Sensorimotor processing of numerical information: a functional near infrared spectroscopy (fNIRS) study

Mariagrazia Ranzini [1]*, Sabrina Brigadoi [2]*, Yeliz Dinç[1], Pietro Scatturin[2], Antonino Vallesi[3], Carlo Semenza[3], Umberto Castiello[1], Marco Zorzi[1,4], Simone Cutini[2]

*These authors contributed equally to this work

[1] Department of General Psychology (DPG), University of Padova, Italy
[2] Department of Developmental Psychology and Socialisation (DPSS), University of Padova, Italy
[3] Department of Neuroscience (DNS), University of Padova, Italy
[4] IRCCS San Camillo Hospital, Venice-Lido, Italy

mariagrazia.ranzini@unipd.it

Background

Previous studies support the idea that sensorimotor processes contribute to the development of mental representations of numerical magnitude [1-3].
In a recent meta-analysis of neuroimaging studies, we have shown that number magnitude comparison and hand grasping share a partially overlapping neural substrate [4].

Overlapping brain regions concern the superior parietal lobules (SPL) in and around the intraparietal sulcus bilaterally (IPS), the supplementary motor area (SMA), and the left precentral gyrus (left PCG).
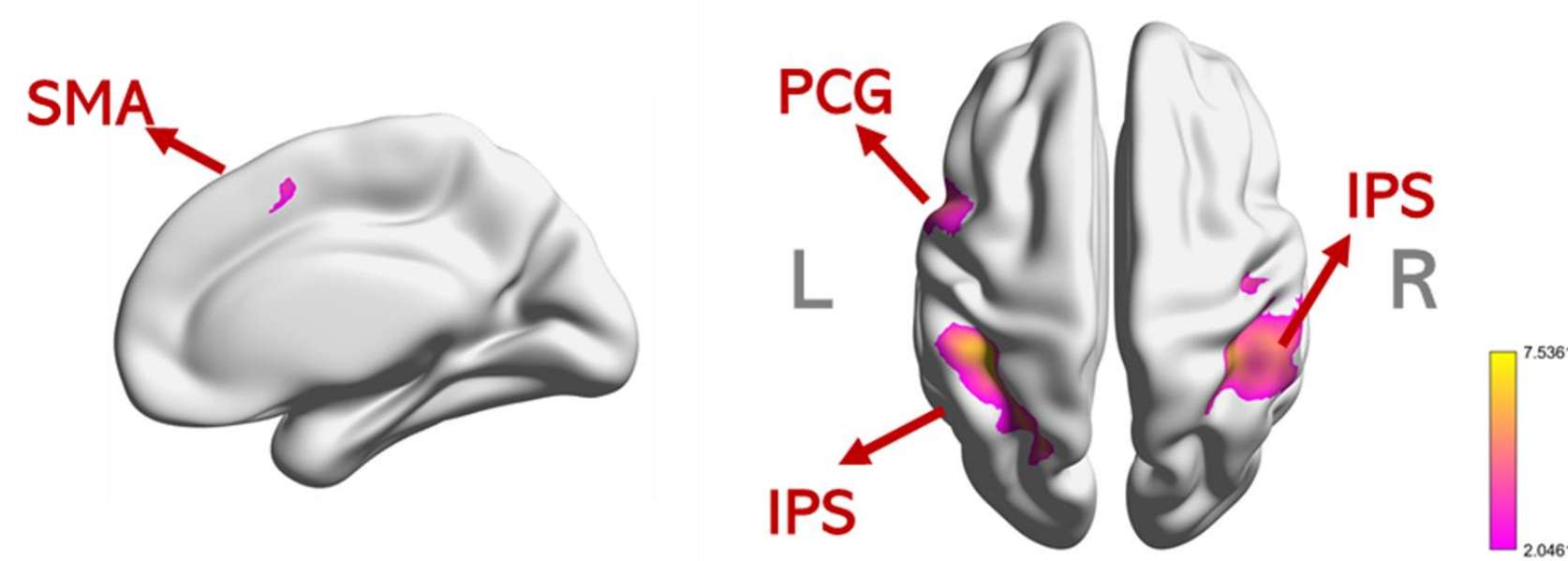
Aim of the Study

In this study we use fNIRS to investigate the activity of cortical areas associated with hand grasping and number processing.
As compared to other neuroimaging techniques, fNIRS is less sensitive to movement artefacts, making it suitable for investigating neural activity during motor tasks.

