NEUROSTIMULAB

neurostimulation laboratory
university milano bicocca

PhD PROGRAM IN NEUROSCIENCE
NEUROSCIENZE
DOTTORATO DI RICERCA

UNIVERSITÀ DEGLI STUDI DI MILANO BICOCCA

OPTIMIZING TDCS PROTOCOLS BY LOOKING FOR THE MOST EFFECTIVE TIMING OF STIMULATION WITH RESPECT TO TASK EXECUTION

Feroldi Sarah[a], Vergallito A.[b], Diani N., Arrigoni E.[a], Pisoni A.[b], Romero Lauro L.J.[b]

[a] *Ph.D. Student in Neuroscience, Department of Medicine and Surgery, University Milano-Bicocca*

[b] *Department of Psychology, University Milano-Bicocca*

XXXI CONGRESSO NAZIONALE SIPF
Siena 9-11 novembre 2023
Museo Santa Maria della Scala

BACKGROUND

- Neurophysiological effects of tDCS on cortical excitability
  - at rest:
    - a-tDCS increased cortical excitability in a widespread network
    - c-tDCS failed to modulate cortical excitability
  - tDCS+task:
    - a-tDCS induced increase in cortical excitability is confined to functionally activated network
    - c-tDCS decreased cortical excitability.

State dependency

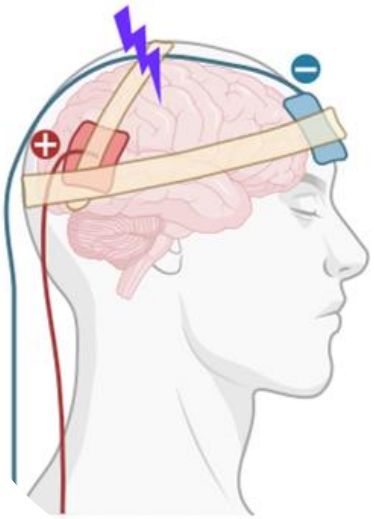
- Studies heterogeneity concerning tDCS + task:
  - priming
  - synergistic
  - consolidator

Bikson & Rahman, 2013; Siebner, et al., 2009; Tatti et al., 2022; Pisoni et al., 2018; Romero Lauro et al., 2014; 2016; Varoli et al., 2018; Vergallito et al., 2023

