 원인

운동기능을 담당하는 뇌심부 구조물(**substantia nigra**) 에 존재하는 억제성 신경세포(**inhibitory neuron**)의 소실로 인하여 연접한 신경망의 **over-activities** 발생

➔ **Movement Disorders** 야기

종류 및 증상

- **Parkinson's Disease**
  - **Tremore at rest state**
  - **lower shaking frequency**
  - **Ceases during purposeful movement**
- **Essential Tremor (본태성 진전)**
  - **Tremore during movement**
  - **Higher shaking frequency**
- **Dyskinesia (이상운동증)**
  - **Power Impairment of voluntary movement**
- **Dystonia (근긴장이상증)**
  - **Disordered tonicity of muscles**



Treatments for Movement Disorders

Ablative Surgery

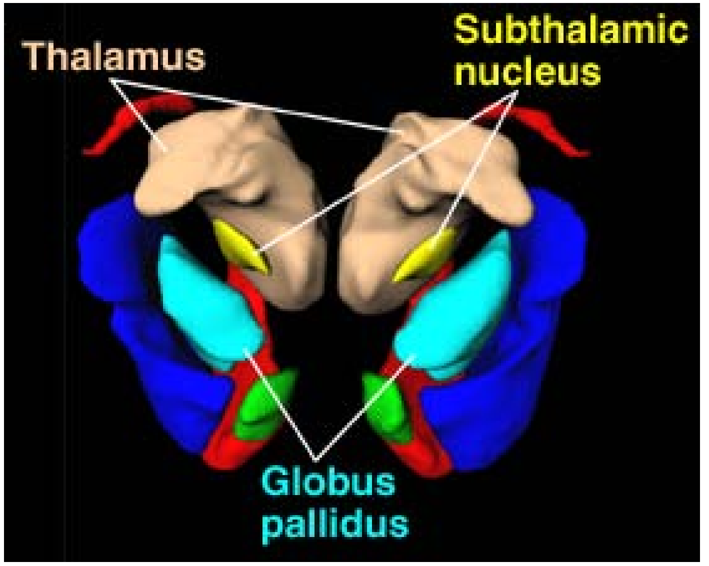
- **Over activities**를 보이는 심뇌부위를 제거함으로서 운동장애를 호전시키는 방법으로 **20**세기 초반부터 연구되어 온 가장 고전적인 방법
- 현재까지도 사용되고 있는 치료법이나, 절제 시 부작용에 의해 주변 뇌의 기능의 손상을 야기할 수 있음.

Drug Medication

- 신경전달물질을 이용한 약물을 투여하여 운동장애를 호전시키는 방법
- 증세가 호전되는 비율이 낮고, 시간의 경과에 따라 효과가 떨어짐.

