

Approcci multi-scala alla registrazione e
stimolazione dell'attività nervosa:
esperienze recenti e prospettive

paolo del giudice

Istituto Superiore di Sanità

<http://neural.iss.infn.it/papers.htm>

Approcci multi-scala alla registrazione e stimolazione dell'attività nervosa: esperienze recenti e prospettive

- Teoria (non oggi)



in parte: RM61 Gr4

- Chip neuromorfi

- Registrazione su larga scala del segnale nervoso

- Stimolazione del tessuto nervoso

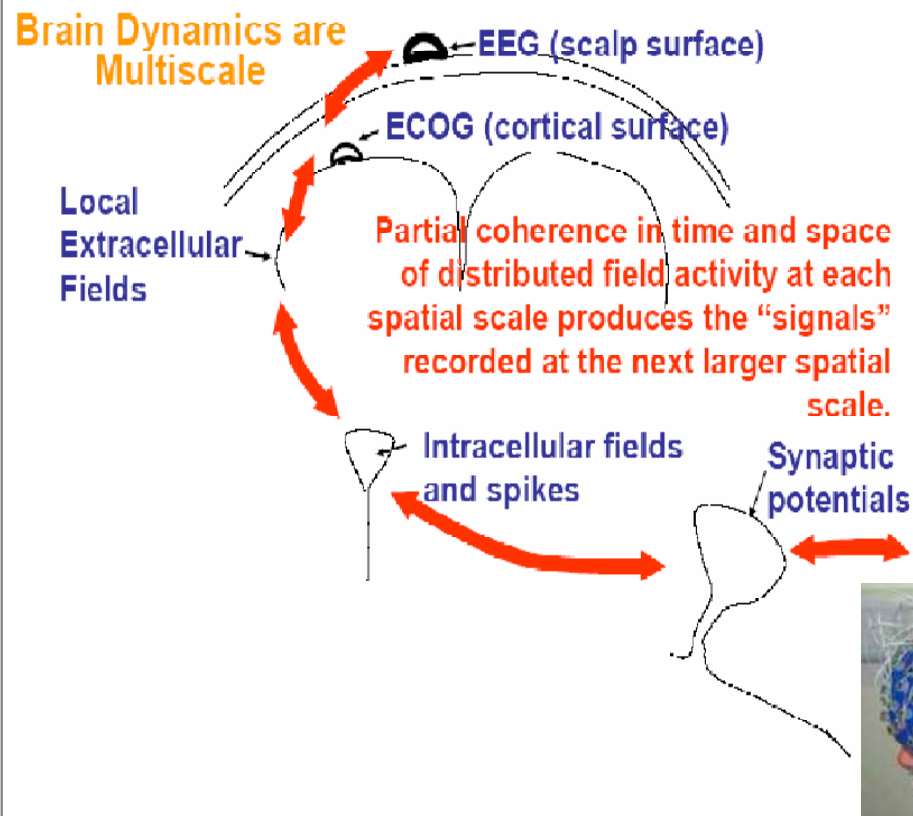


in parte: GRECO Gr5



(neuro-riabilitazione)

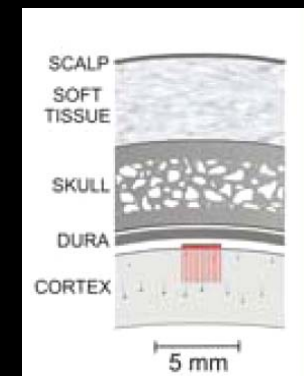
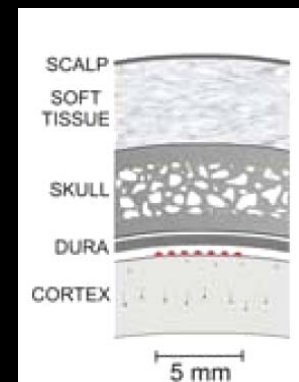
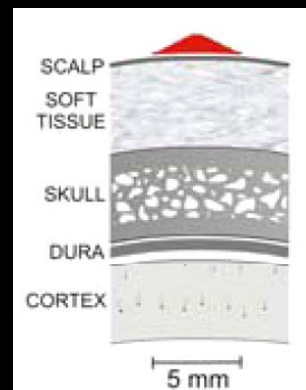
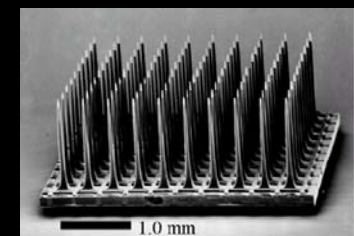
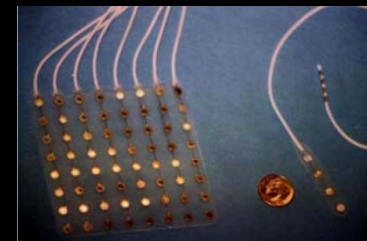
Segnali dal cervello: gerarchia di scale (spaziali e temporali)



EEG

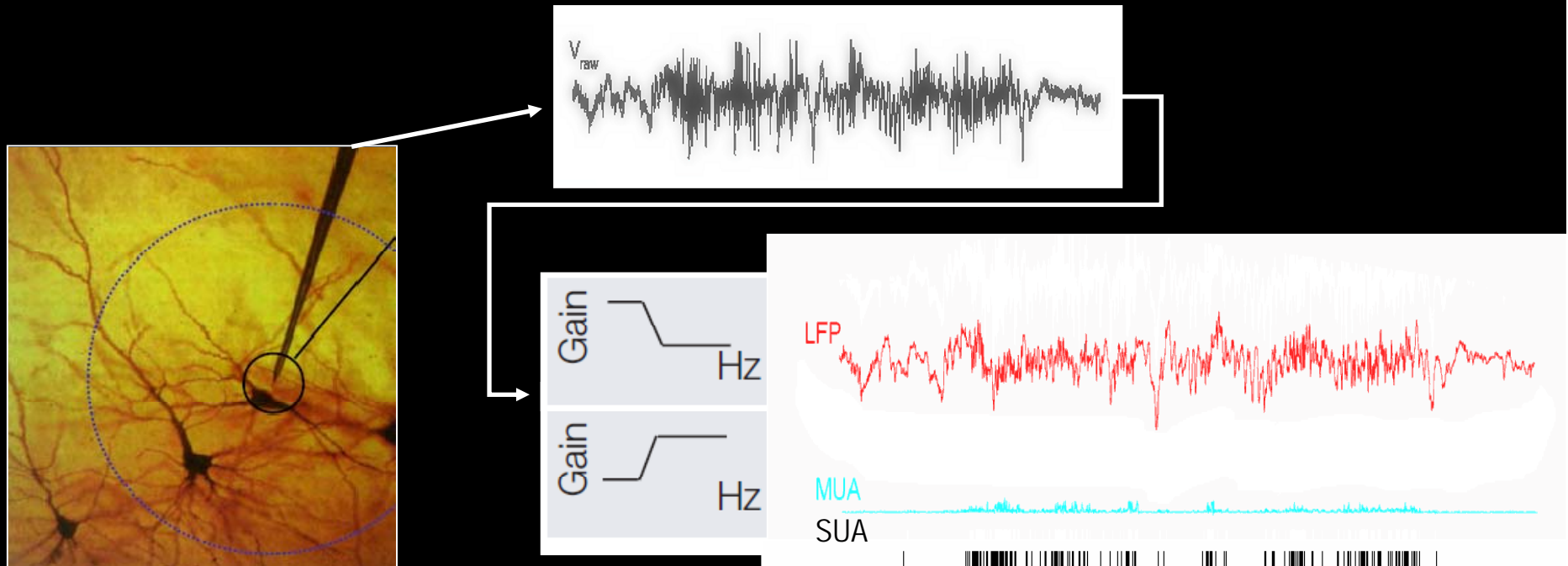
griglie epicorticali

Matrici di elettrodi per impianti cronici



Segnali di popolazione

Segnali di popolazione: LFP & MUA



MUA:

