

Moving Ahead with Embodied Cognitive Neuroscience

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Motivation

Finding a biologically grounded cognitive ontology for cognitive neuroscience, inspired by embodied approaches to cognition.

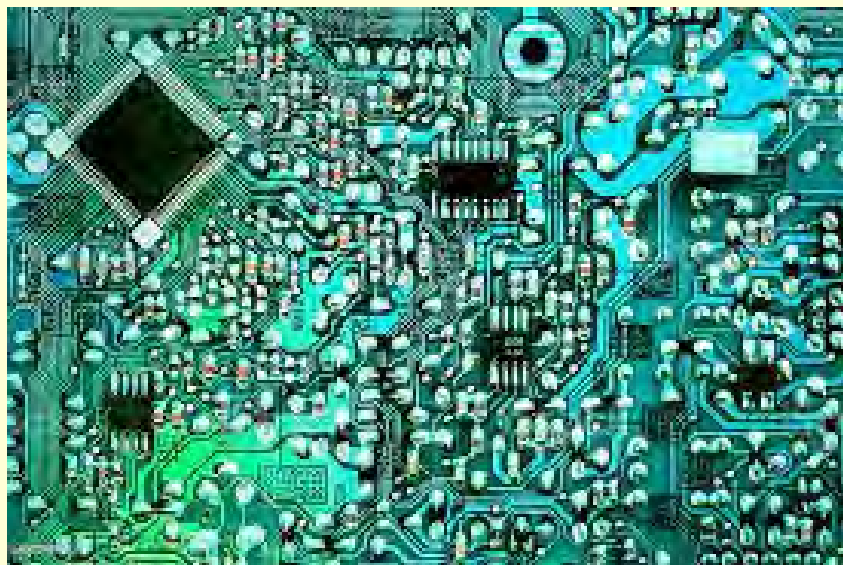
Cognitive Ontology

- *Formal description of basic building block processes, along with their properties and interrelationships* (Hastings et al., 2014)
- Two issues:
 - Not have well-defined building-block processes
 - The BB processes did not emerge from studying the biological systems



Where did
they come
from?

