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
    - Electrocorticography
    - 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-Bioenginering

- Stimulation
- Recording
- Interaction

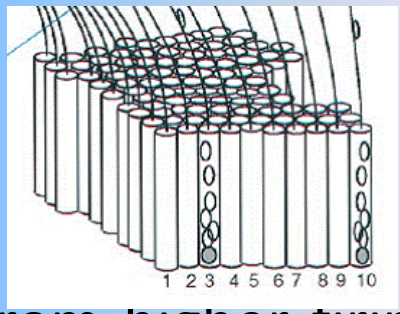
BCI

- In the primary motor cortex direction of movements is coded in the activity of neurons (Georgopoulus et al, 1983).
- Neurons in the premotor cortex show a similar directional tuning except that hey discharge before the movement.

- Practioners of Indina medidatibe Yoga can control their brain rhytms (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).

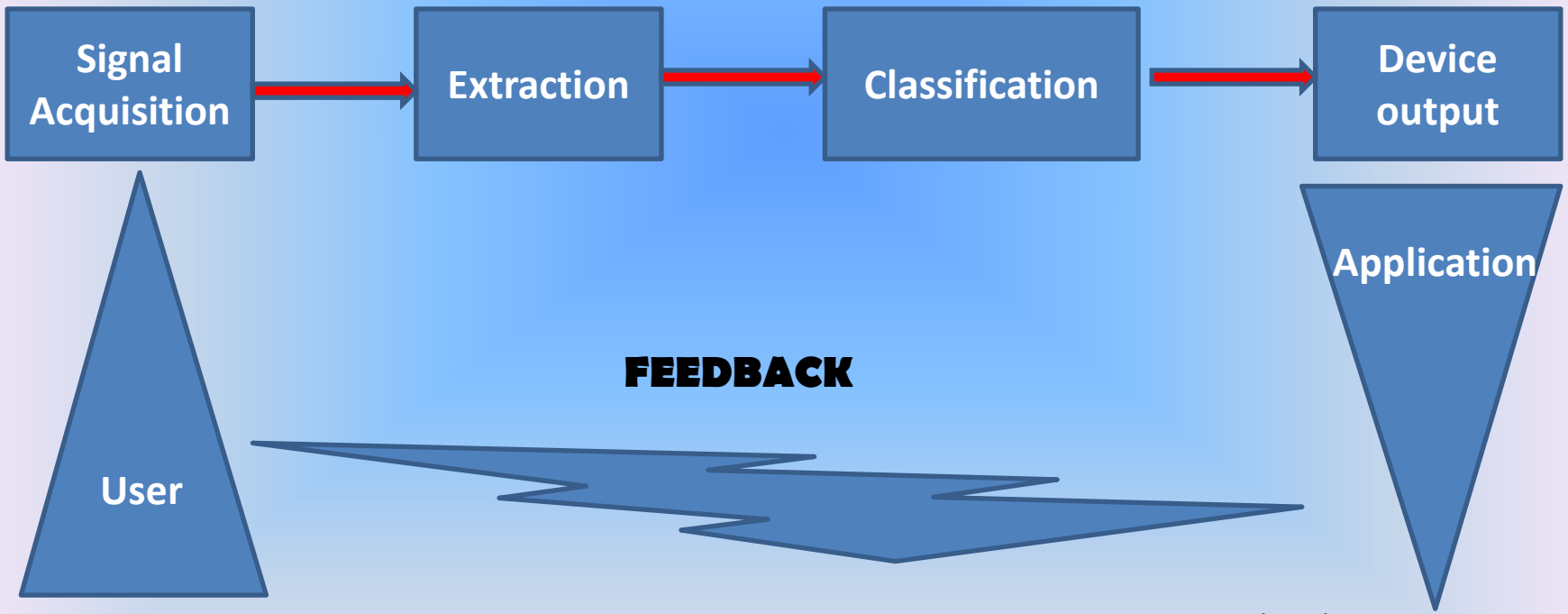


- Increased gamma band activity can derive from higher firing rate of the recorded neurons or by (+ important) increasing coherence of in the spiking neurons (Ray et al, 2008).