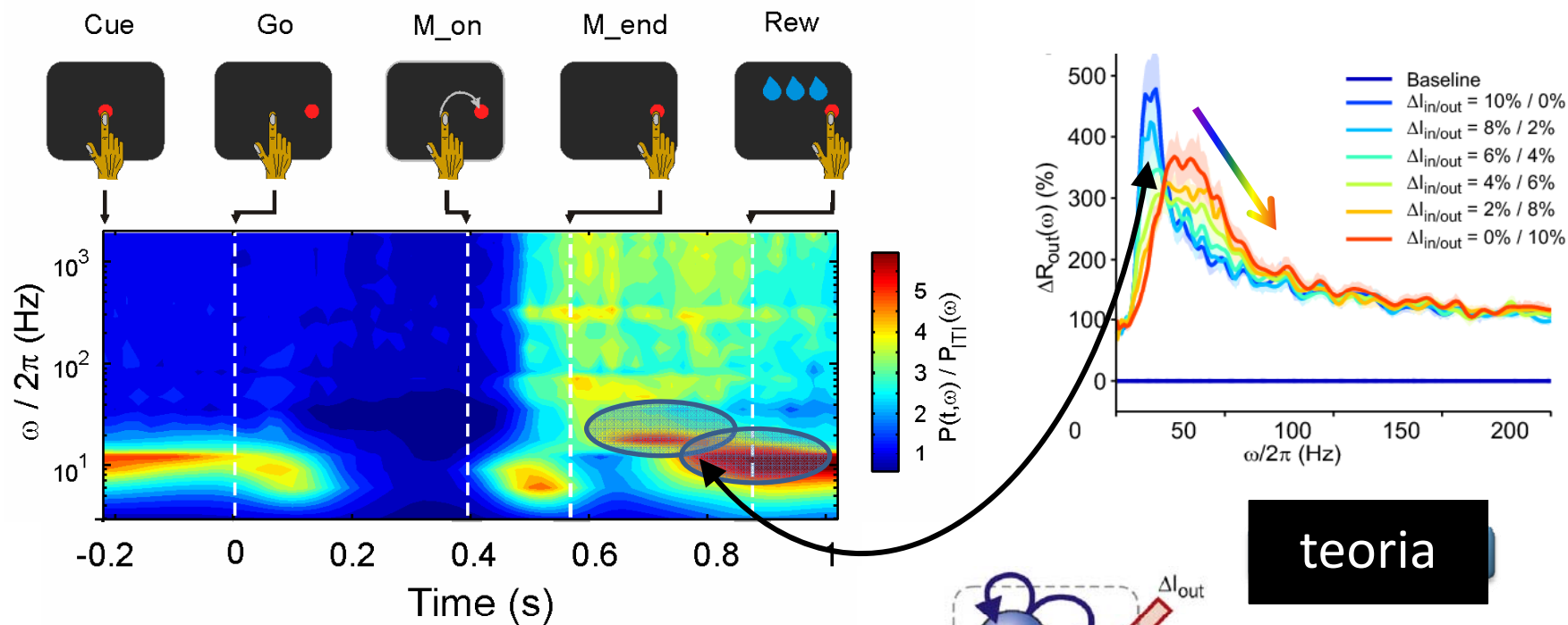
- Misura aggregata di attività spiking all'interno di una regione $\sim 200 \mu\text{m}$ intorno alla punta dell'elettrodo

LFP: *origine e interpretazione ancora controversa*

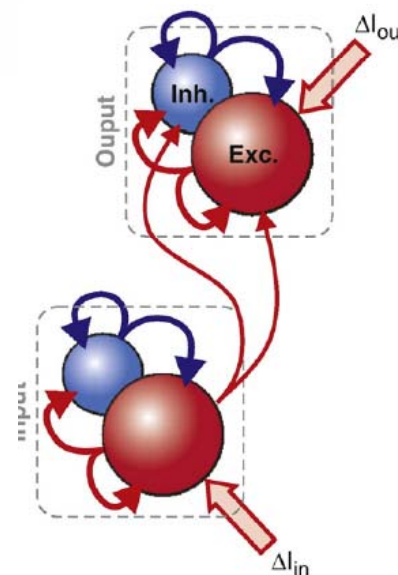
- Riflette l'input sinaptico medio all'interno di una regione $\sim 500- 1000 \mu\text{m}$ intorno alla punta dell'elettrodo? (ipotesi prevalente)
- Riflette modulazioni lente dell'attività spiking?

Modulazioni spettrali di LFP and MUA in-vivo

Registrazioni in-vivo in compiti di reaching (S. Ferraina, Sapienza)



teoria



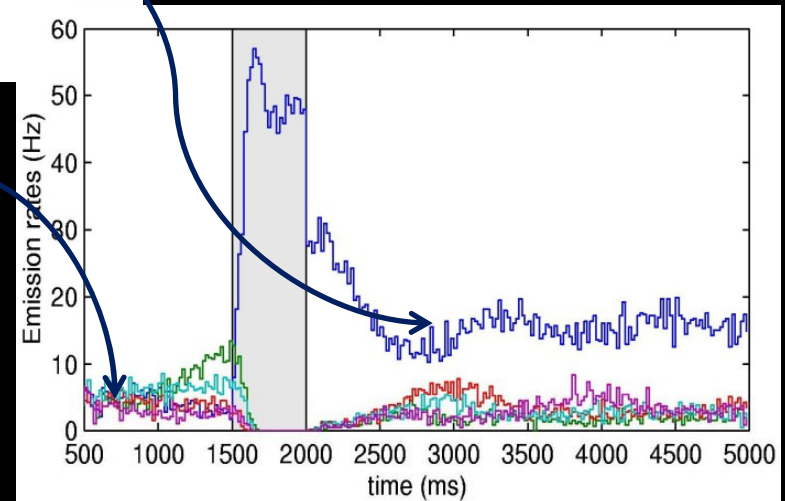
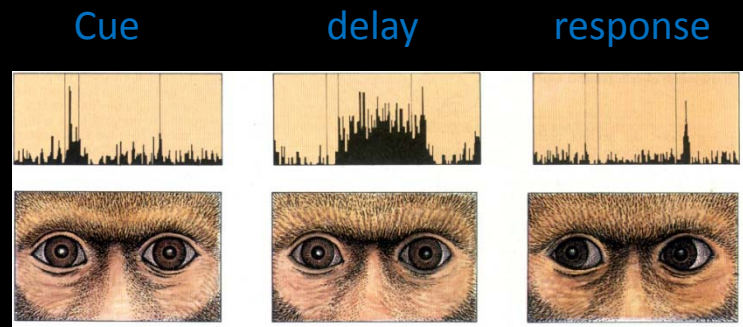
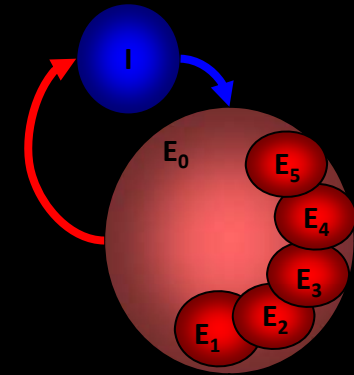
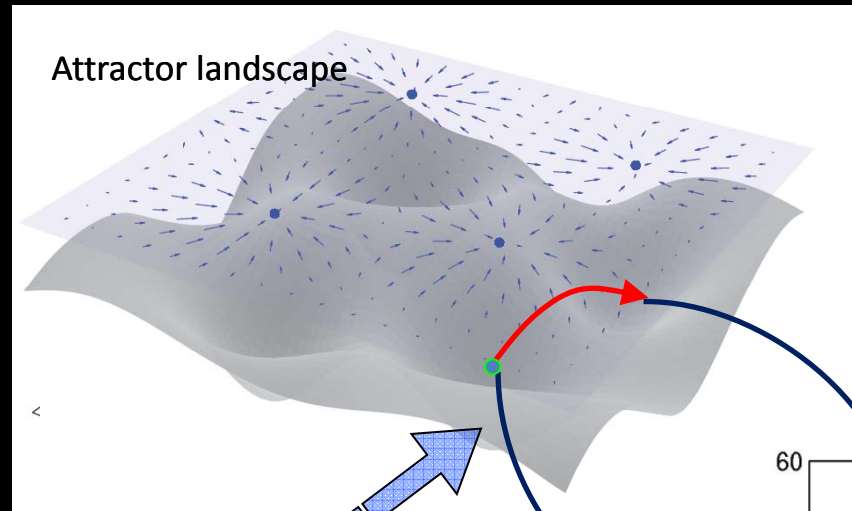
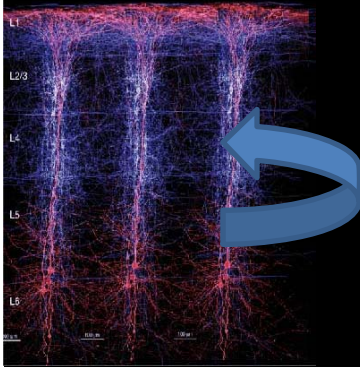
M.Mattia, S. Ferraina. P. Del Giudice,
NeuroImage 2010

