Beta Rebound as an Index of Temporal Integration of Somatosensory and Motor Signals

Speaker: *Pasquale Cardellicchio*

IIT@UniFe Center for Translational Neurophysiology,

Istituto Italiano di Tecnologia, Ferrara, Italy

Sensorimotor integration during movement:

During voluntary movement, the somatosensory system not only passively receives signals from the external world but also actively processes them via interactions with the motor system (Umeda et al., 2019).

The neurofunctional integration of somatosensory and motor signals may be derived from the brain electromagnetic oscillatory dynamics recorded from the scalp.

- Alfa (8-12 Hz)

- Beta (~13-30 Hz) neural activity.

ISTITUTO ITALIANO DI TECNOLOGIA

Università degli Studi di Ferrara

Event-related spectral perturbations (ERSPs):

Two types of event-related spectral perturbations (ERSPs) are generally described during the execution of movements:

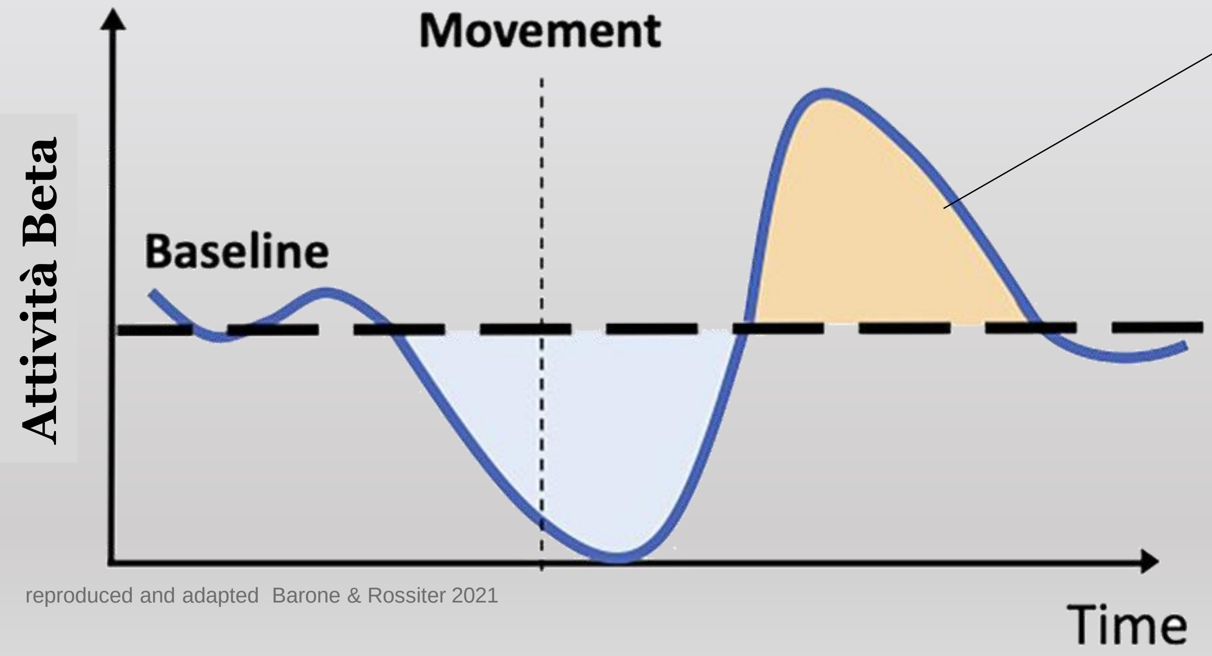
- reduction in both the Beta and Alpha frequency bands (event related desynchronization or ERD)
- Increase of Beta relative to baseline (event-related synchronization or ERS).

The ERD is observed immediately before movement onset and is sustained throughout the movement (movement related beta decrease or MRBD; Jasper and Penfield,1949; Salmelin and Hari, 1994a; Pfurtscheller et al., 2003;Jurkiewicz et al., 2006).

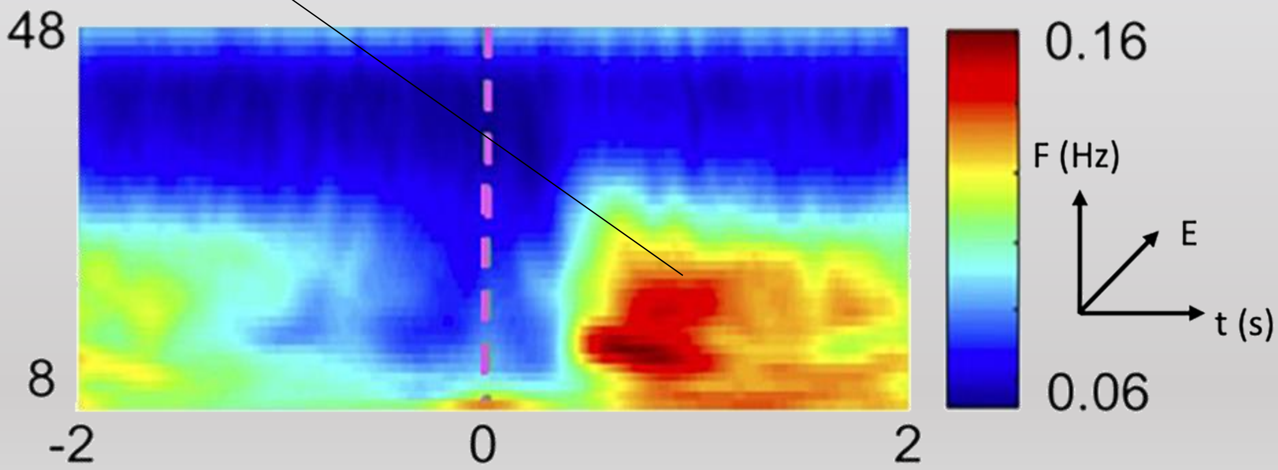
Clear beta ERS follows movement cessation and exhibits a period of high amplitude, which can last for several seconds (post-movement beta rebound o PMBR; Jurkiewicz et al., 2006; Neuper et al., 2006).

Beta rebound

Principal sources of Beta are sensorimotor cortex and basal ganglia.



reproduced and adapted Barone & Rossiter 2021



Beta oscillation hypothesis

A role for beta as an active process, which interferes with the encoding of incoming information while promoting the existing state—i.e., "*status quo*"—of the system.

Specifically, the beta rebound might reflect a ''*resetting*'' of the sensorimotor system (Engel and Fries, 2010) with the functional role of updating the nervous system with the current state of the periphery

Beta power seem to be based on an ''*inhibitory*'' process, gating the transfer of information to or from SI and M1 *(Sherman et al., 2016; Shin et al., 2017)*.

This inhibitory process is supported by the administration of benzodiazepines (enhancing GABA-A-mediated inhibition) that <u>increases</u> beta oscillations in the human sensorimotor cortex *(Jensen et al., 2005)*.

ISTITUTO ITALIANO DI TECNOLOGIA

Università degli Studi di Ferrara

Beta rebound as index

- Transcranial Magnetic Stimulation (TMS)
(Chen et al.,1998; Aono et al., 2013; Takemi et al., 2013)

- passive movements (Cassim et al., 2001)

- Action observation /imagination

- somatosensory stimulations
(Neuper and Pfurtscheller, 2001; Cheyne et al., 2003; Gaetz and Cheyne, 2006).