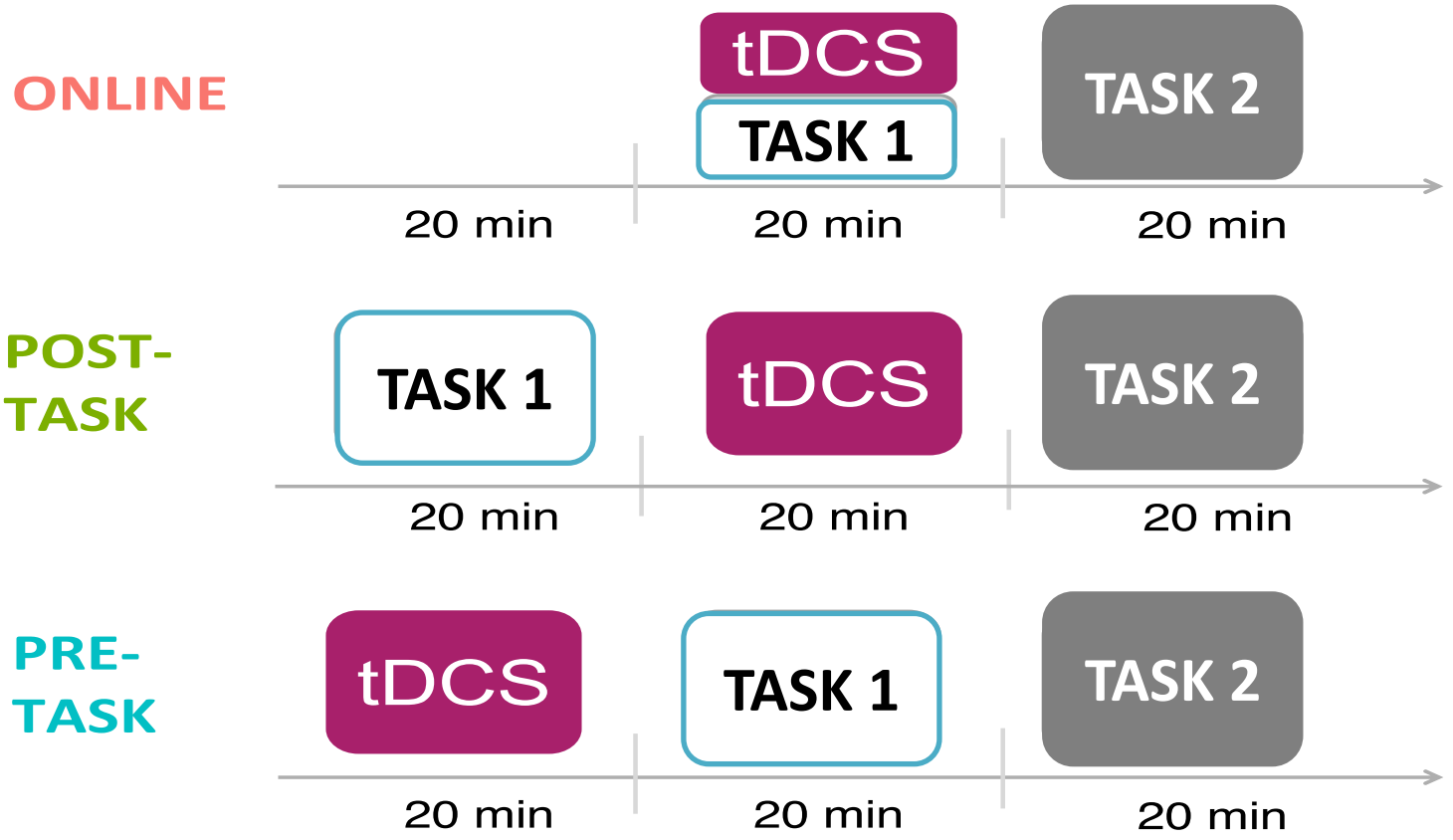
AIM

This study aims to investigate how different coupling of the stimulation induced by tDCS with the endogenous stimulation induced by a concurrent task execution might result in stronger behavioral effects for both polarities.

tDCS device



STUDY DESIGN



SHAM

in one of these configurations, counterbalanced between participants

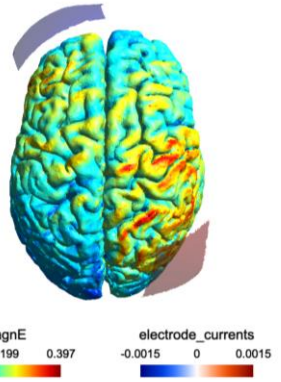
MATERIALS AND METHODS

STUDY 1: ANODAL-tDCS

PARTICIPANTS	28 healthy right-handed (21 F; 7 M)
AGE	22.6 ± 1.9 (range 19 - 27)
EDUCATION	16.5 ± 1.7 (range 13 - 18)

STUDY 2: CATHODAL-tDCS

PARTICIPANTS	14 healthy right-handed (10 F; 4 M)
AGE	27 ± 8.7 (range 19 - 55)
EDUCATION	16.5 ± 2.6 (range 13 - 21)

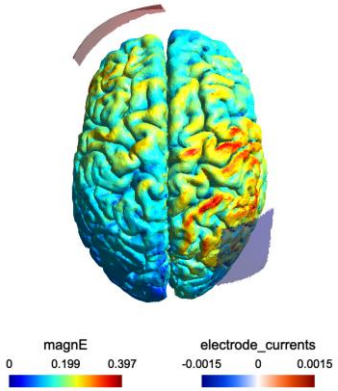


tDCS PARAMETERS:

Target electrode: rPPC (25 cm^2)

Reference electrode: left SO area (35 cm^2)