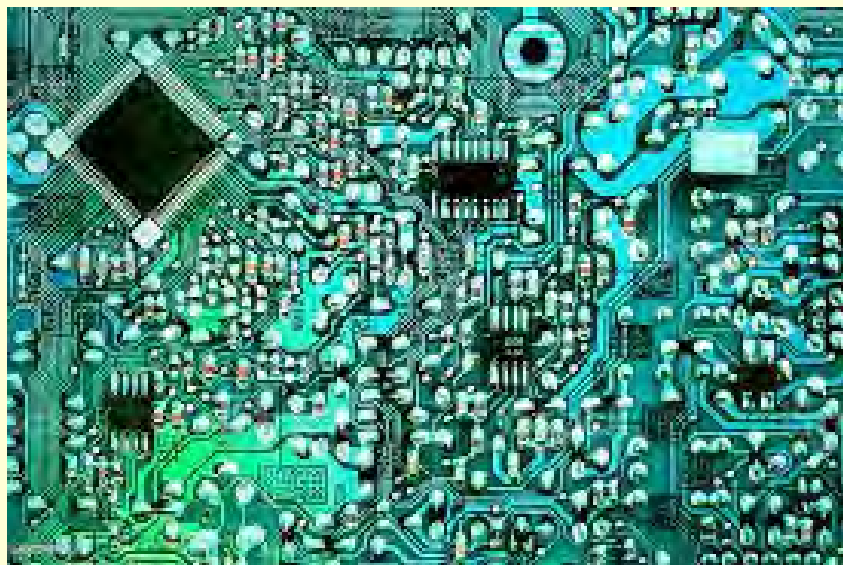




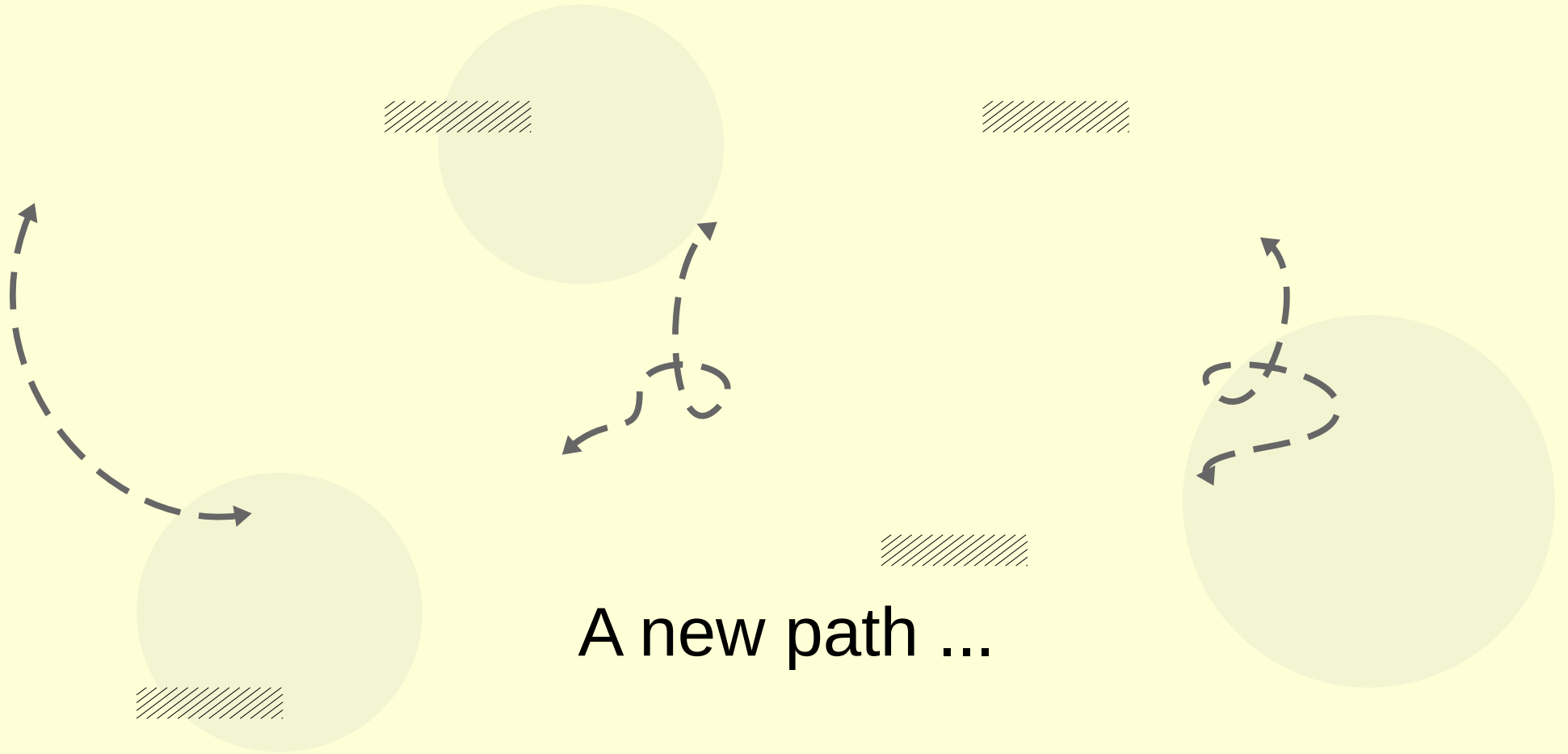
Questions in Cognitive Neuroscience

Where?

What?