V. D'Andrea et. al., in preparazione

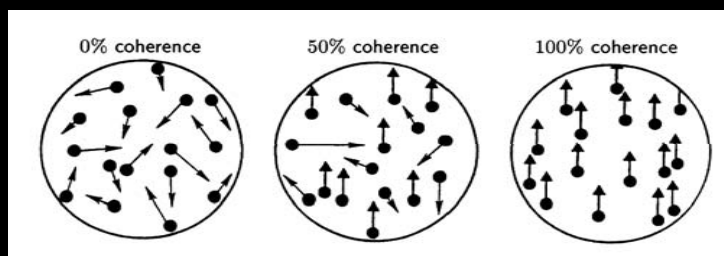
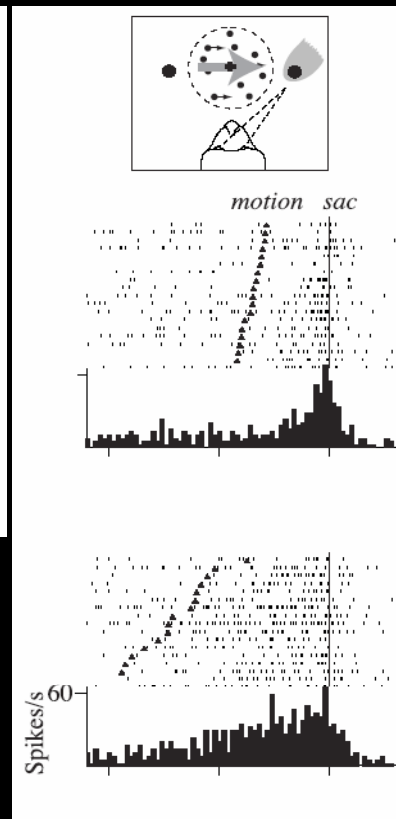
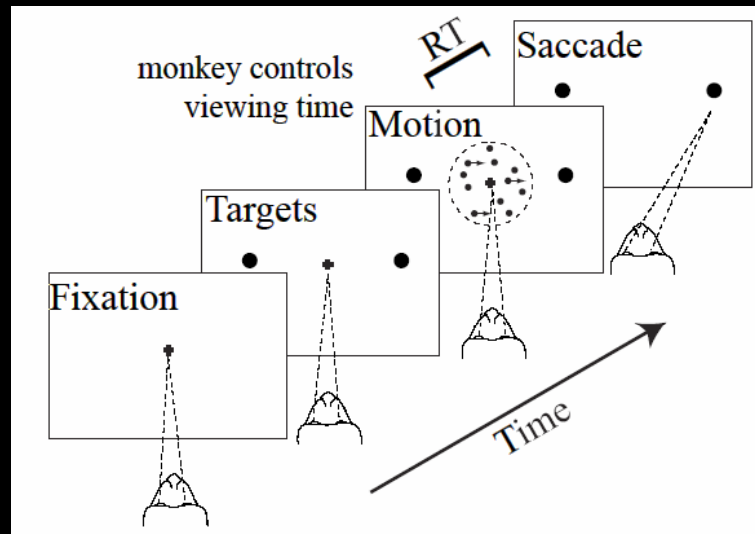
dinamica ad attrattori

un elemento computazionale versatile

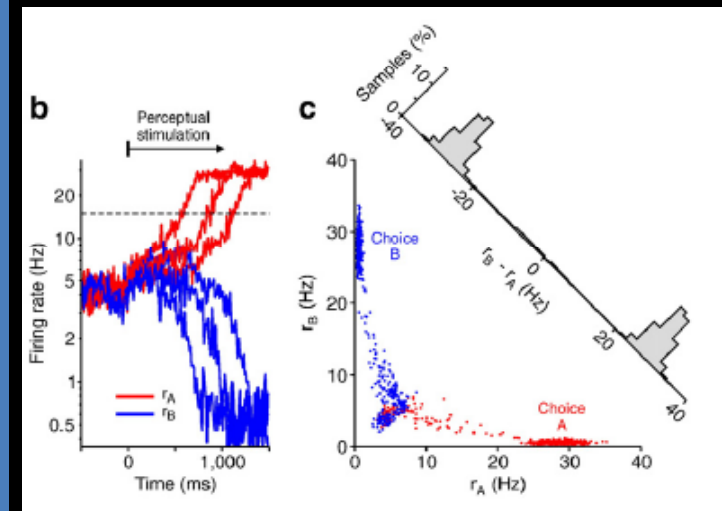
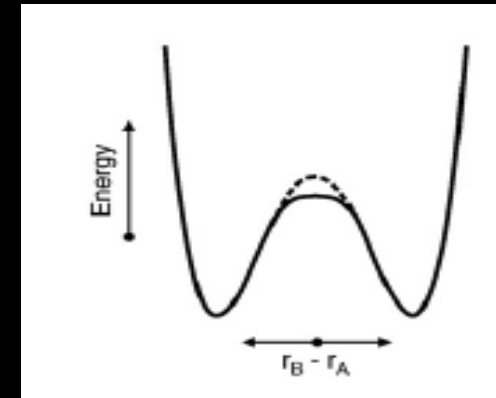
Attrattori: possibile substrato dell'attività auto-sostenuta Working memory e oltre



Oltre la working memory: dinamica ad attrattori per la decisione percettiva



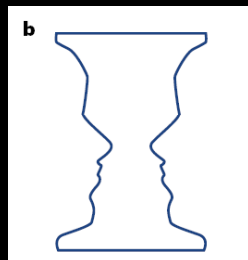
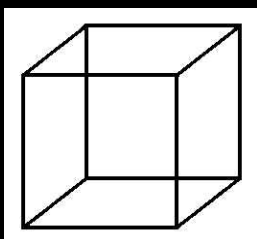
Roitman and Shadlen, J. Neurosci., 2002.