1.5 mA for 20 minutes



MATERIALS AND METHODS

TASK 1: PCT
POSNER CUEING TASK

3 blocks x 96 trials each

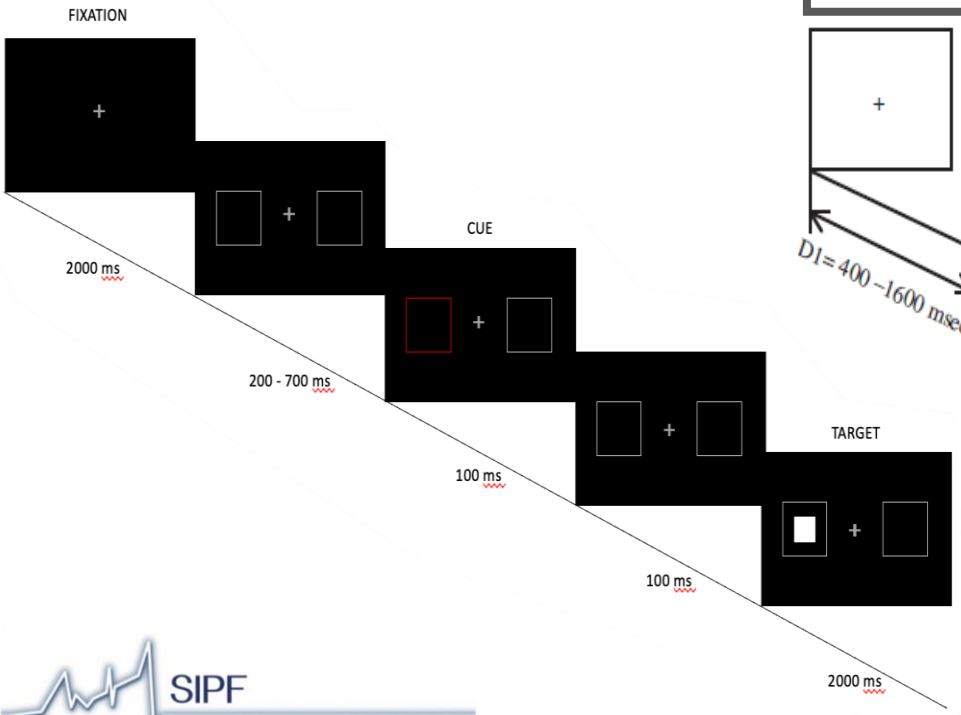
CUE: valid vs. invalid

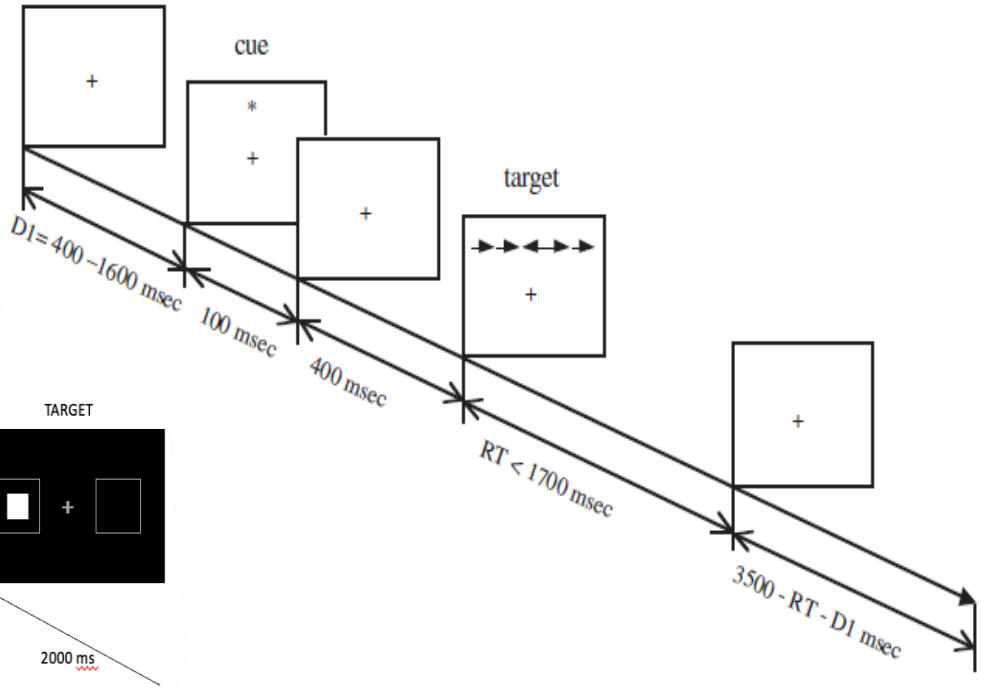
TASK 2: ANT
ATTENTION NETWORK TEST

3 blocks x 96 trials each

CUE: valid, invalid, null, double

TARGET: congruent, incongruent, neutral





www.neurostimulab.it

MATERIALS AND METHODS

Statistical Analysis

- Study 1 and 2 were analyzed separately
- two mixed models (ACC and RTs)
- **fixed effects in ANT: stimulation timing (4 levels), target (3 levels), and cue (4 levels)**
- random effect: subjects' intercept

RESULTS – ATTENTION NETWORK TEST

ACCURACY ~ (stimulation*cue*target) + trial + (1|ID)

STUDY 1: ANODAL-tDCS

↑ for congruent target
($\chi^2(2)= 1216.03$; $p<.001$)

↑ for valid cue ($\chi^2(3)= 16.22$; $p<.01$)

↑ with trial ($\chi^2(1)= 25.65$; $p<.001$)

No main effect of stimulation timing (p=0.34)

Interaction stimulation timing*cue
($\chi^2(9)= 17.36$; $p<.05$)

STUDY 2: CATHODAL-tDCS

↑ for congruent target
($\chi^2(2)= 962.21$; $p<.001$)

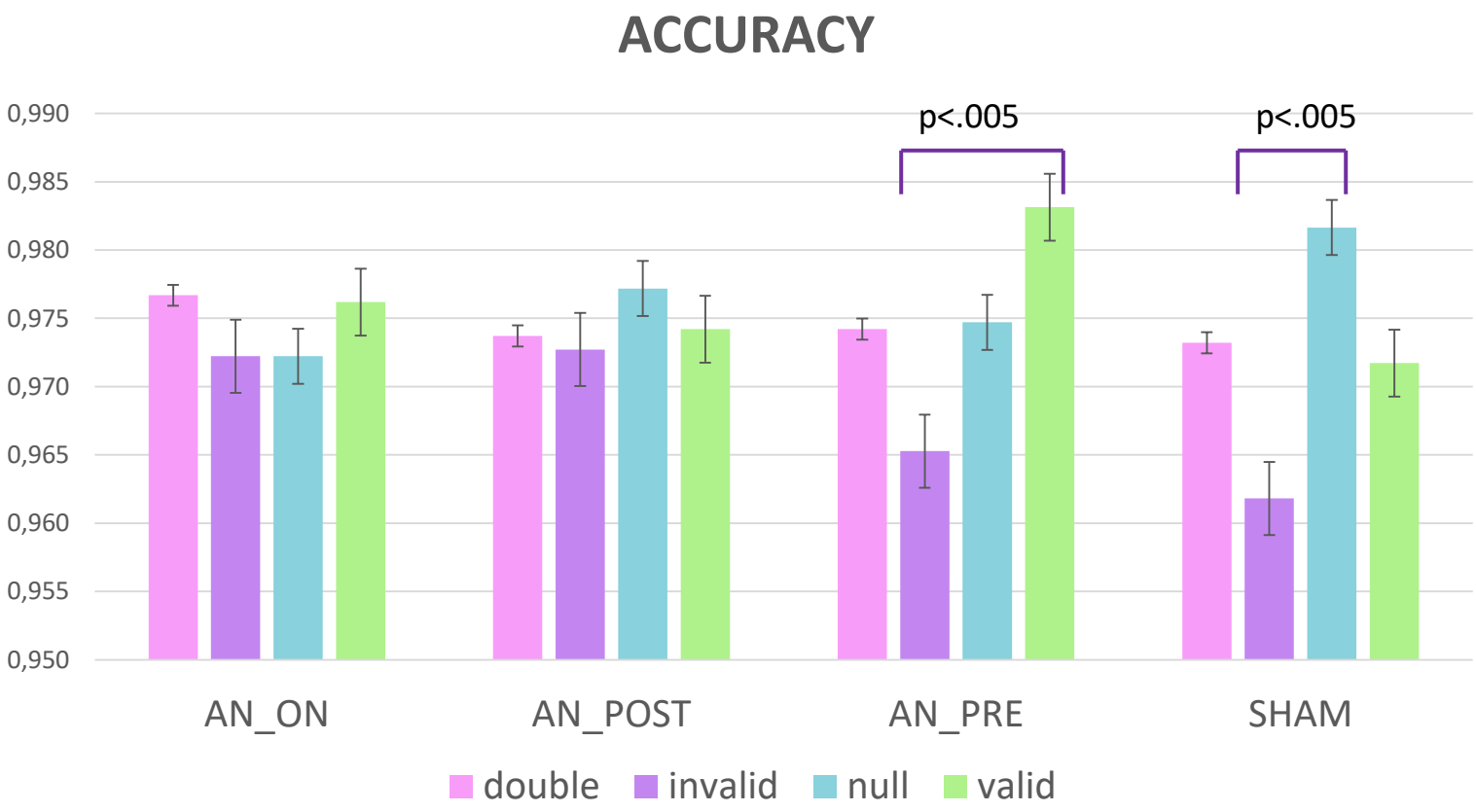
↑ for valid cue ($\chi^2(3)= 39.1$; $p<.01$)