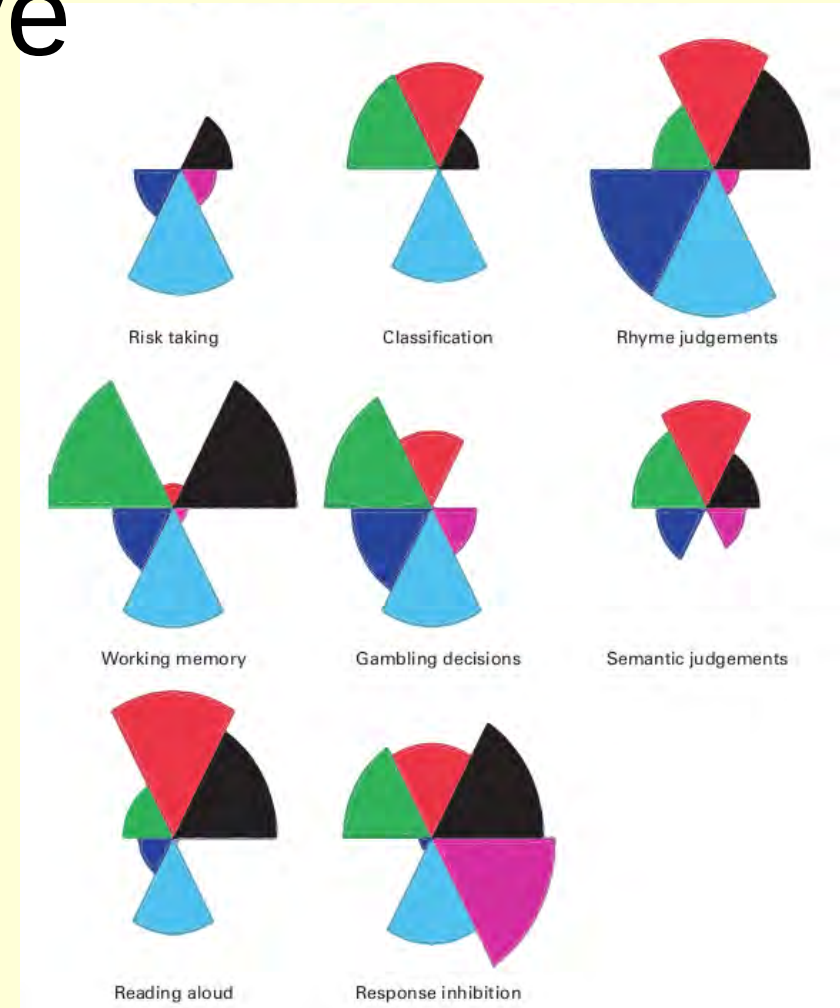
Need for new functional cognitive ontologies based on the study of biological systems.

