# Toward Quantitative Neurofunctional Feedback During TMS: A Concurrent TD-NIRS Approach

**Michele Lacerenza[1], Costanza Iester[2], Chiara Motto[1], Laura Bonzano[3,4], Marco Bove[2,4], Simone Cutini[5], Sabrina Brigadoi[5].**

*[1]PIONIRS srl, Milan, Italy; [2]Department of Experimental Medicine, University of Genoa, Genoa, Italy; [3]Department of Neuroscience, Rehabilitation, Ophthalmology, Genetics, Maternal and Child Health, University of Genoa, Genoa, Italy; [4]IRCCS Azienda Ospedaliera Metropolitana, Genoa, Italy; [5]Department of Developmental Psychology and Socialization, University of Padova, Padua, Italy.*

*mail: lacerenza@pionirs.com*

## 1. INTRODUCTION:

Transcranial magnetic stimulation (TMS) provides a non-invasive approach to modulate and probe cortical excitability, while NIRS measures task-related changes in cortical hemodynamics. Their combination enables the investigation of the relationship between cortical stimulation, neural activity and local hemodynamic responses. However, concurrent TMS–NIRS measurements remain technically challenging because of: 1) mechanical interaction between the TMS coil and optical probes; 2) hair-related limitations in scalp–probe coupling; 3) difficulty in selectively assessing cortical versus superficial hemodynamic contributions.

### Why TD-NIRS?

**01** Absolute [$HbO_2$] and [HHb]

**02** Improved discrimination of superficial and cortical contributions

**03** Low sensitivity to motion/pressure

## 2. METHODS:

*Figure 1. Measurement setup, including TD-NIRS, TMS coil and EMG*

*Figure 2. H2 probe, equipped with spring-loaded retractable tips.*

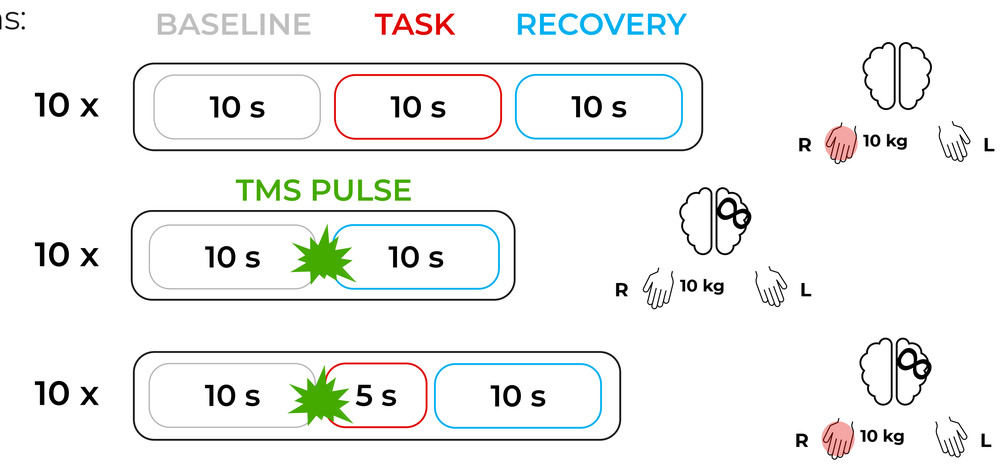
Measurements were performed using a TD-NIRS system (NIRSBOX-DUAL, PIONIRS, Italy) equipped with two optical probes (H2, PIONIRS, Italy) positioned over the left and right primary motor regions (C3/C4). TMS stimulation intensity was adjusted to evoke motor-evoked potentials (MEPs ≈ 1 mV) in the target hand muscles, measured by electromyography (EMG).
Three participants were measured under three conditions:

**(A)** Functional task (No TMS)
Handgrip task without coil stimulation.

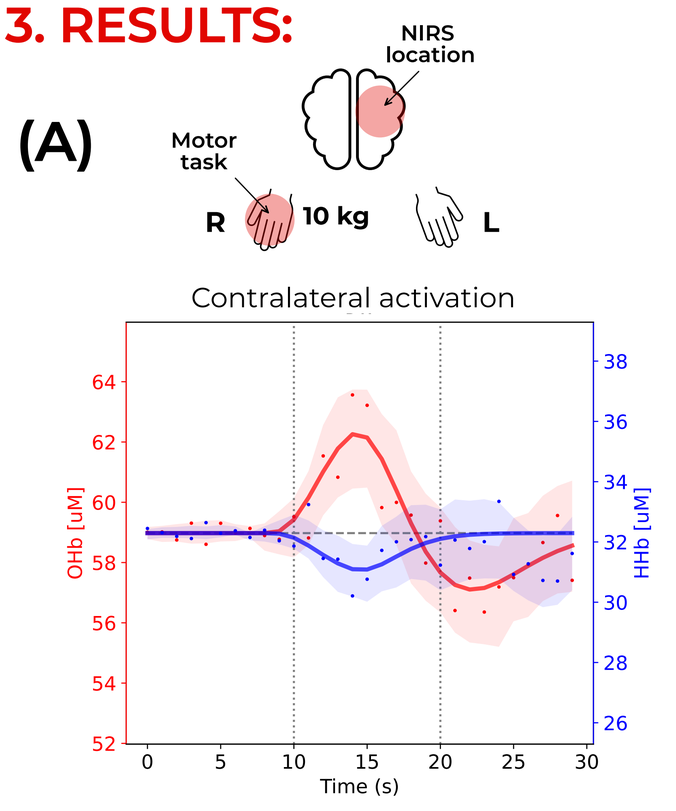
**(B)** TMS only
TMS coil positioned over the probe, single-pulse TMS was delivered over the motor cortex.

**(C)** TMS + functional task
Handgrip task with the TMS coil positioned over the motor cortex and simultaneous single-pulse TMS.

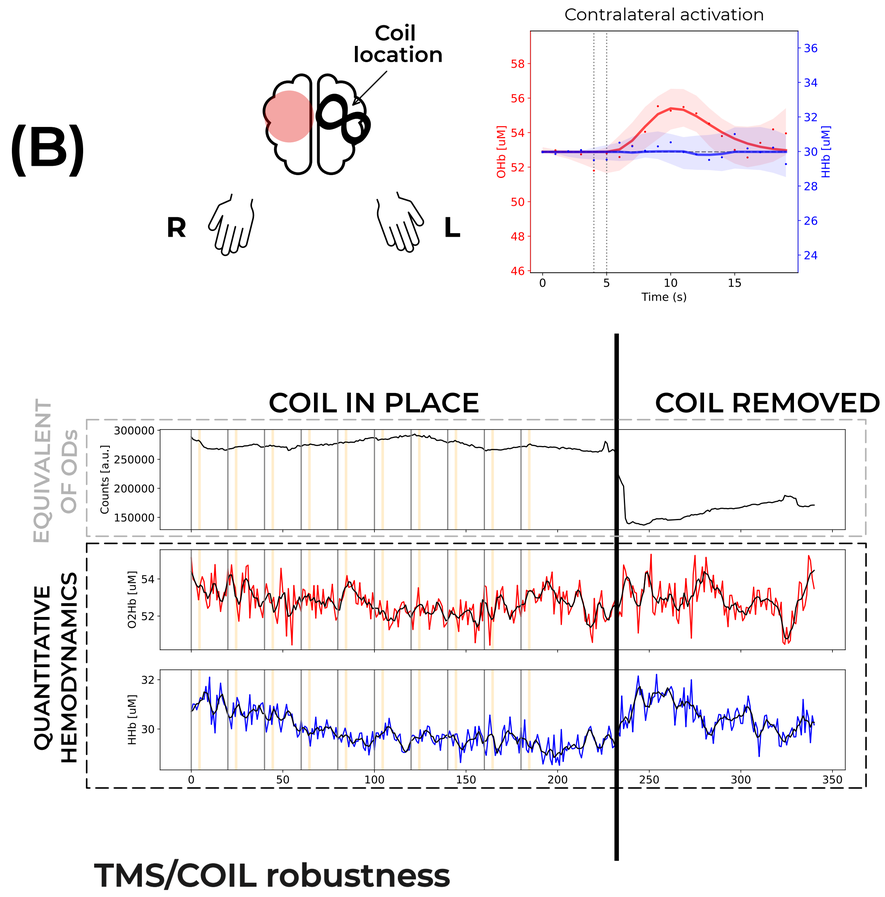
INTERACT!