We expect to observe activity during both numerical magnitude processing and grasping from channels over the IPS, the left PCG, and the SMA.
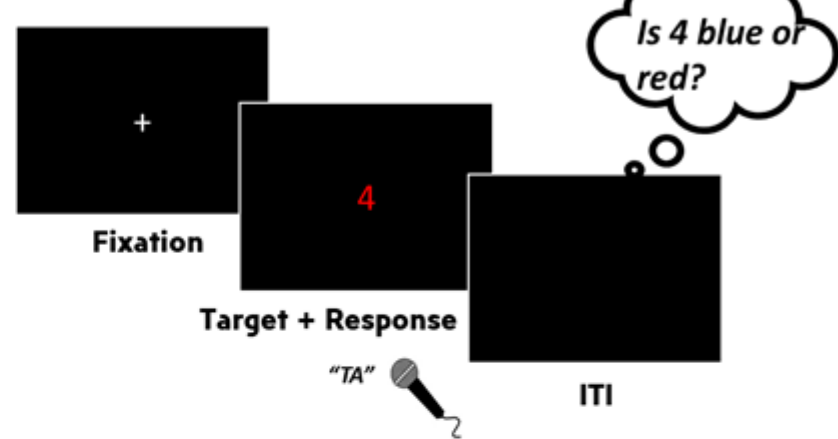
Method