Deep Brain Stimulation

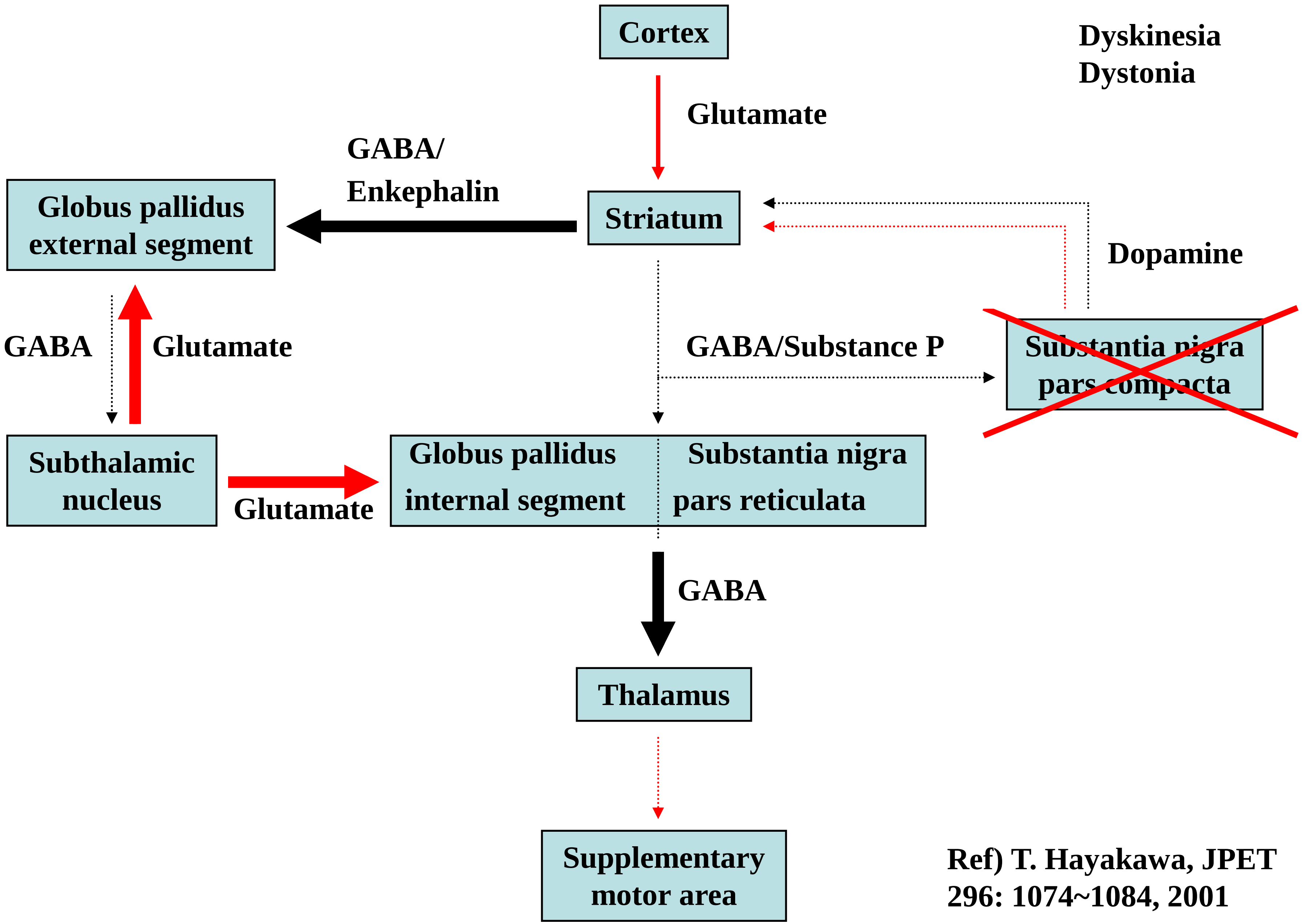
- 병변 부위에 전극을 삽입하여 전류자극을 줌으로서 운동장애를 극적으로 호전시키는 방법
- **Tremor**를 포함한 각종 운동장애에 효과가 있는 것으로 밝혀져 활발히 연구가 진행 중에 있음.



Three Stimulating Targets of DBS

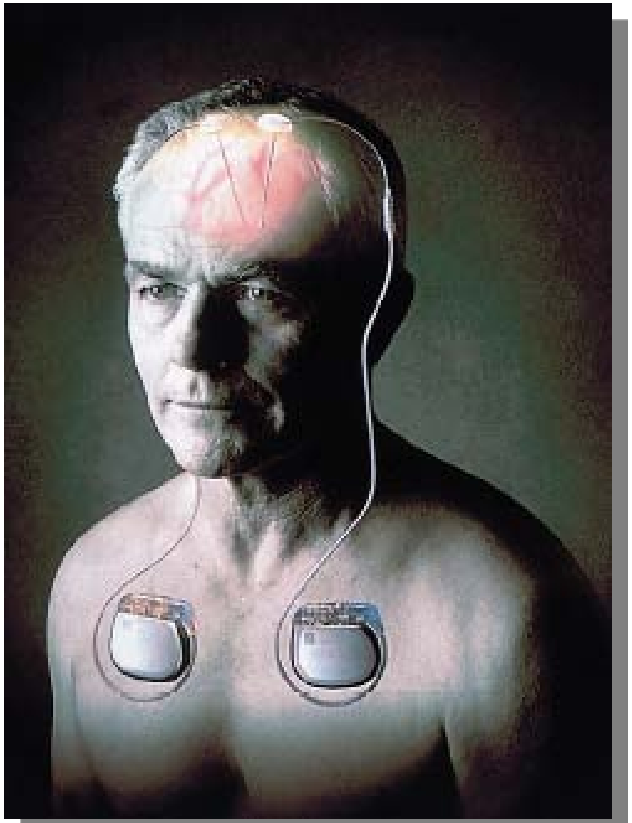
- **Thalamic nucleus (**시상핵**)**
- **Subthalamic nucleus (**시상하핵**)**
- **Globus pallidus (**창백핵**)**