- 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



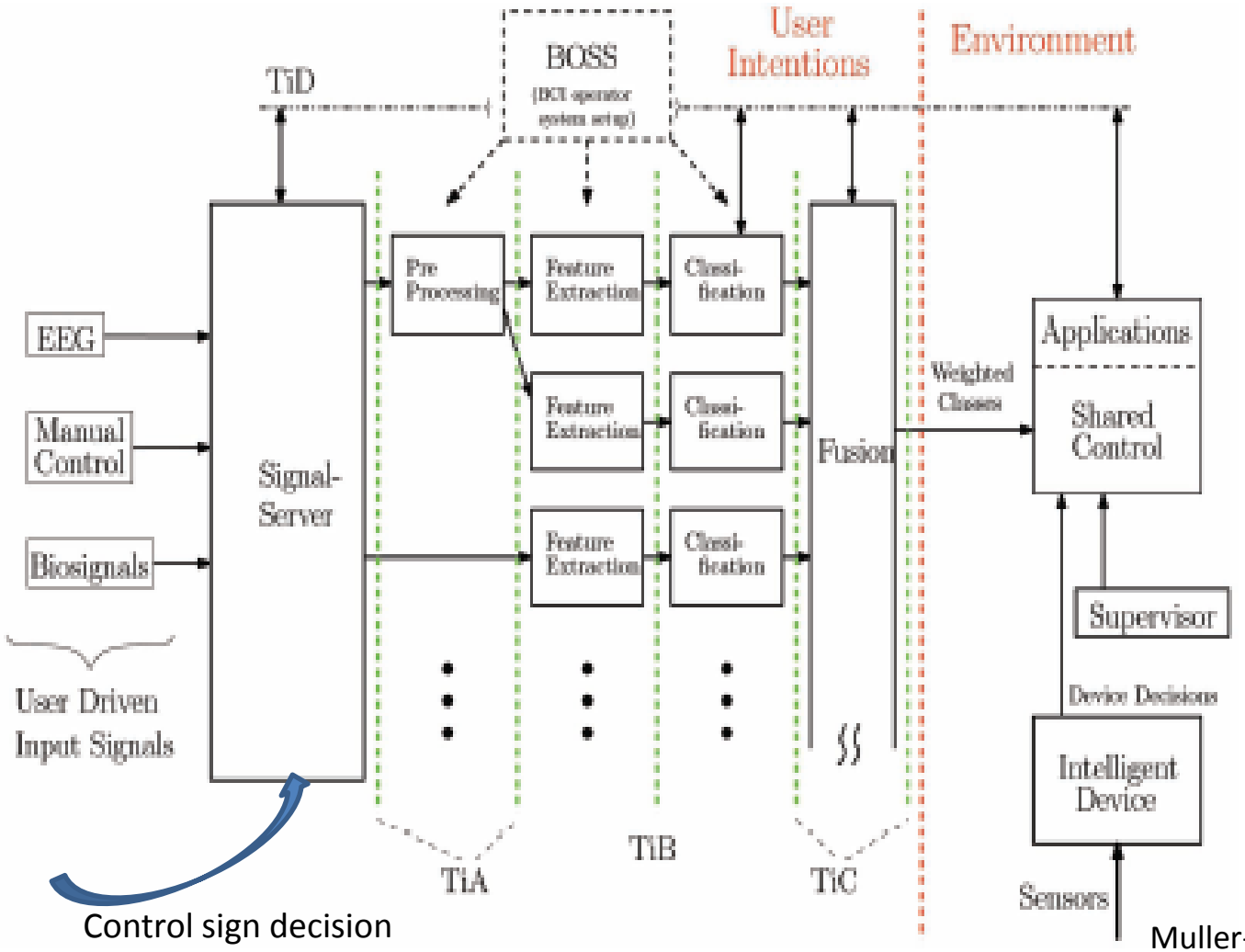
BCI

- **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

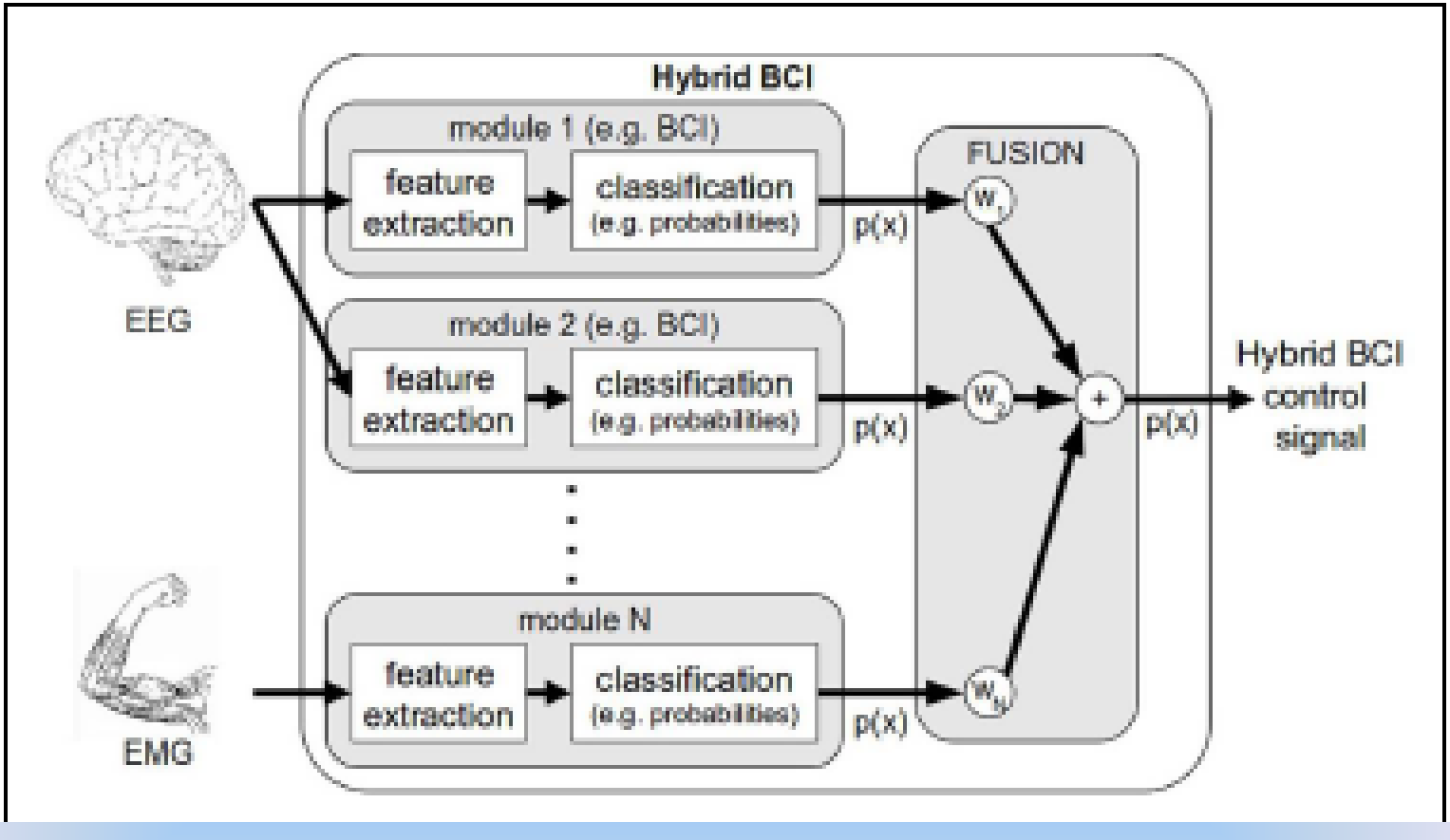
- Brain (patient)-computer Interface
  - Hybrid
    - Module 1
    - Module 2
    - Module 1+2

BCI



Muller-Putz et al, 2011

BCI

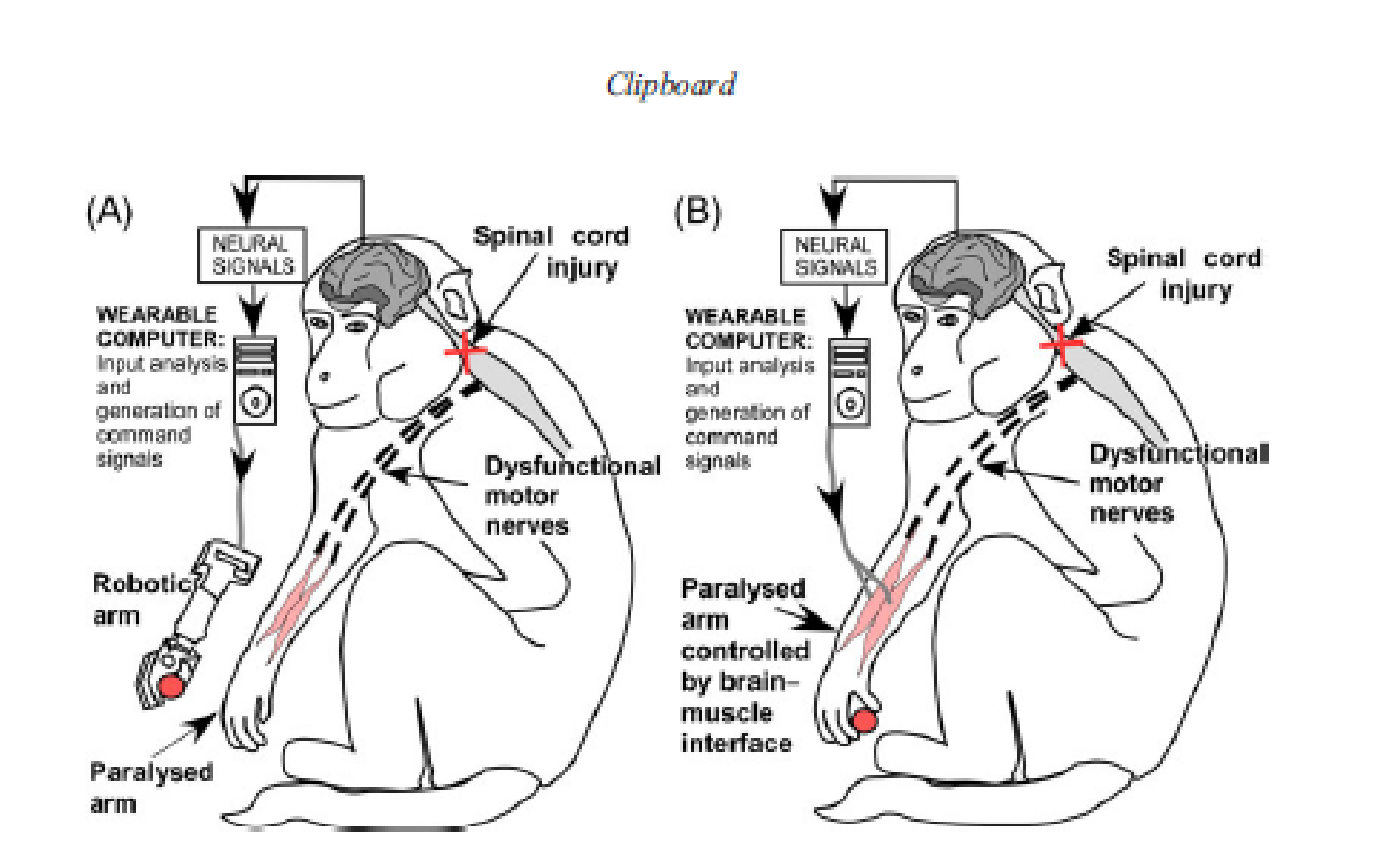


Dynamic weight update:

