Symbolic number, hand reach and grasp: common and number-specific brain areas

Mariagrazia Ranzini

Marie Curie Fellow

Department of General Psychology (DPG)
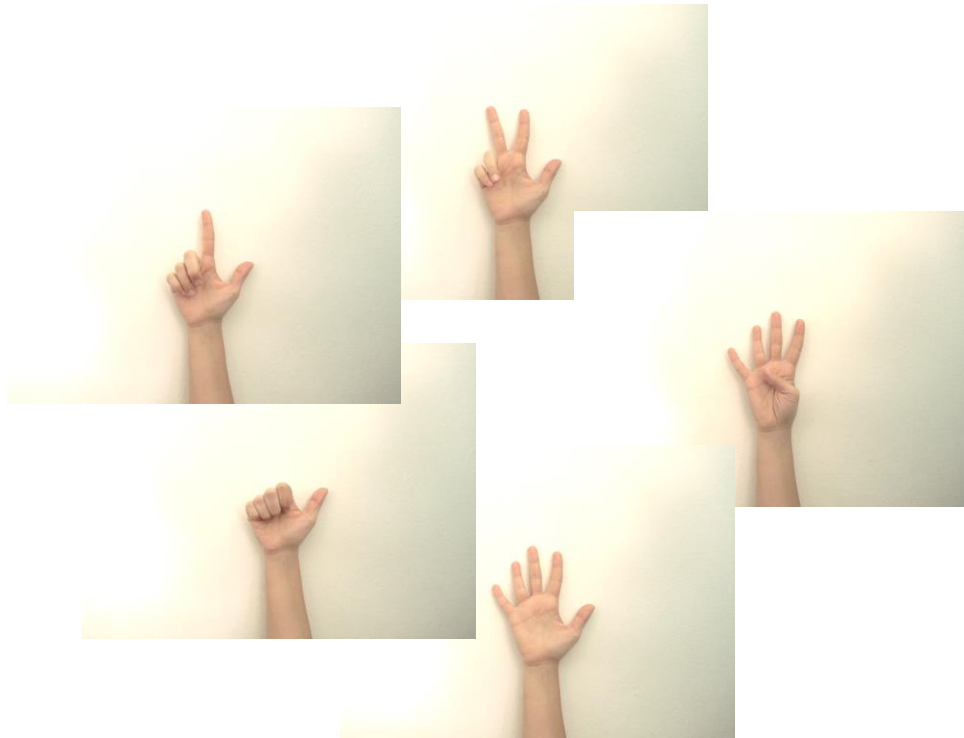
University of Padua (Italy)

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Grasping and Reaching in Number Processing
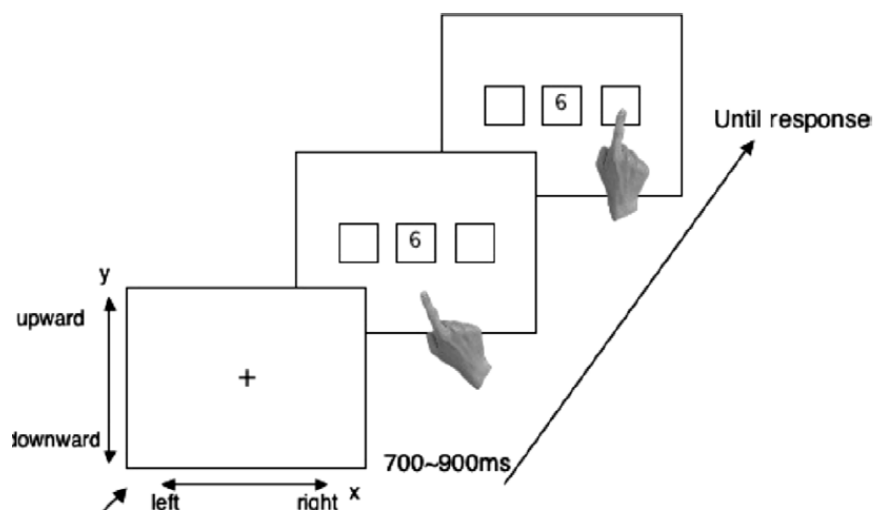
Background: numbers and the hands

Finger counting

Number-hand action interactions

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Background: numbers and the hands
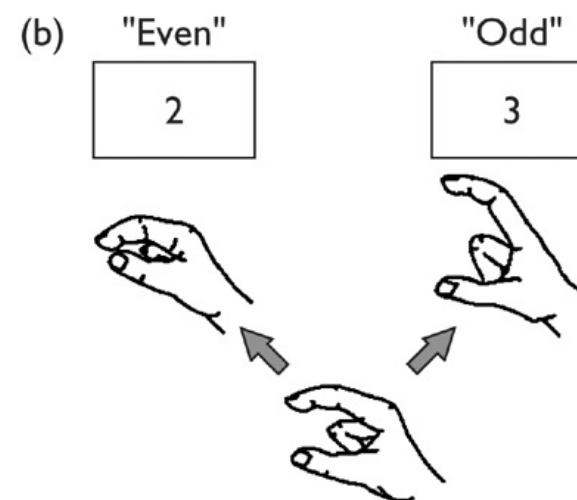
Effects of number on hand action