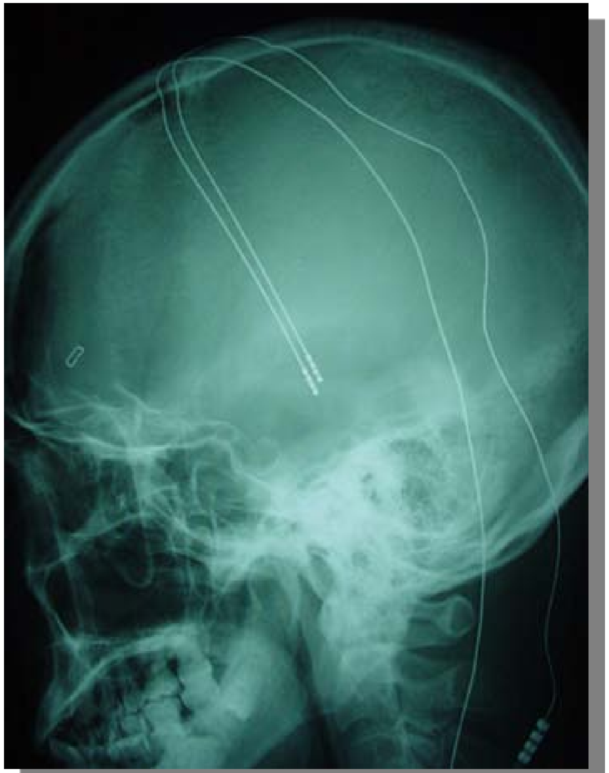
PD pathway



Ref) T. Hayakawa, JPET 296: 1074~1084, 2001

DBS; Deep Brain Stimulation

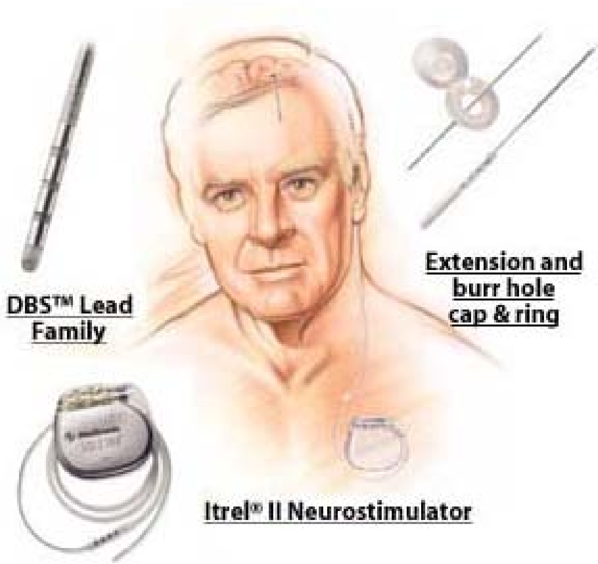




DBS system 구성

Implantable Components

- Self-powered neurostimulator
- Electrode
- Connection leads



Patient Component

Use magnet link to turn neurostimulator off or on

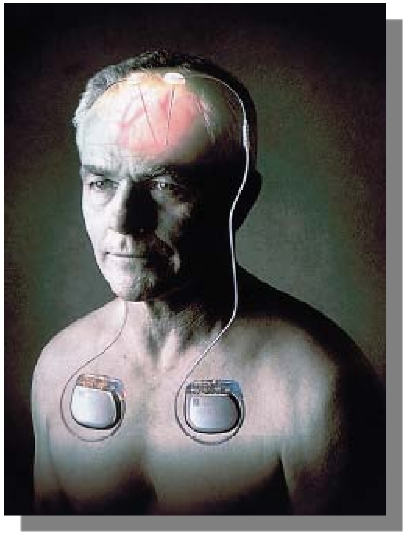
Physician Programmer

Programmer, printer, and programming head. Communicate via telemetry to adjust neurostimulator parameters.

Neurological Test Stimulator

Device tests the effectiveness of stimulation intraoperatively or during a test stimulation period.

DBS Video



Medtronic Inc. Activa® Tremor Control Therapy

DBS new applications

1. Parkison's disease
2. Pain Control
3. OCD(Obsessive-compulsive_disorder)
4. Awakening from Vegetative State
5. Dementia
6. Memory making

Obsessive–compulsive disorder (OCD)

An anxiety disorder characterized by involuntary intrusive thoughts. When a sufferer begins to acknowledge these intrusive thoughts, the sufferer then develops anxiety based on the dread that something bad will happen. The sufferer feels compelled to voluntarily perform irrational, time-consuming physical behaviors to diminish the anxiety. Sufferers often try to keep their compulsive behaviors hidden from others, often to avoid embarrassment, humiliation or to avoid being seen as strikingly odd or different from others. If the condition is not realized by an undiagnosed sufferer, they may scold themselves in frustration as to why they are thinking or acting the way they are.

Obsessive–compulsive disorder (OCD)

Although the acts of those who have OCD may appear paranoid and come across to others as psychotic, an OCD sufferer is able to recognize their thoughts and subsequent actions as irrational, which is what makes the illness so distressing. The psychological self-awareness of the irrationality of the disorder may be painful; a sufferer may be plagued by doubt and uncertainty regarding their own feelings and behaviors. A principal challenge faced by OCD sufferers is learning to manage their own behaviors without constant reassurance from others.

OCD is the fourth most common mental disorder and is diagnosed nearly as often as the physiological ailments asthma and diabetes mellitus.