physiological;technical

Muller-Putz et al, 2011

BCI



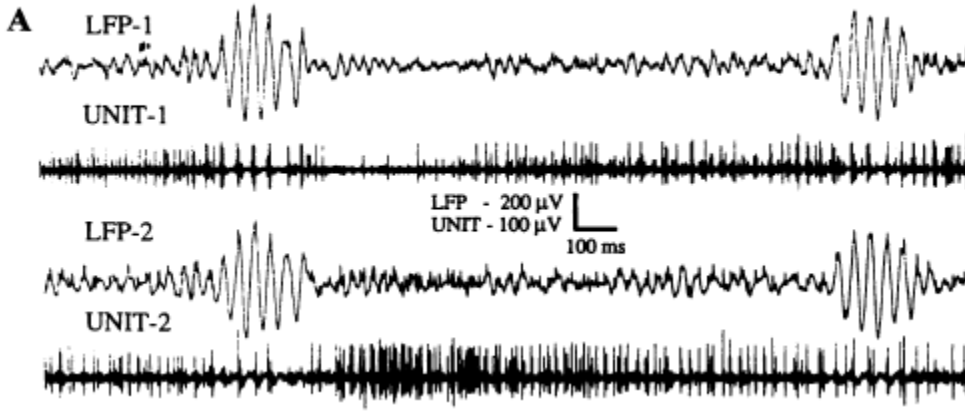
Rajan & Jain, 2011

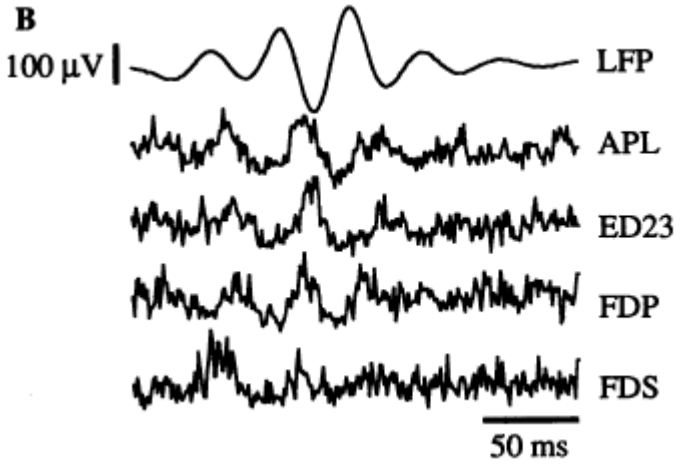
Cortical oscillations

Proc. Natl. Acad. Sci. USA
Vol. 89, pp. 5670–5674, June 1992
Neurobiology

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

VENKATESH N. MURTHY AND EBERHARD E. FETZ*



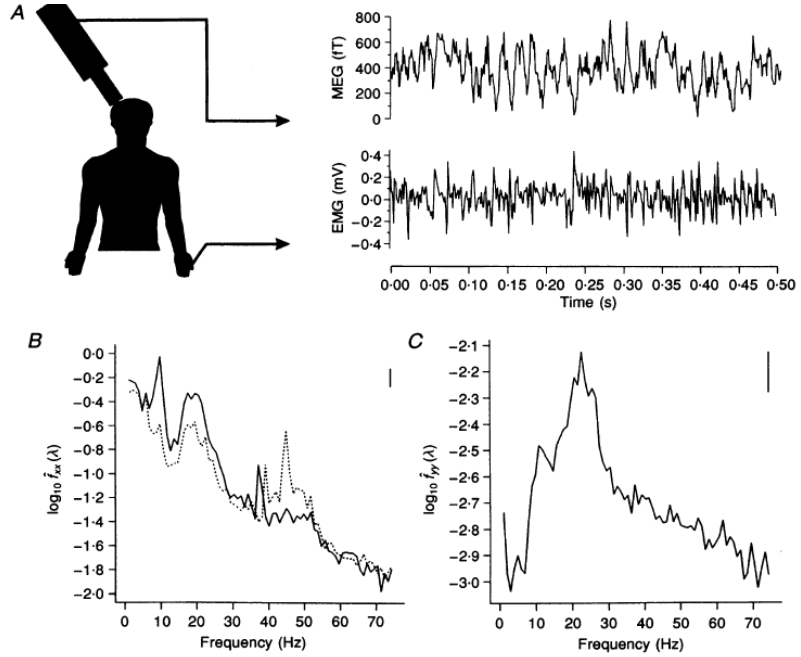


Cortical oscillations

Journal of Physiology (1995), **489.3**, *pp.*917–924

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 *



Cortical oscillations

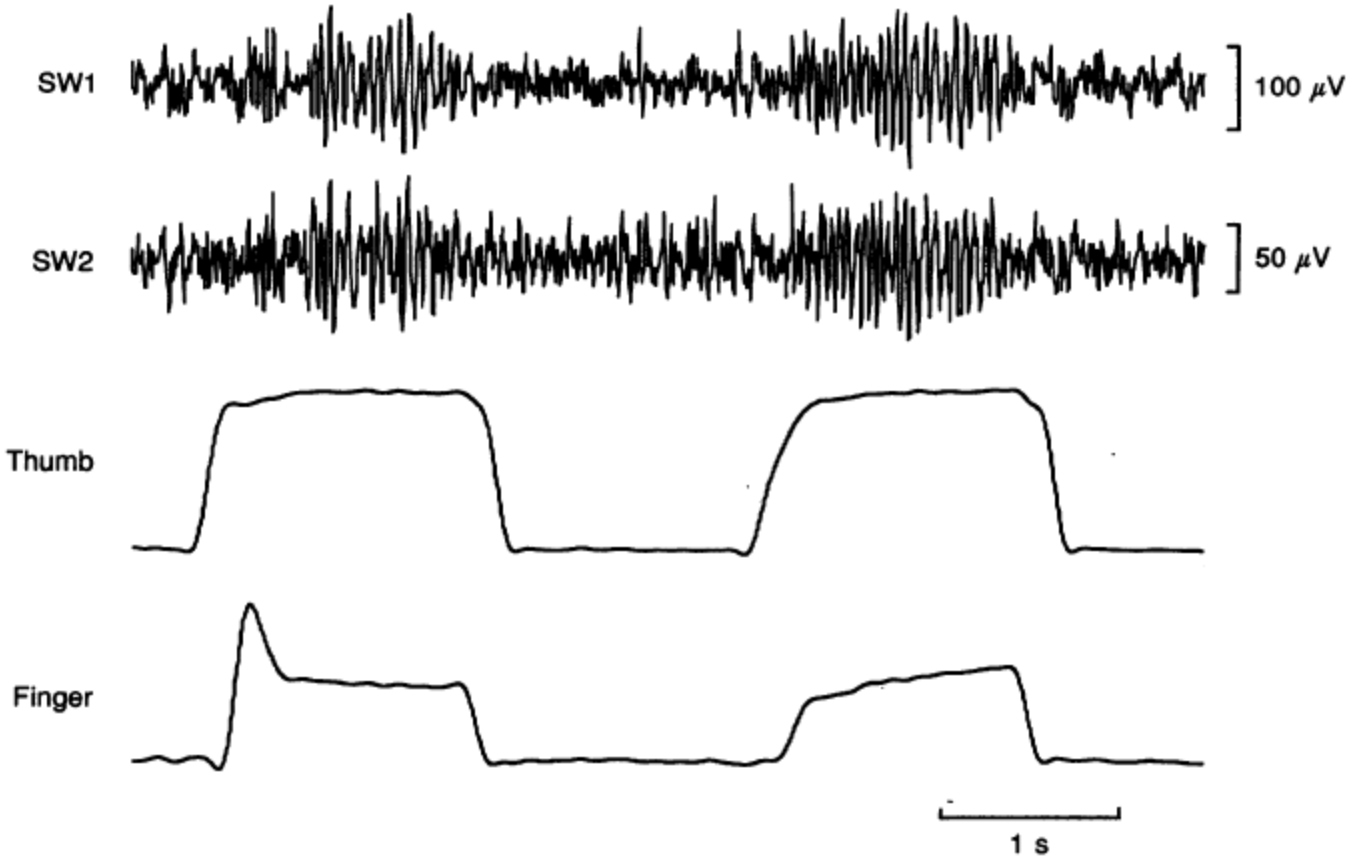
Journal of Physiology (1997), **501.1**, *pp.*225–241

Coherent oscillations in monkey motor cortex and hand muscle EMG show task-dependent modulation

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

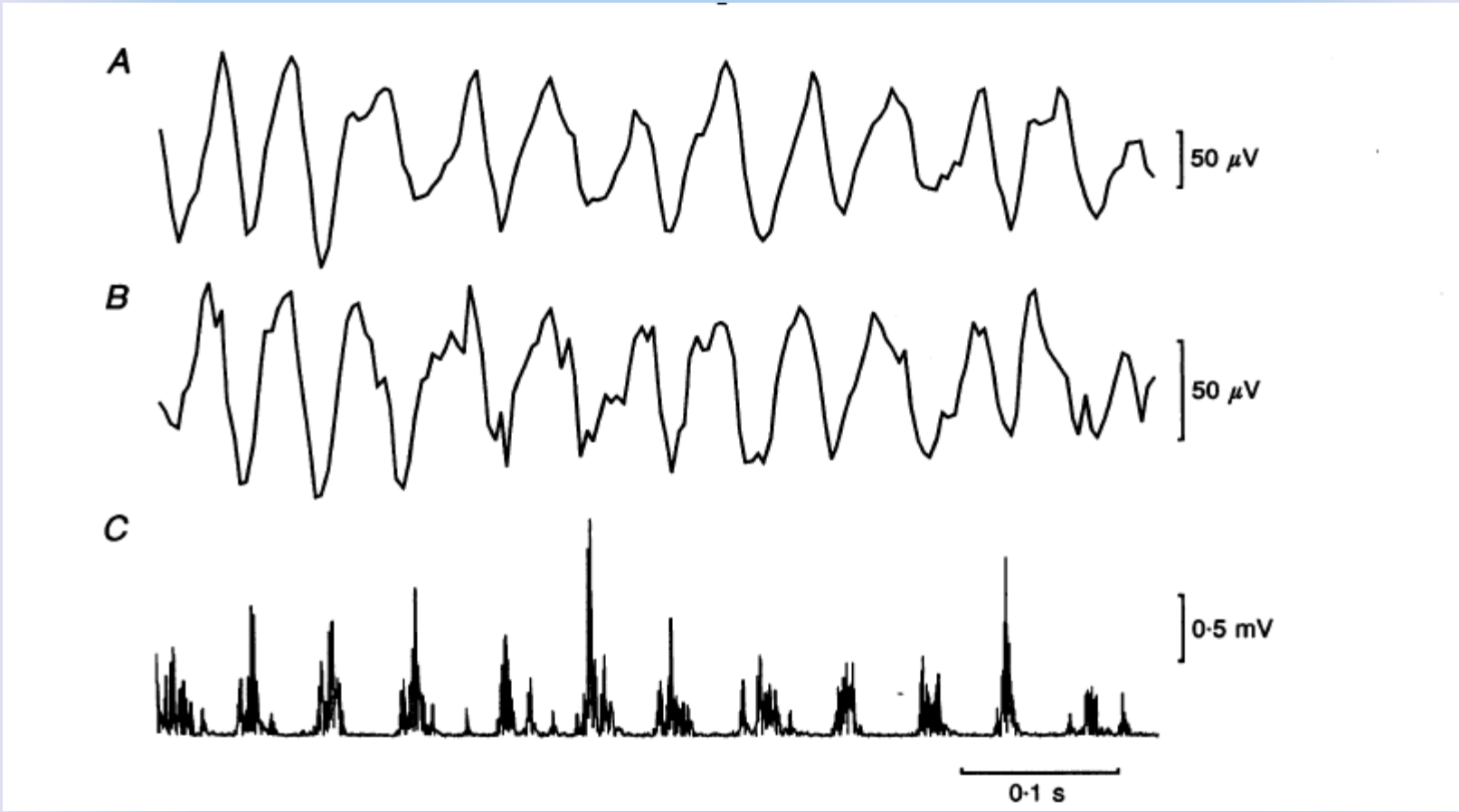
It is concluded that oscillations in the range 20–30 Hz are present in monkey motor cortex, are coherent between spatially separated cortical sites, and encompass the pyramidal tract output neurones. They are discernable in the EMG of active muscles, and show a consistent task-dependent modulation.

