Modeling the mirror neuron system and its role in concept/language grounding

-

Work in progress

Serge Thill, Boris Duran, Paul Hemeren &
Tom Ziemke (tom.ziemke@his.se)

Cognition & Interaction Lab

University of Skövde, Sweden

Outline

- ROSSI project
- Our approach to modeling the mirror neuron system and its role in grounding concepts/language
- Current and future work

ROSSI

= emergence of communication in RObots through Sensorimotor and Social Interaction

3-year FP7 STREP, March 2008 - February 2011 involving six labs:

- cognitive neuroscience
  - Parma, Lübeck
- experimental psychology
  - Bologna (coord.)
- neurocomputational modeling
  - Skövde
- robotics
  - Ankara, Aberystwyth

COGNITIVE SYSTEMS

ROSSI partners

Embodied Cognition Lab, University of Bologna, Italy (**UNIBO**)

Department of Neuroscience, University of Parma, Italy (**PRM**)

Sensorimotor Integration group, University of Lübeck, Germany (**ITM**)

Cognition & Interaction Lab, University of Skövde, Sweden (HIS)

Kovan Research lab, Middle East Technical University, Turkey (**METU**)

Intelligent Robotics Group (IRG), Aberystwyth University, Wales (**AU**)

ROSSI – General objectives

to provide new **neuroscientific & psychological insights into the sensorimotor grounding of human conceptualization and language use**, in particular the role of canonical and mirror neurons as underlying the use of nouns and verbs,

to develop **novel approaches to sensorimotor grounding of robotic conceptualization and language use** (more precisely, verbal labeling of objects and actions), based on the insights gained under (a) and richer computational & robotic models of the underlying neural mechanisms.

ROSSI Objectives

1. To build robots that are able to detect object affordances, i.e. that respond with the appropriate motor response to different object characteristics (e.g., size, orientation, weight)

2. To develop robots that can interact socially with humans on the basis of a common way to approach objects

Language grounding

3. To equip robots with a very basic form of **language:**

a. **Nouns** - verbal labels identifying graspable objects, coherent actions on such objects, e.g. “ball” - canonical neurons

b. **Verbs** - verbal labels expressing actions upon objects, e.g. “grasp” - mirror neurons

c. **Noun-verb combinations** – ‘sentences’ of actions and objects words, execution of corresponding motor programs, e.g. “grasp ball” - mirror & canonical neurons.

Affordances

Affordances = What the environment offers to the acting organism

They are:

- emergent, the outcome of a process
- relational (object, context, organism)
- unique to a given organism
- variable
- new affordances can emerge (e.g., incorporation of tools as bodily extensions)

Stable & variable affordances

Stable: emerge from rather stable / invariant properties of objects: e.g., size

Variable: emerge from temporary object characteristics: e.g., orientation

Working hypothesis: stable affordances are automatically part of object representation: beyond the dichotomy of automatic vs. task dependent activation of affordances

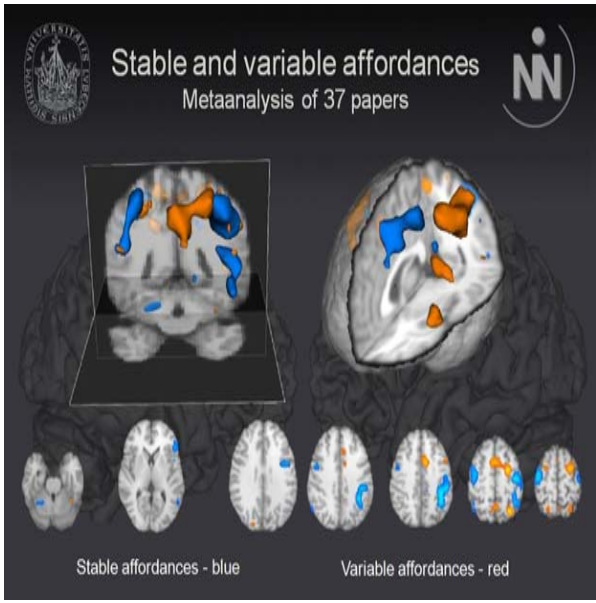
Stable & variable affordances

Bologna, Parma:

Behavioral studies: during language comprehension we form a motor prototype based on stable affordances

Lübeck: Meta-analysis of brain imaging studies: 2 different neural networks

Skövde: Extension of the MNS2 model to include the neural network of variable affordances



Modeling

Two complementary approaches:

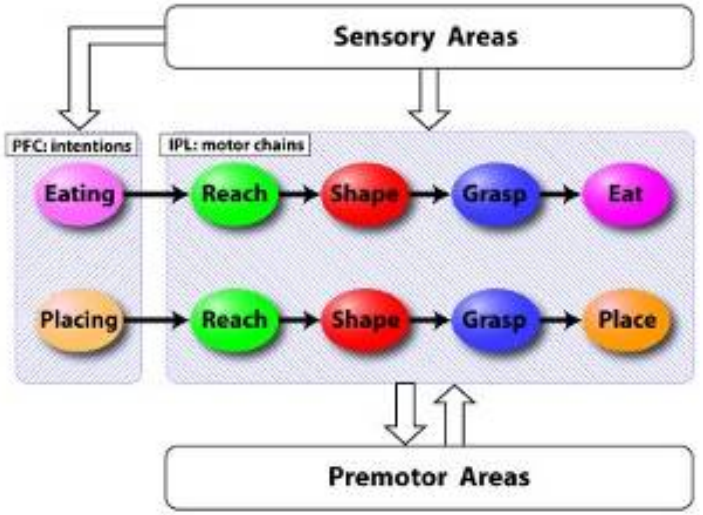
1. Combination of MNS2 model and Chain model with an emphasis on biologically plausible models (Skövde)

2. Affordance formalization as starting point, behavioral and neural results as inspiration source (Ankara)

Action and motor chains

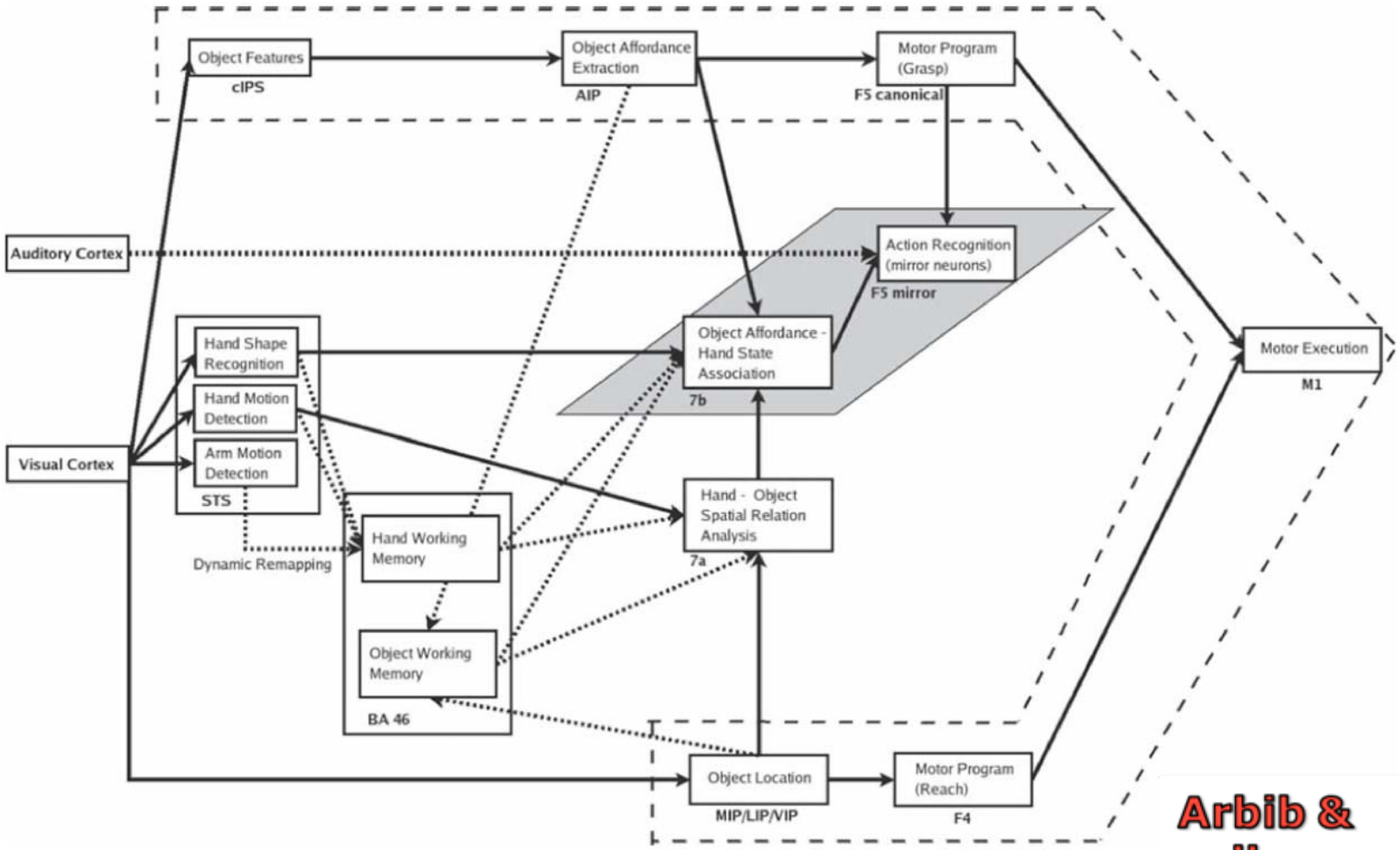
Motor chains: actions coded in terms of the overall goal / motor chain composed by motor acts (Fogassi et al., 2005).