DBS can help memory making.

http://www.nature.com/news/2009/090529/full/news.2009.529.html

Mice grew inserted active neurons after deep brain stimulation. Electrodes into certain parts of the brain — in a technique known as deep brain stimulation — can stimulate the growth of new neurons that are used in memory formation, according to research in mice.
The findings show that artificially created neurons can be fully functional — a topic of hot debate in the neuroscience community. Knowing that the cells are functional, rather than just useless growths, is a boost for those seeking to use the treatment against Alzheimer's disease and other memory-degeneration disorders. "I'm hoping to help people who have difficulty remembering things," says Scellig Stone, a neurosurgery resident and PhD candidate at the University of Toronto.

BCI (Brain Computer Interface)

In the futuristic vision of the Wachowski brothers' movie trilogy "The Matrix," humans dive into a virtual world by connecting their brains directly to a computer......




Movie fiction: *The Matrix, Bionic Woman, Spider Man, i Robot....etc.*

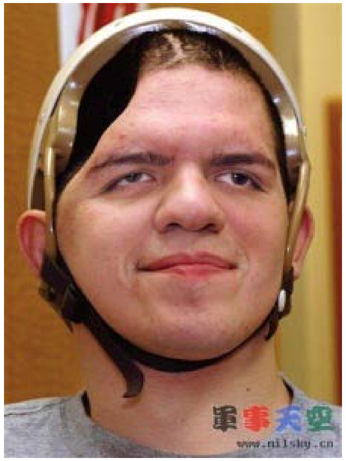
한림대 이현주자료

Motivation for BCI/BMI Research

In USA, more than 200,000 patients live with the motor sequelae (consequences) of serious injury. There are two ways to help them restore some mot or function:

- Repair the damaged nerve axons
- **Build neuroprosthetic device**

BrainGate by **Cyberkinetics**



Frank Sandoval

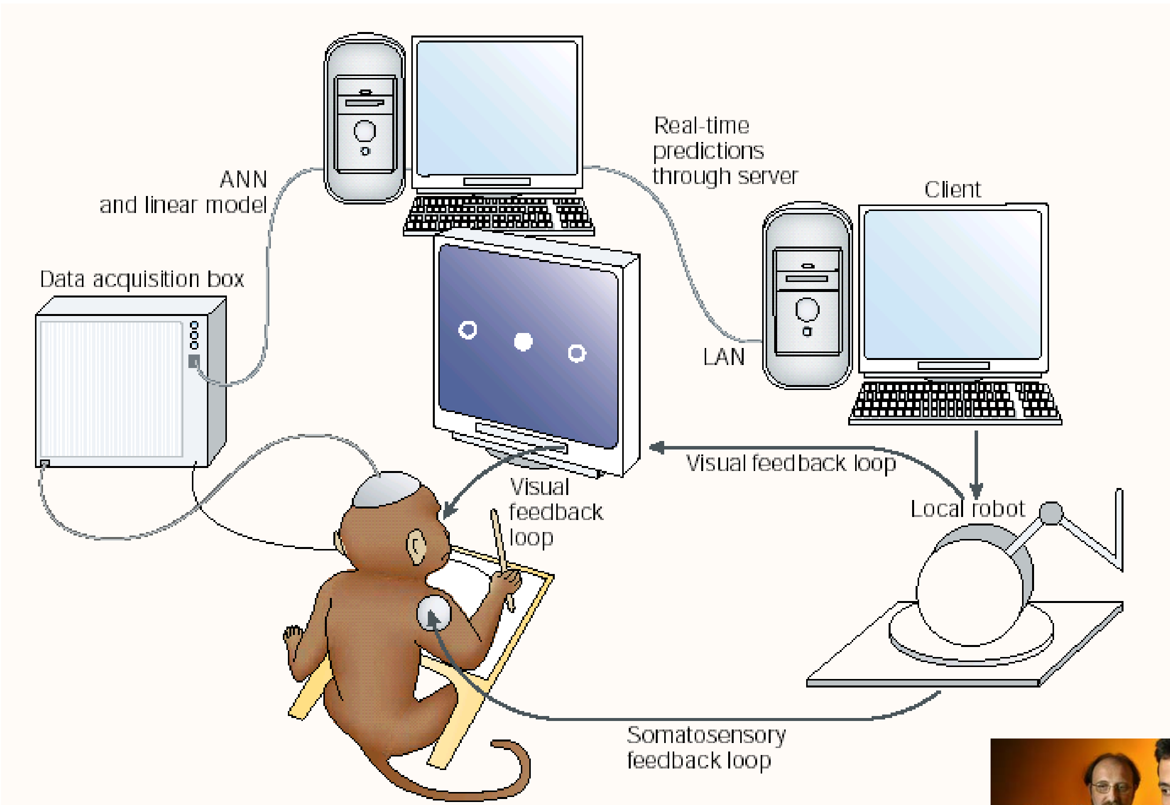
Nicolelis, 2001

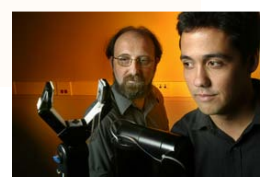
Brain-Computer Interface (BCI)

Sometimes called a **direct neural interface** or a **brain-machine interface**, is a direct communication pathway between a brain (or brain cell culture) and an external device.