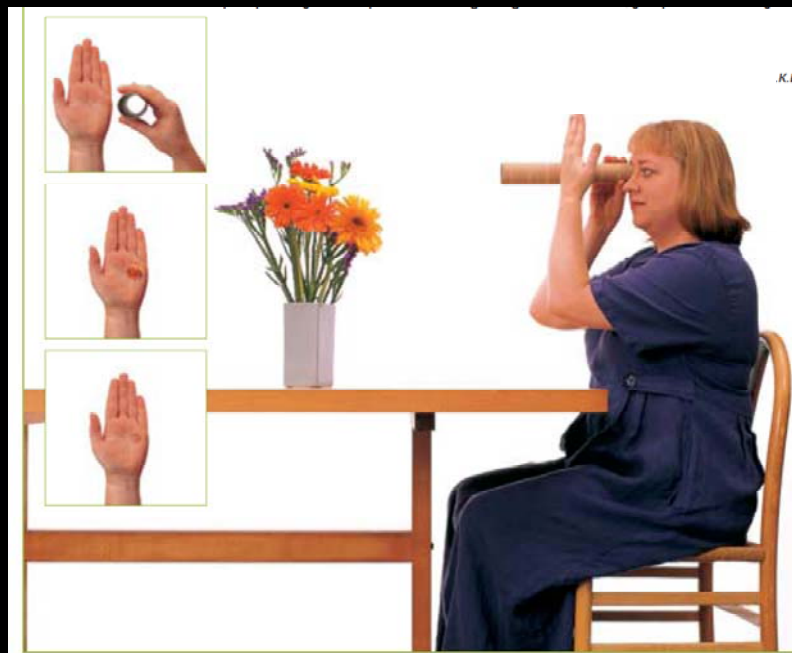
XJ Wang, Neuron 2002, 2008

D Martì, G. Deco, M. Mattia, G. Gigante, P. Del Giudice, PLoS Oe 2008

Attrattori in paesaggi più complicati: percezione multistabile

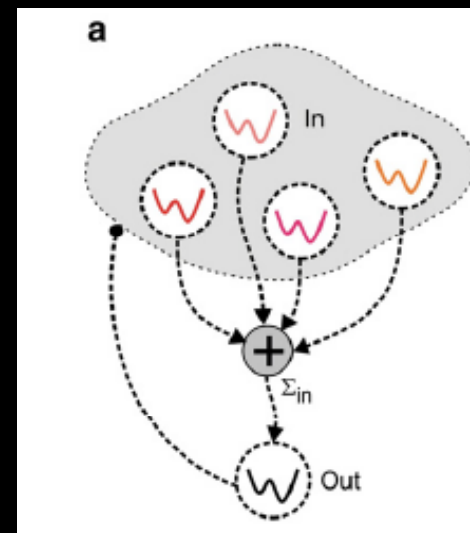


ambiguous figures



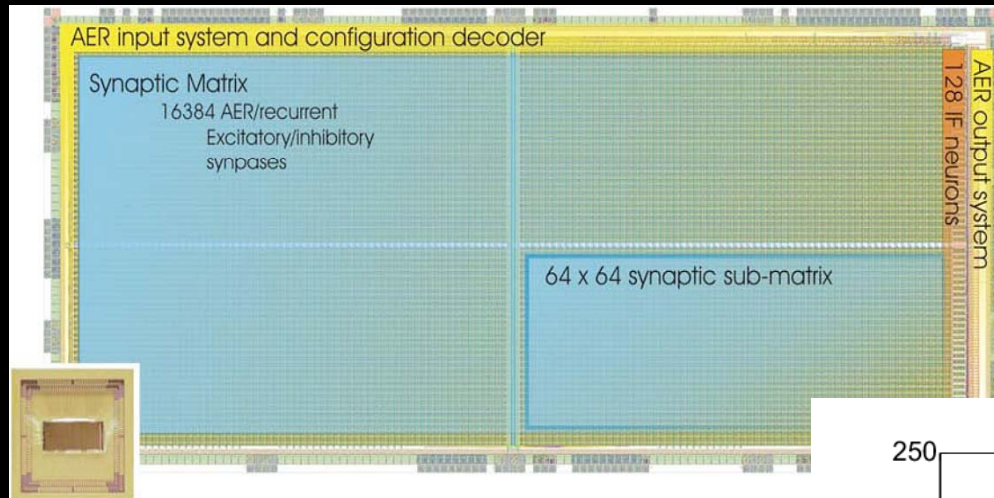
binocular rivalry

G. Gigante, M. Mattia, P. Del Giudice, PRL 2007
J. Braun, M. Mattia, NeuroImage 2010

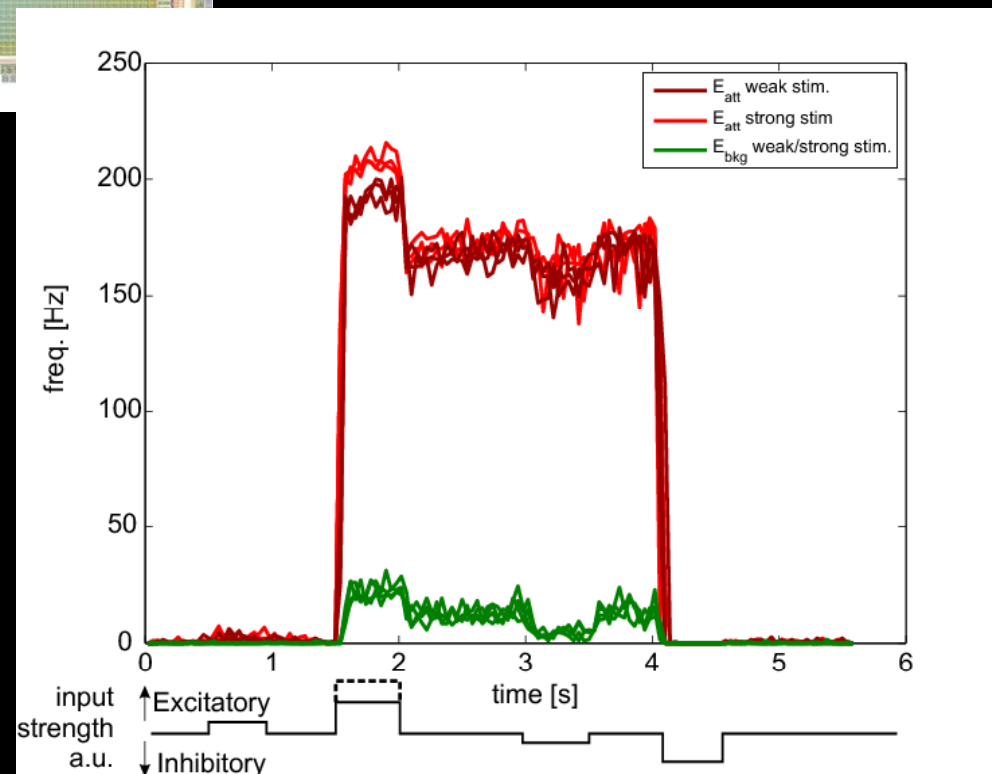


**Emulare l'attività nervosa
Chip 'neuromorfi'**

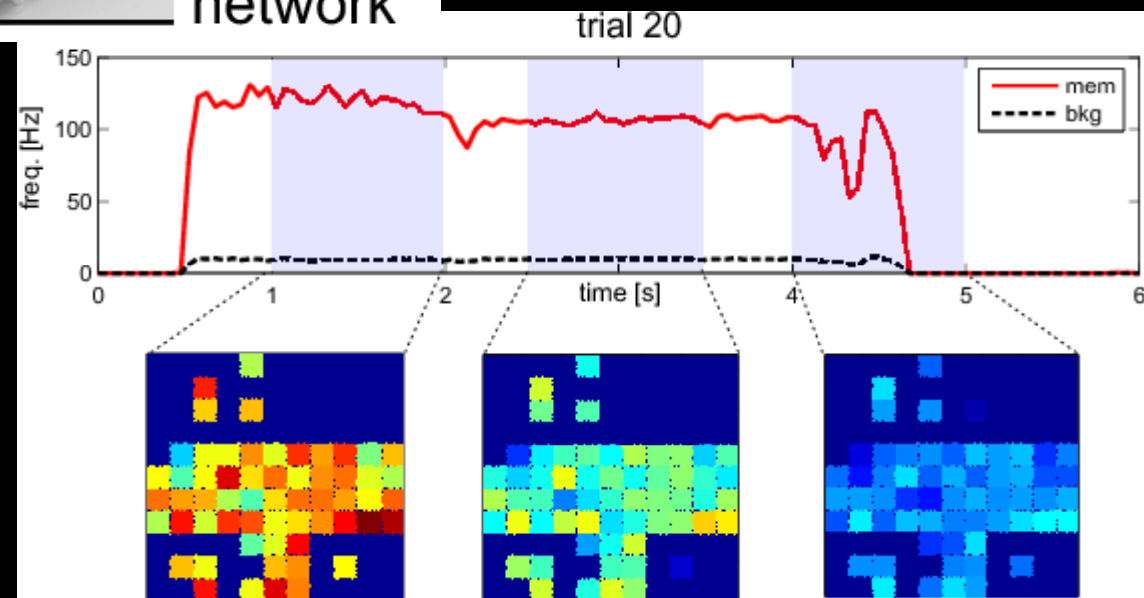
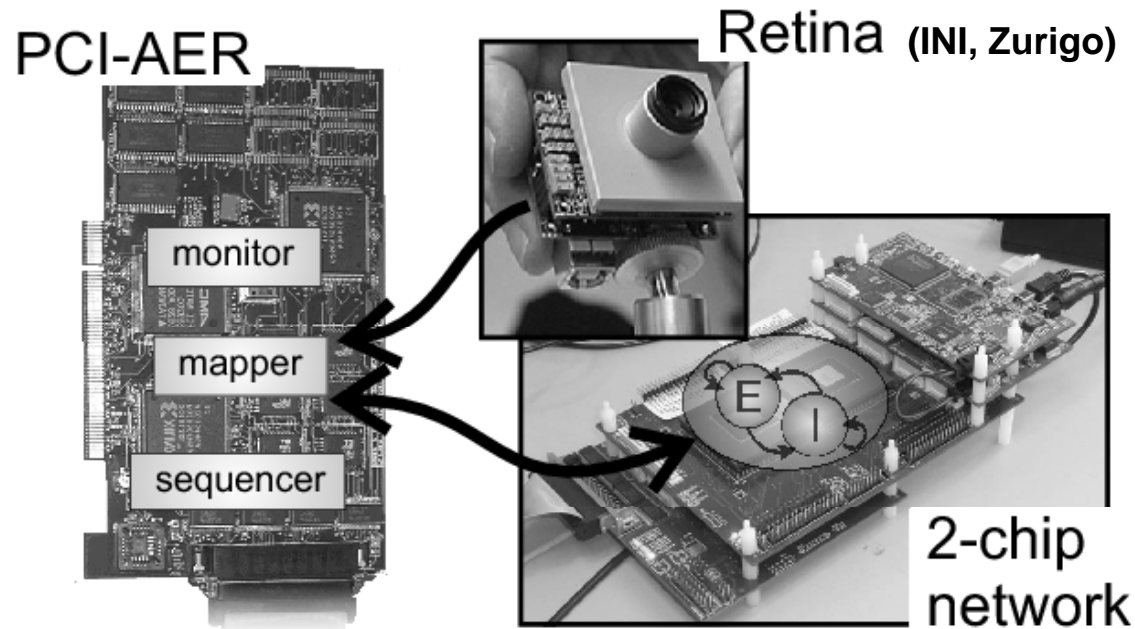
Dinamica ad attrattori in chip neuromorfi