Numbers & reaching

Song, & Nakayama, 2008

→ See also: Gianelli et al. 2012; Girelli et al. 2016; Rugani et al. 2017 ...
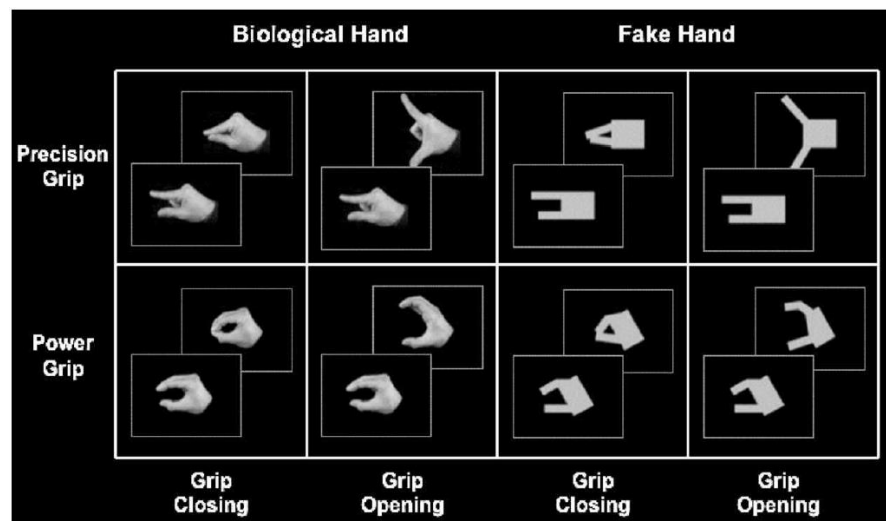
Numbers & grasping

Andres et al., 2004

→ See also: Andres et al., 2008; Badets et al., 2007; Moretto & Di Pellegrino, 2008, De Carli & al. 2022 ...

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Background: numbers and the hands

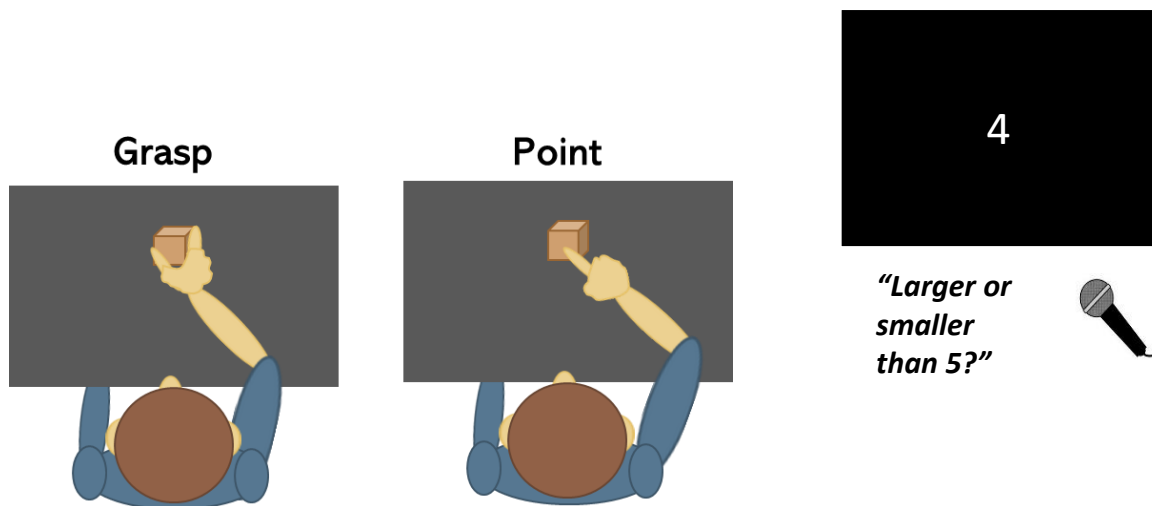## Effects of hand action on number processing