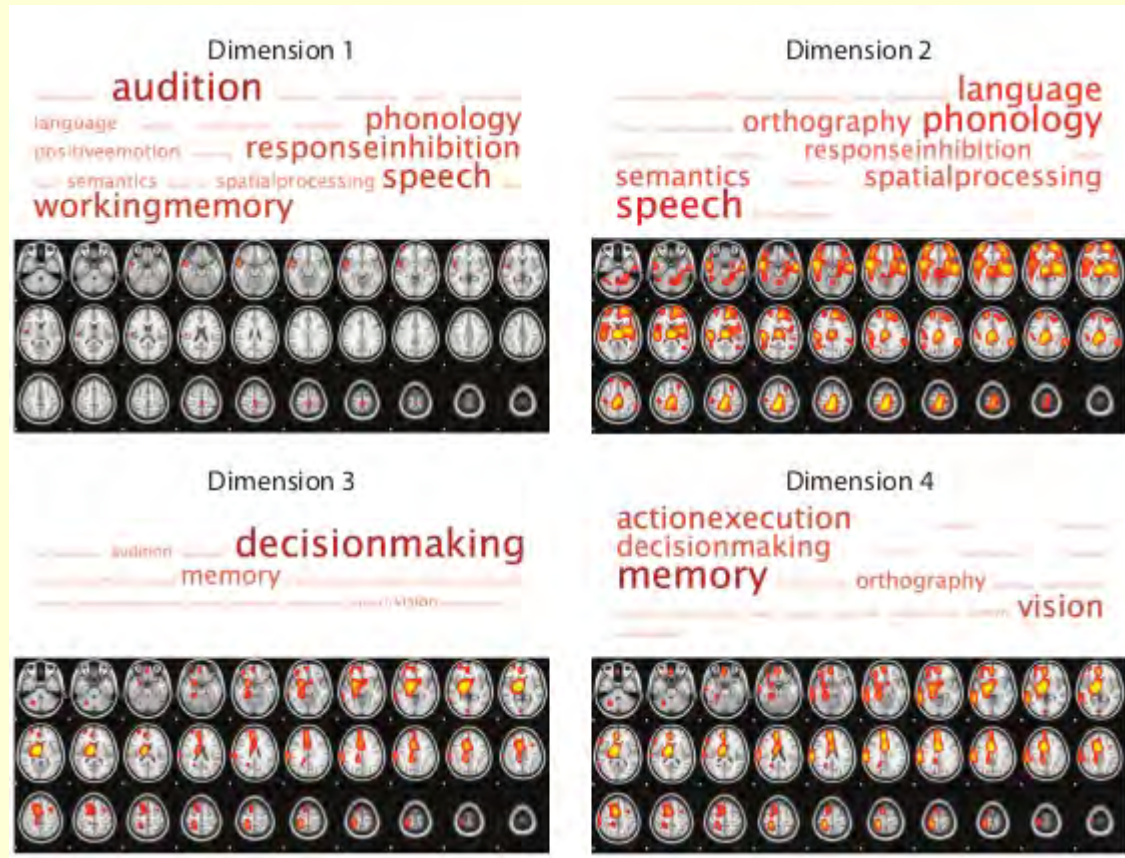
How do we know the core processes?



Finding New Cognitive Ontologies

- Machine learning & data mining tools to determine selective associations between tasks & brain structures, across large scale data sets





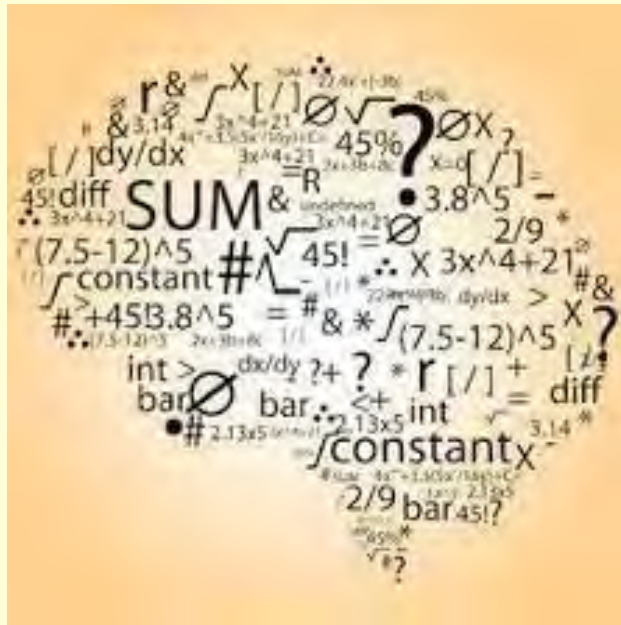
Associations of mental concepts with dimensions and dimensions with brain regions. (Poldrack, 2009)

Making sense of cognitive ontologies

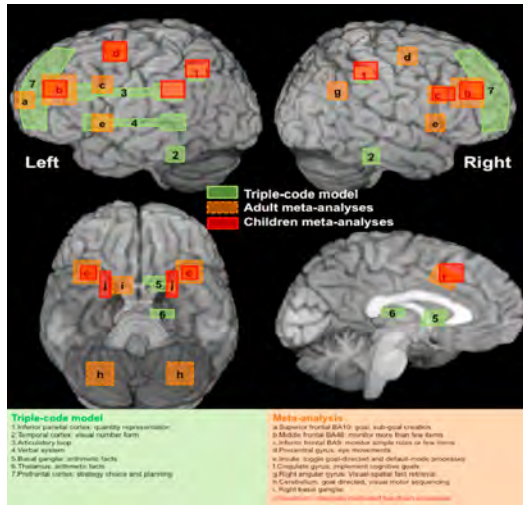
- Neuroscientifically Relevant Psychological (NRP) Factors (Anderson, 2014)
- Transient assembly of neural sub-systems
- A shift in the theoretical framework
 - Evolutionary perspectives & neural reuse
 - Embodied approaches to cognition