P. Camillieri, M. Giulioni, M. Mattia,
J. Braun, P. Del Giudice,
IJCNN2010

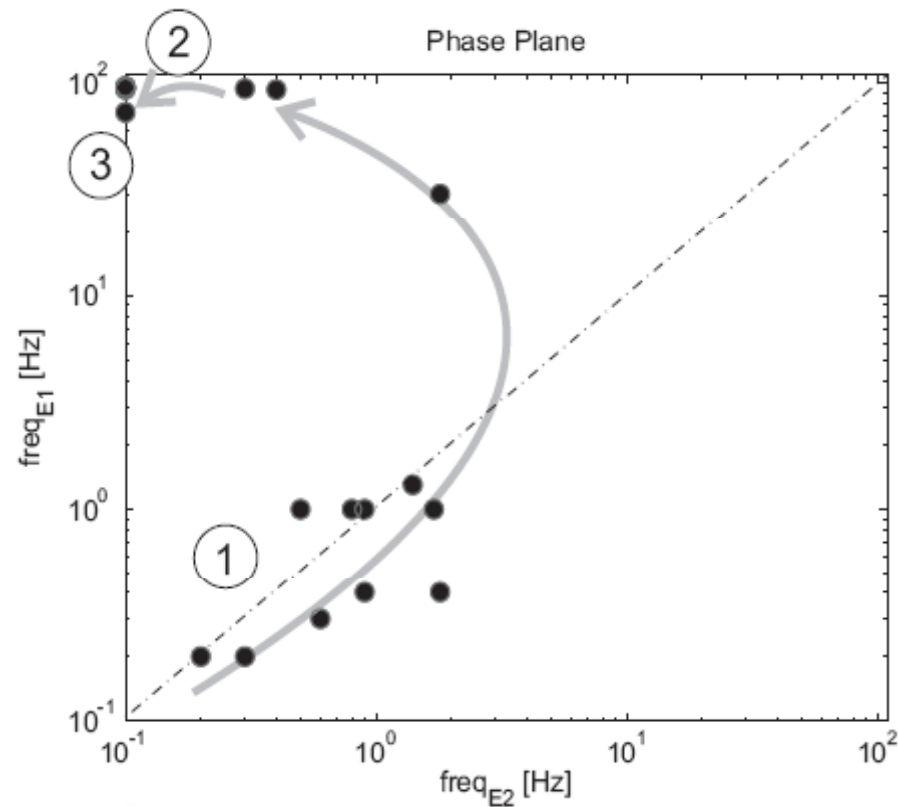
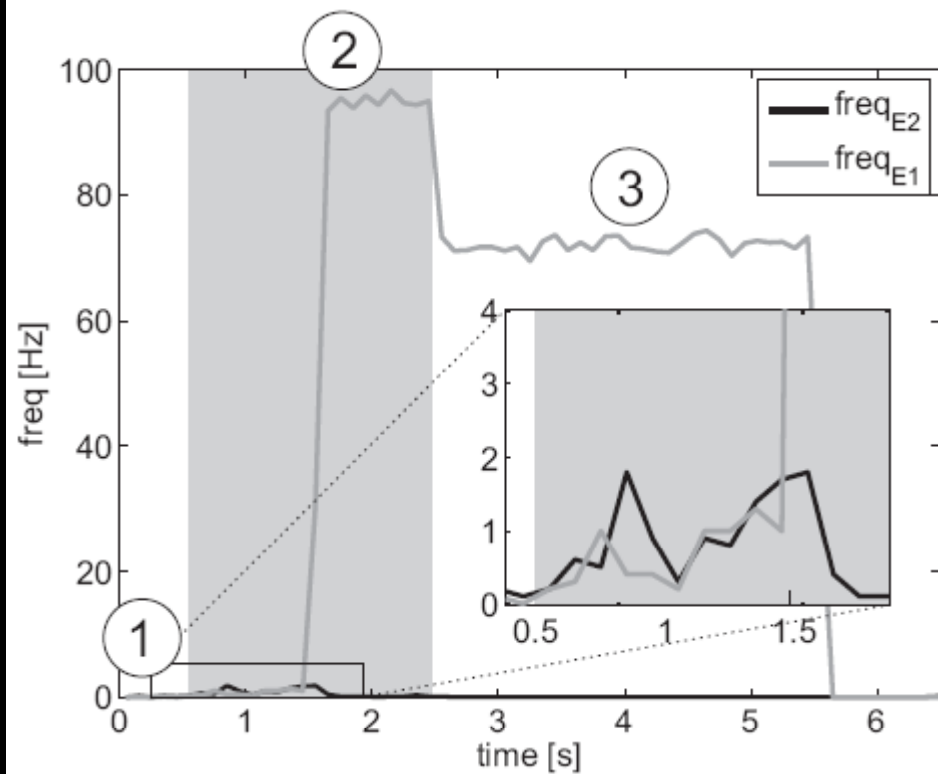


Costruire attrattori su chip neuromorfi: Apprendimento di stimoli visivi in tempo reale