Observing grasping & numbers

Badets & Pesenti, 2010

→ See also: Badets & Pesenti, 2011; Badets et al., 2012; Ranzini et al., 2011 …
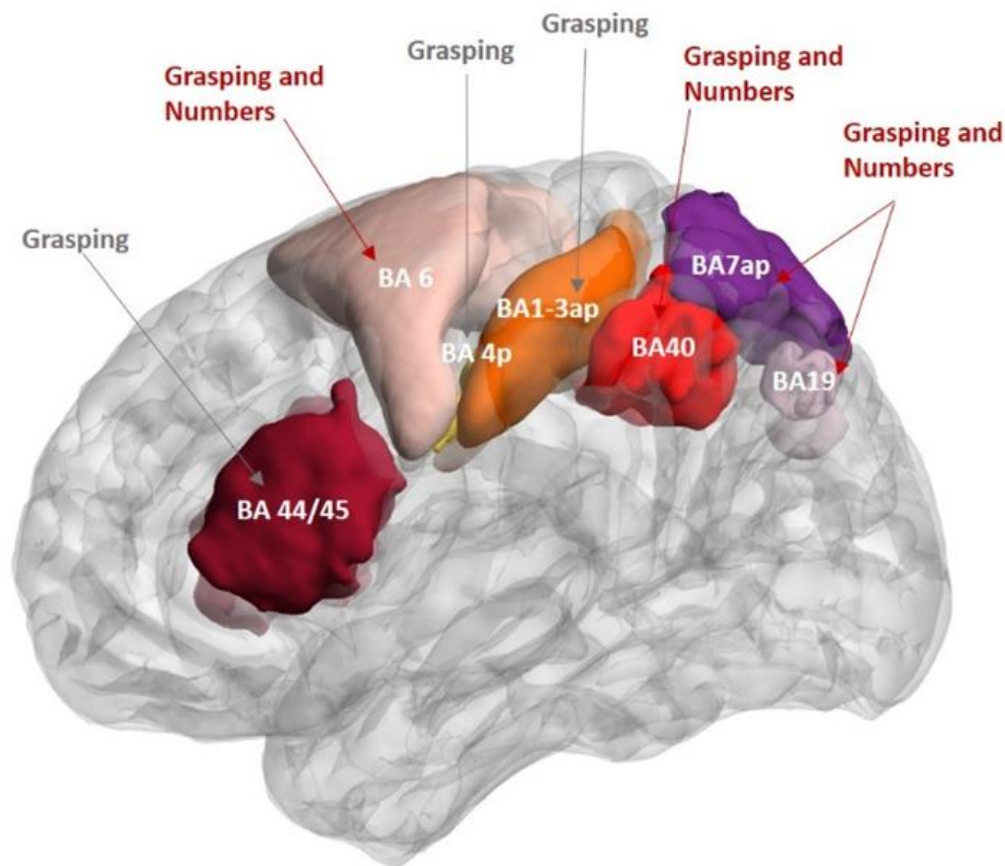
Executing hand action & numbers

"Larger or smaller than 5?"

Ranzini et al., 2022

→ See also: Geers et al., 2021; Ranzini et al. 2011 …

Background: numbers and the hands

Grasping and Numbers

Grasping

Grasping

Grasping

Grasping and Numbers

Grasping and Numbers

Grasping

BA 6

BA1-3ap

BA 4p

BA40

BA7ap

BA19

BA 44/45

Hand action and number processing rely on similar **fronto-parietal brain regions** (Gerstmann, 1940; Dehaene et al., 2003; Simon et al., 2002; Simon et al., 2004)

Few studies have investigated the **neural correlates of the interactions between number processing and hand actions** (e.g., Andres et al., 2012; Simon et al., 2002).

Aim and method of the study

Do number processing, and processes related to hand action involve **common brain areas**?
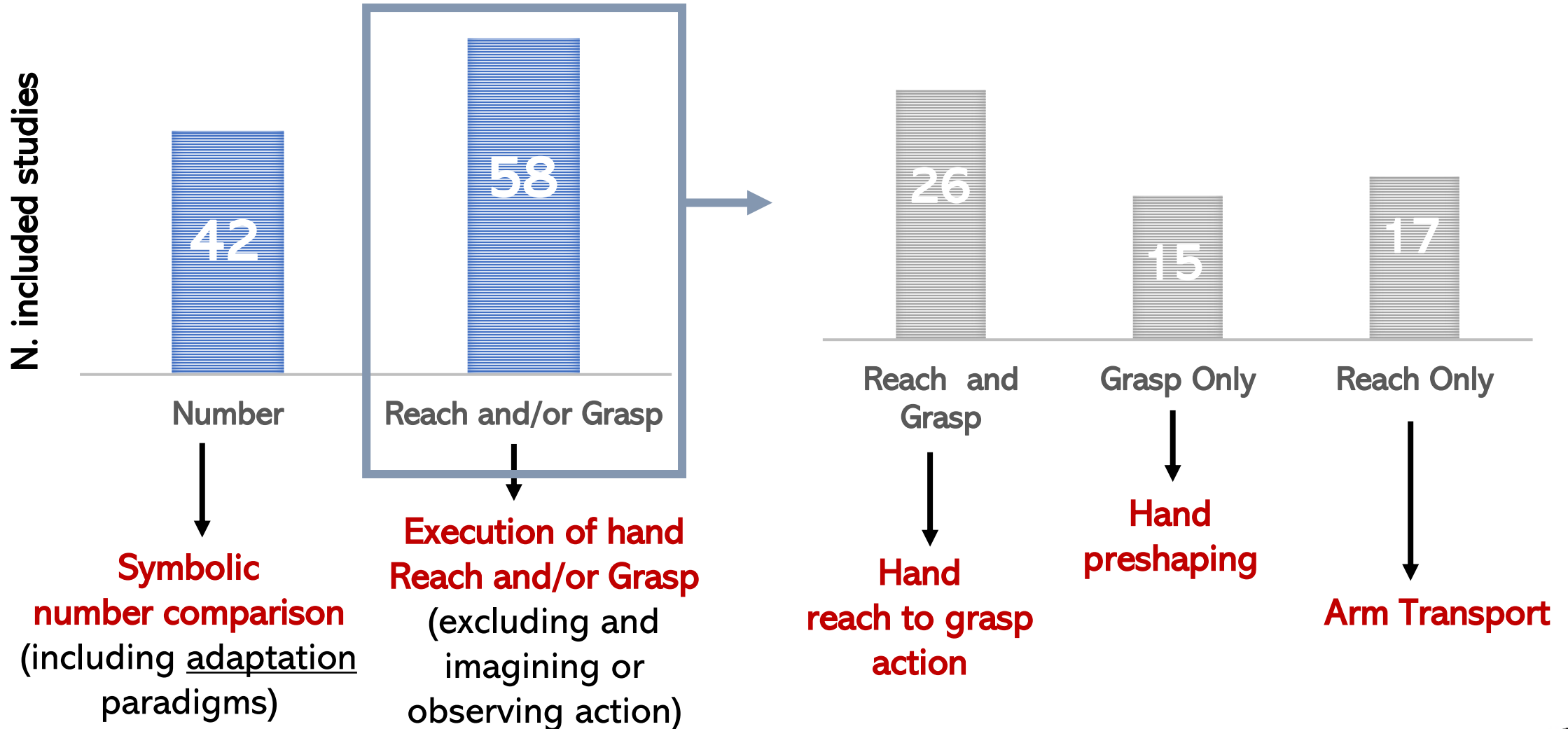
Meta-analysis of neuroimaging studies to investigate the degree overlap between brain areas involved in **number, hand reach and grasp**.