Cortical oscillations



Baker et al, 1997

Cortical oscillations



Baker et al, 1997

Cortical oscillations

Neural Discharge and Local Field Potential Oscillations in Primate Motor Cortex During Voluntary Movements

John P. Donoghue, Jerome N. Sanes, Nicholas G. Hatsopoulos and Gyöngyi Gaál

J Neurophysiol 79:159-173, 1998.

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.

Cortical oscillations

ELSEVIER

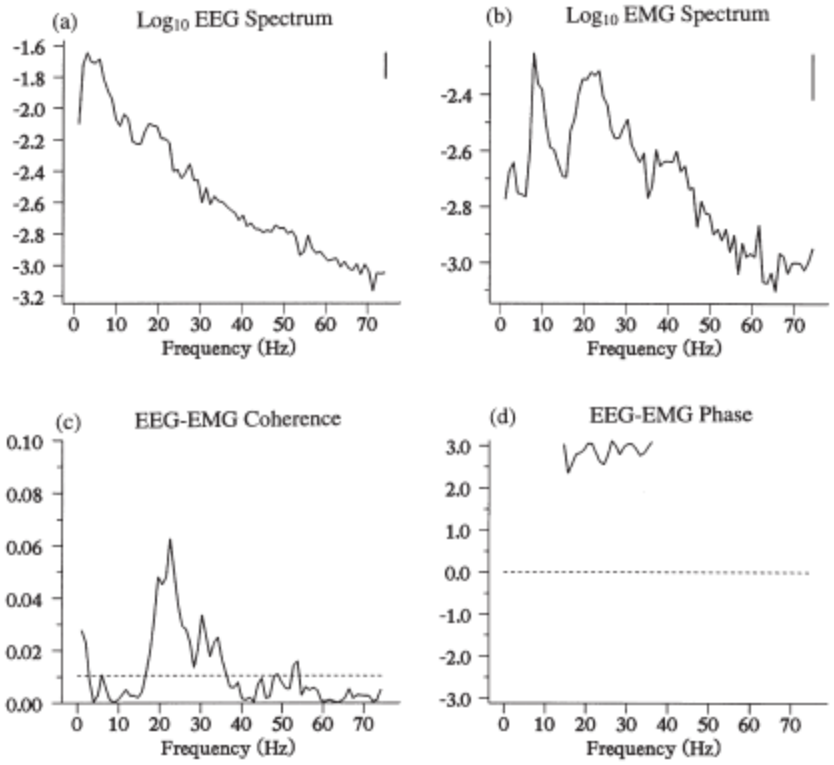
Neuroscience Letters 241 (1998) 5–8

Neuroscience Letters

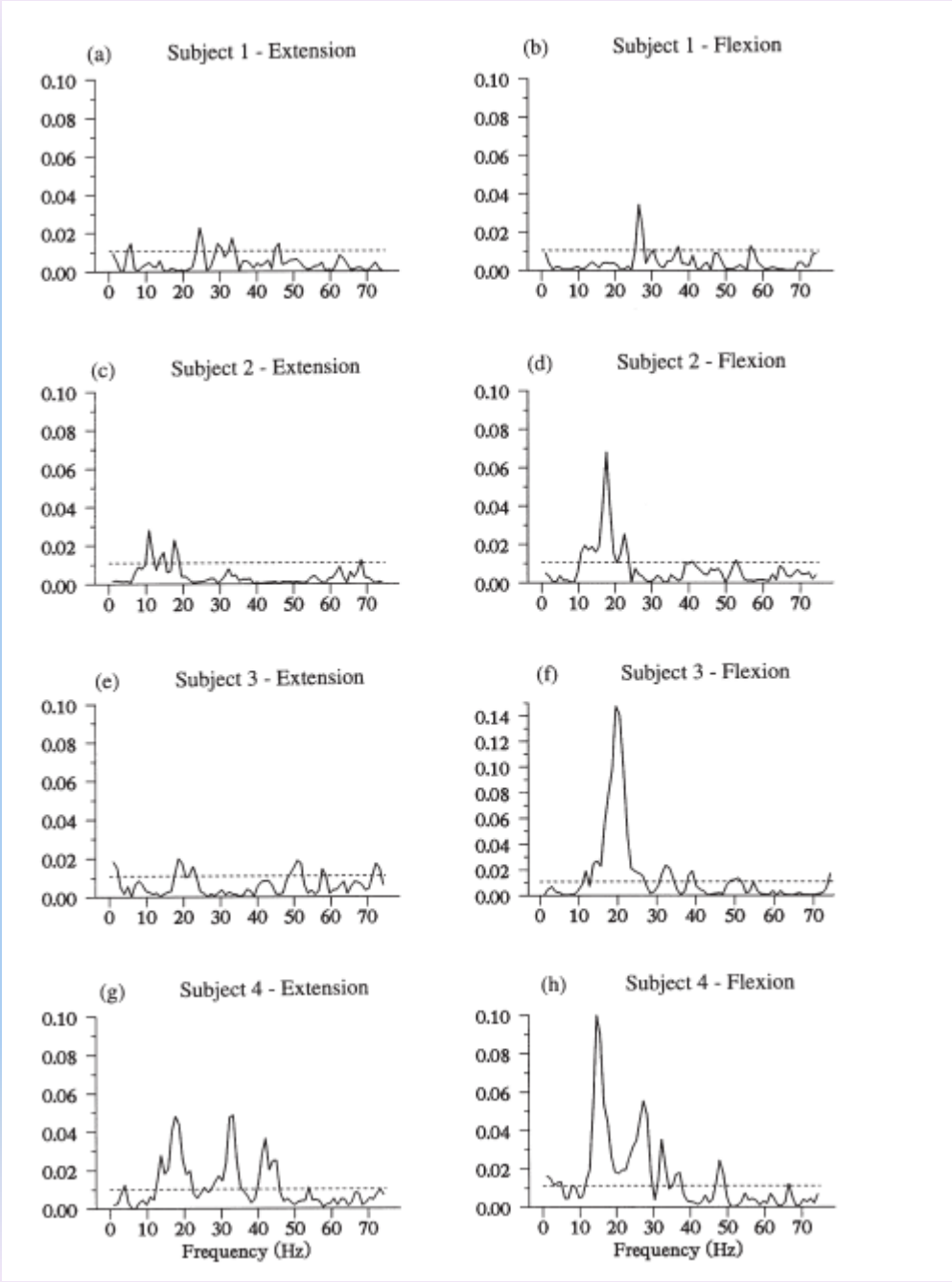
Using electroencephalography to study functional coupling between cortical activity and electromyograms during voluntary contractions in humans

David M. Halliday[a,*], Bernard A. Conway[b], Simon F. Farmer[c], Jay R. Rosenberg[a]