한림대 이현주자료

BCI with Neurons in Motor Brain Area





Duke University Medical Center neurobiologist Miguel Nicolelis with an owl monkey and a robot arm which monkeys learned to operate using only their brain signals

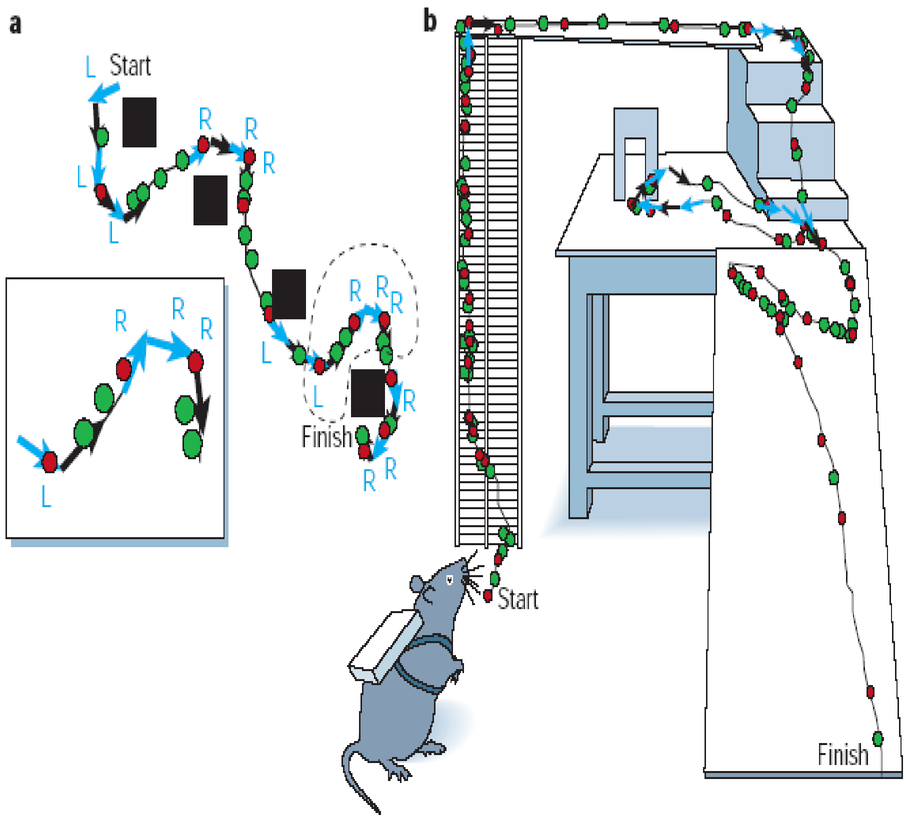
CNN.com

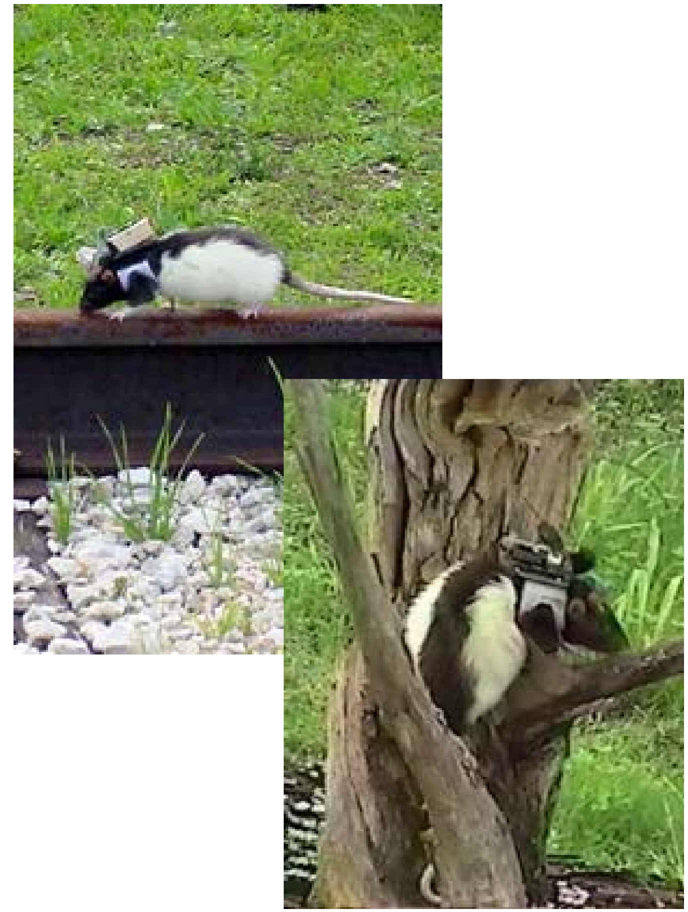
Learning to control a brain-machine interface for reaching and grasping by primates.