Beta rebound as index

Electrical peripheral stimulation of afferent pathways (i.e., median nerve stimulation or MNS; Salmelin and Hari, 1994a; Salenius et al., 1997) is followed by a clear rebound in the Beta range

These observations suggest that somatosensory reafference may play a critical role in the generation of a beta rebound.

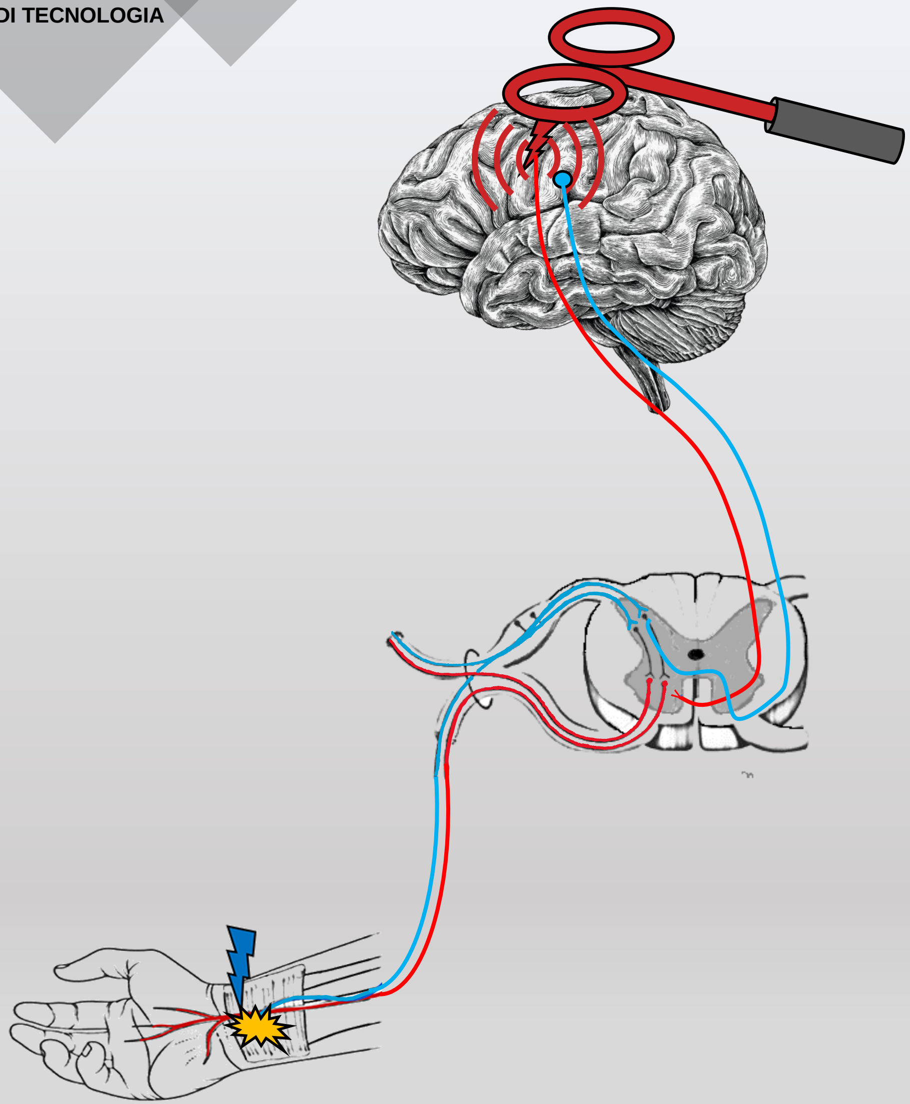
return-to-baseline stage (Müller et al., 2003)?

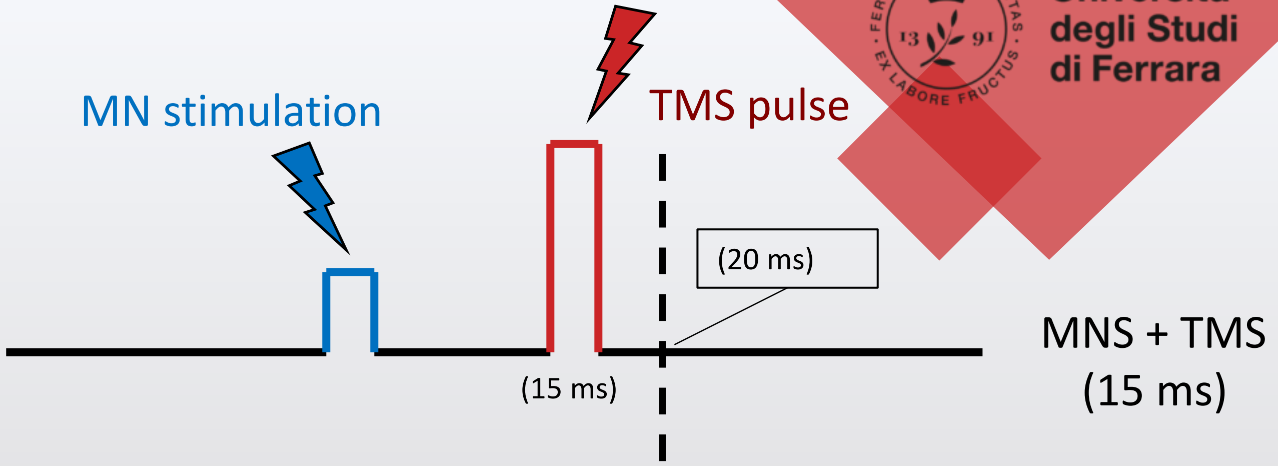
The first afferent volley requires about 20 ms to reach its cortical targets (Cohen and Starr, 1987; Allison et al., 1989)