Numerical cognition

- Studies the cognitive, developmental, and neural bases of mathematical skills

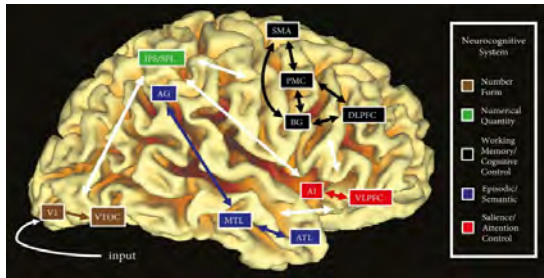


Models in Numerical Cognition

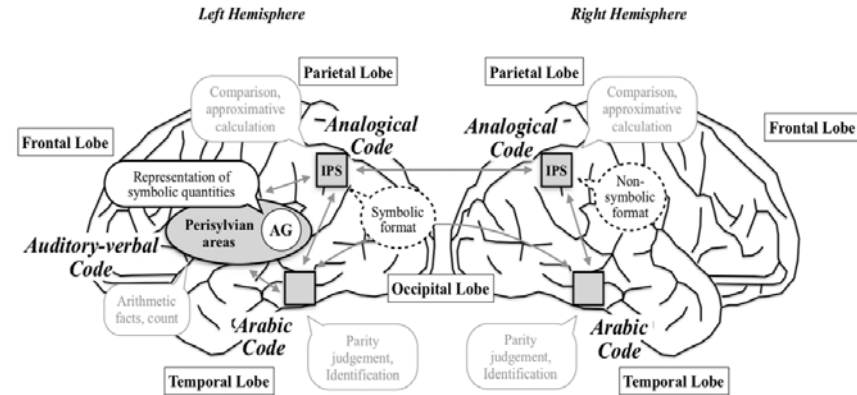


Quantity representation
 Visual number form
 Articulatory loop
 Verbal system
 Arithmetic facts
 Strategy choice and planning
 Goal, sub-goal creation
 Monitor simple rules or few items
 Implement cognitive goals
 Visual-spatial fact retrieval
 Visual-motor sequencing

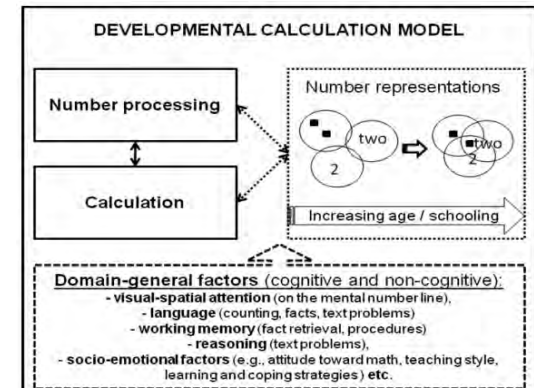
Arsalidou, M. et al. (2018). Brain areas associated with numbers and calculations in children: Meta-analyses of fMRI studies.



Menon, V. (2014). Arithmetic in the Child and Adult Brain.



Faye, et al. (2019). Numerical cognition: A meta-analysis of neuroimaging, transcranial magnetic stimulation and brain-damaged patients studies.



Kaufmann, L. (2011). Meta-analyses of developmental fMRI studies investigating typical and atypical trajectories of number processing and calculation.