No main effect of trial (p=0.68)

No main effect of stimulation timing (p=0.93)

RESULTS – ATTENTION NETWORK TEST

Interaction stimulation*cue ($\chi^2(9)= 17.36$; $p<.05$)



RESULTS – ATTENTION NETWORK TEST

RTs ~ (stimulation*cue*target) + trial + (1|ID)

STUDY 1: ANODAL-tDCS

Interaction target*cue
($\chi^2(6)= 5.24$; $p<.001$)

↓ for congruent target
($\chi^2(2)= 6594.56$; $p<.001$)

↓ for valid cue ($\chi^2(3)= 933.22$; $p<.001$)

↑ with trial ($\chi^2(1)= 11.33$; $p<.001$)

↑ for stimulation timing
($\chi^2(3)= 39.18$; $p<.001$)

STUDY 2: CATHODAL-tDCS

Interaction target*cue
($\chi^2(6)= 12.8$; $p<.05$)

↓ for congruent target
($\chi^2(2)= 3541.74$; $p<.001$)

↓ for valid cue ($\chi^2(3)= 504.56$; $p<.001$)

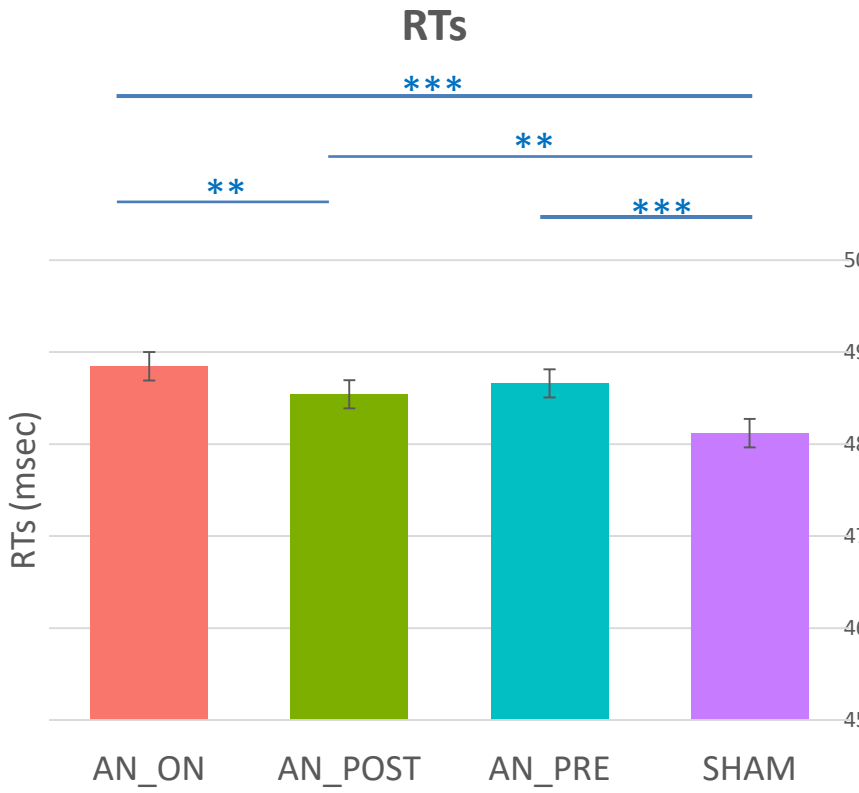
↑ with trial ($\chi^2(1)= 6.92$; $p<.005$)

↑ for stimulation timing
($\chi^2(3)= 52.01$; $p<.001$)