↓

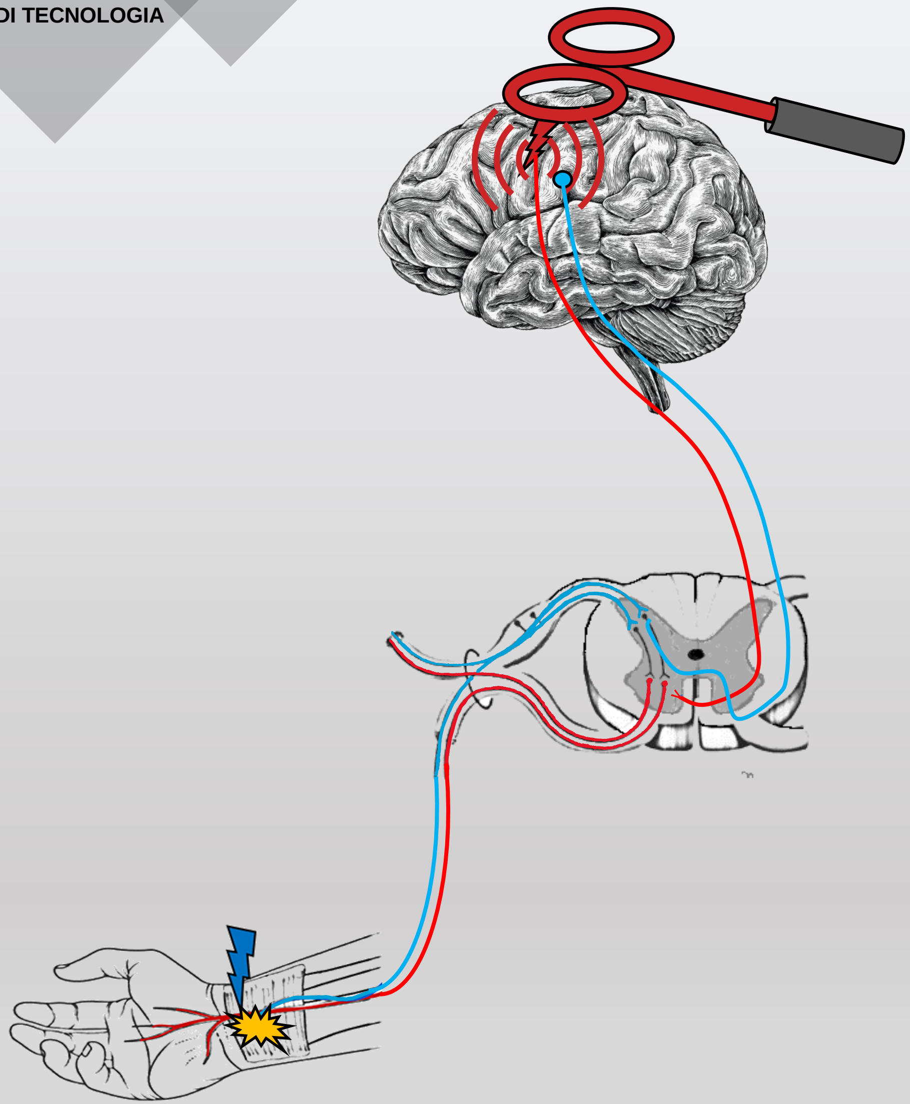
We used the Beta rebound to investigate the timing of the somatosensory integration.