Research on Fingers and Numbers

- Neural resource overlap between finger tapping & arithmetic (Soylu & Newman; 2011, 2016)
- Impact of finger counting habits on arithmetic performance (Newman & Soylu, 2014)
- Relation between finger gnosis & neural correlates of arithmetic (Soylu et al., 2018)
- Structural brain correlates of finger gnosis (Soylu et al., 2019)
- Visual processing of finger-numeral configurations, with ERPs (Soylu et al. 2019)



Example: Magnitude Processing

- An association between processing physical magnitudes and numerical ones.
- IPS important for num. processing (Ansari, 2007; Dehaene et al., 2003).
- Bilateral IPS supports both phys. & num. magn. (Fias et al., 2003, Sokolowski, 2017)
- In both humans and monkeys, IPS responsible for integration of multimodal info—proprioception, and planning and execution of object-oriented actions (e.g., grasping, object manipulation) (Grefkes & Fink, 2005 for a review).



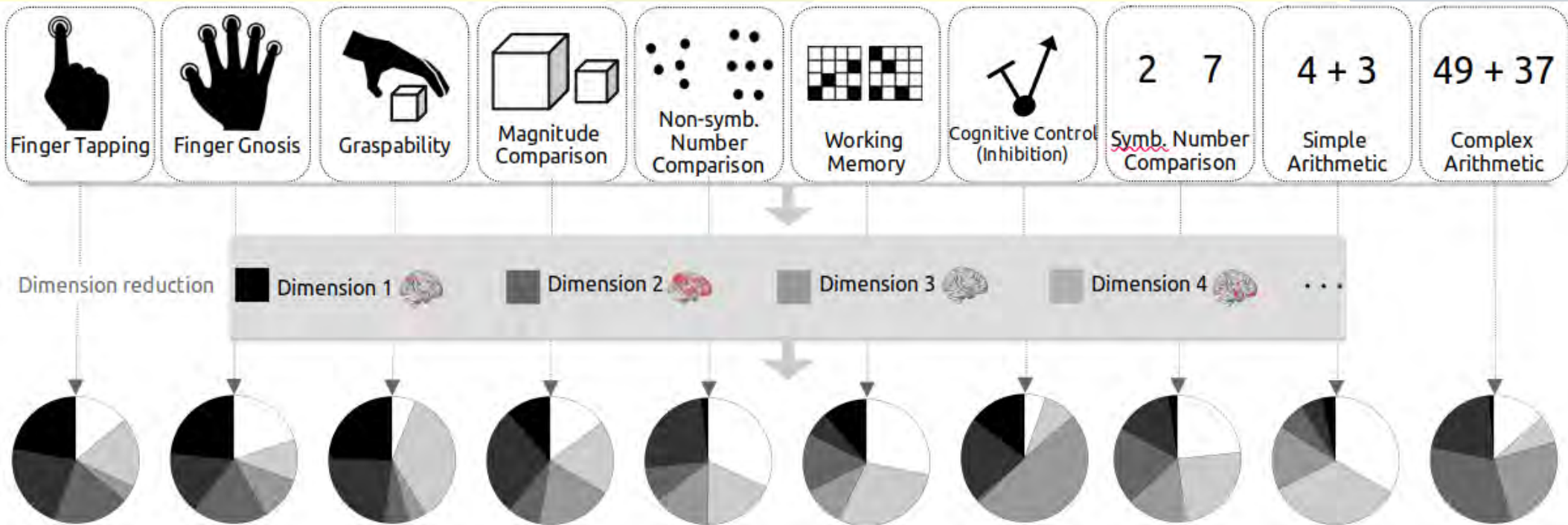