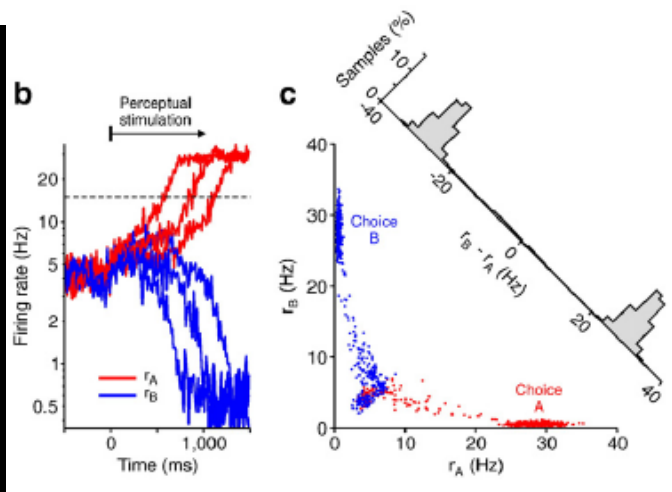


F. Corradi, L. Federici, V. Dante, M. Giulioni, in preparazione

Usare un chip ad attrattori per prendere decisioni



F. Corradi, L. Federici, V. Dante,
M. Giulioni, P. Del Giudice
in preparazione

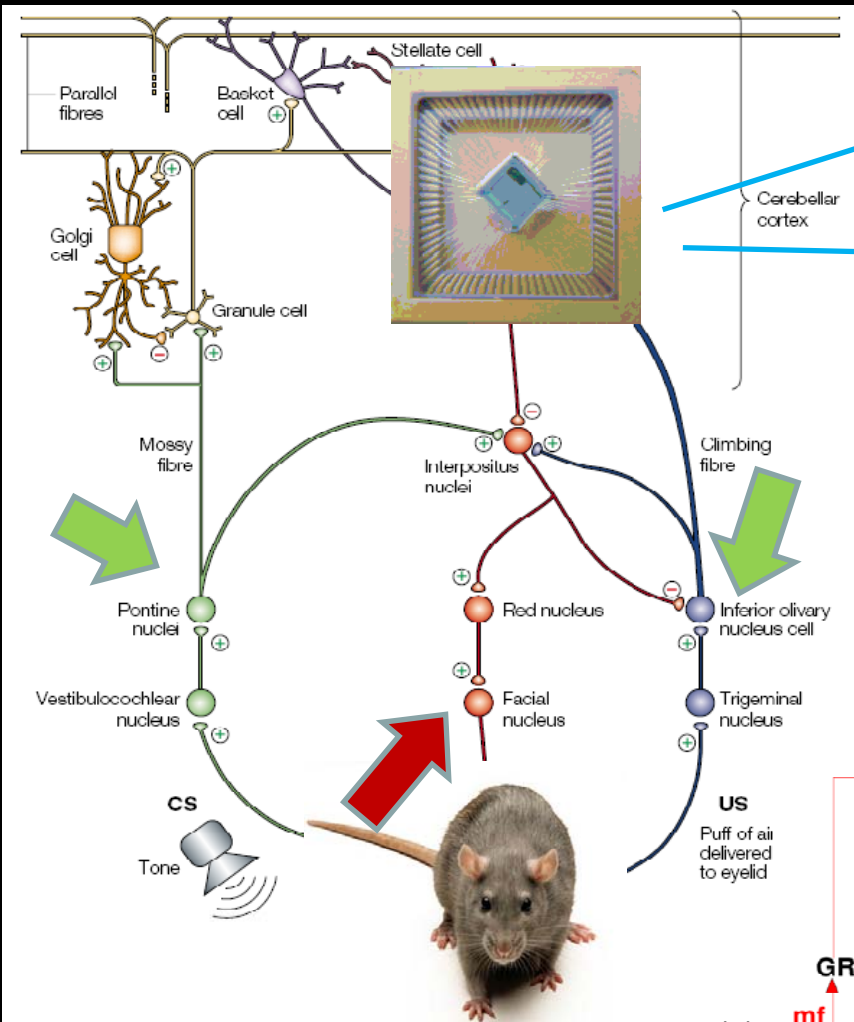


Neuro-prosthetics

Una struttura molto 'ordinata': il cervelletto

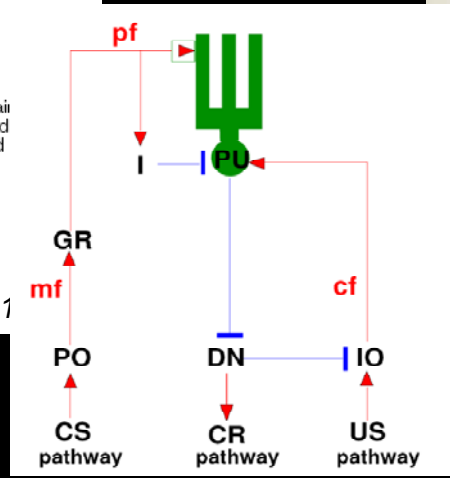
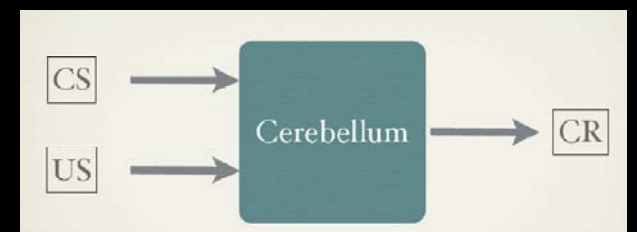
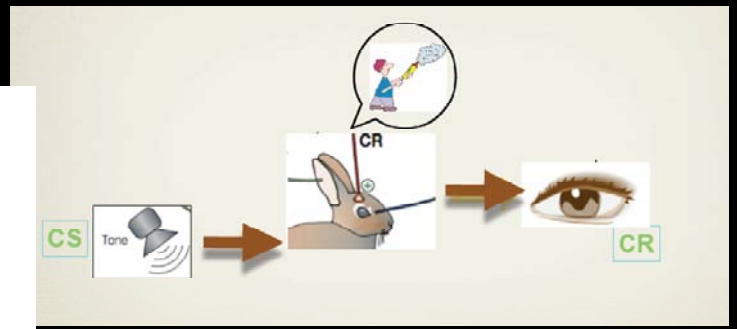
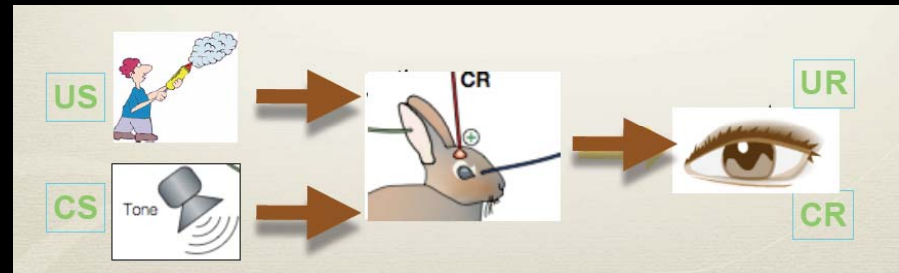
Progetto EU Renachip

“Rehabilitation of a discrete motor learning function by a prosthetic chip”



lesione/invecchiamento

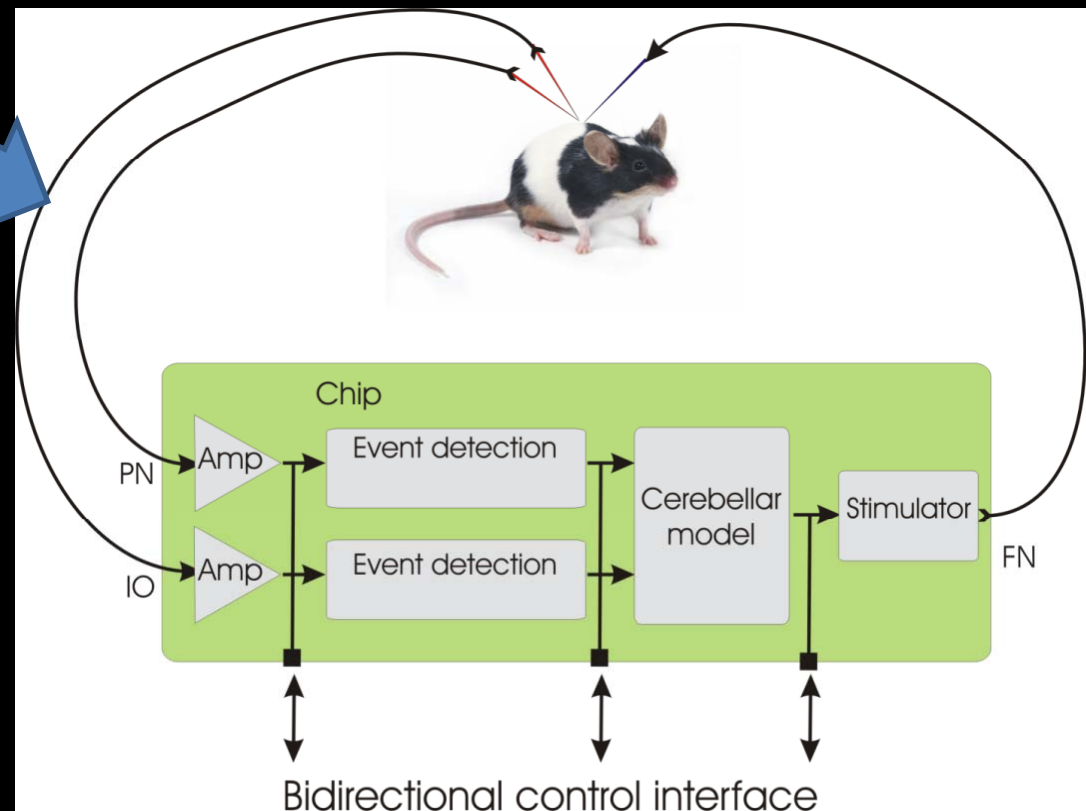
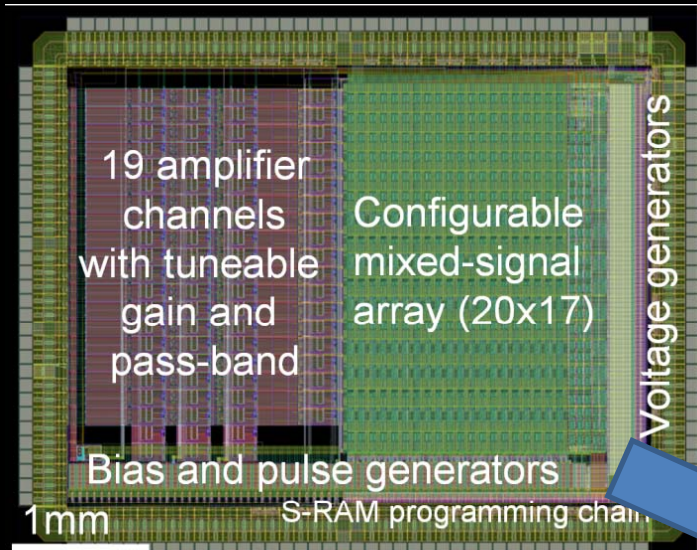
Neuromorphic chip to restore the function (!?!)



J. F. Medina et al. Nat Rev Neurosci. 2002 Feb;3(2):1

Progetto EU Renachip

“Rehabilitation of a discrete motor learning function by a prosthetic chip”



S. Bamford, M. Giulioni
BIOCAS 2010

M. Giulioni, S. Bamford et al
in preparazione

Verso nuove strategie di neuro-riabilitazione

stroke

Riabilitazione post-stroke

Verso nuove strategie basate sulla stimolazione elettrica corticale

- Riabilitazione motoria: tipicamente esiti insoddisfacenti
- Promuovere migliore recupero: stimolazioni non invasive (TMS, tDCS)
- Promuovere migliore recupero: stimolazioni invasive (periferiche o corticali)
- Abbinamento stimolazione – riabilitazione motoria
- Stimolazione a loop aperto vs loop chiuso:
 - * qui cerchiamo di dare un contributo *

BRAIN REORGANIZATION UNDER CORTICAL STIMULATION
(BRUCOS)

GRIGLIE CORTICALI (GRECO)



INFN
Sapienza
CNR

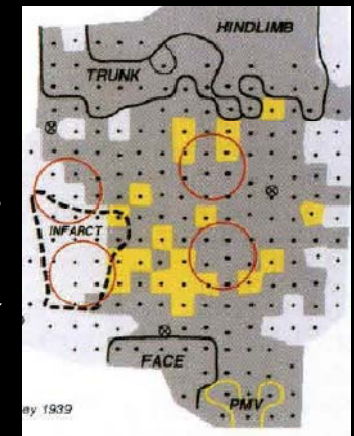
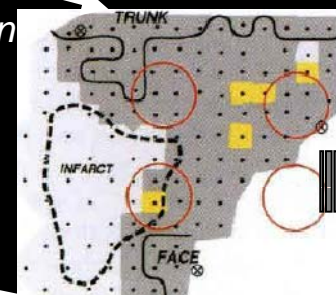
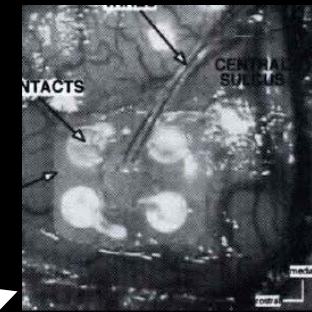
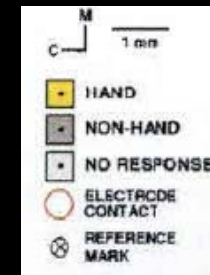


ISS, Sapienza, Columbia, Northwestern

Background

Accumulating evidence on the therapeutic potential of cortical and sub-cortical stimulation for motor impaired patients

- *motor post-ischemic damage recovery in animal models*
 - *pre-infarct training on unimanual task*
 - *map of hand movement representation*
 - *ischemic damage destroying hand representation*
 - *second motor map to guide positioning of stimulation electrodes*
 - *after months of spontaneous recovery, subthreshold stimulation*
 - *third motor map weeks after stimulation:*
 - new hand representations*
 - improved performances*
- *tolerability and safety of direct electrical stimulation in human patients (J. Brown et al., Neurosurgery 2006)*