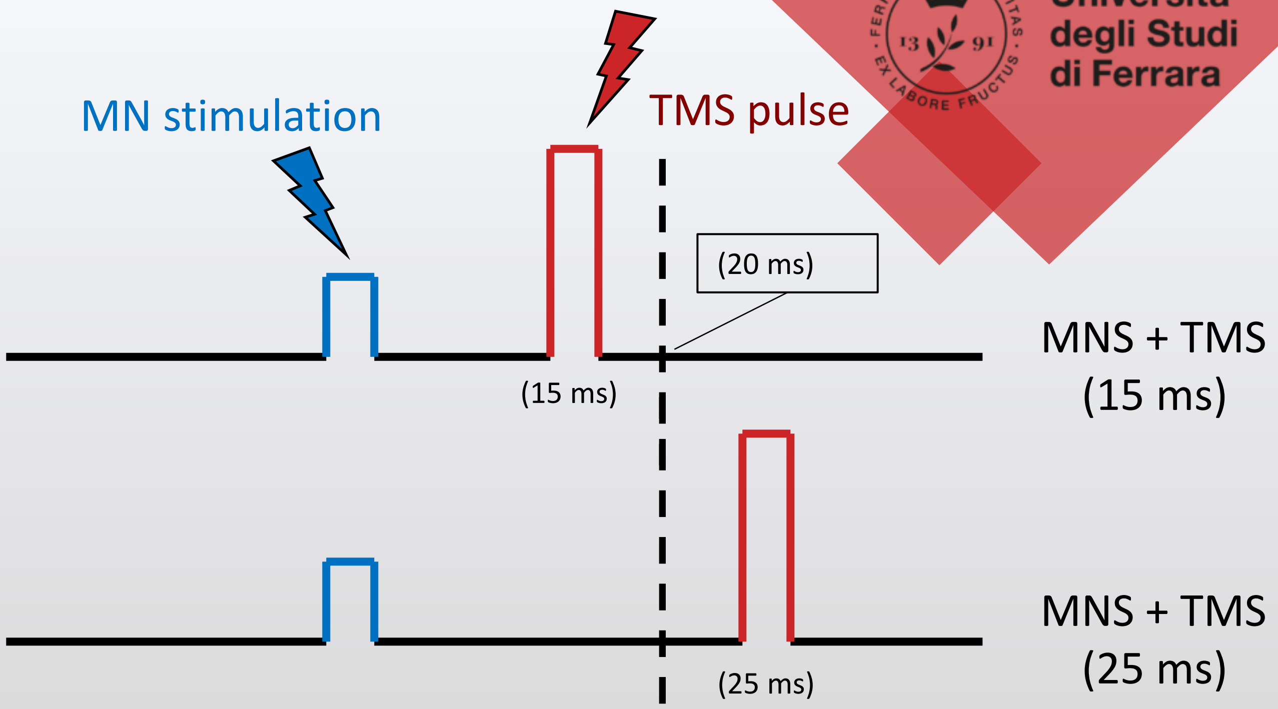
Different temporal integrations



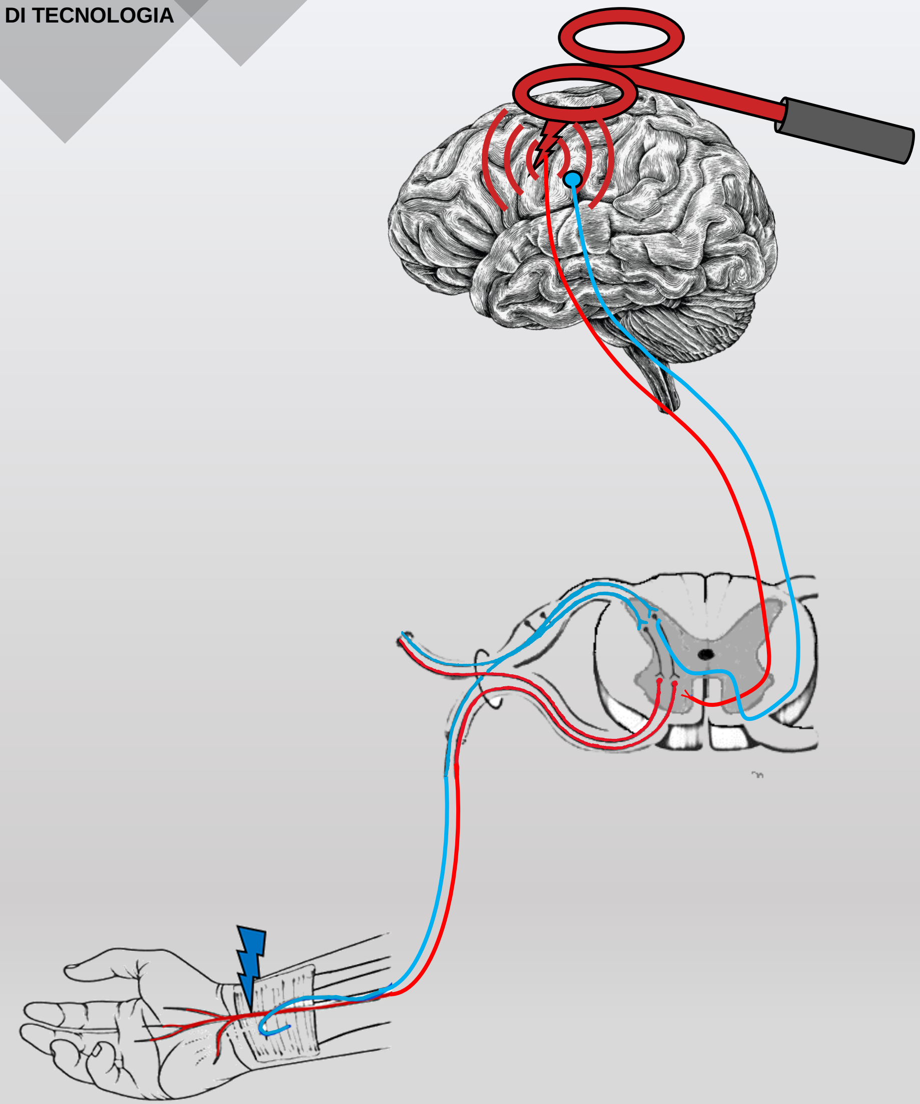


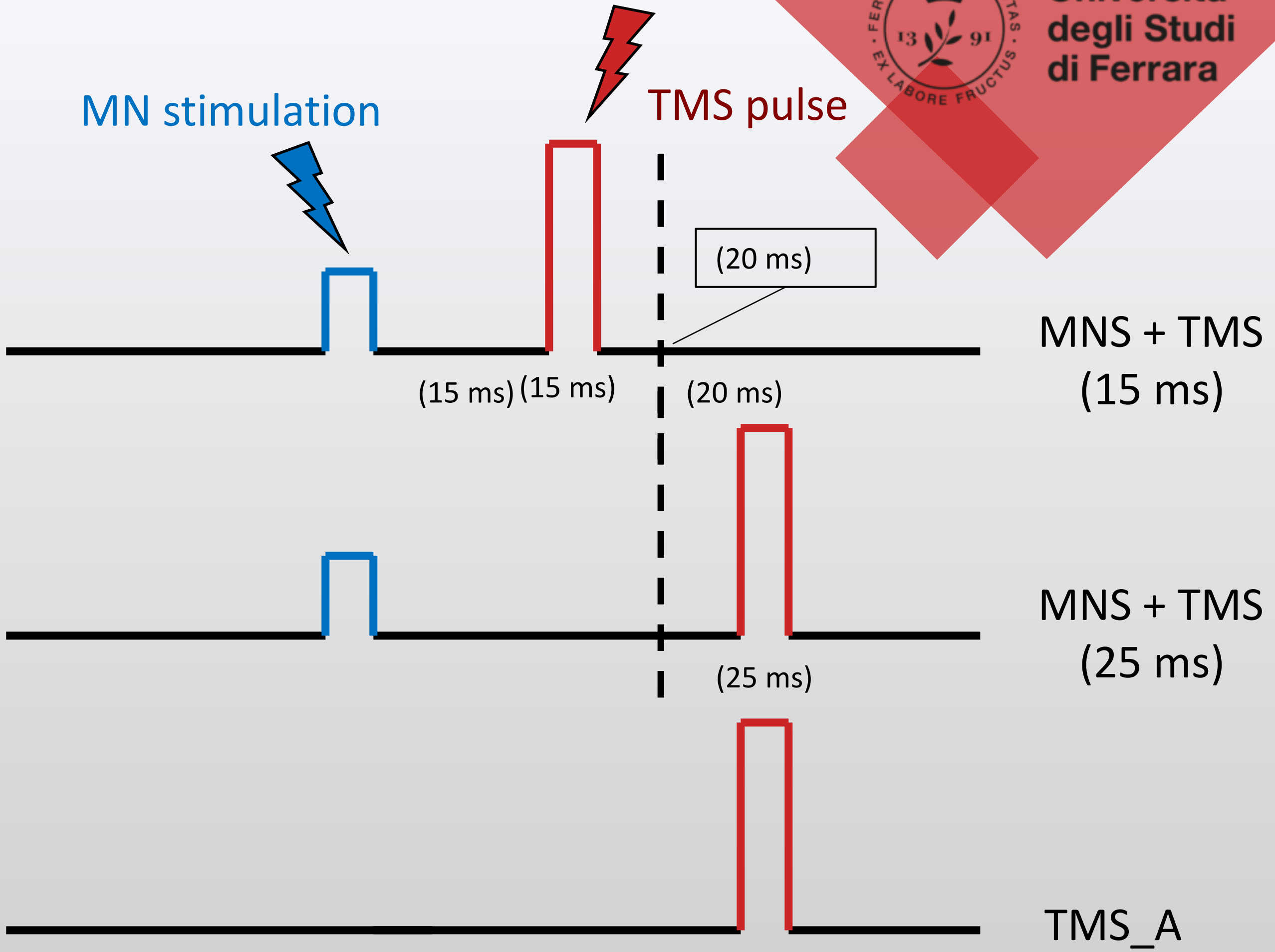
Different temporal integrations



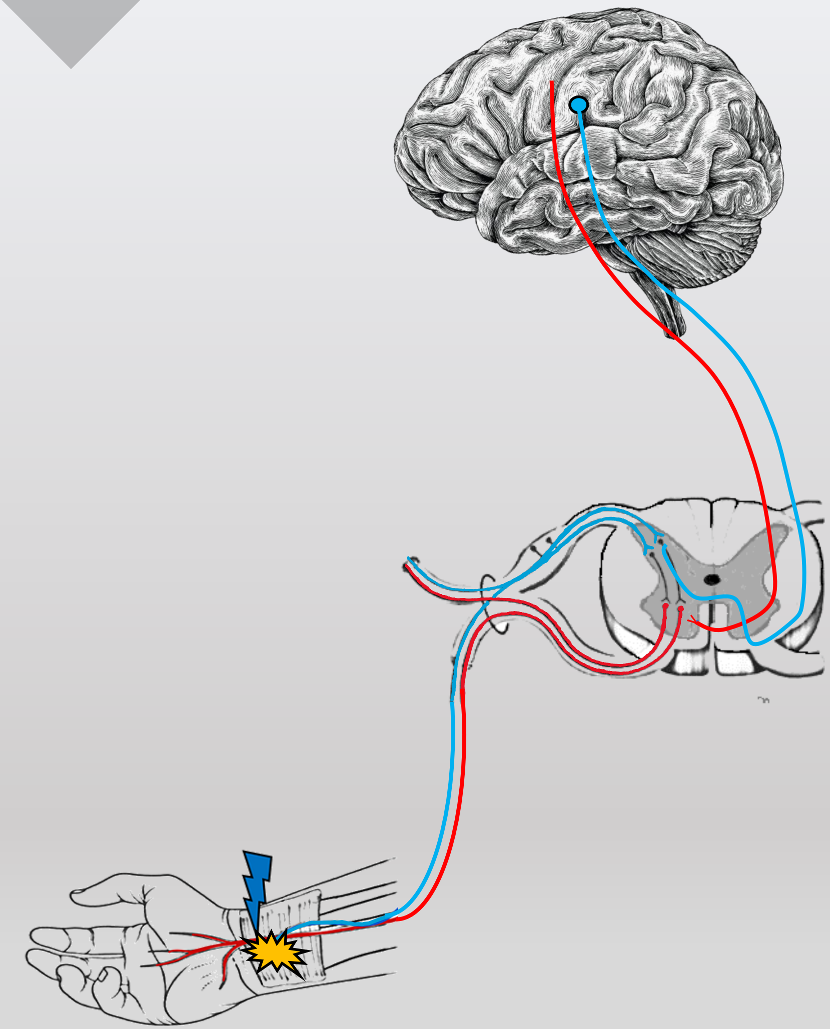