Nicolelis et al., PLoS Biology 2003

‘Ratbot’

BCI with Pleasure Center stimulating for control





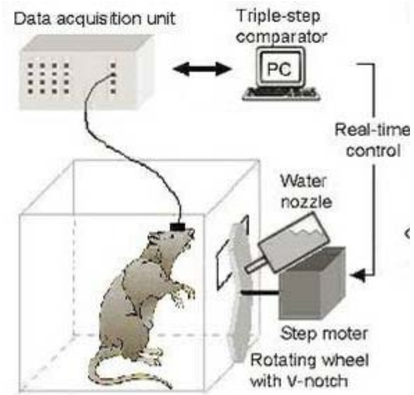
Rat navigation guided by remote control

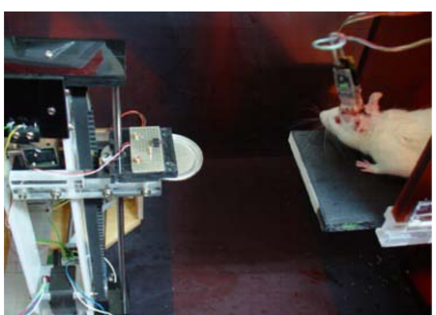
Chapin et al., Nature, 2002

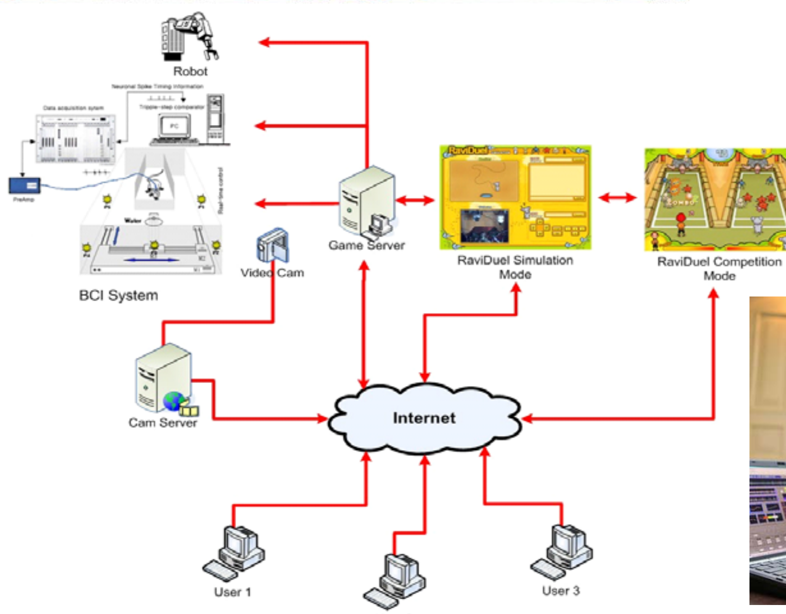
한림대 이현주자료

'Super Animals'

Encoding based Brain Machine Interface – Hallym Univ.