Moher et al., 2009; Müller et al., 2018

Article search and selection

Planned analyses

SDM-PSI method for coordinate-based meta-analysis: seed-based d mapping with permutation of subject images (Albajes-Eizagire et al., 2019)

Meta-analyses of studies on symbolic number comparison, hand reach and/or grasp

Conjunction analyses between studies on symbolic number comparison and hand reach and/or grasp

Aim: confirm and extend the results of previous meta-analyses and reviews on number and on hand-related processes.

Aim: confirm and define previous observations on common areas involved in number and hand action.

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Results: meta-analytical map of symbolic number processing
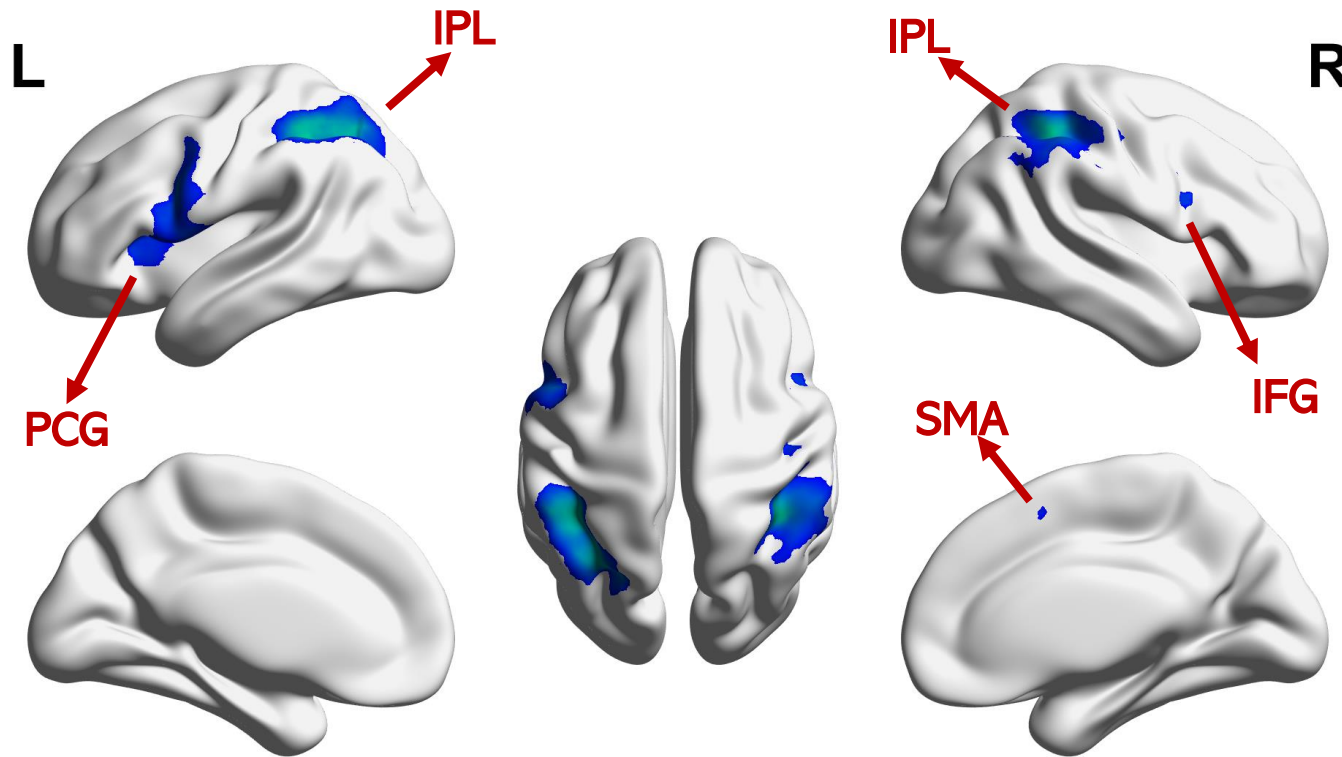
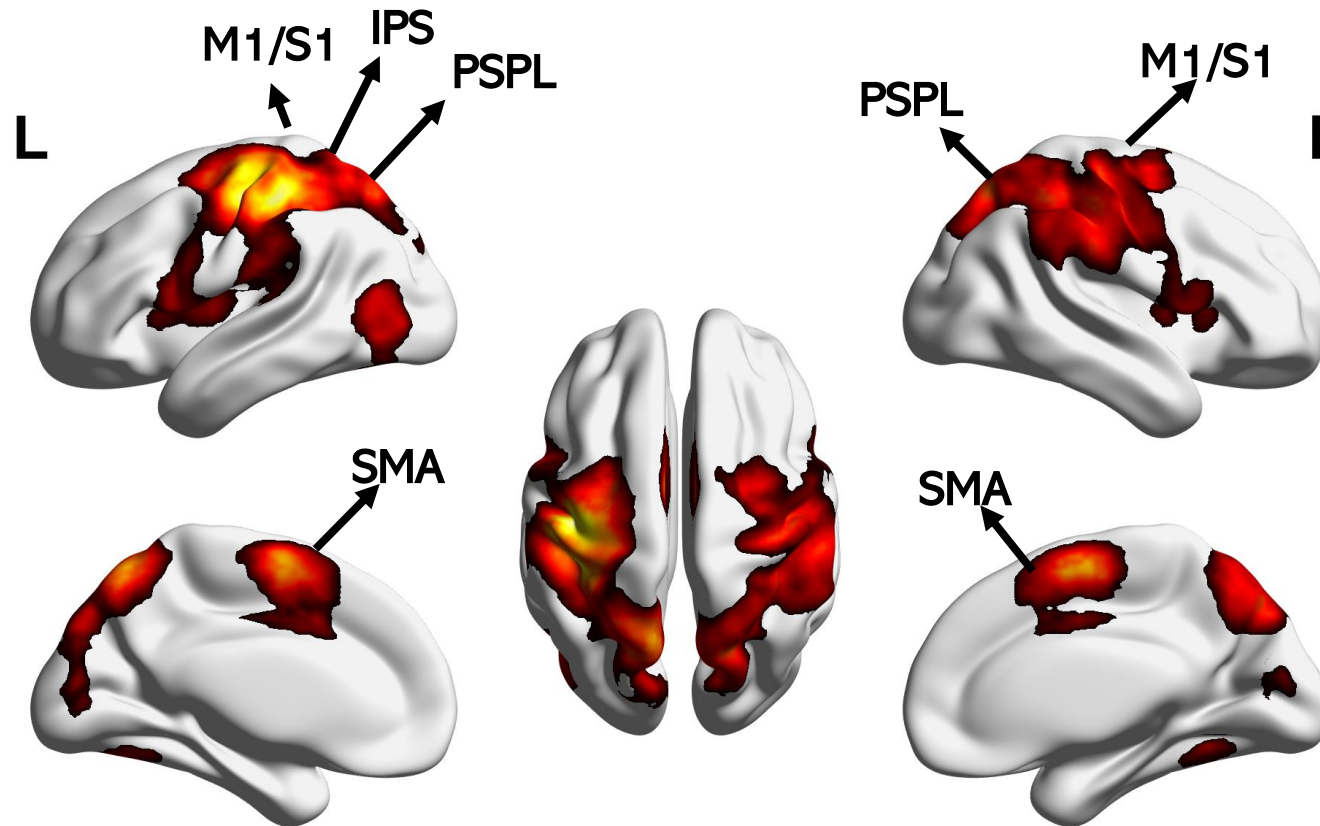| Area	Main peaks MNI coordinates
IPL = inf. parietal lobule	-42, -44, 50
IPL = inf. parietal lobule	-40, -42, 48
PCG = precentral gyrus	-50, 8, 32
IFG =inferior frontal gyrus	48, 12, 34
SMA = suppl. motor area	4, 10, 46