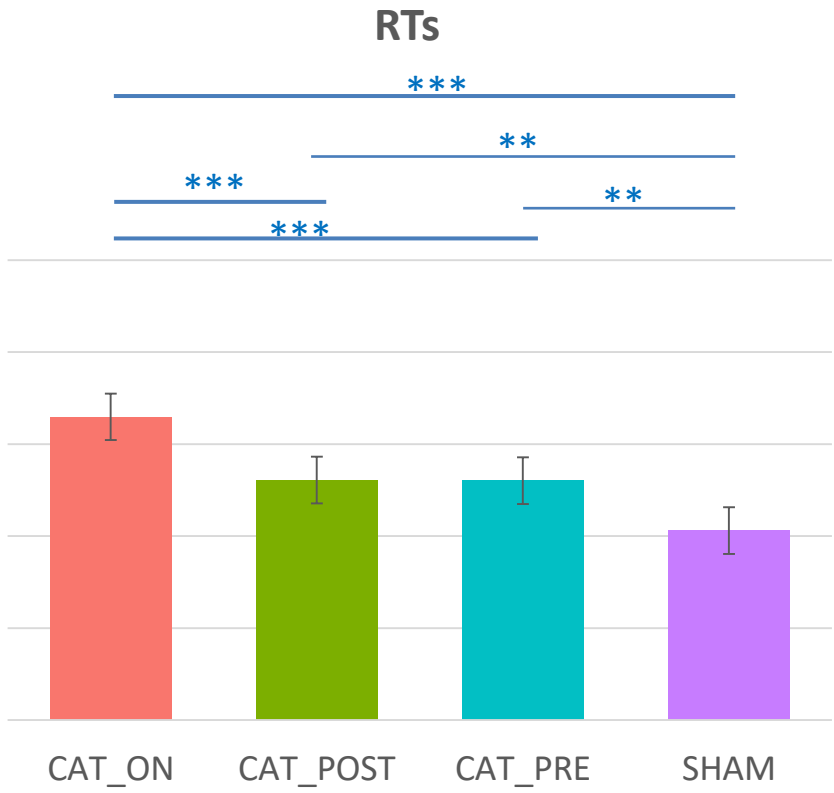
RESULTS – ATTENTION NETWORK TEST

RTs ~ (stimulation*cue*target) + trial + (1|ID)

STUDY 1: ANODAL-tDCS



STUDY 2: CATHODAL-tDCS



www.neurostimulab.it

MATERIALS AND METHODS

Statistical Analysis

- Study 1 and 2 were analyzed separately
- two mixed models (ACC and RTs)
- **fixed effects in PPC: stimulation timing (4 levels) and cue (2 levels)**
- random effect: subjects' intercept

RESULTS – POSNER CUEING TASK

ACCURACY ~ (stimulation*cue) + trial + (1|ID)

STUDY 1: ANODAL-tDCS

↑ for valid cue ($\chi^2(1)= 259.85$; $p<.001$).

↓ with trial ($\chi^2(1)= 6.32$; $p<.05$).

No main effect of stimulation timing ($p=0.30$)

STUDY 2: CATHODAL-tDCS

↑ for valid cue ($\chi^2(1)= 275.59$; $p<.001$)

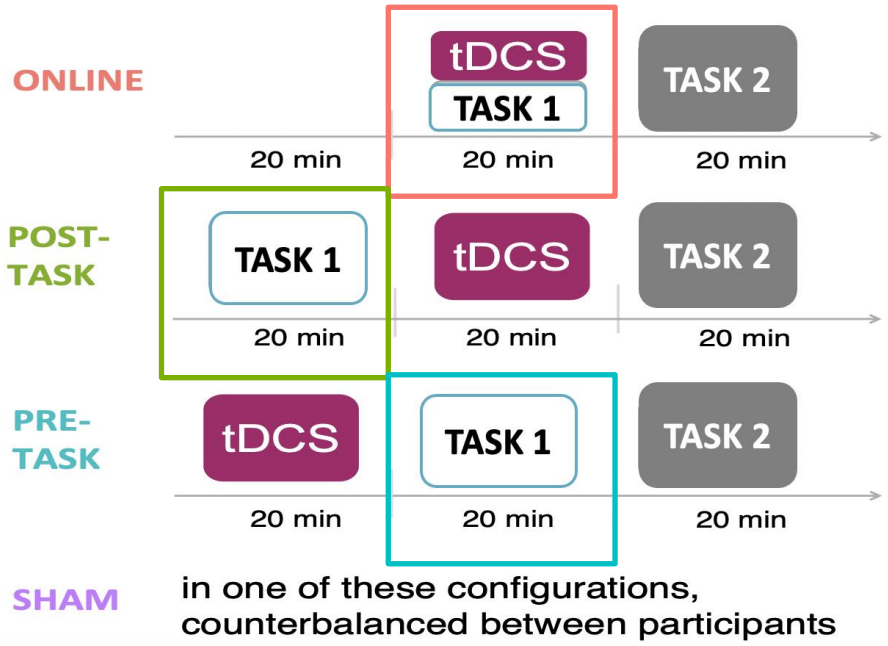
No main effect of trial ($p=0.56$)