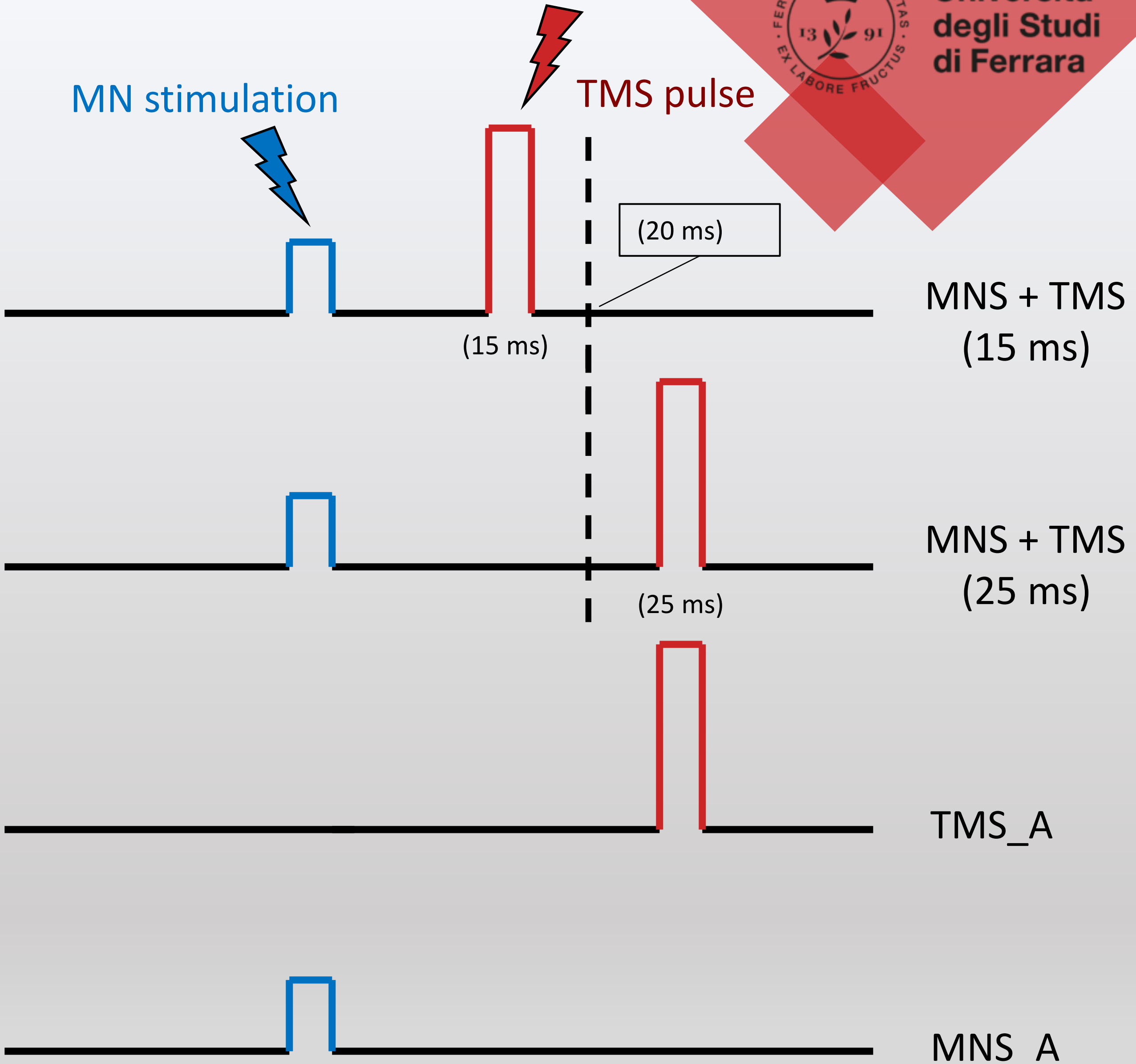
Different temporal integrations





Different temporal integrations





Time-frequency plots

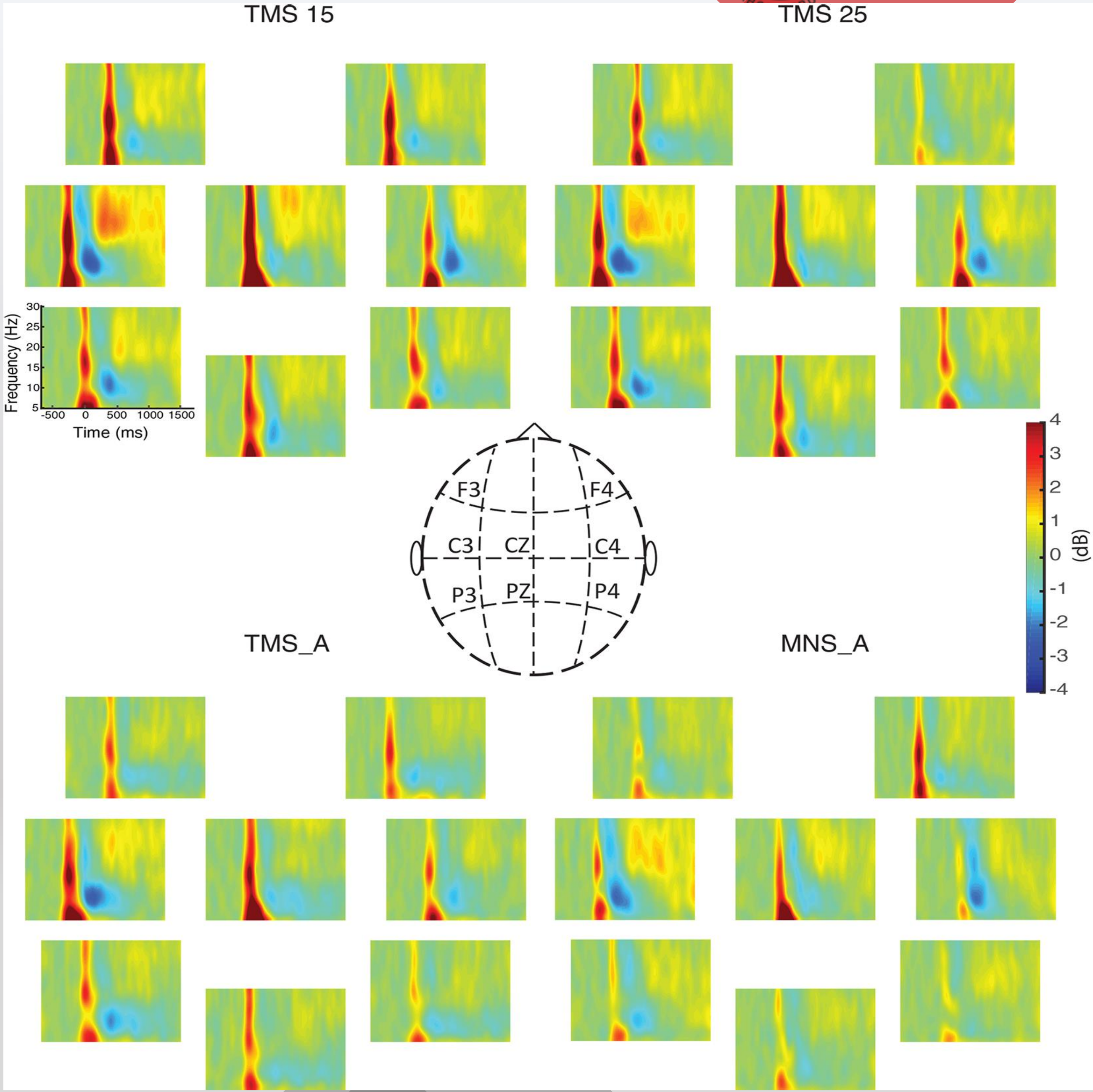
10 subjects
100 trials in each condition