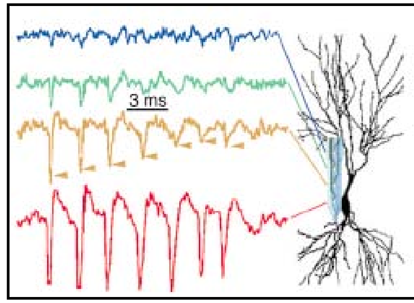


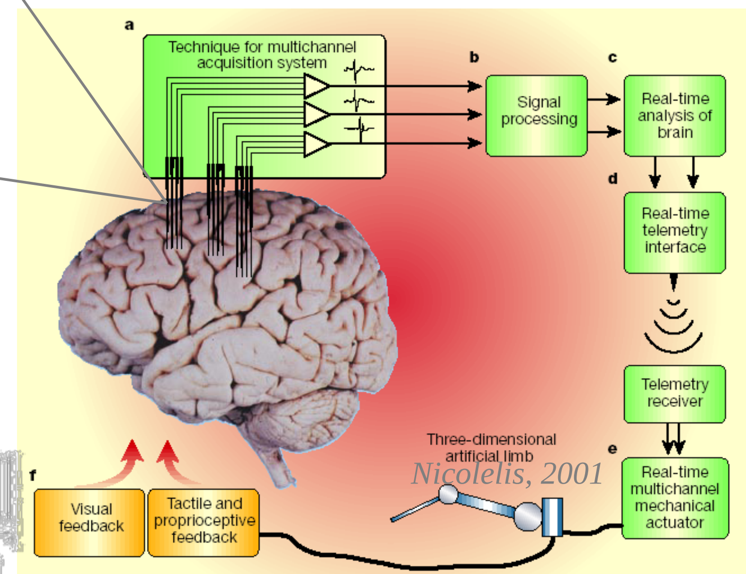


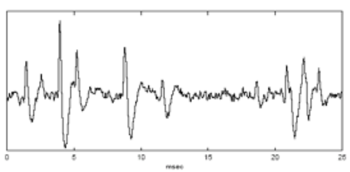
한림대 이현주자료

Neuron Spike based BCI

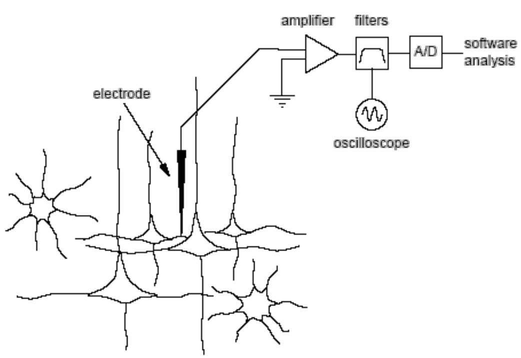
- **high speed real time control**
- **invasive**
- **risk for clinical application**

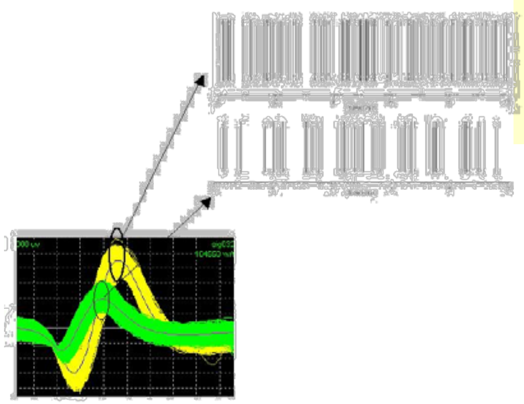






Spike sorting





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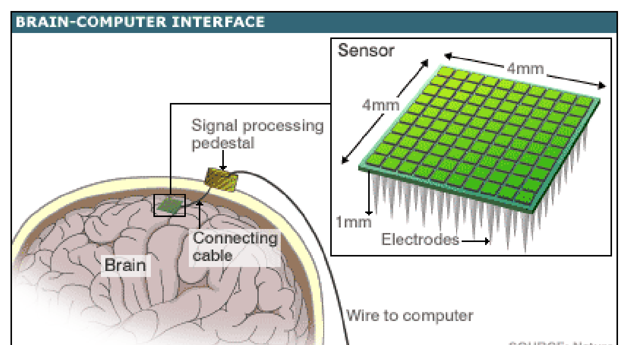
Non-invasive

Vs.

Invasive



한림대 이현주자료

Neuroprosthetic control systems based on intelligent devices and supervisory control

- Schematic of the proposed framework

Andersen Lab, Brown Univ.

