CLINICAL NEUROPHYSIOLOGY: engineering and medicine

Mamede de Carvalho
Neurophysiology

- Neurophysiology
  - Nervous system function
    - Central
    - Peripheral

- Electrophysiology
  - Cellular
  - Supra-cellular
Clinical Neurophysiology

- **Clinical Neurophysiology** is a medical specialty that studies the central and peripheral nervous systems through the recording of bioelectrical activity
  
  - Spontaneous
  - Stimulated.
Clinical Neurophysiology

• Brain
  – Recording
    • EEG (conventional, monitoring, provocative tests....)
    • Sleep
    • Electroencephalography
    • Evoked potentials (conventional, laser, contact heat ....)
    • Magnetoencephalography
    • Functional Imaging （MRI, PET...）
Clinical Neurophysiology

• Brain
  – Stimulation
    • TMS
    • Electrical Stimulation
    • Transcranial direct current stimulation (tDCS)
    • Cortical Simulation
    • Deep brain stimulation
Clinical Neurophysiology

• Peripheral Nervous System
  – Stimulation-Recording
    • Nerve conduction studies (motor/sensory/microneurography)
    • SSR and other sweating tests
    • Muscle stimulation (muscle fiber, electrical impedance ...)
    • Threshold-tracking
Clinical Neurophysiology

• Peripheral Nervous System
  – Recording
    • Electromyography (surface, needle, single-fiber...)
    • RR variation
    • Microneurography
Clinical Neurophysiology-Bioengineering

- Stimulation
- Recording
- Interaction
BCI

- In the primary motor cortex direction of movements is coded in the activity of neurons (Georgopoulos et al, 1983).
- Neurons in the premotor cortex show a similar directional tuning except that they discharge before the movement.
- Practitioners of Indina medidatibe Yoga can control their brain rhythms (Khare and Nigam, 2000)
- Even a single neuron can be voluntarily modulated (Fetz, 1969; Feltz & Finocchio, 1971).
BCI

• High frequency gamma band (70-300 Hz) activity recorded over the gyrus correlates to single-unit activity (Miller, 2010).

• Increased gamma band activity can derive from higher firing rate of the recorded neurons or by (+ important) increasing coherence of in the spiking neurons (Ray et al, 2008).

• BCI record cortical electrical activity, analyze it using mathematical algorithms to predict the intended movement and use output to generate command signals.
BCI

• Brain (patient)-computer Interface

Signal Acquisition → Extraction → Classification → Device output

Feedback

User

SELF-CONTROL BRAIN ACTIVITIES

Communication
Control neuroprotheses
Control proper muscles
BCI

- **Brain (patient)-computer Interface**
  - **EEG recording** (microelectrodes, subdural, epidural, on the skin)
    - Event-related desynchronization
      - Power of the signal in specific frequency bands
      - Phase-locking factor
  - Imaging
  - Doppler
  - Minor muscle activity
  - ...

BCI

- Brain (patient)-computer Interface
  - Hybrid
    - Module 1
    - Module 2
    - Module 1+2
BCI

Control sign decision

Muller-Putz et al, 2011
Dynamic weight update:
physiological;technical

Muller-Putz et al, 2011
BCI

Rajan & Jain, 2011
Cortical oscillations

Coherent 25- to 35-Hz oscillations in the sensorimotor cortex of awake behaving monkeys

Venkatesh N. Murthy and Eberhard E. Fetz*
Cortical oscillations

Synchronization between motor cortex and spinal motoneuronal pool during the performance of a maintained motor task in man

B. A. Conway, D. M. Halliday*, S. F. Farmer†, U. Shahani‡, P. Maas§, A. I. Weir‡ and J. R. Rosenberg*
Coherent oscillations in monkey motor cortex and hand muscle EMG show task-dependent modulation