TMS:(MEPs) in right *opponens pollicis* (OP)

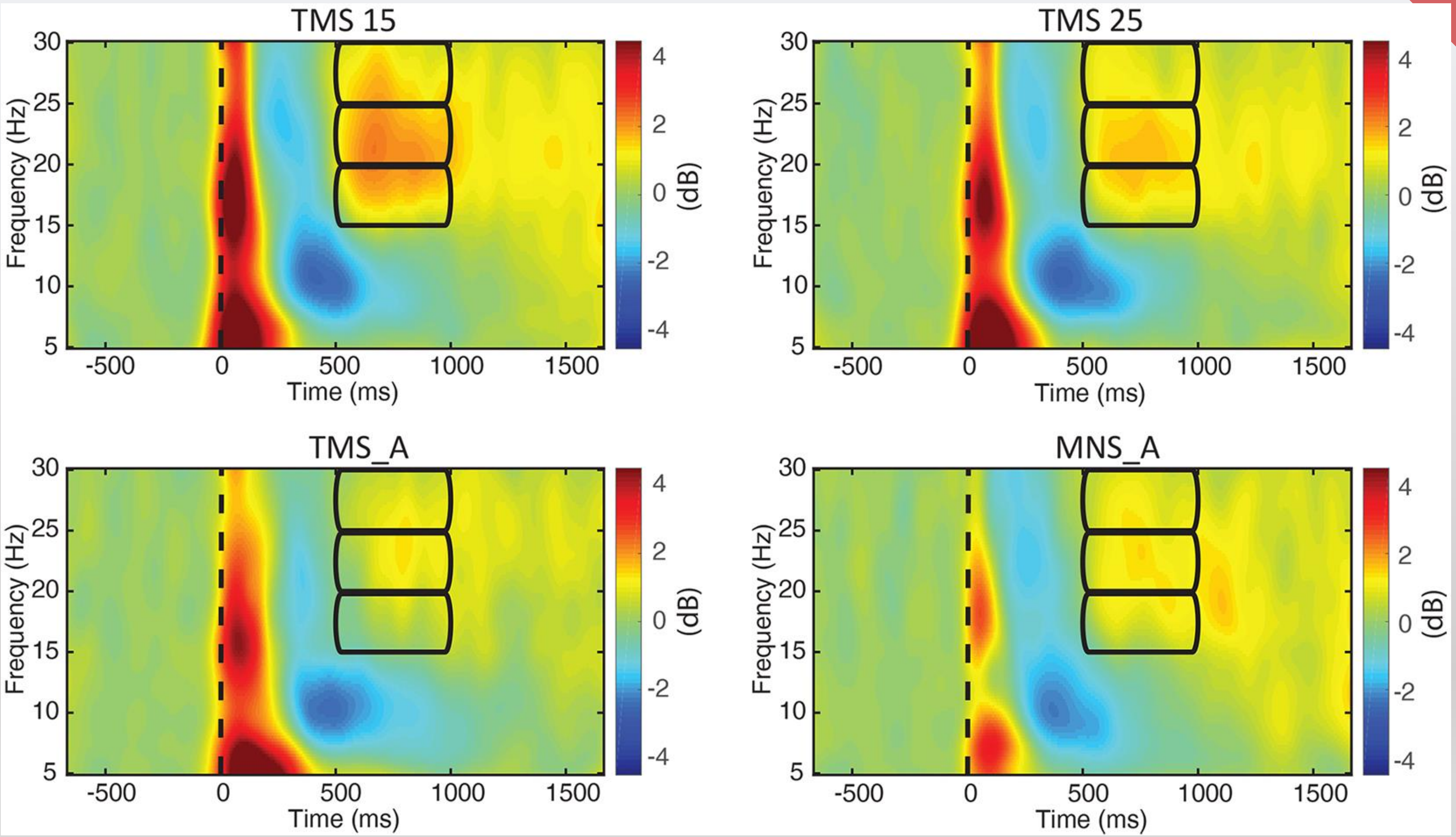
EEG: 8 channels
(sensorimotor area)

Increase of Beta power:

- 500 – 1000 ms
- central electrodes
- hemisphere contralateral for MNS



Event related spectral perturbation C3:



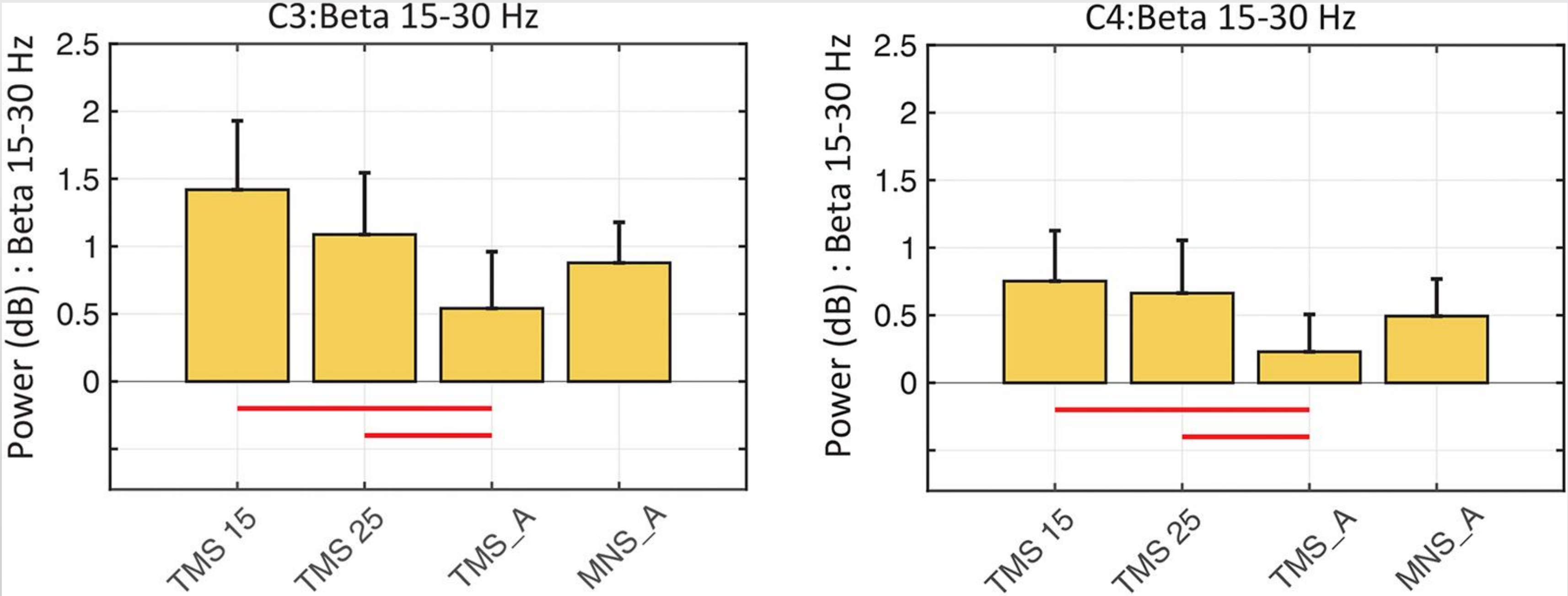
Beta rebound (15-30 Hz) in C3 e C4

C3:

TMS15 > **TMS_A** *($p < 0.01$)*
TMS25 > **TMS_A** *($p = 0.03$)*

C4:

TMS15 > **TMS_A** *($p = 0.02$)*
TMS25 > **TMS_A** *($p < 0.01$)*



ISTITUTO ITALIANO DI TECNOLOGIA

Università degli Studi di Ferrara

Results C3 C4 in different beta sub-bands.

C3 low beta power (15-20 Hz)

TMS15 (*p = 0.02*)	>	TMS_A
TMS25 (*p = 0.01*)		
MNS_A (*p = 0.02*)		

C3 middle beta band (20-25 Hz)

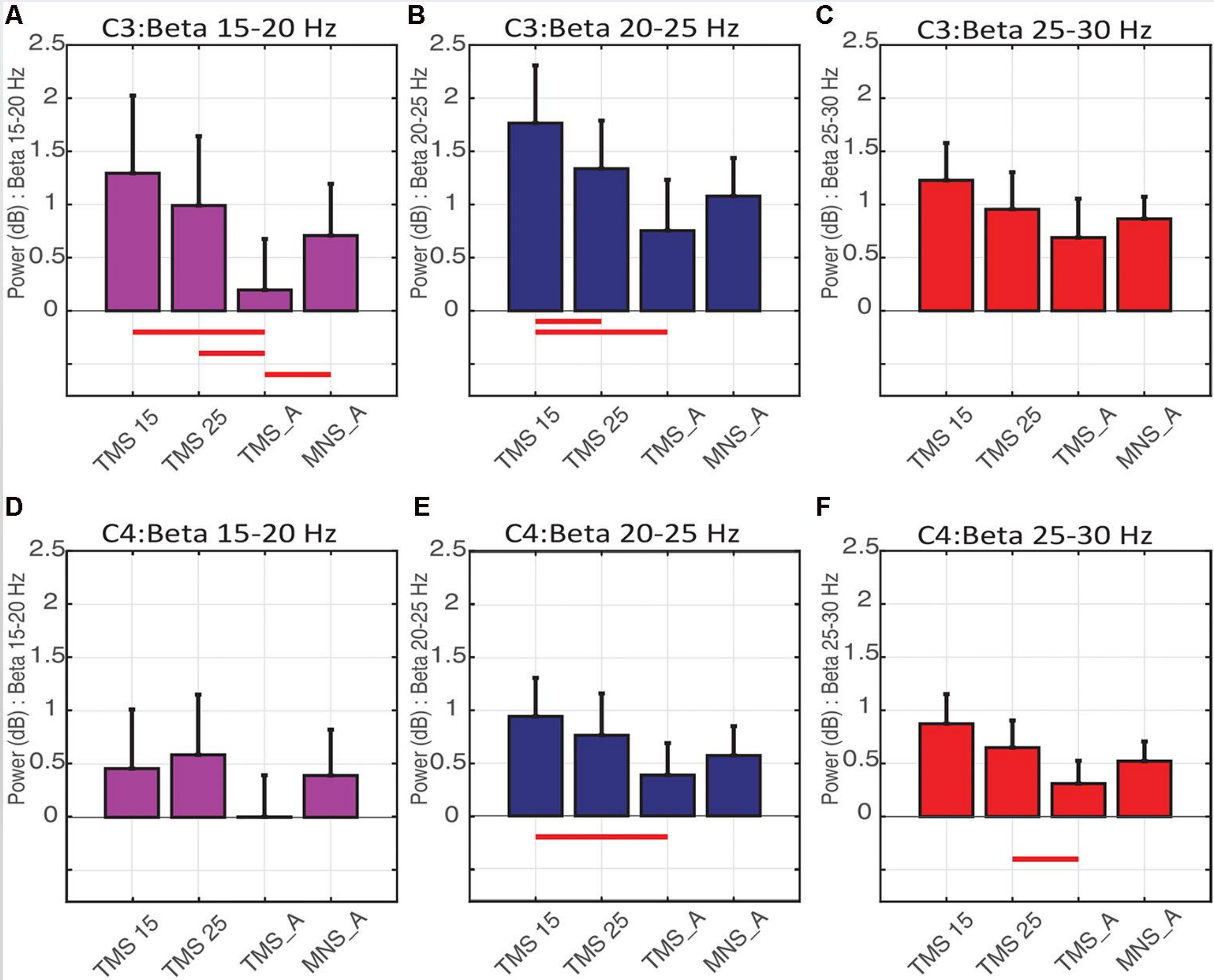
TMS15	>	TMS25 (*p = 0.04*)
		TMS_A (*p < 0.01*)

C4 middle beta band (20-25 Hz)

TMS15	>	TMS_A (*p = 0.3*)

C4 high beta band (25-30 Hz)

TMS25	>	TMS A (*p = 0.04*)



ISTITUTO ITALIANO DI TECNOLOGIA @UniFe

Università degli Studi di Ferrara

Discussioni:

Left Hemisphere:

β rebound:
decreased in TMS_A in 15-20 Hz:
Index of integration process of peripheral signal.

Modulation in delay between MNS + TMS in 20-25 Hz:
TMS15 > TMS25

it is possible to observe "*state-dependency*" effects such that processing of the afferent volley is modulated by the preconditioning of the motor cortex.

Right Hemisphere :

MNS + TMS in 20-25 Hz: aumento in TMS15
MNS + TMS in 25-30 Hz: aumento in TMS25
multiple mechanisms of integration of sensory and motor signals may be at play, in parallel, in the beta band.

Motor and somatosensory areas communicate *via* spatiotemporally coordinated activities spanning multiple bands, respectively indexing the effect of efference on afferent signal processing (middle beta, contralateral to MNS) and the effect of afference on efferent signal generation (high beta, ipsilateral to MNS).