Results: meta-analytical map of hand reaching and grasping
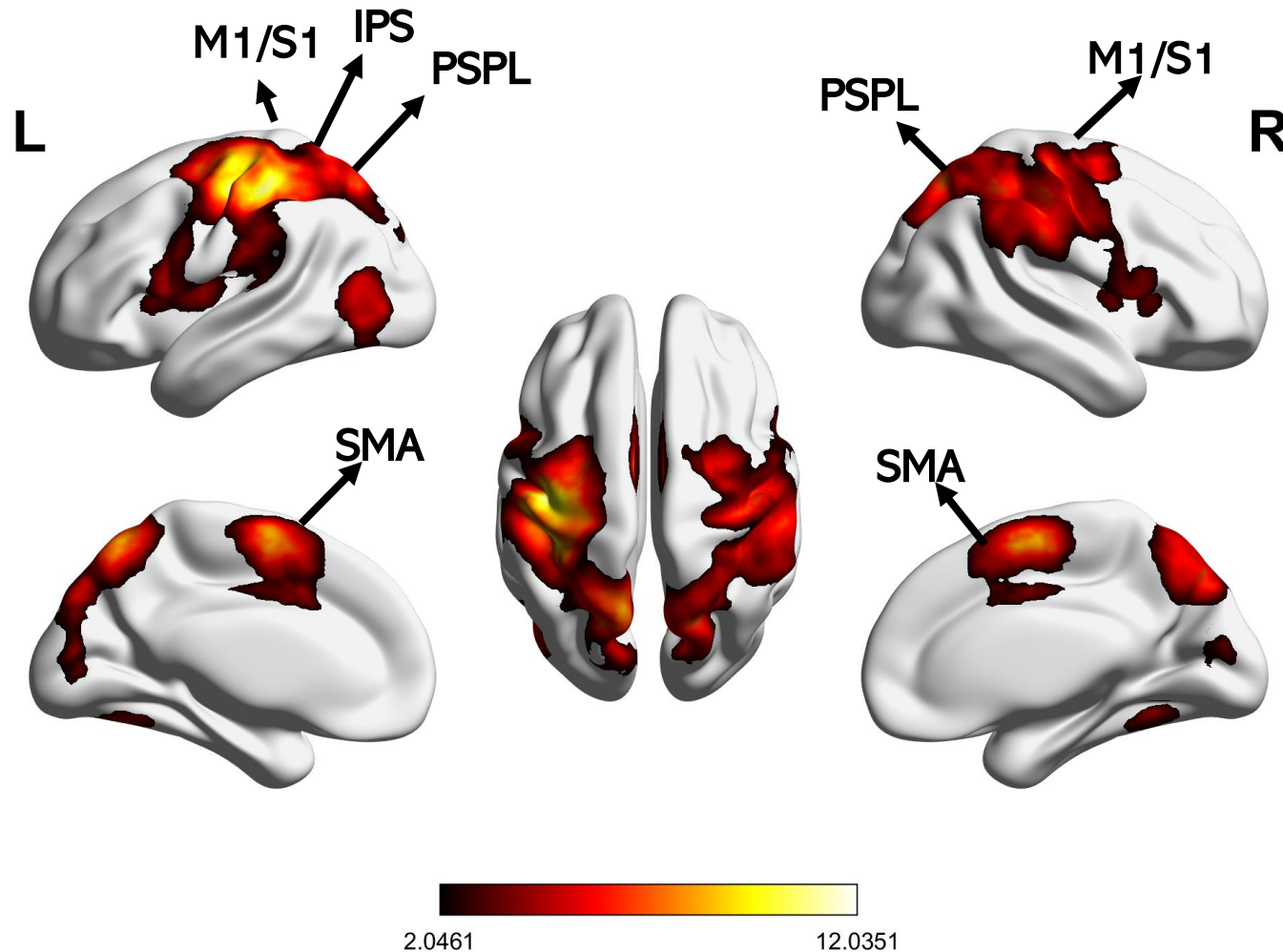
Area	Main peak and subpeaks MNI coordinates
M1= primary motor cortex	-36, -20, 52
S1= primary somatosensory cortex	-40, -30, 52
aIPS = anterior intraparietal sulcus	-38, -44, 46
PSPL = posterior superior parietal lobule	22,-60,58
SMA = suppl. motor area	-2, 2, 54
SMA = suppl. motor area	6, 2 56

Results: meta-analytical map of hand reaching and grasping

Results: conjunction between number, hand reach and grasp

Area	Main peak MNI coordinates
IPL = inf. parietal sulcus	40, -44, 48
IPL = inf. parietal sulcus	-42, -40, 50
PCG = precentral gyrus	-52, 6, 22
SMA = suppl. motor area	4, 10, 46

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Results: conjunction between number, hand reach and grasp

Number & Hand Reach

Number & Hand Grasp

SMA
[MNI coord. 4,10,46]

L

R

SPL
[MNI coord. -22, -62, 54]

IPL
[MNI coord. 34,-50,50]

5.1560

1.7743

IPL
[MNI coord. -40,-38,52]