Materials and procedure: event-related design. Four tasks: color detection (n. trials = 32), number comparison (n. trials = 64), hand squeeze (n. trials = 32), hand grasp (n. trials = 32).
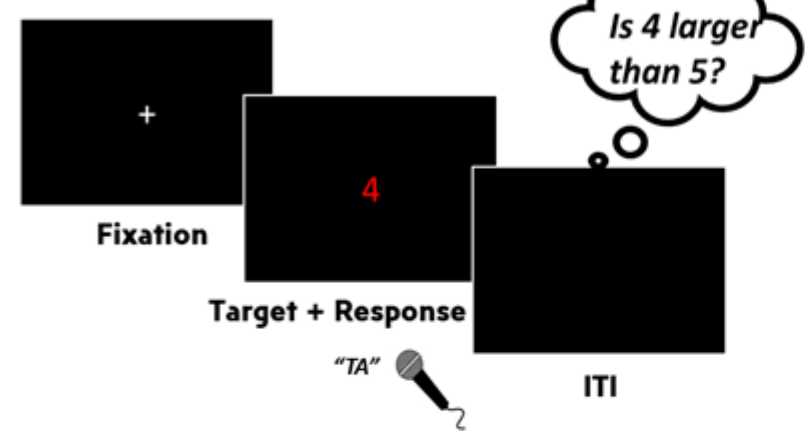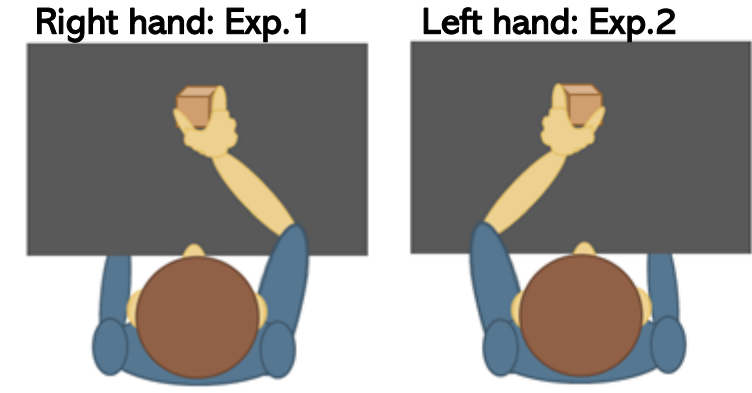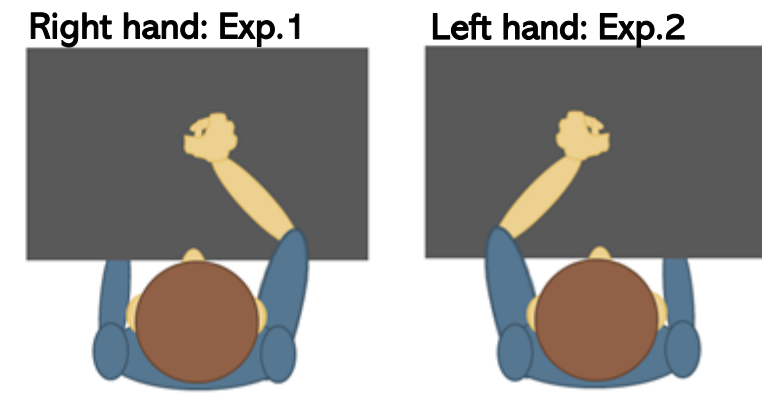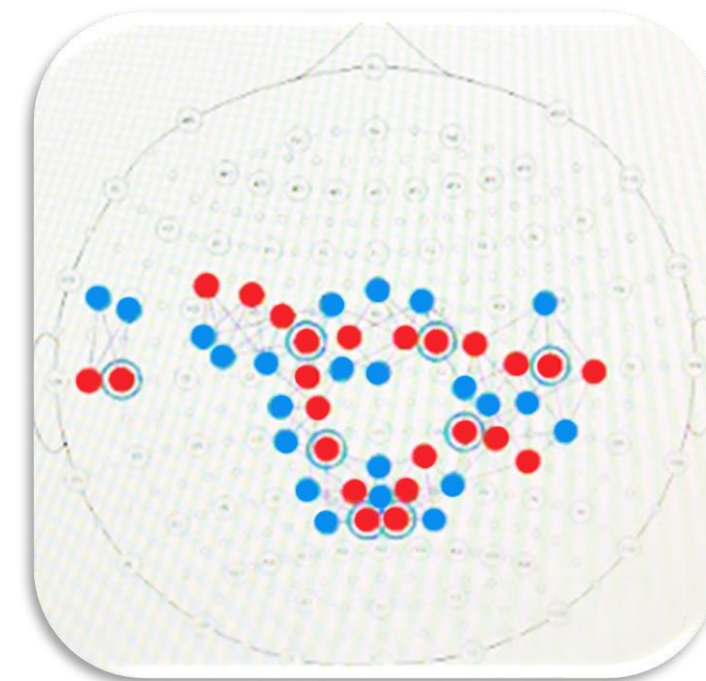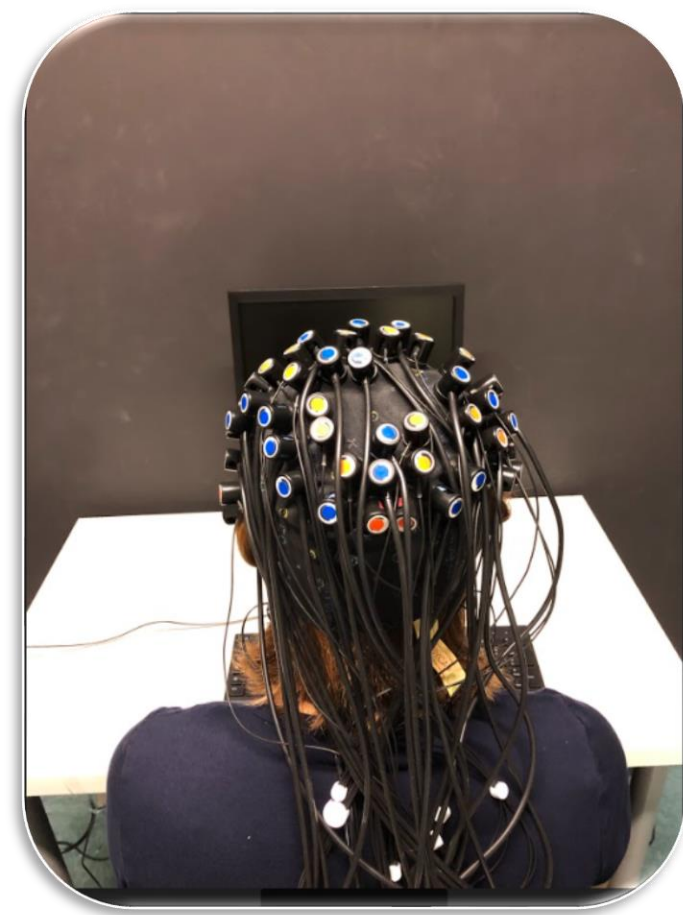