Conclusion/ take home message:

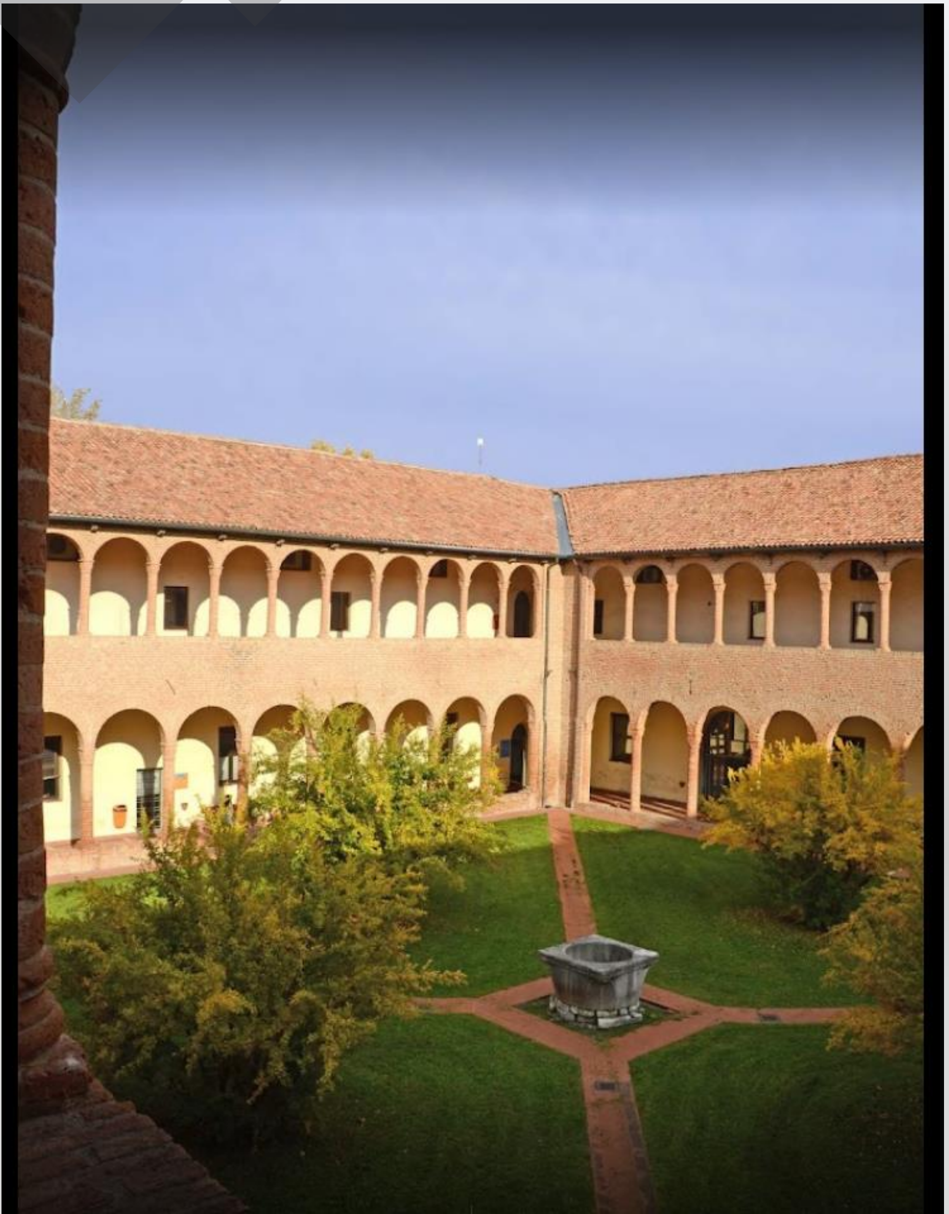
Beta has become more broadly implicated in endogenous top-down processing and sensorimotor integration(Barone & Rossiter., 2021).

somatosensory and motor neural circuitries participate in a single functional system in the service of motor control.

temporal integration of afferent and efferent signals plays a key role in the genesis of the beta rebound and that these signals may be carried in parallel by different beta sub-bands.

Multiple mechanisms of integration of sensory and motor signals, in parallel, in the beta band.

Thank you!



Luciano Fadiga

Alessandro d' Ausilio

Andrea Casarotto

Elisa Dolfini

Pauline Hilt

ISTITUTO ITALIANO DI TECNOLOGIA

Università degli Studi di Ferrara

Reference:

Allison, T., McCarthy, G., Wood, C. C., Darcey, T. M., Spencer, D. D., and Williamson, P. D. (1989). Human cortical potentials evoked by stimulation of the median nerve. I. Cytoarchitectonic areas generating short-latency activity. J. Neurophysiol. 62, 694–710.

Aono, K., Miyashita, S., Fujiwara, Y., Kodama, M., Hanayama, K., Masakado, Y., et al. (2013). Relationship between event-related desynchronization and cortical excitability in healthy subjects and stroke patients. Tokai J. Exp. Clin. Med. 38, 123–128.

Cassim, F., Monaca, C., Szurhaj, W., Bourriez, J. L., Defebvre, L., Derambure, P., et al. (2001). Does post-movement beta synchronization reflect an idling motor cortex? Neuroreport 12, 3859–3863.

Chen, R., Yaseen, Z., Cohen, L. G., and Hallett, M. (1998). Time course of corticospinal excitability in reaction time and self-paced movements. Ann. Neurol. 44, 317–325.

Cheyne, D., Gaetz, W., Garnero, L., Lachaux, J. P., Ducorps, A., Schwartz, D., et al. (2003). Neuromagnetic imaging of cortical oscillations accompanying tactile stimulation. Cogn. Brain Res. 17, 599–611. **Cohen, L. G., and Starr, A. (1987).** Localization, timing and specificity of gating of somatosensory evoked potentials during active movement in man. Brain 110, 451–467.

Gaetz, W., and Cheyne, D. (2006). Localization of sensorimotor cortical rhythms induced by tactile stimulation using spatially filtered MEG. NeuroImage 30, 899–908.

Jasper, H., and Penfield, W. (1949). Electrocorticograms in man: effect of voluntary movement upon the electrical activity of the precentral gyrus. Arch. Psychiatr. Nervenkr. 183, 163–174.

Jurkiewicz, M. T., Gaetz, W. C., Bostan, A. C., and Cheyne, D. (2006). Post-movement beta rebound is generated in motor cortex: evidence from neuromagnetic recordings. NeuroImage 32, 1281–1289. **Müller, G. R., Neuper, C., Rupp, R., Keinrath, C., Gerner, H. J., and Pfurtscheller, G. (2003).** Event-related beta EEG changes during wrist movements induced by functional electrical stimulation of forearm muscles in man. Neurosci. Lett. 340, 143–147.

Neuper, C., Wörtz, M., and Pfurtscheller, G. (2006). Chapter 14 ERD/ERS patterns reflecting sensorimotor activation and deactivation. Prog. Brain Res. 159, 211–222.

Pfurtscheller, G., Graimann, B., Huggins, J. E., Levine, S. P., and Schuh, L. A. (2003). Spatiotemporal patterns of beta desynchronization and g synchronization in corticographic data during self-paced movement. Clin.

Salenius, S., Schnitzler, A., Salmelin, R., Jousmäki, V., and Hari, R. (1997). Modulation of human cortical rolandic rhythms during natural sensorimotor tasks. NeuroImage 5, 221–228.

Salmelin, R., and Hari, R. (1994). Characterization of spontaneous MEG rhythms in healthy adults. Electroencephalogr. Clin. Neurophysiol. 91, 237–248.

Takemi, M., Masakado, Y., Liu, M., and Ushiba, J. (2013). Event-related desynchronization reflects downregulation of intracortical inhibition in human primary motor cortex. J. Neurophysiol. 110, 1158–1166.

Umeda, T., Isa, T., and Nishimura, Y. (2019). The somatosensory cortex receives information about motor output. Sci. Adv. 5(7):eaaw5388.

Short-latency afferent inhibition