5.1560

1.7743

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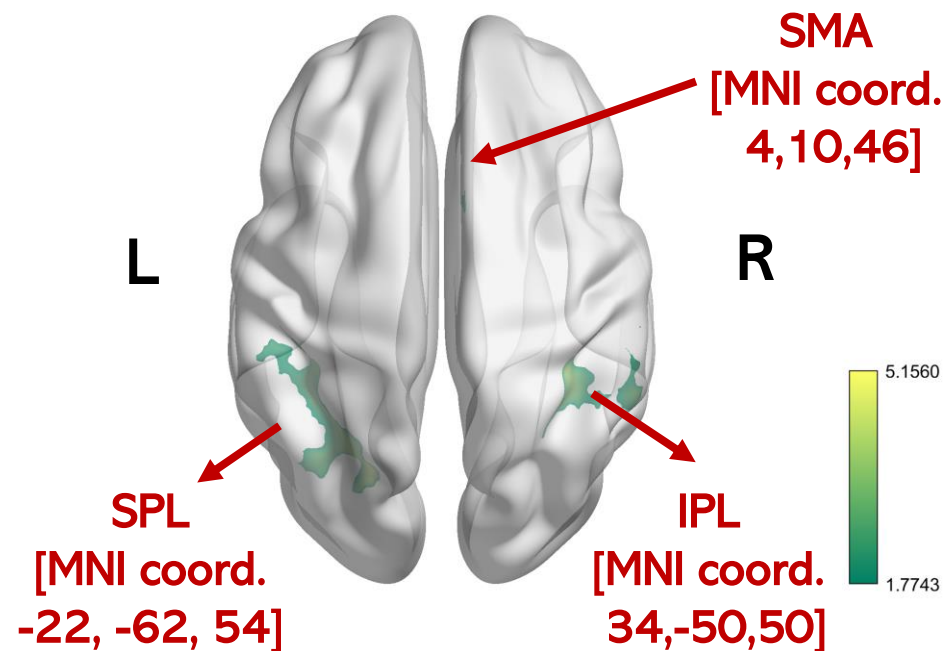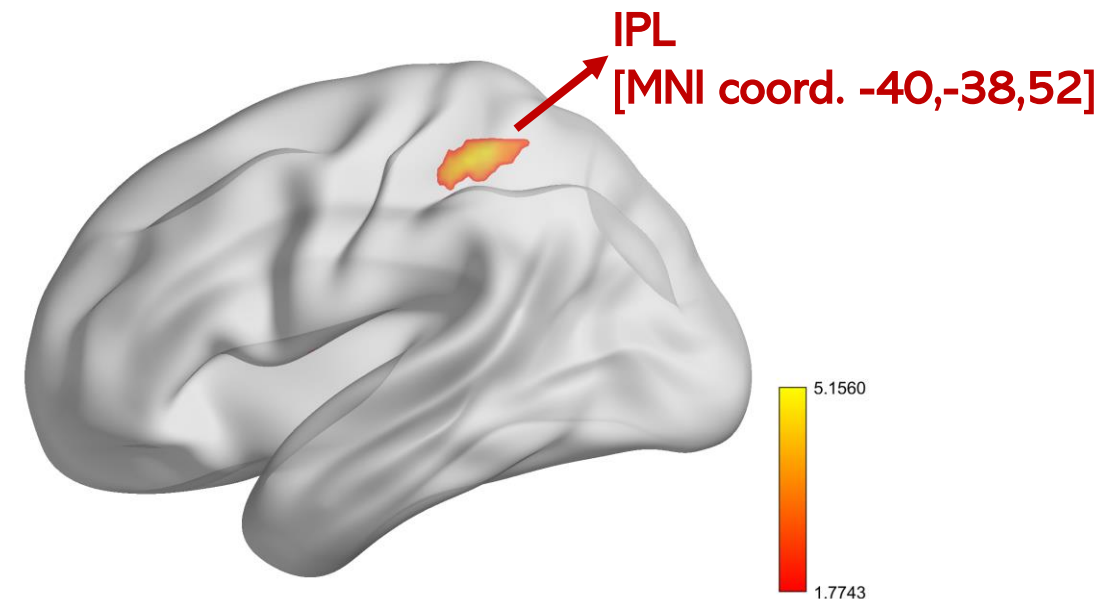
Results: functional characterization

Category	Terms	Correlation coefficient (Pearson)
Hand and Action	action observation, action, actions, finger movements, finger tapping, executed, execution, finger, grasping, hand, hands, imitation, index finger, motor task, motor, movement, movements, reaching, sensorimotor, tapping, tools, visuomotor	.22 (.10-.39)
Memory and Imagery	Imagery, memory load, memory wm, motor imagery, rehearsal, working memory	.22 (.12-.30)
Space, Eye, and Attention	attention network,attention, attentional, eye field, eye fields, eye movements, eye, frontal eye, orienting, saccade, saccades, spatial attention, spatial, visual, visually, visuospatial	.20 (.10-.29)
Number	arithmetic, calculation, subtraction	.20 (.13-.28)
Language	language, letter, orthographic, phonological, reading, speech production, verbal, word	.14 (.12-.20)
Other	articulatory, conflict, contralateral, coordination, demands, force, gain, handed, interference, load, mainteinance, mirror, monitoring, performance, planning, preparation, preparatory, production, rotation, sensory, sequential, somatorensory, stimulation, symbolic, tactile, target, task difficulty, task, tasks, touch, working	.17 (.10-.42)

(www.neurosynth.org)

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Summary of results and discussion

- The brain network of number processing is **largely embedded** in the sensorimotor network for hand reaching and grasping.

- Overlap is observed in left and right **IPS**, left **PCG**, and **SMA**.

Registered Report

A common neural substrate for number comparison, hand reaching and grasping: A SDM-PSI meta-analysis of neuroimaging studies

Mariagrazia Ranzini [a,*], Cristina Scarpazza [b,h], Joaquim Radua [d,e,f], Simone Cutini [c,g], Carlo Semenza [a] and Marco Zorzi [b,h]

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Follow-up analyses

→ … are there brain areas selectively involved in number processing?