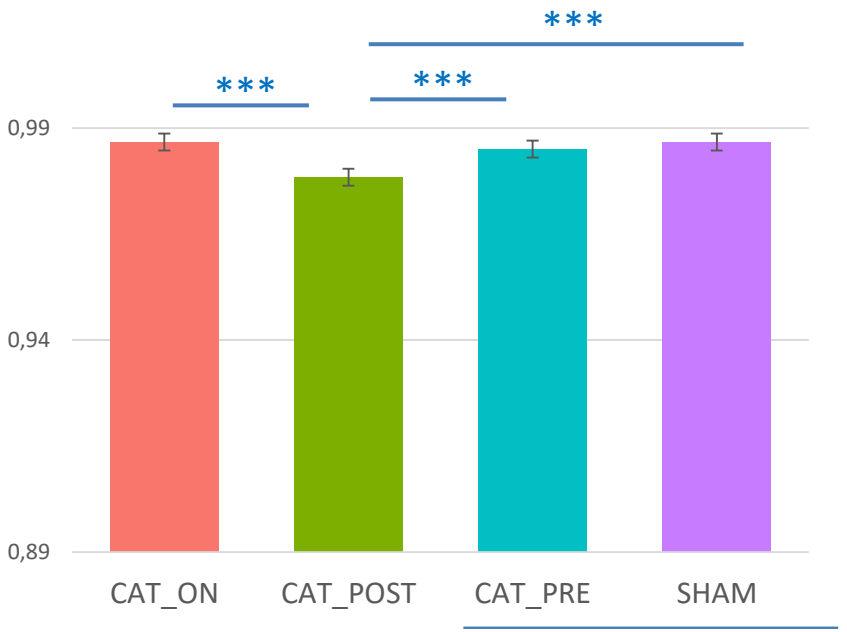
↑ with stimulation ($\chi^2(3)= 11.95$; $p<.005$)

RESULTS – POSNER CUEING TASK

ACCURACY ~ (stimulation*cue) + trial + (1|ID)

STUDY 2: CATHODAL-tDCS





www.neurostimulab.it

SIPF
Società Italiana di Psicofisiologia e Neuroscienze Cognitive

RESULTS – POSNER CUEING TASK

RTs ~ (stimulation*cue) + trial + (1|ID)

STUDY 1: ANODAL-tDCS

↓ for valid cue ($\chi^2(1)= 3652.86$; $p<.001$)

No main effect of trial.

↓ for stimulation timing
($\chi^2(3)= 86.14$; $p<.001$)

STUDY 2: CATHODAL-tDCS

↓ for valid cue ($\chi^2(1)= 3275.09$; $p<.001$)

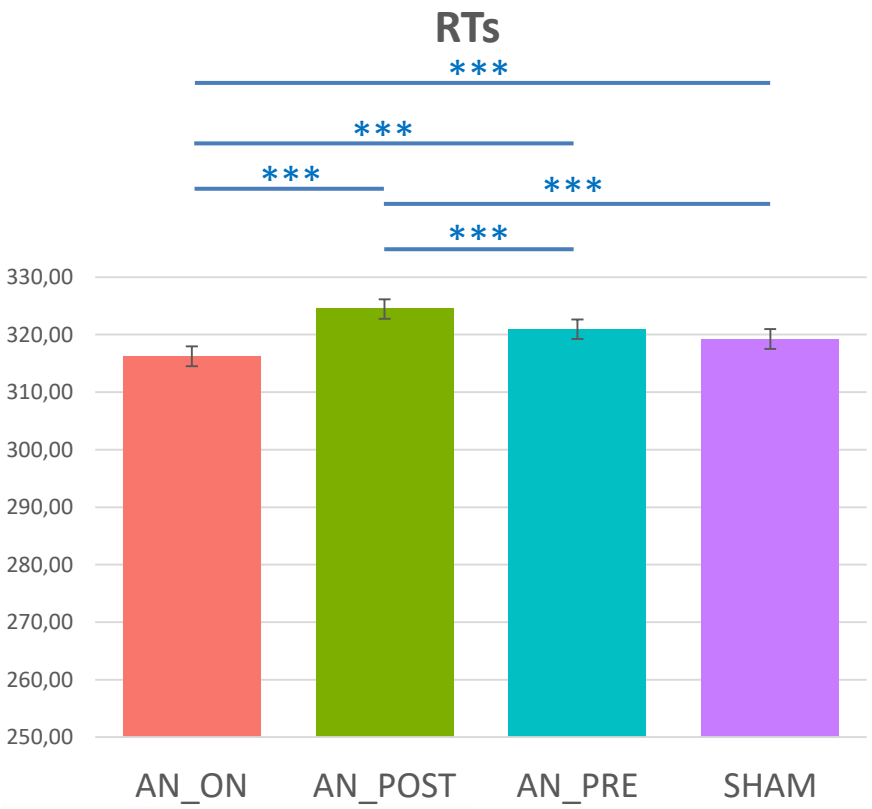
↑ for trial ($\chi^2(1)= 17.81$; $p<.001$)

↑ for stimulation timing
($\chi^2(3)= 17.38$; $p<.001$)