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

Cortical oscillations

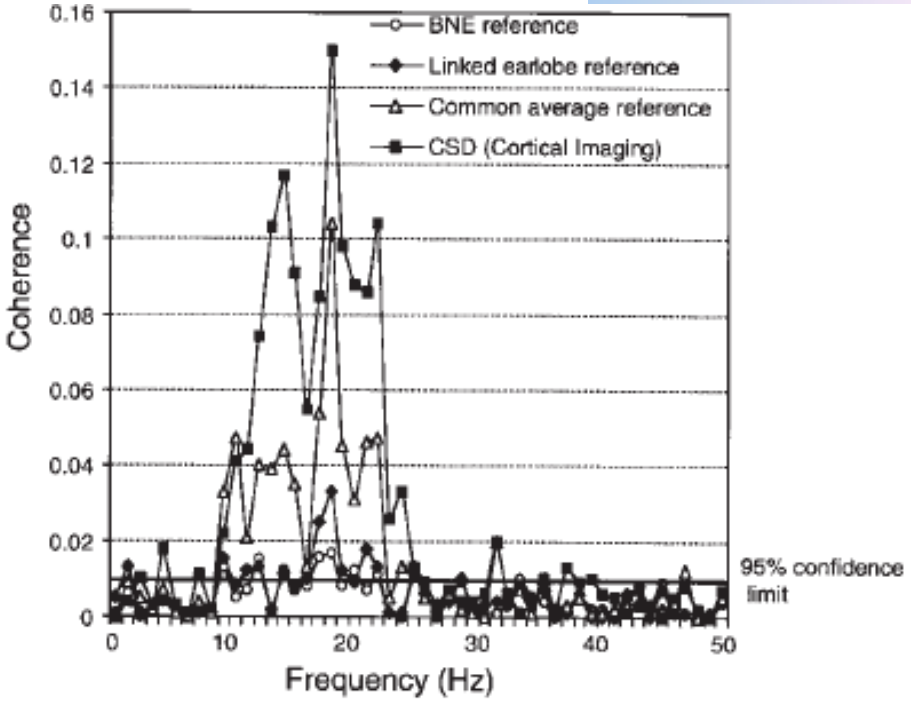
ELSEVIER

Clinical Neurophysiology 110 (1999) 1892–1899

www.elsevier.com/locate/clinph

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

Tatsuya Mima, Mark Hallett*

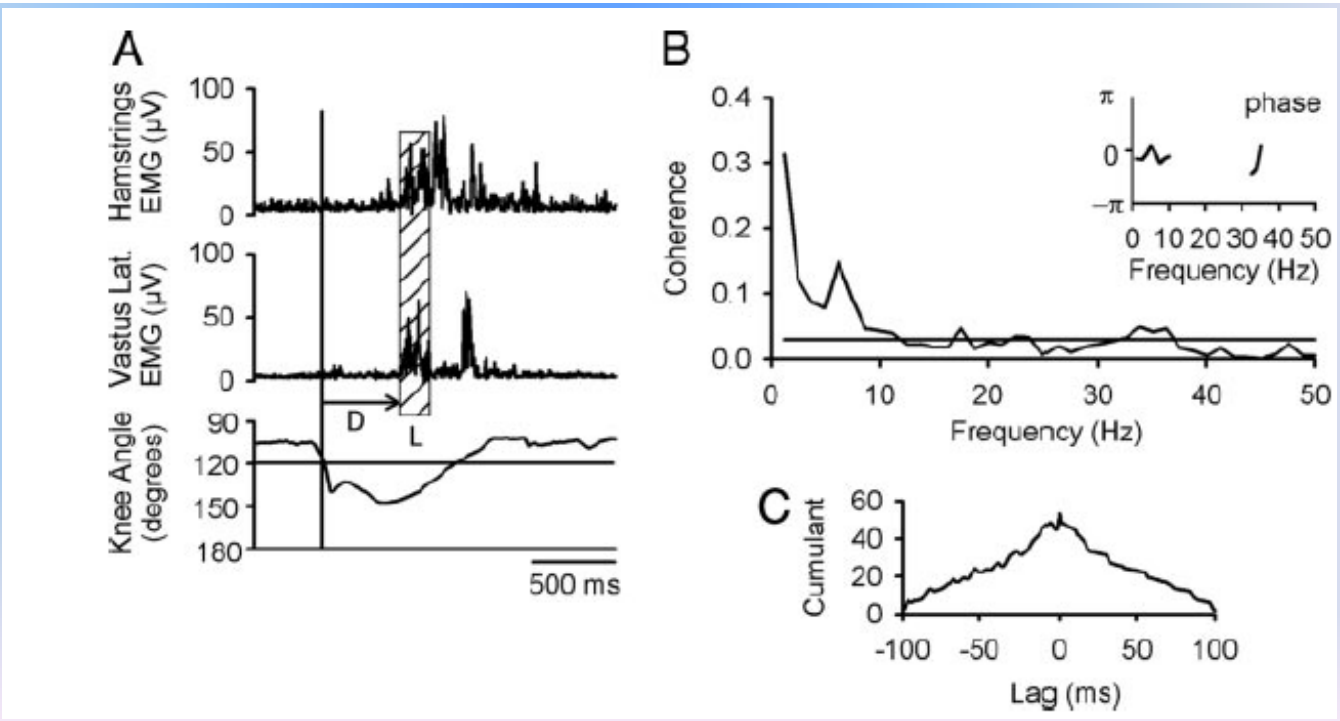


Cortical oscillations

J Neurophysiol 95: 2580–2589, 2006.
First published January 11, 2006; doi:10.1152/jn.01289.2005.

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?

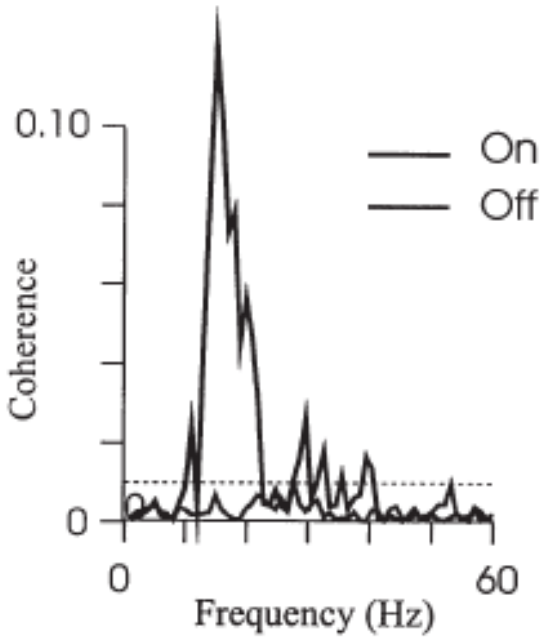


Fig. 4. Coherence spectra between EMG of forearm extensors and MEG over the contralateral Rolandic area for a patient with Parkinson's disease after withdrawal and reinstitution of levodopa treatment. Note that MEG–EMG coherence in the beta and gamma bands is restored by levodopa. The thin horizontal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

Grosse et al, 2002

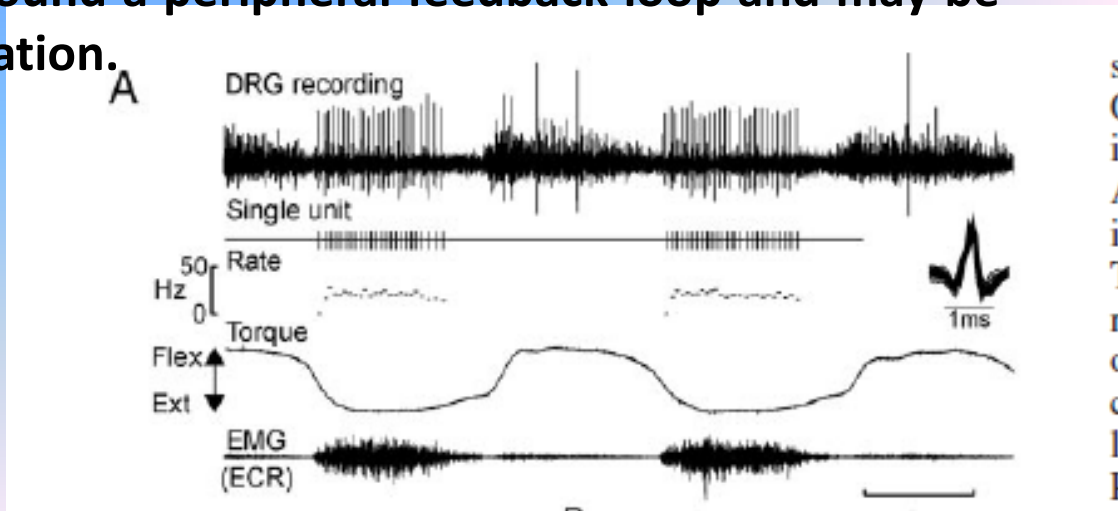
Cortical oscillations- only cortex?

Afferent Encoding of Central Oscillations in the Monkey Arm

Stuart N. Baker, Matthew Chiu and Eberhard E. Fetz

J Neurophysiol 95:3904-3910, 2006. doi:10.1152/jn.01106.2005

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.

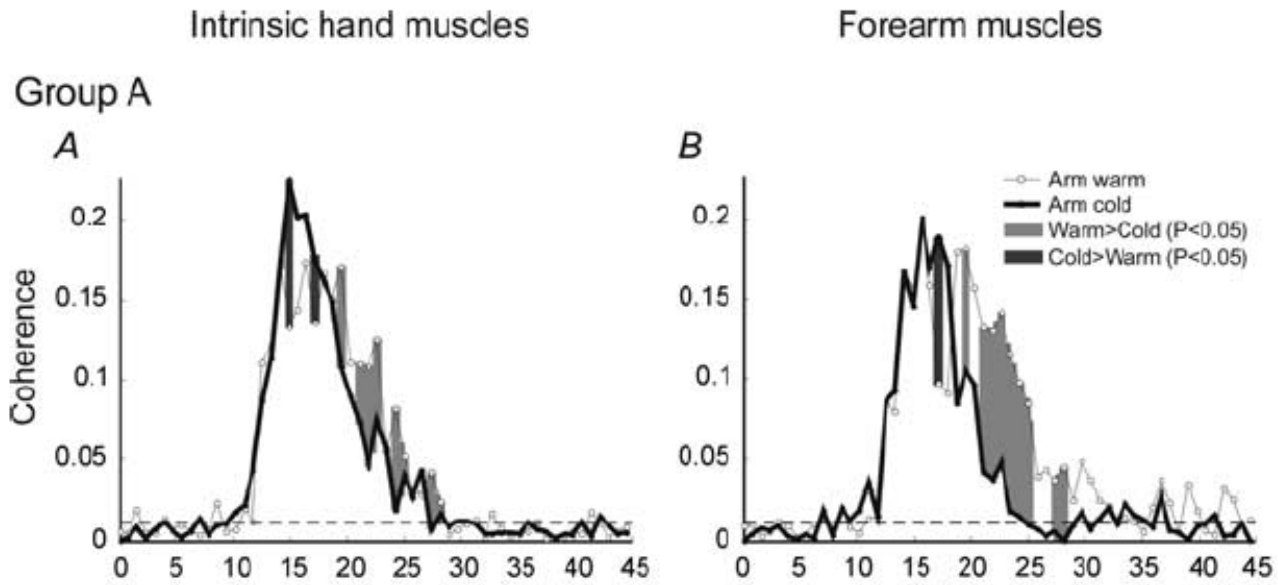


Cortical oscillations- only cortex?