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Contrast analyses of number vs. hand reach or grasp

Number vs. Hand Reach

IFG
[MNI coord.
44,10,22]

2.6468

1.0869

IPL
[MNI coord.
40,-36,40]

Number vs. Hand Grasp

SPL
[MNI coord.
-22,-66,50]

2.6468

1.0869

Mathematical Cognition and Learning Society Conference 2022

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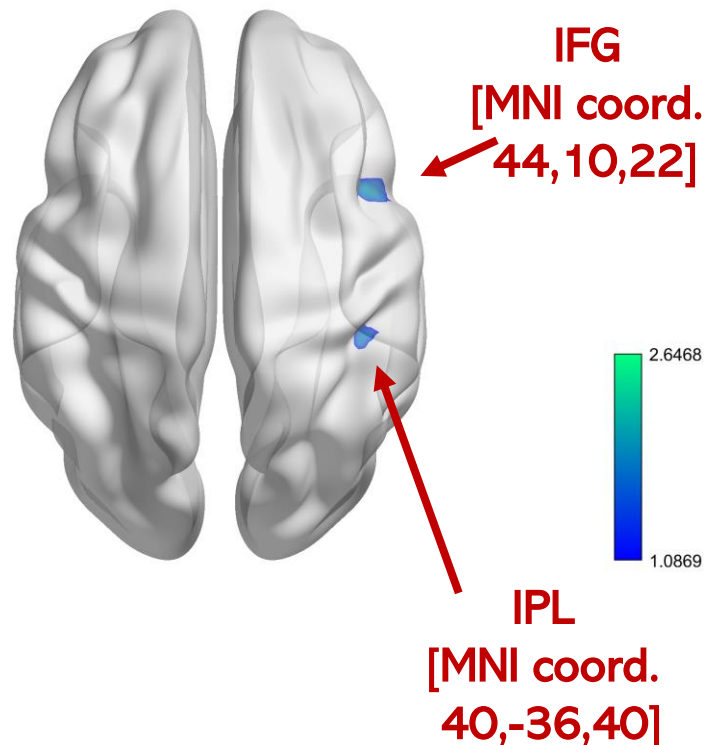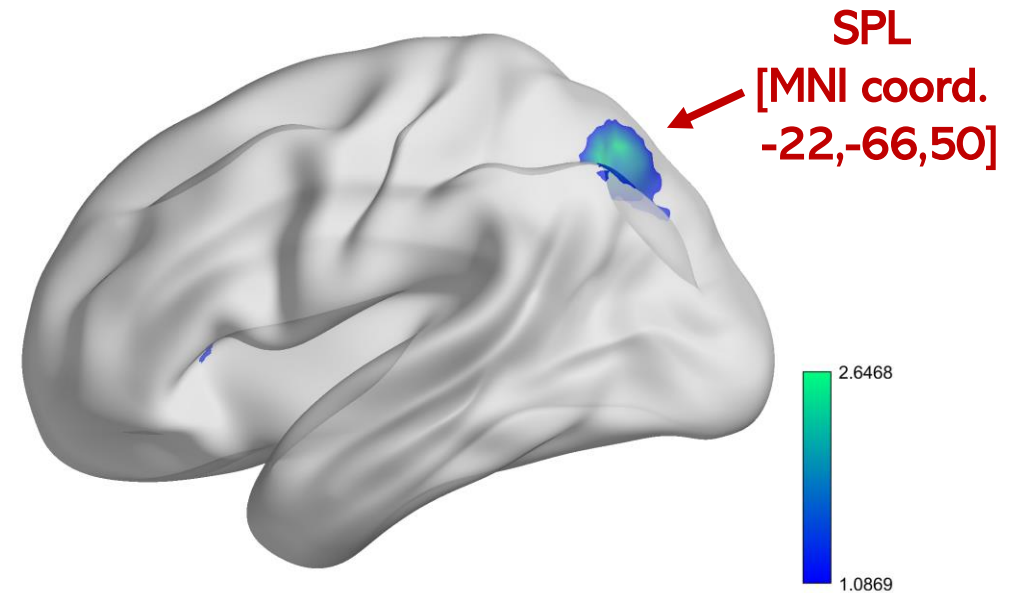
Summary of results and discussion

- **SPL** $\rightarrow$ part of the three parietal circuits for number processing (Dehaene et al., 2003)

- **Right IFG** $\rightarrow$ associated with calculation (Arsalidou & Taylor, 2011), but also with visuospatial attention and working memory (e.g., Cona & Scarpazza, 2019)

- **Right Supramarginal Gyrus** $\rightarrow$ associated with calculation in previous neuropsychological and direct cortical electrostimulation studies (reviewed by Semenza & Benavides Varela, 2018)

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Conclusion

- **Nature and nurture** probably both contribute to the **settlement of number processes** into sensorimotor mechanisms.

- <u>Future studies will need to clarify</u>:

→ the **contribution of the motor system from infancy to adulthood**: are these networks overlapping at a larger extent during childhood (e.g., Berteletti & Booth, 2016)?

→ the **role of education and expertise**: is the overlap between the number and the hand action networks modulated by individual differences in numerical abilities and mathematical expertise?

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Many thanks for your attention

email: mariagrazia.ranzini@unipd.it

In collaboration with:

Joaquim Radua (IDIBAPS)

Simone Cutini (UNIPD-DPSS)

Carlo Semenza (UNIPD-DNS)

Marco Zorzi (UNIPD-DPG)

Cristina Scarpazza (UNIPD-DPG)

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