S. N. Baker, E. Olivier and R. N. Lemon

It is concluded that oscillations in the range 20–30 Hz are present in monkey motor cortex, are coherent between spatially separated cortical sites, and encompass the pyramidal tract output neurones. They are discernable in the EMG of active muscles, and show a consistent task-dependent modulation.
Cortical oscillations

Baker et al, 1997
Cortical oscillations

Baker et al, 1997
Cortical oscillations

Synchronous oscillations occurred at sites as much as 5 mm apart, suggesting widespread coupling of neurons and LFP signals in motor cortex. Widespread coupling of oscillatory signals is consistent with the concept that temporal coding processes operate in motor cortex. However, because the relationship between neuronal discharge and the appearance of fast oscillations may be altered by behavioral condition, they must reflect a global process active in conjunction with motor planning or preparatory functions, but not details of motor action encoded in neuronal firing rate.
The coherence in the beta band appears during weak tonic contraction, particularly when attention is directed towards the motor task (Kristeva-Feige et al., 2002) and is abolished by movement.
Cortical oscillations

Halliday et al, 1998
Electroencephalographic analysis of cortico-muscular coherence: reference effect, volume conduction and generator mechanism

Tatsuya Mima, Mark Hallett

Cortical oscillations
Cortical oscillations

Changes in Cortically Related Intermuscular Coherence Accompanying Improvements in Locomotor Skills in Incomplete Spinal Cord Injury

Jonathan A. Norton and Monica A. Gorassini
Department of Biomedical Engineering, Centre for Neuroscience, University of Alberta, Edmonton, Alberta, Canada
Cortical oscillations- only cortex?

Fig. 4. Coherence spectra between EMG of forearm extensors and MEG over the contralateral Rolandic area for a patient with Parkinson’s disease after withdrawal and reinstitution of levodopa treatment. Note that MEG–EMG coherence in the beta and gamma bands is restored by levodopa. The thin horizontal line indicates the 1% confidence level.

Grosse et al, 2002
Seven of 52 cells were identified as Group Ia afferents by the production of narrow postspike facilitation in spike-triggered averages of rectified EMG. These identified afferents showed significant coherence, and directed coherence, with EMG over a wide frequency range. Oscillations are known to appear in muscle activity; their presence in afferent firing as well implies that central oscillations pass around a peripheral feedback loop and may be involved in sensorimotor integration.
Cortical oscillations- only cortex?

Manipulation of peripheral neural feedback loops alters human corticomuscular coherence

C. Nicholas Riddle¹ and Stuart N. Baker²
Cortical oscillations - only cortex?

Hansen & Nielsen, 2004
Cortical oscillations—only cortex?

Hansen & Nielsen, 2004
Cortical oscillations - only cortex?

Contributions of descending and ascending pathways to corticomuscular coherence in humans

Claire L. Witham, C. Nicholas Riddle, Mark R. Baker and Stuart N. Baker
Cortical oscillations - marked inter-individual variability

Riddle & Baker, 2005
A subcortical oscillatory network contributes to recovery of hand dexterity after spinal cord injury

Yukio Nishimura,1,2,* Yosuke Morichika1 and Tadashi Isa1,2,3

Cortical oscillations-pyramidal tract lesion
MOTOR UNITS coherence

Changes in Motor Unit Synchronization Following Central Nervous Lesions in Man

By S. F. Farmer, M. Swash*, D. A. Ingram† and J. A. Stephens

With 9 figures
Printed in Great Britain
MOTOR UNIT SYNCHRONIZATION

A  Unaffected (right) 1DI

B  Affected (left) 1DI

1st month post-stroke

3rd month post-stroke

5th month post-stroke

6th month post-stroke

10th month post-stroke
Reduction of Common Synaptic Drive to Ankle Dorsiflexor Motoneurons During Walking in Patients With Spinal Cord Lesion


MUSCLE-MUSCLE coherence

Grosse et al, 2002
MUSCLE-MUSCLE coherence
pyramidal tract lesion