Participants: 44 right-handed healthy adults, mean age=22y/o, 31 F (Exp. 1: N=30; Exp. 2: N=14)

Probe placement: fronto-parietal array covering hand grasping and number networks from [4] and over a control region (left anterior temporal lobe)


106 Channels: 24 sources, 23 detectors, and 8 short-separation (SS) channels
System: Nirscout - Nirx

Preprocessing and analyses of fNIRS data

Data preprocessing:
- ✓ motion correction: Wavelet transformation;
- ✓ Motion artifact: amplitude change > .5, SD > 12;
- ✓ Low-pass filtering: .5 Hz;
- ✓ OD to concentration conversion;
- ✓ Exclusion of data from trials with incorrect responses;
- ✓ GLM with SS channels regression (greatest correlation);

fNIRS data were preprocessed with Homer3 (v1.32.3).
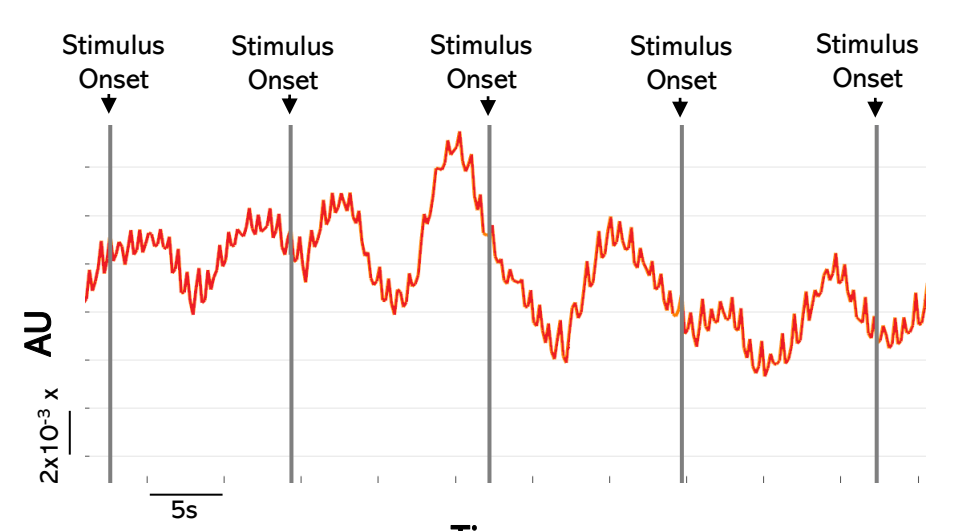
Data analyses:
- ✓ Active channels were defined as channels showing significant hemodynamic response compared to baseline for both ΔHbO and ΔHbR (FDR correction for multiple comparisons);
- ✓ The spatial distribution of active channels was compared between conditions.