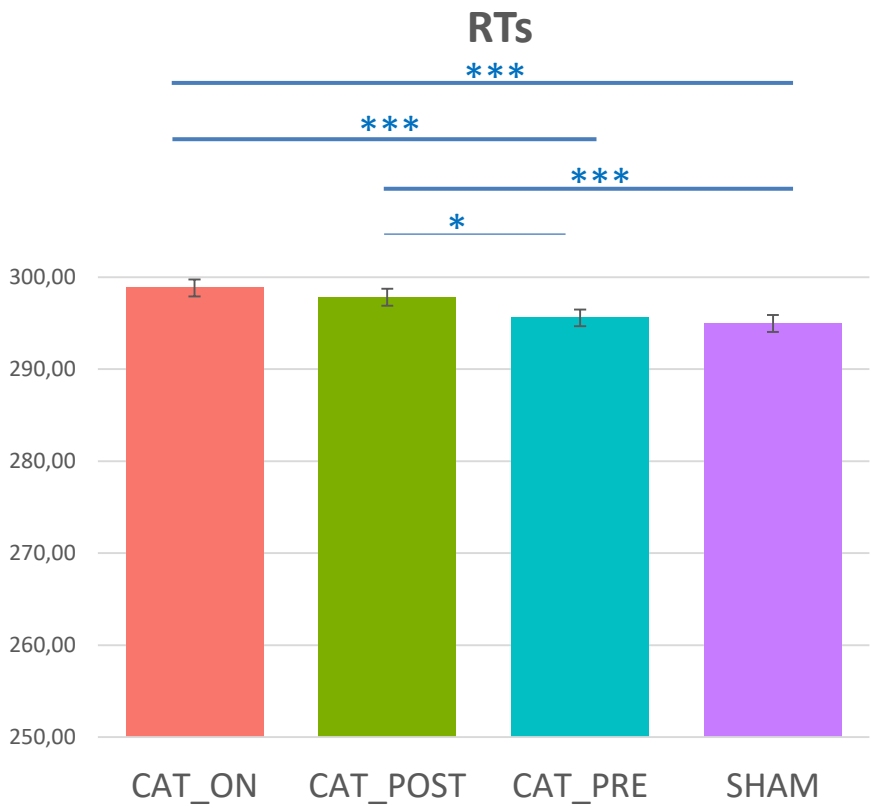
RESULTS – POSNER CUEING TASK

RTs ~ (stimulation*cue) + trial + (1|ID)

STUDY 1: ANODAL-tDCS



STUDY 2: CATHODAL-tDCS



www.neurostimulab.it

GENERAL CONCLUSION

Behavioral effects depend on the stimulation timing.

Greater modulation in online condition or after preactivating the network.
Our results further confirm the **state dependency** of tDCS' behavioral effect.

- Timing matters

The polarity-dependent effect emerges only in online conditions.

- Obtaining more evidence could pave the way to optimize tDCS use in clinical protocols.