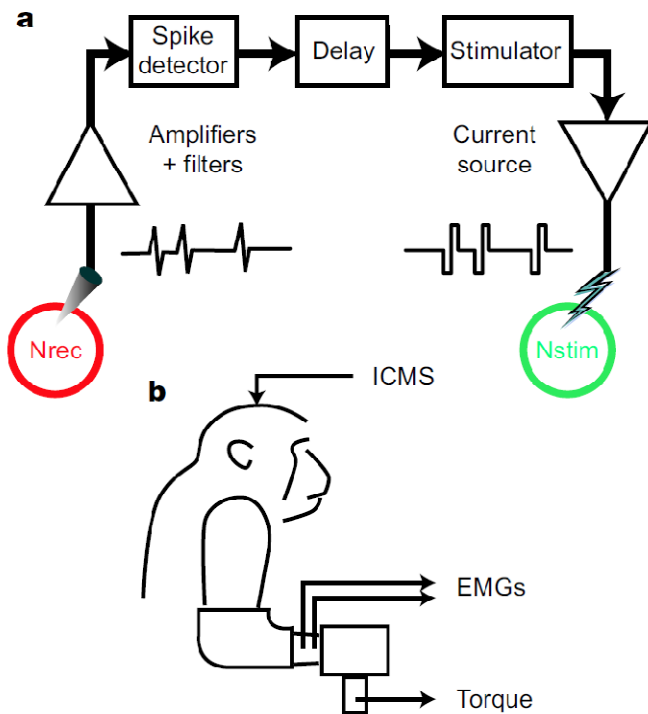
Background: Brain stimulation to promote synaptic reorganization

Long-term motor cortex plasticity induced by an electronic neural implant

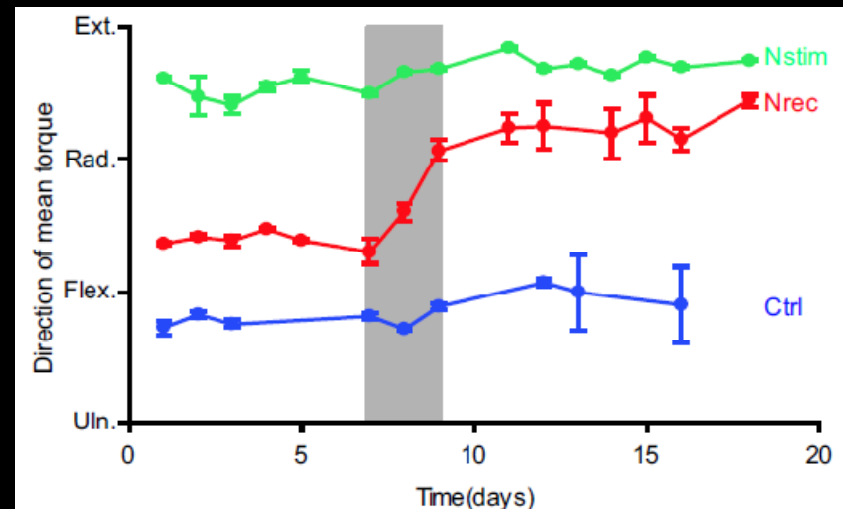
Andrew Jackson¹, Jaideep Mavoori² & Eberhard E. Fetz¹

2006 Nature

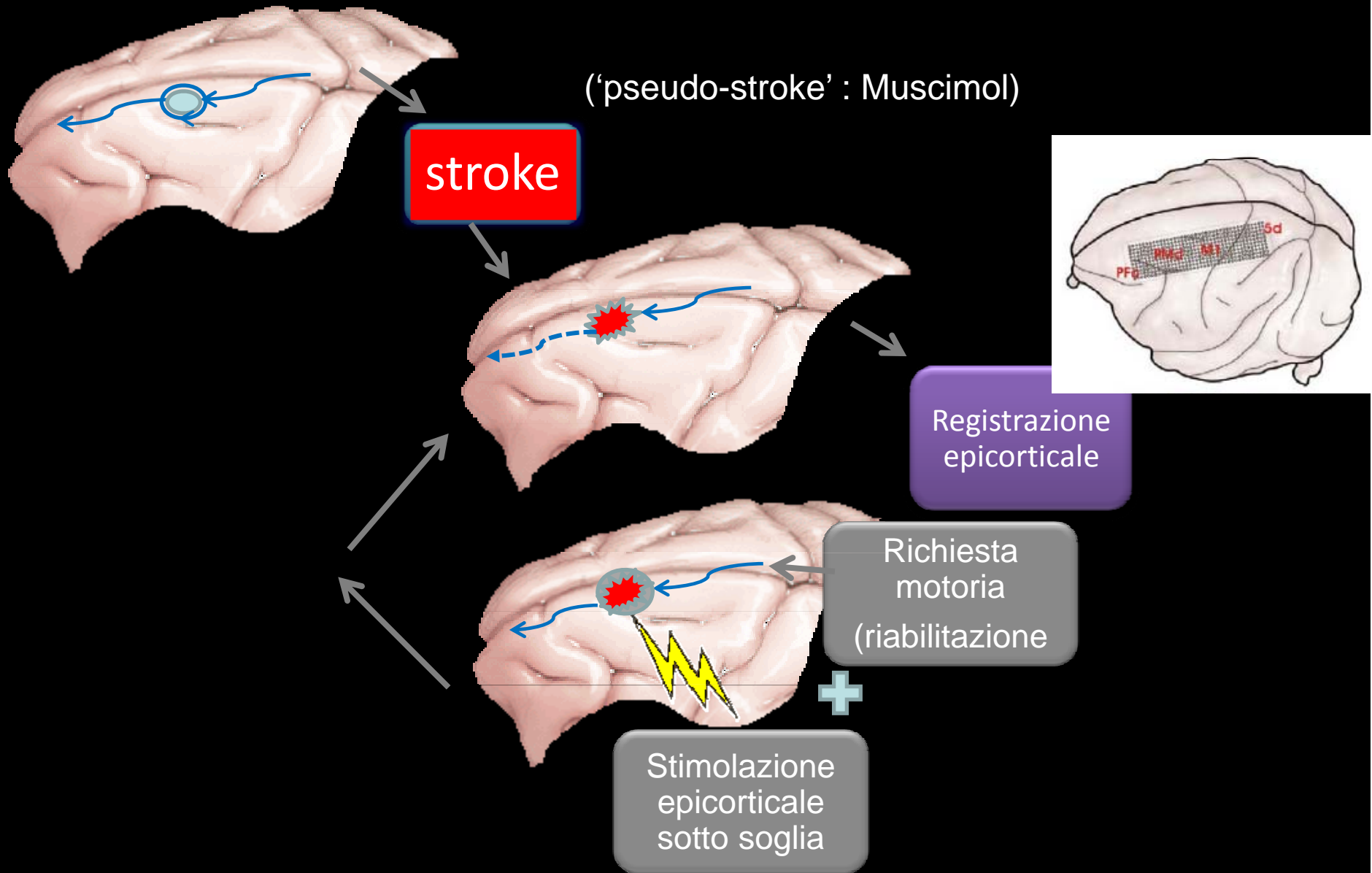
An autonomously operating electronic implant used action potentials recorded on one electrode to trigger electrical stimuli delivered at another location. Over one or more days of continuous operation, the output evoked from the recording site shifted to resemble the output from the corresponding stimulation site, in a manner consistent with the potentiation of synaptic connections between the artificially synchronized populations of neurons. Changes persisted in some cases for more than one week, whereas the output from sites not incorporated in the connection was unaffected. This method for inducing functional reorganization *in vivo* by using physiologically derived stimulus trains may have practical application in neurorehabilitation after injury.