Behavioural results

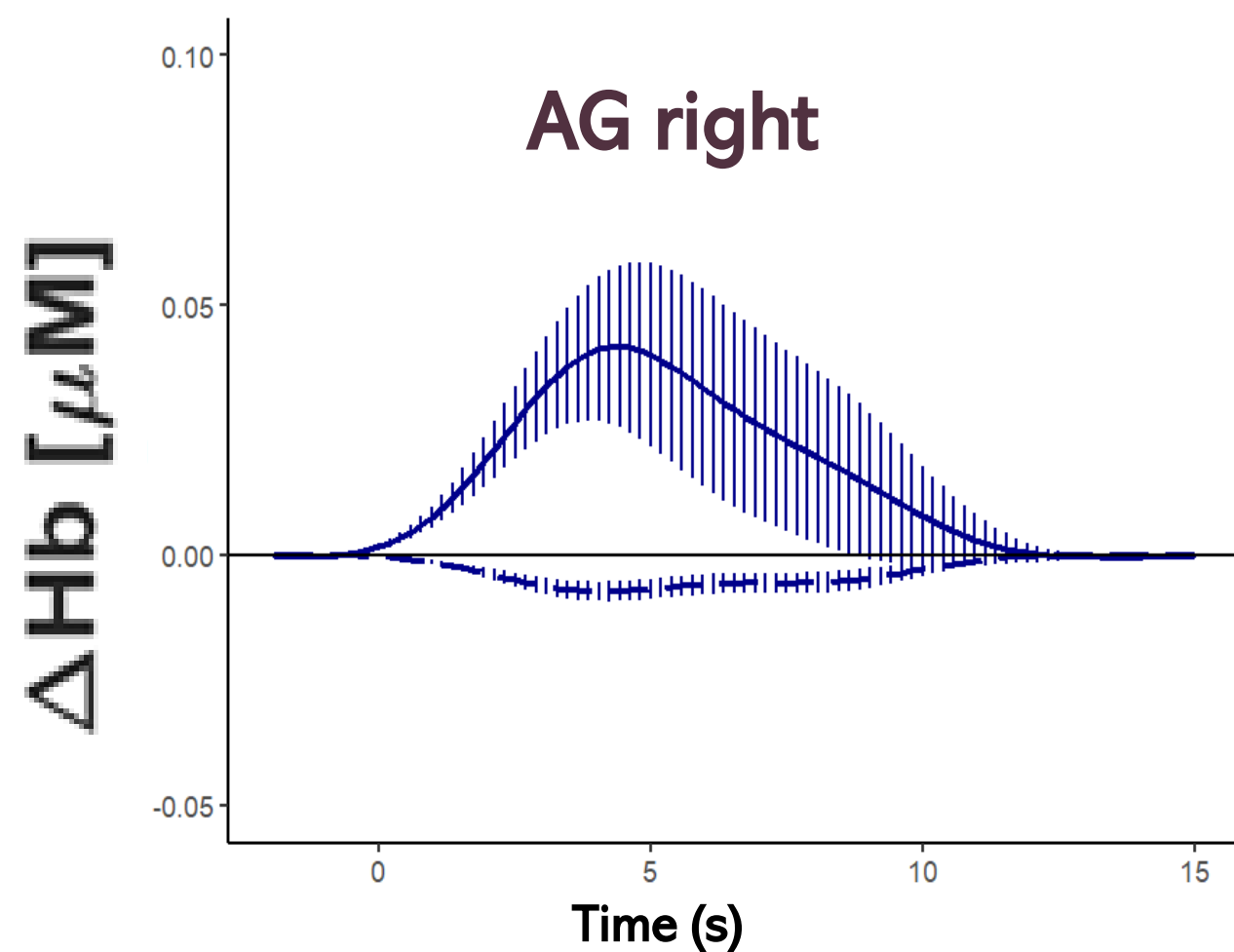Number comparison and color detection:
- ✓ Accuracy in both tasks was very high (>95%).
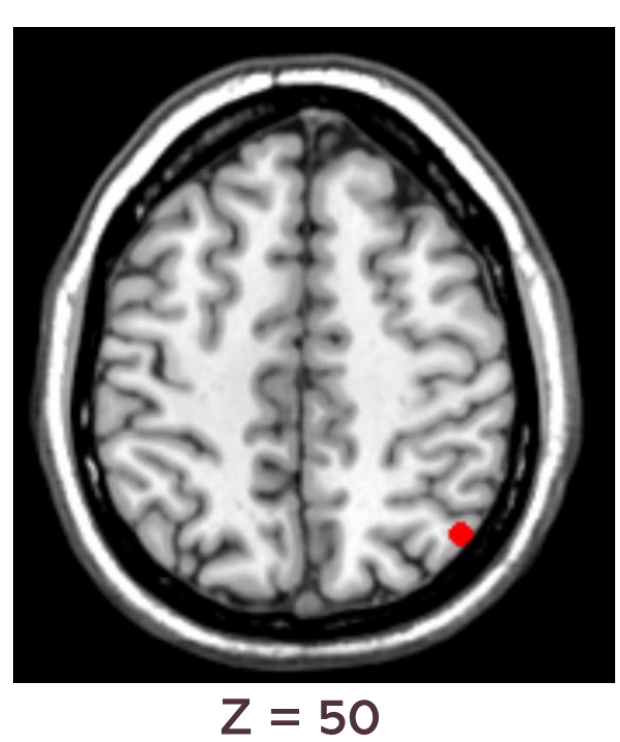
Calculation abilities:

At the end of the session without fNIRS recording, participants executed calculation tasks including mental calculation (24 trials: addition, subtraction).
- ✓ Accuracy was above chance level (76% correct, SD=13, p<.001).

fNIRS results

Each channel is represented as a connection line, and it accounts for significant activity of the area in and around the light trajectory.

Channels over left and right SPL, the left PCG, and right precuneus were significantly active during both number comparison and grasping.

Activity during both number comparison and grasping

SPL right   PCG left   Precuneus right   SPL left
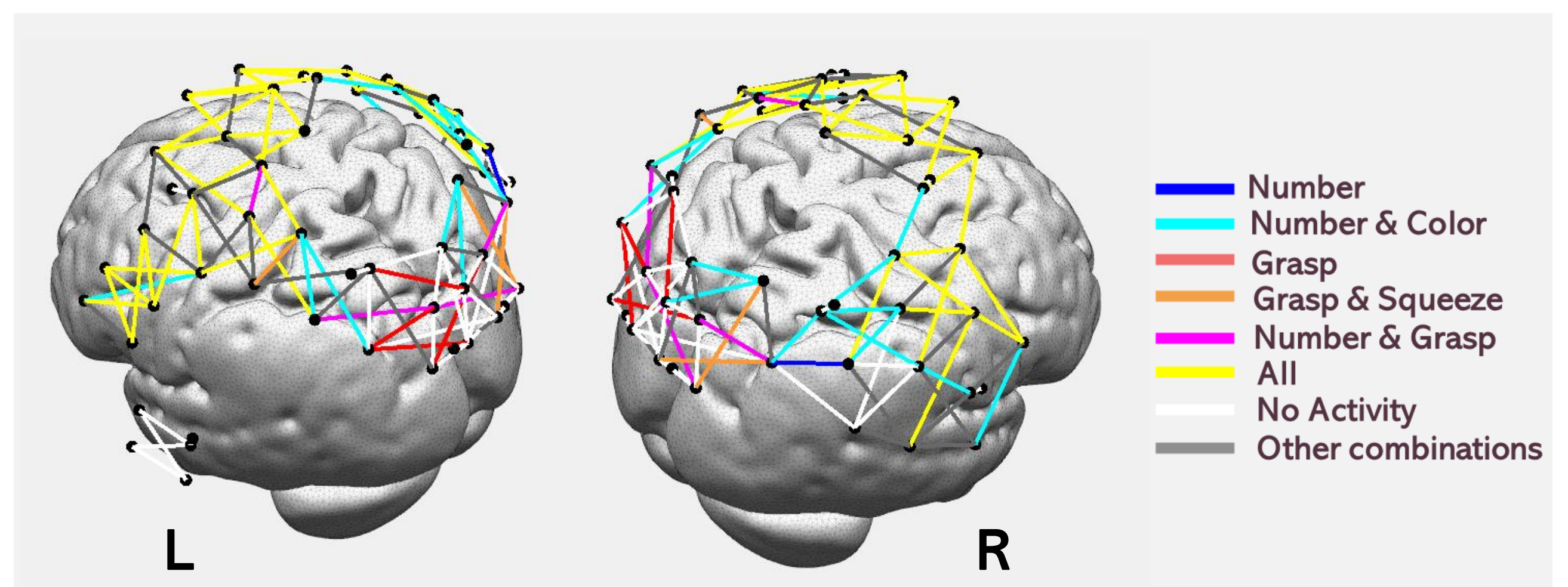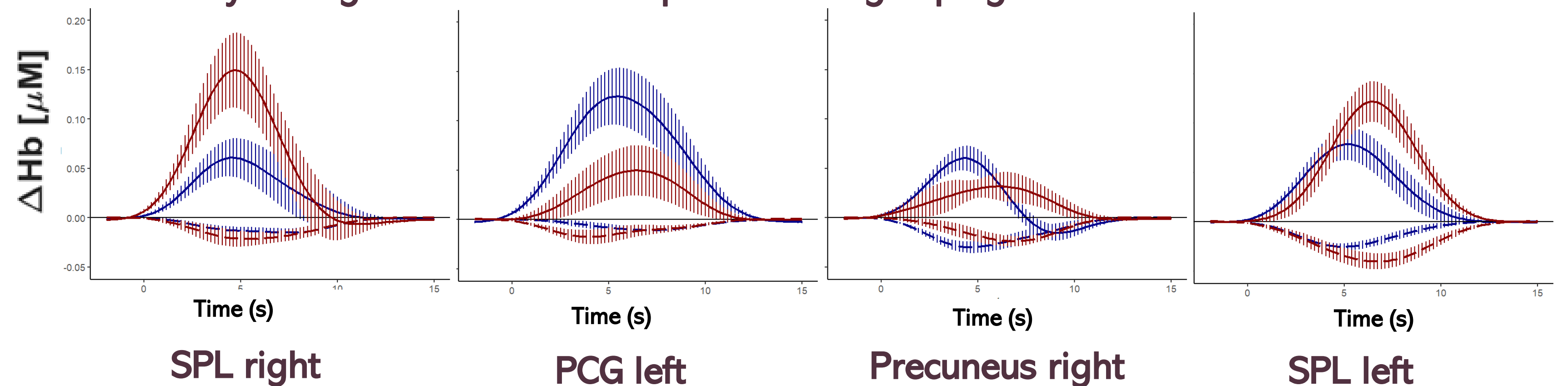
Number-specific cerebral activity

AG right

In this channel, cerebral activity during number comparison was not significantly correlated with the performance in mental calculation.

Z = 50

Conclusions

- ✓ From these preliminary findings we can highlight both common and specific neural activity associated with hand action and number processing, confirming previous observations [4];
- ✓ The analyses of data from experiment 1 had shown activity over the right parietal area nearby the angular gyrus correlating with performance in mental calculation;
- ✓ Considering data from both experiments allowed confirming number specific activity over the right parietal area, however not correlating with arithmetical performance.
- ✓ Further analyses will investigate the contribution of performing motor tasks with the left or right hand on these preliminary results.

References. [1] Fischer, M. H. (2012). Cognitive processing, 13(1), 161-164. [2] Andres, M., et al. (2008). Cortex, 44(4), 414-419. [3] Ranzini, M., et al. (2022). PLOS ONE, 17(6), e0269557. [4] Ranzini, M., et al. (2022). Cortex, 148, 31-67.