NEUROSTIMULAB

neurostimulation laboratory
university milano bicocca

UNIVERSITÀ DEGLI STUDI DI MILANO BICOCCA

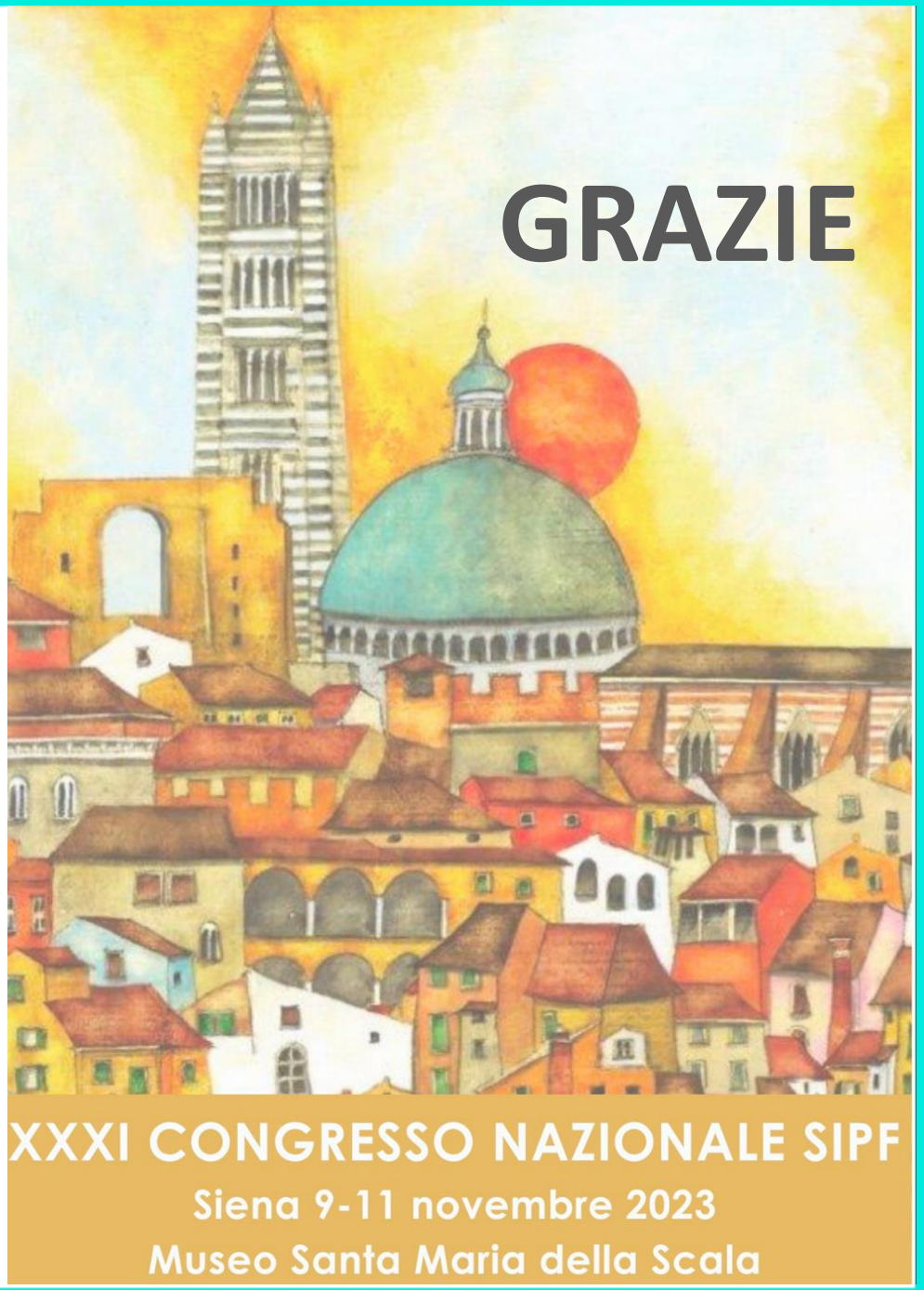
PhD PROGRAM IN EUROSCIENCE
EUROSCIENZE

Eleonora Arrigoni

Alberto Pisoni

Alessandra Vergallito

Leonor Romero Lauro



www.neurostimulab.it

NEUROSTIMULAB

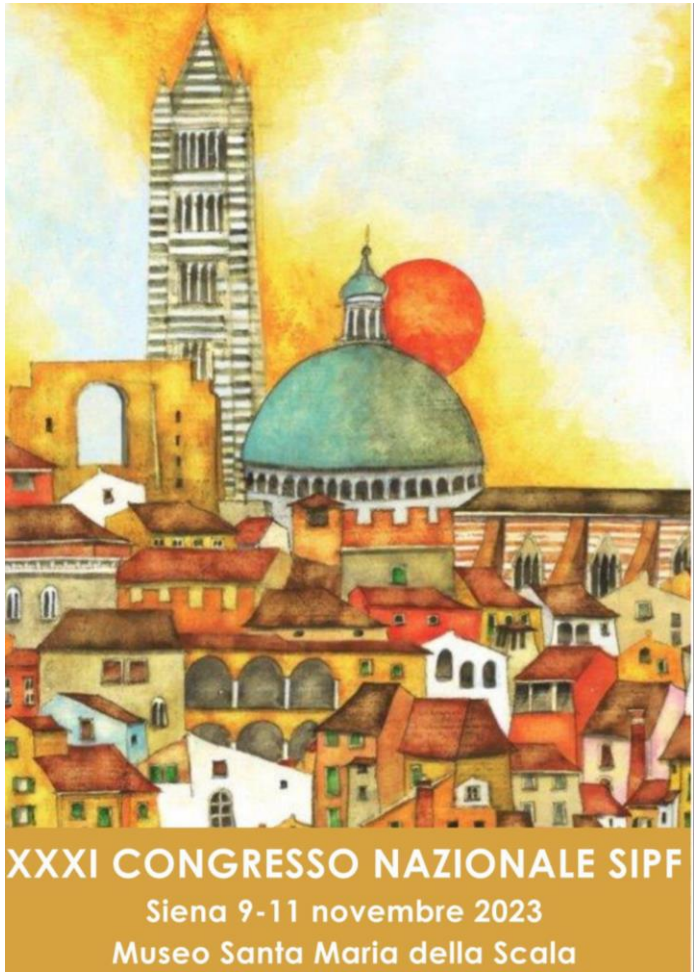
neurostimulation laboratory
university milano bicocca

UNIVERSITÀ DEGLI STUDI DI MILANO BICOCCA

PHD PROGRAM IN EUROSCIENCE

EUROSCIENZE

SLIDE AGGIUNTIVE



ABSTRACT

- Previous studies from our group showed how the neurophysiological effects of tDCS depend on the background activity of the stimulated area: at rest anodal tDCS increased cortical excitability in a widespread network (Romero Lauro et al., 2014; 2016), while participants' involvement in a task during tDCS restricted such increment along the functionally activated network (Pisoni et al., 2018).
- This study aims at investigating how different coupling of the stimulation induced by tDCS with the endogenous stimulation induced by a concurrent task execution might result in stronger behavioral effects.
- We applied anodal tDCS for 20 minutes to the right posterior parietal cortex before, after, or during a visuospatial attention task (Posner task, PT) to find the most effective coupling between stimulation and task execution to induce greater changes in participants' performance on a second visuospatial task (Attention Network Task, ANT).
- This resulted in a within-subject study in which 26 healthy adults participated in four experimental sessions, one sham and three anodal, counterbalanced between participants.
- Statistical analyses were carried out using a mixed-model regression inserting accuracy and reaction times (RTs) as dependent variables and the subjects' intercept as a random factor.
- In line with previous literature, participants were more accurate and faster for congruent targets or valid cues.
- We found an interaction between stimulation and target condition ($\chi^2(6)= 12.31$; $p=.055$): in particular, stimulation applied after PT improved accuracy when the target is neutral in the ANT, compared to online stimulation ($p<.05$).
- Stimulation had a main effect on RTs ($\chi^2(3)= 56,48$; $p<.001$), and, interestingly, the stimulation both during-PT and pre-PT resulted in prolonged RTs in the ANT compared to post-PT and sham conditions ($p<.05$).
- Our preliminary results further confirm the dependence of anodal tDCS behavioral effect on the background activity of the targeted brain area, showing an advantage of pre-activating the targeted brain area with a similar task before the stimulation compared to not pre-activate.

BACKGROUND

- Several studies converge in suggesting that tDCS effects might depend on the background activity of the stimulated area [1, 2, 3].

- Nevertheless, studies are typically heterogeneous considering the coupling of brain stimulation and cognitive tasks, sometimes delivering tDCS before the task (as priming), sometimes during (as synergistic), and sometimes after (as consolidator) [4].

- Previous studies from our group showed how the neurophysiological effects of tDCS depend on the background activity of the stimulated area: at rest anodal tDCS increased cortical excitability in a widespread network (Romero Lauro et al., 2014; 2016), while participants' involvement in a task during tDCS restricted such increment along the functionally activated network (Pisoni et al., 2018).

[1] Bikson & Rahman, 2013; [2] Pisoni et al., 2018; [3] Siebner, et al., 2009; [4] Tatti et al., 2022.