Neurochip delivers a single stimulus pulse to Nstim 5 ms after every action potential detected at Nrec



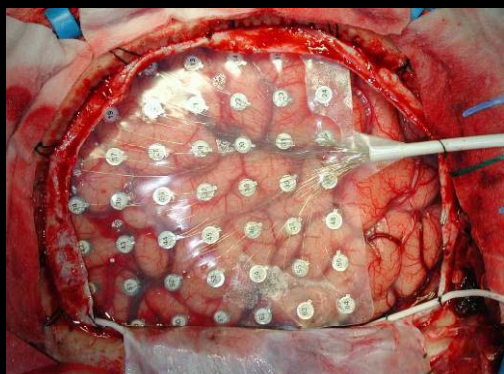
Verso un approccio a loop chiuso alla riabilitazione post-stroke



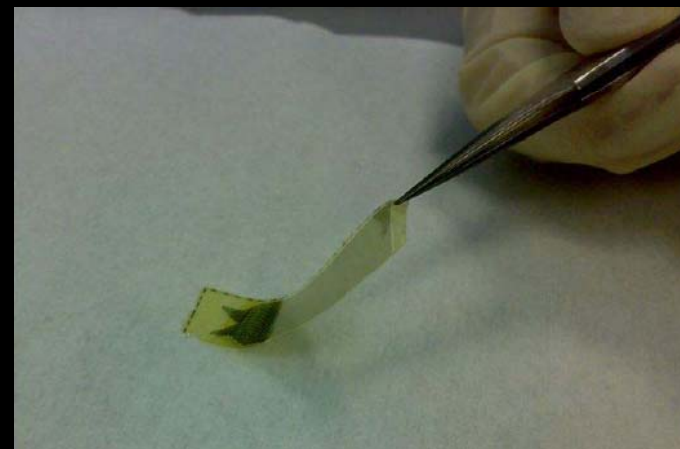
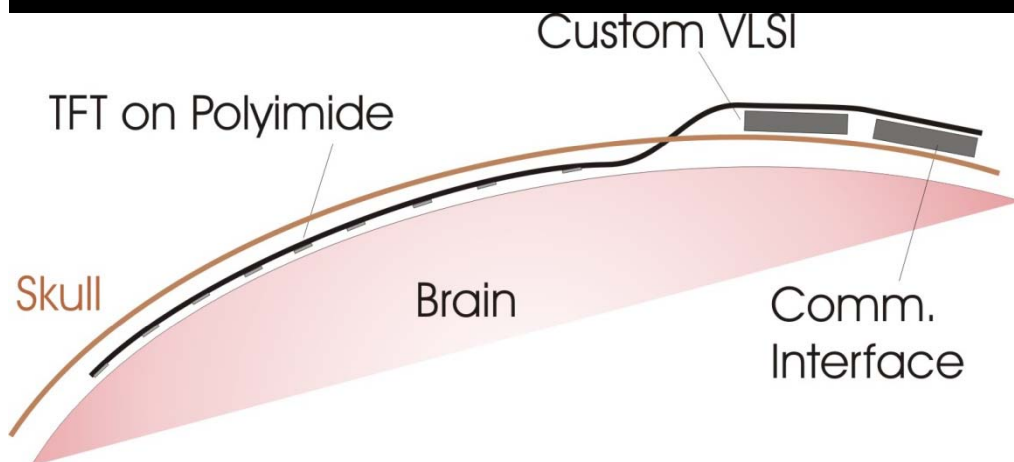
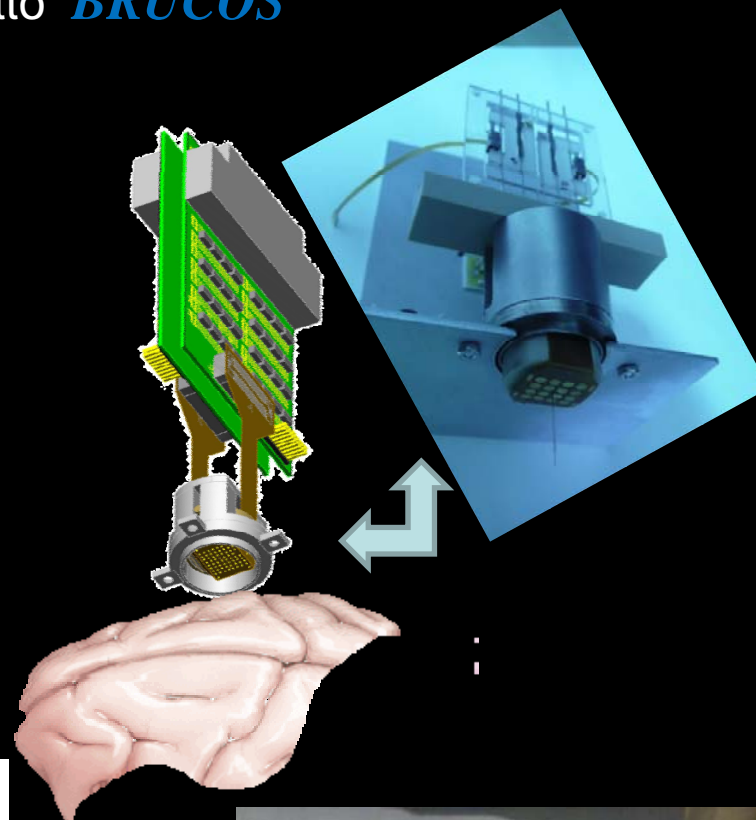
Stimolazione simultanea multi-sito?

Nuovi strumenti per un approccio a loop chiuso alla riabilitazione post-stroke

progetto *GRECO*



progetto *BRUCOS*



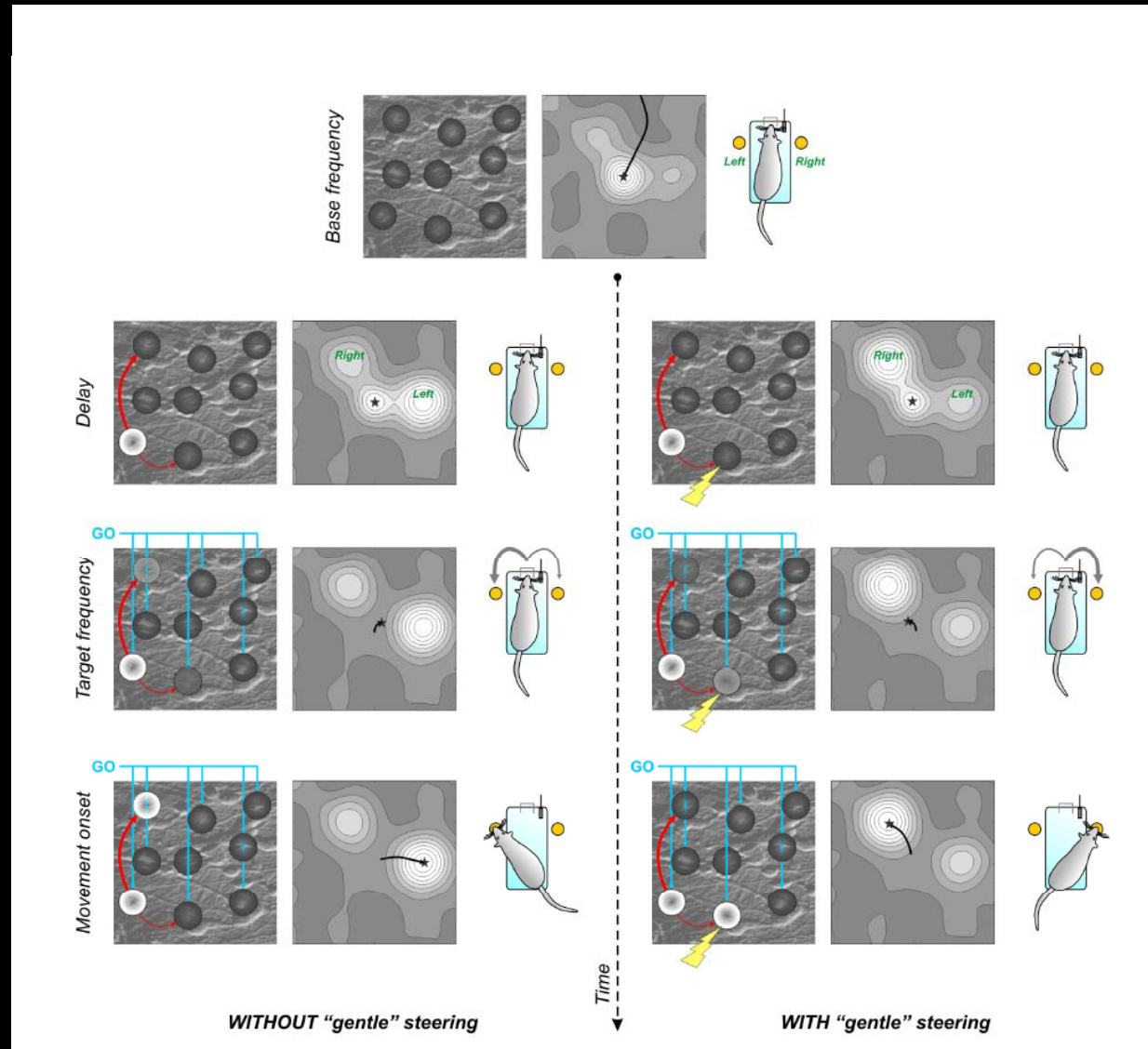
Tra scienza di base e applicazioni

Influenzare gentilmente l'attività nervosa

Gentle stimulation as a probe into the system's dynamics



CORONET



Precari e non...

M. Mattia



teoria e simulazioni

S. Bamford



chip e interfacce

M. Giulioni



V. Dante



E. Petetti



elettronica e interfacce

Studenti

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F. Corradi

L. Federici

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P. Barucca

Sapienza – Roma, UPF Barcelona, Univ. Magdeburg, Univ. Genova, IDIBAPS – Barcelona, TECHNION – Haifa, SISSA – Trieste, Columbia - NY