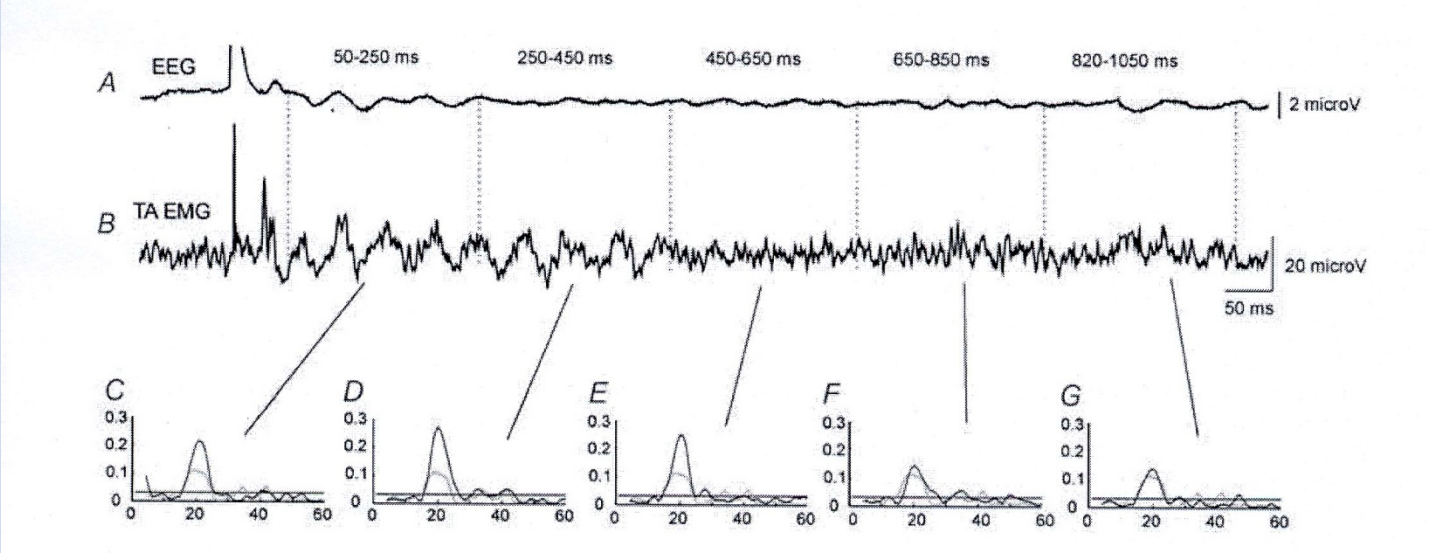
J Physiol 566.2 (2005) pp 625–639

Manipulation of peripheral neural feedback loops alters human corticomuscular coherence

C. Nicholas Riddle[1] and Stuart N. Baker[2]

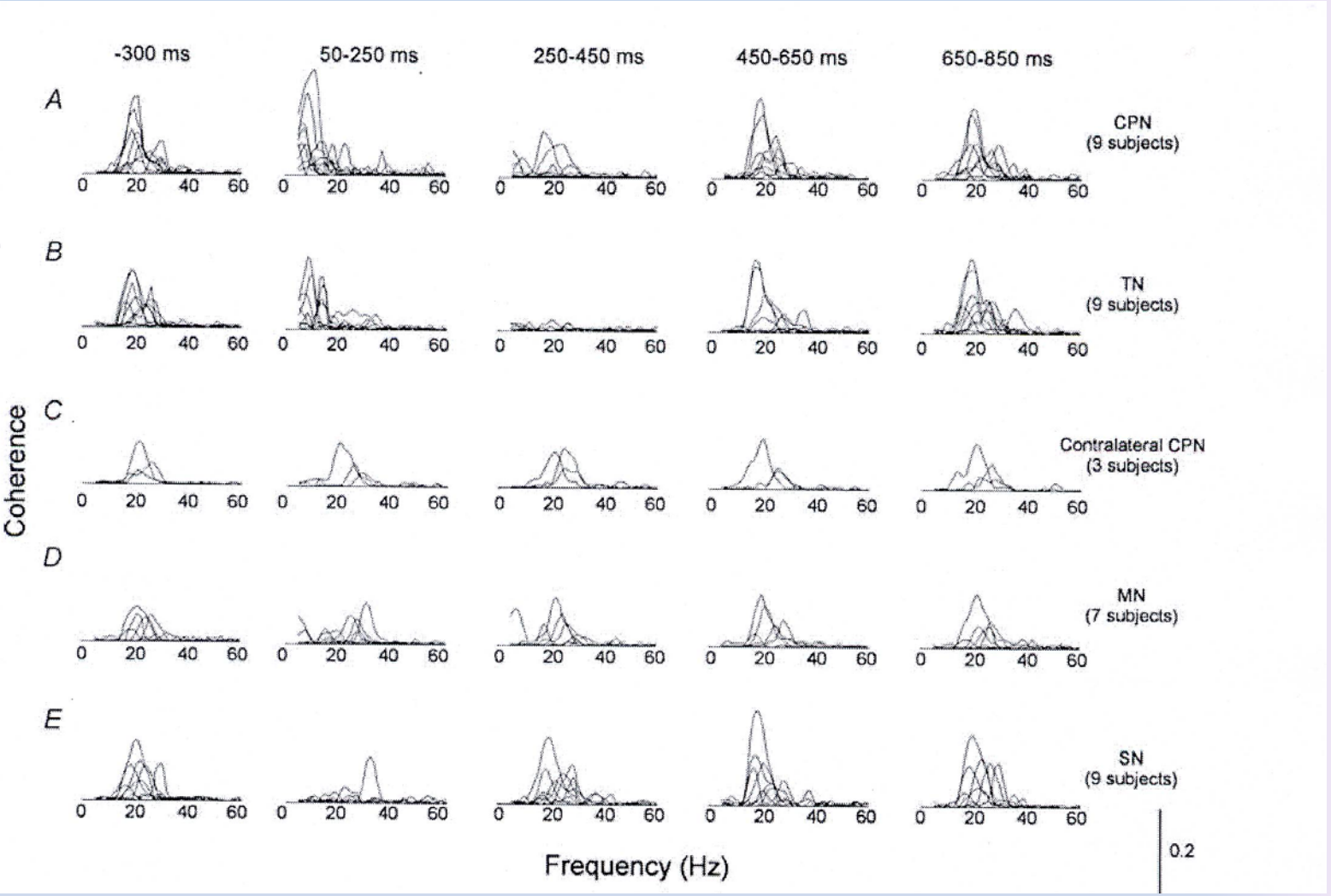


Cortical oscillations- only cortex?



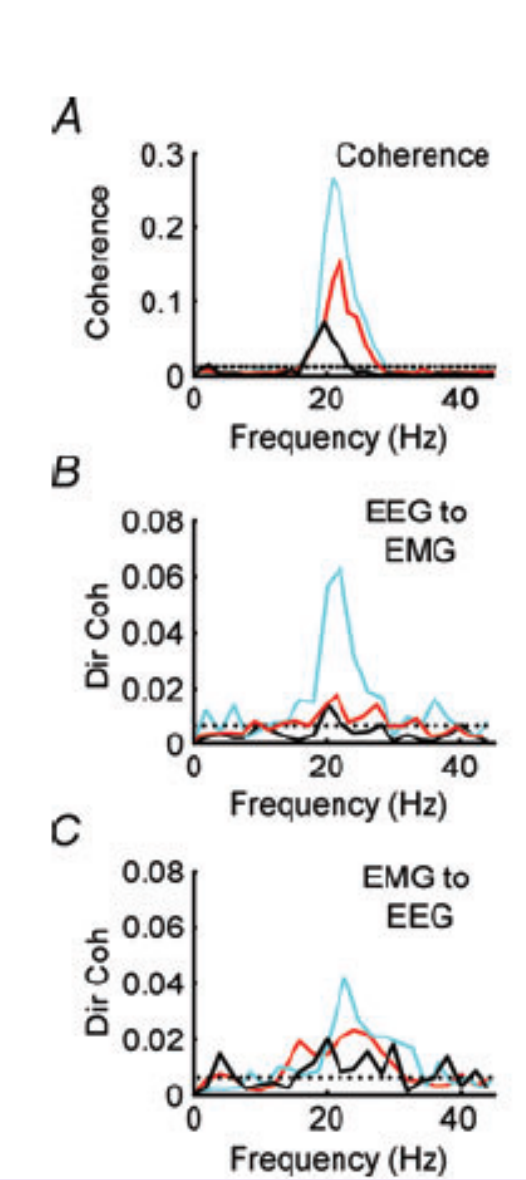
Hansen&Nielsen, 2004

Cortical oscillations- only cortex?