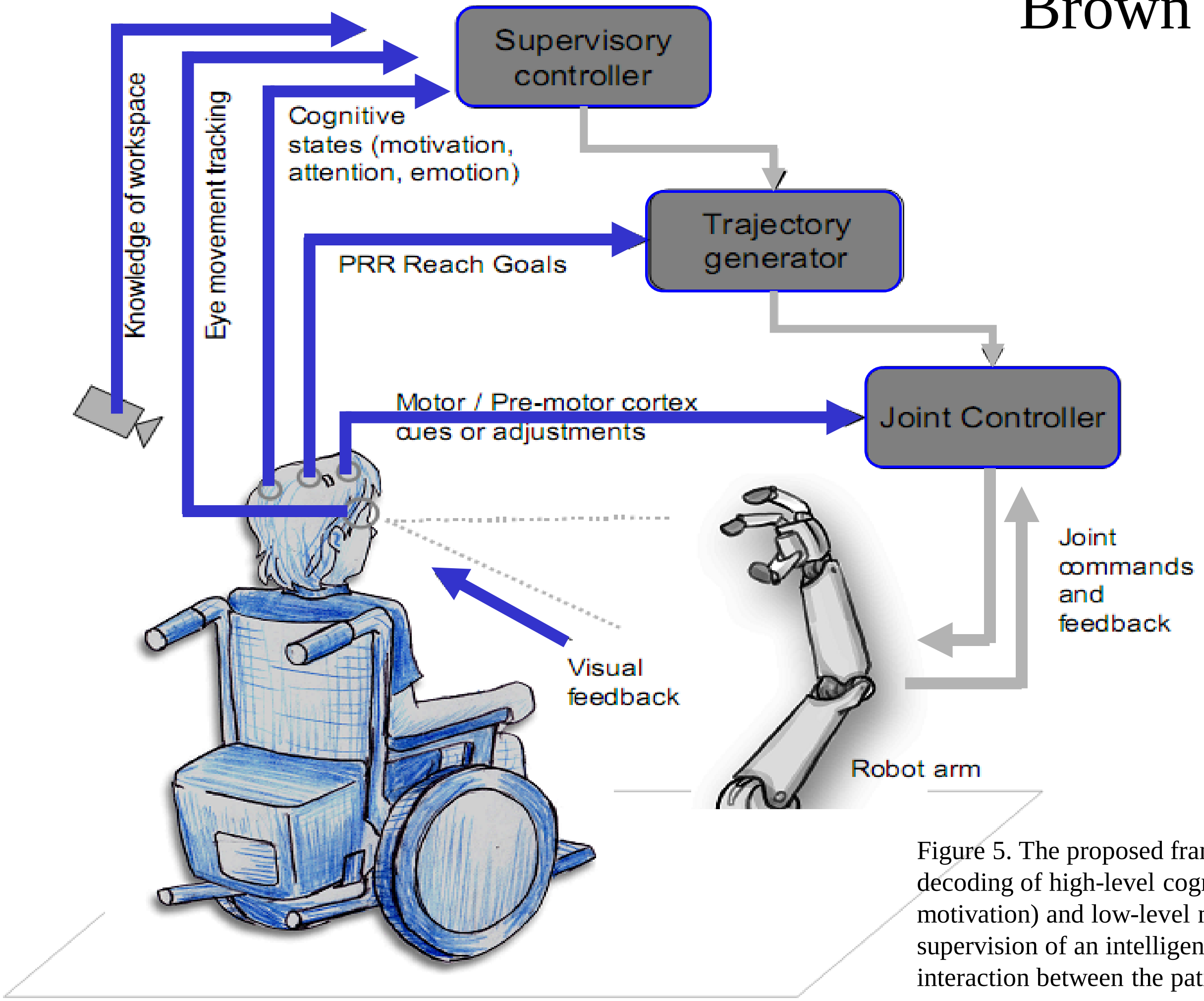
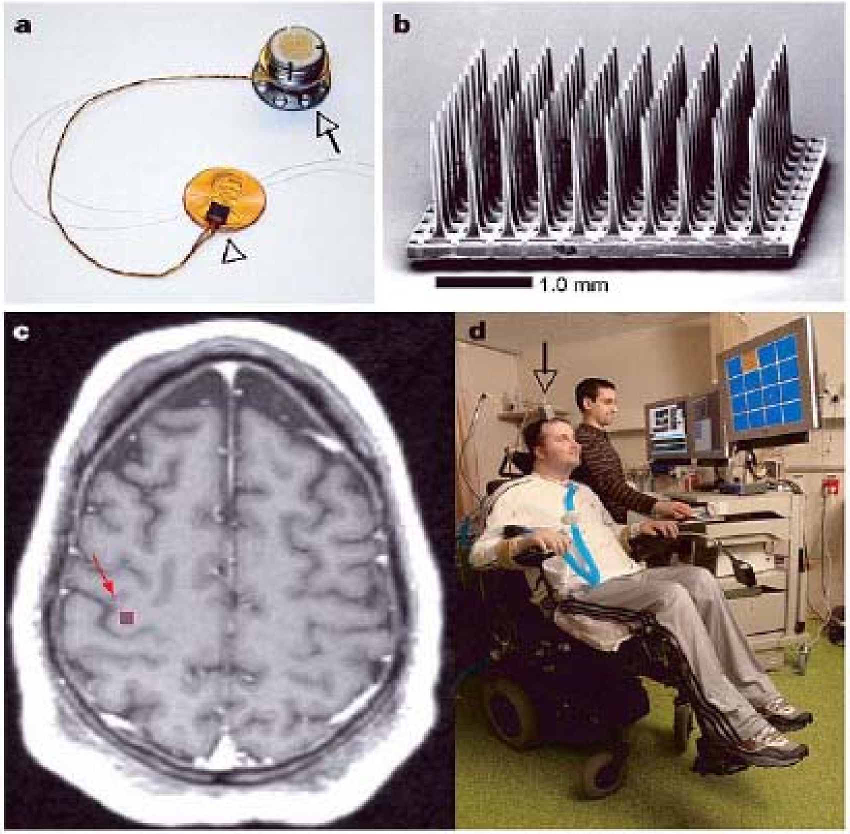


Figure 5. The proposed framework emphasizes parallel decoding of high-level cognitive variables (reach goals, motivation) and low-level motor variables under the supervision of an intelligent system, which manages the interaction between the patient and the robot arm.

BrainGate and placement, and the participant



Human Study :

Donohue Lab, Brown Univ.