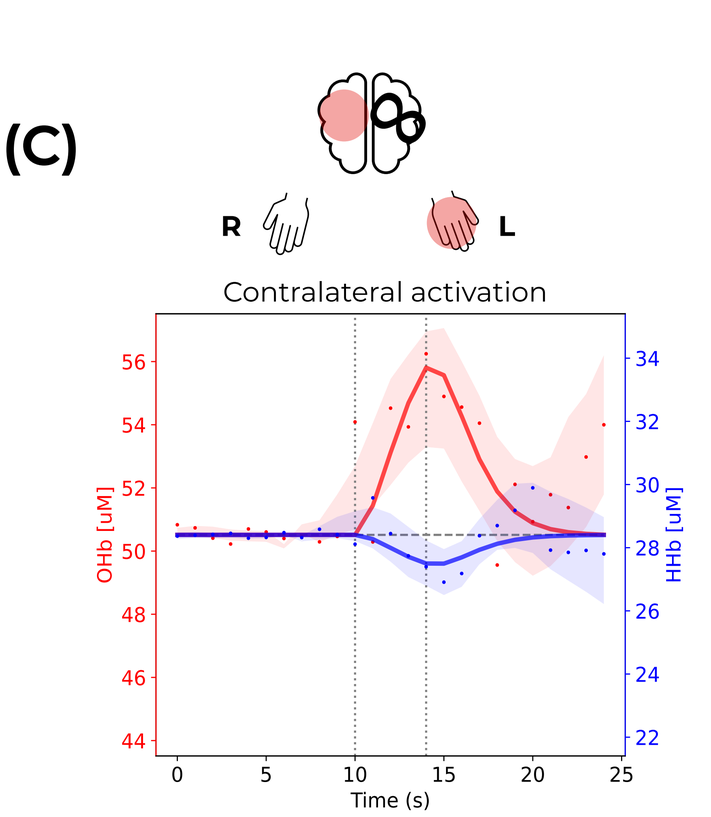

## 3. RESULTS:




**Motor-task validation**
Handgrip tasks performed without the TMS coil produced the expected task-related hemodynamic response functions.




**TMS/COIL robustness**
The coil was removed halfway through the acquisition. Despite the change in photon count rate, the retrieved hemodynamic variables remained stable under adequate signal-to-noise conditions.




**Concurrent TD-NIRS + TMS**
The presence of the optical probe beneath the coil requires an increase of 20% in stimulation intensity.

## 4. CONCLUSION and FUTURE PERSPECTIVES:

TD-NIRS provides quantitative, depth-sensitive hemodynamic information while remaining compatible with concurrent TMS, offering a promising framework for multimodal investigation of cortical excitability and neurovascular responses. Future studies in larger cohorts will be needed to characterize TMS-induced hemodynamic effects and assess the potential of this approach for neurophysiological and clinical neurostimulation applications.

## 5. REFERENCES:

[1] Curtin A. et al, (2019), Front. Neurosci. doi: 10.3389/fnins.2019.00084
[2] Bisio A. , et al., (2025) NeuroImage. doi: 10.1016/j.neuroimage.2025.121432.