Hansen&Nielsen, 2004

Cortical oscillations- only cortex?

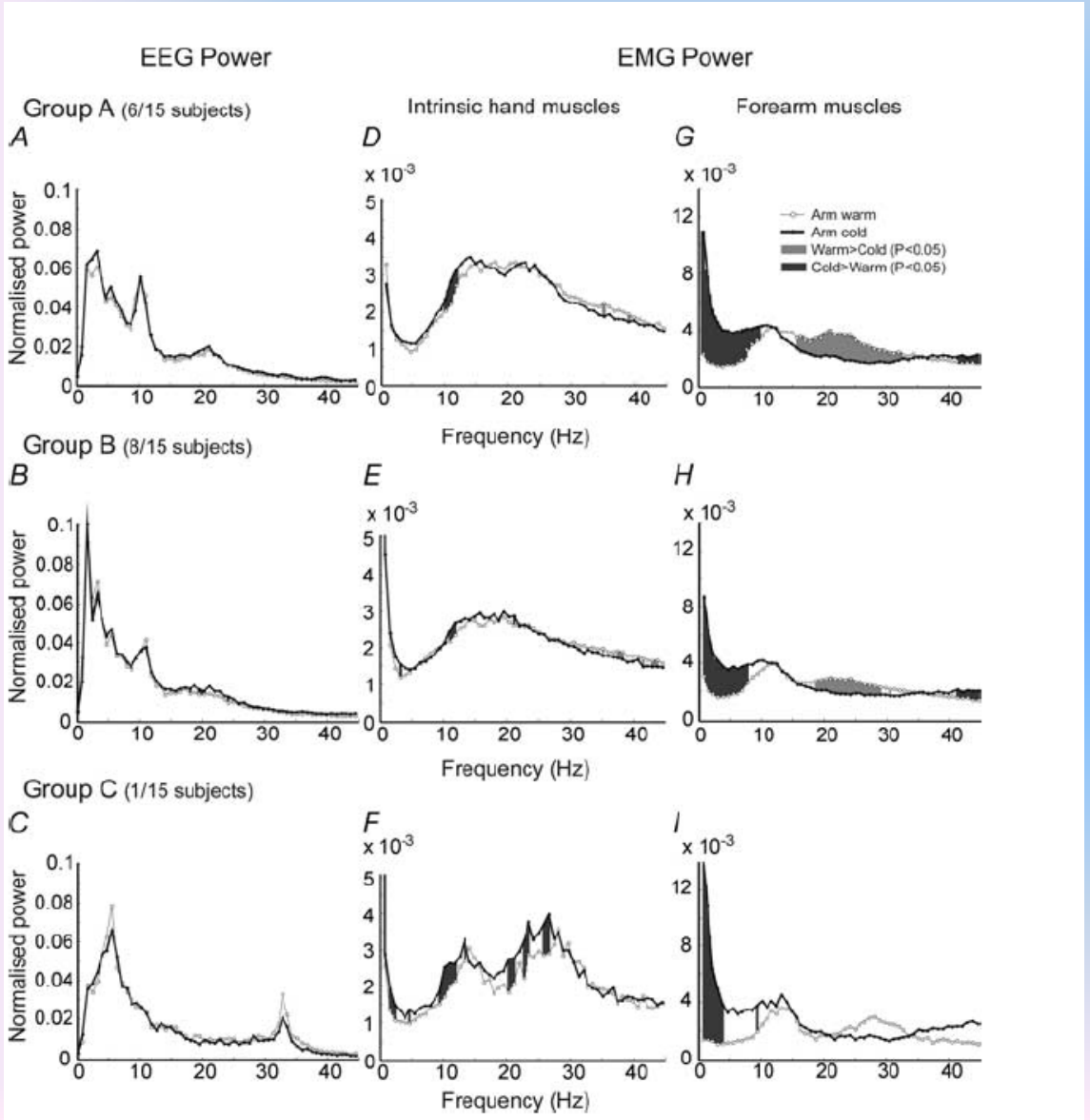


J Physiol 589.15 (2011) pp 3789–3800

Contributions of descending and ascending pathways to corticomuscular coherence in humans

Claire L. Witham[1], C. Nicholas Riddle[2], Mark R. Baker[1] and Stuart N. Baker[1]

Cortical oscillations-
marked inter-individual variability



Riddle&Baker, 2005

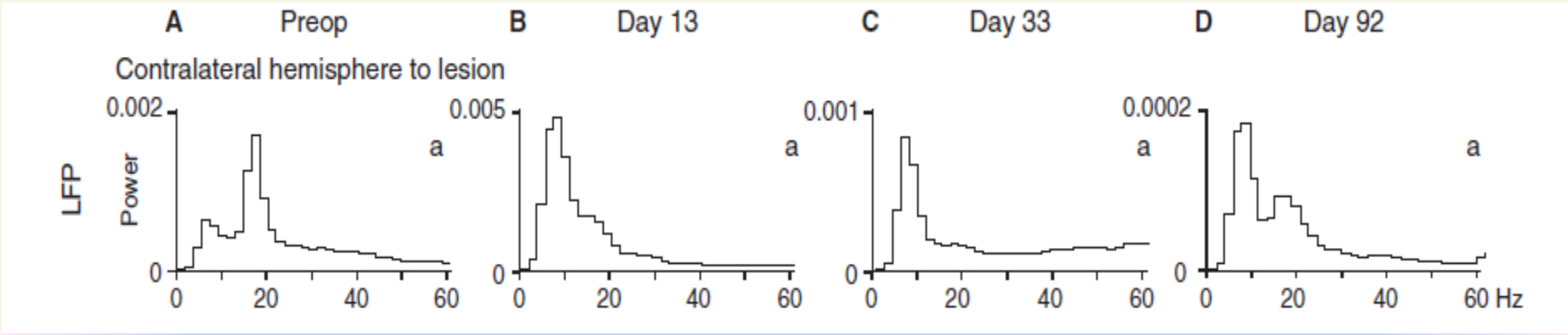
Cortical oscillations-
pyramidal tract lesion

doi:10.1093/brain/awn338 Brain 2009: 132; 709–721 | 709

BRAIN
A JOURNAL OF NEUROLOGY

A subcortical oscillatory network contributes to recovery of hand dexterity after spinal cord injury

Yukio Nishimura,[1,2,*] Yosuke Morichika[1] and Tadashi Isa[1,2,3]