Action-Specific Perception

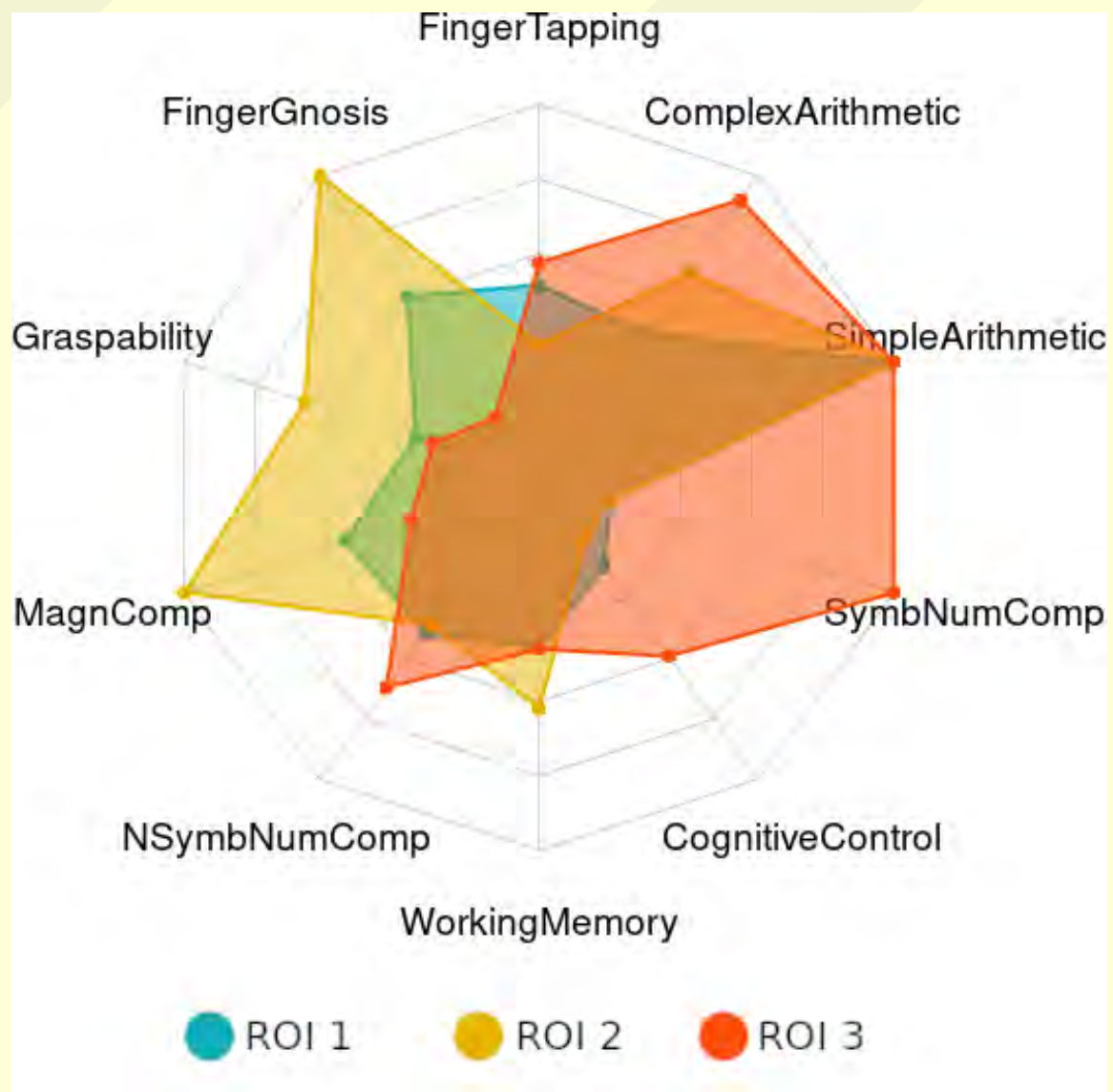
- Not just perceive an objective magnitude, but take into account own body/morphology, and action possibilities.
 - graspability judged relative to hand size (Linkenauger et al., 2013)
 - easier to grasp objects estimated to be closer (Linkenauger et al., 2009)
 - object sizes perceived relative to body size (van der Hoort et al., 2011)
- ... estimations of slope, volume, weight, time, distance etc., → estimations of magnitude are influenced by bodily capacities and perceived affordances (Philbeck & Witt, 2015 for a review).

Issues with the current conceptualization

- Magnitude and verbal processing localized to single regions
- Does not capture the contributions of multimodal sensorimotor networks
- Does not relate to brain-body-environment interactions
- Interpretations involve reverse inference

Future Study Design







Thank you!

Questions?

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