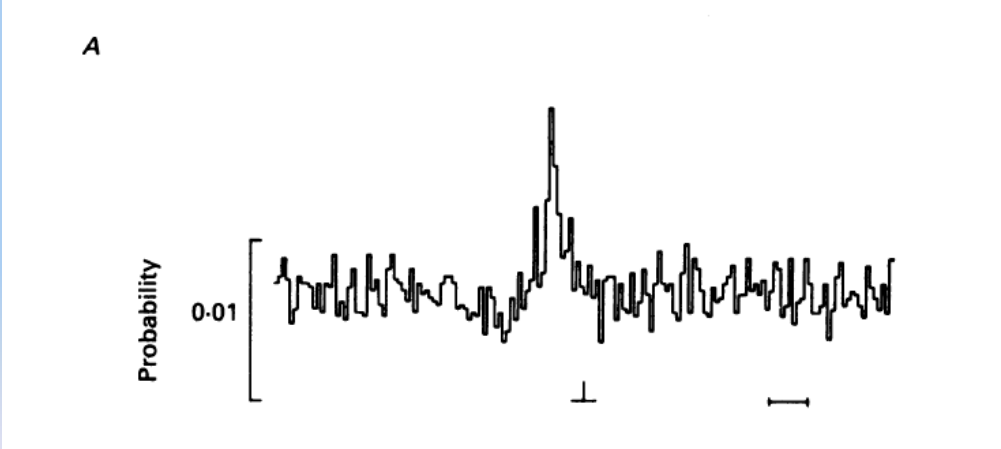


MOTOR UNITS coherence

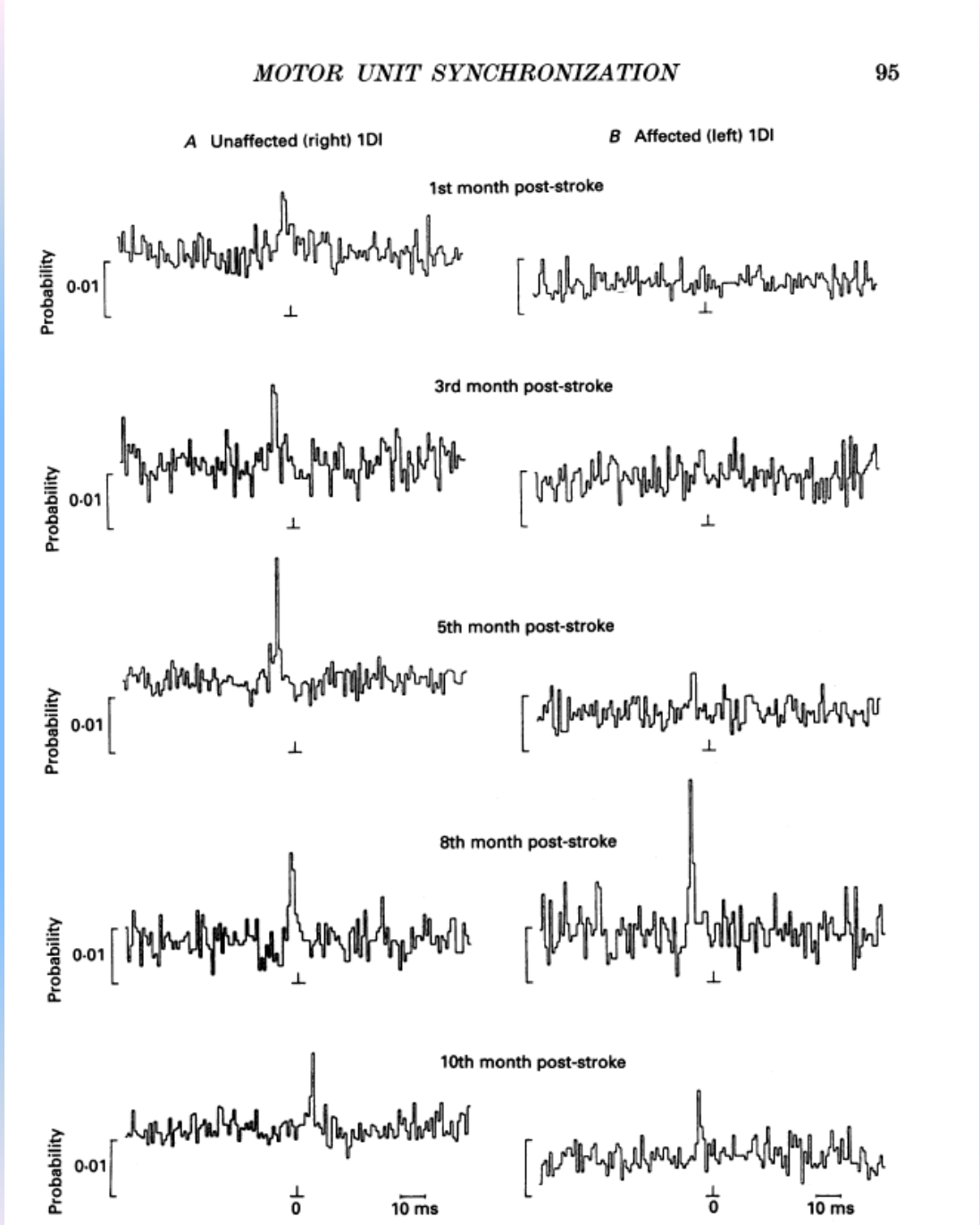
Journal of Physiology (1993), **463**, *pp.* 83–105
With 9 figures
Printed in Great Britain

CHANGES IN MOTOR UNIT SYNCHRONIZATION FOLLOWING CENTRAL NERVOUS LESIONS IN MAN

By S. F. FARMER, M. SWASH*, D. A. INGRAM† and J. A. STEPHENS



MOTOR UNITS coherence

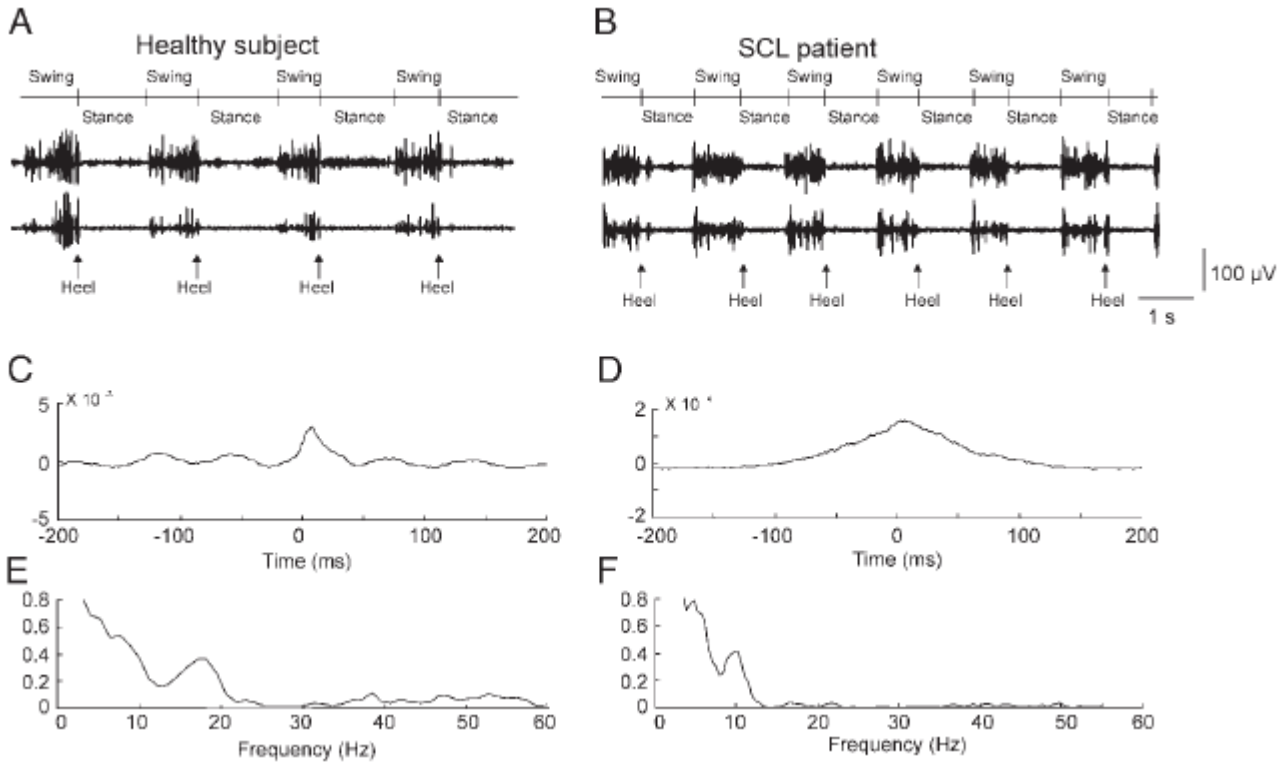


MOTOR UNITS coherence

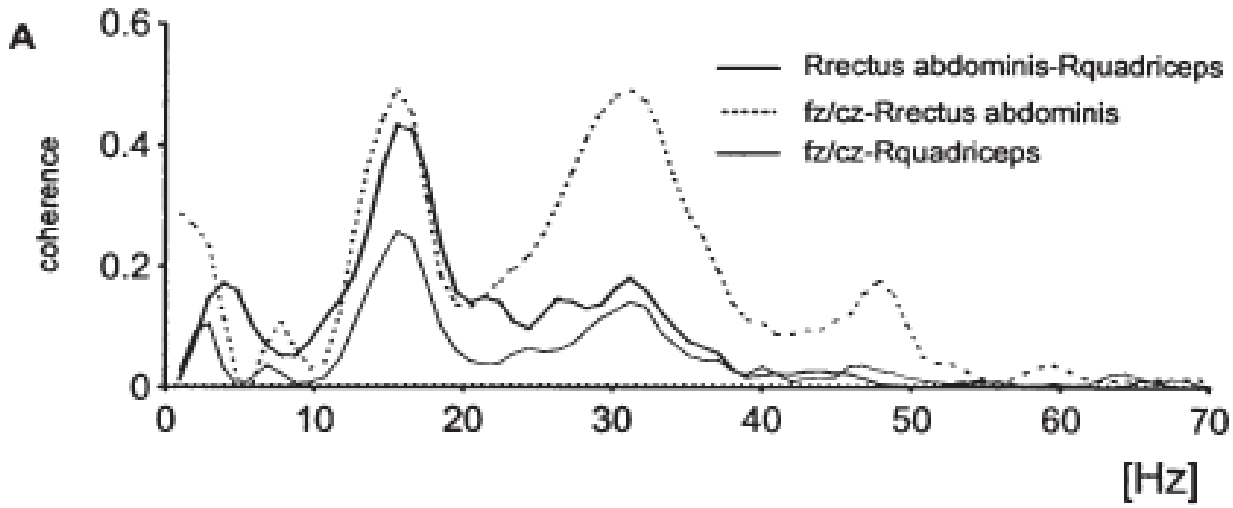
Reduction of Common Synaptic Drive to Ankle Dorsiflexor Motoneurons During Walking in Patients With Spinal Cord Lesion

N. L. Hansen, B. A. Conway, D. M. Halliday, S. Hansen, H. S. Pyndt, F. Biering-Sørensen and J. B. Nielsen

J Neurophysiol 94:934-942, 2005. First published 30 March 2005; doi:10.1152/jn.00082.2005



MUSCLE-MUSCLE coherence



Grosse et al, 2002

MUSCLE-MUSCLE coherence pyramidal tract lesion