CHAIN model, Chersi et al.



Our aim: Integration of MNS2 and Chain model: emergence rather than hard-coding of motor primitives

MNS2 model

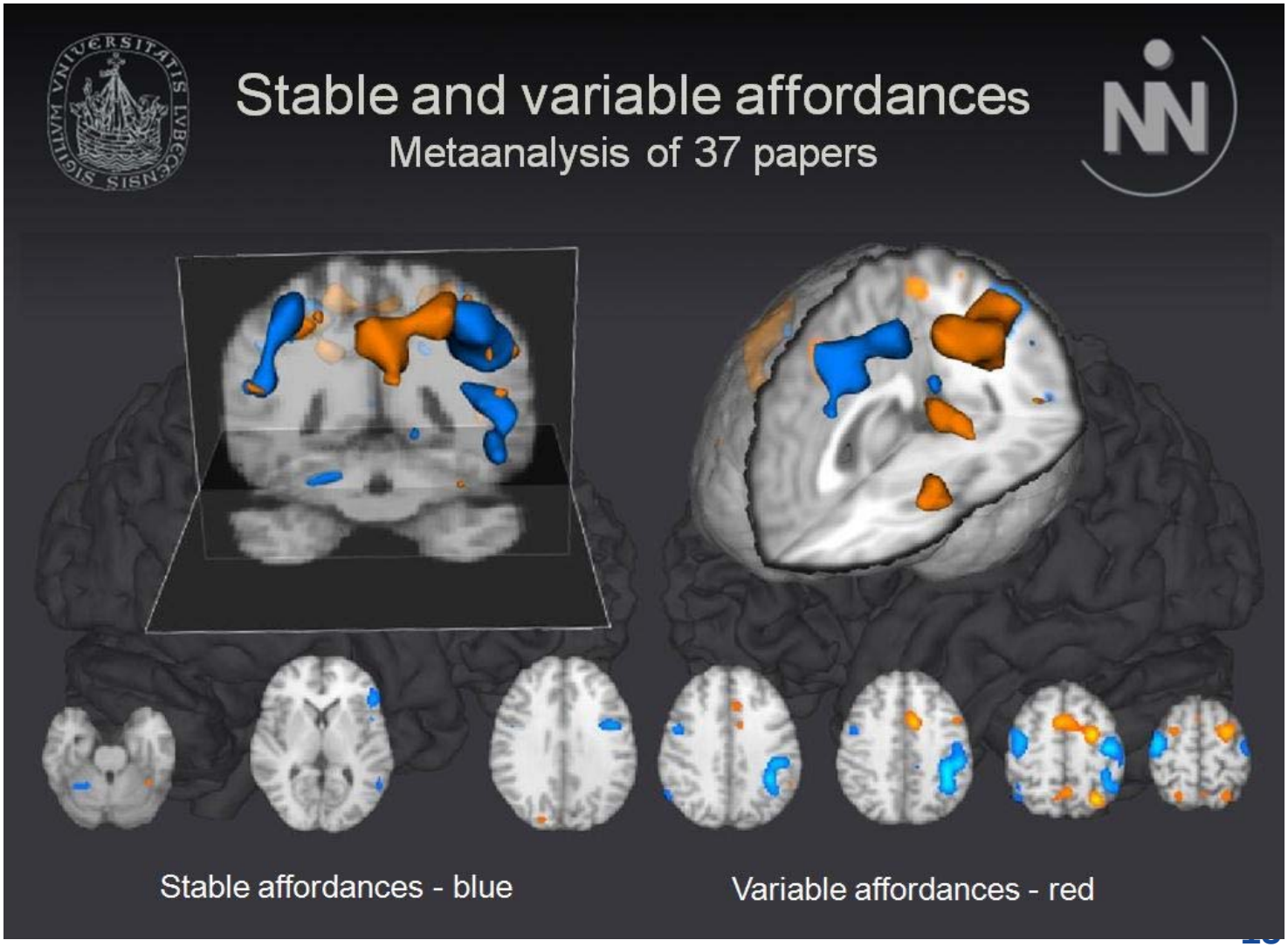


Arbib & colleagues

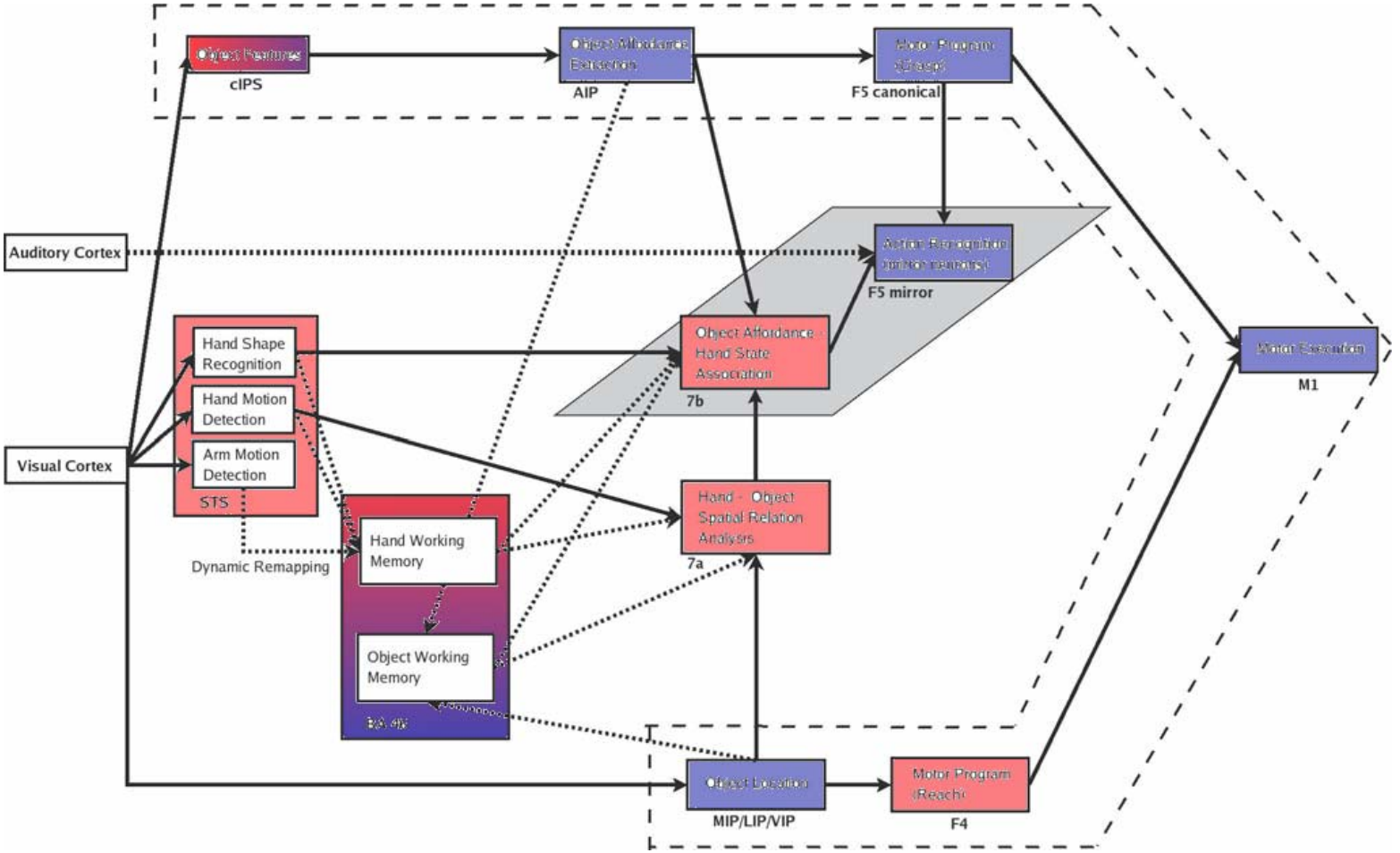
MNS2 model

- Based on monkey data
- Useful overall connectivity model
  - maps well to anatomical regions
    - cf. Lübeck's meta-analysis (human)
- Not a model of mirror neurons
  - simple backpropagation training
  - specificity of mirror neurons not modeled
  - mirror neuron activity not used for much

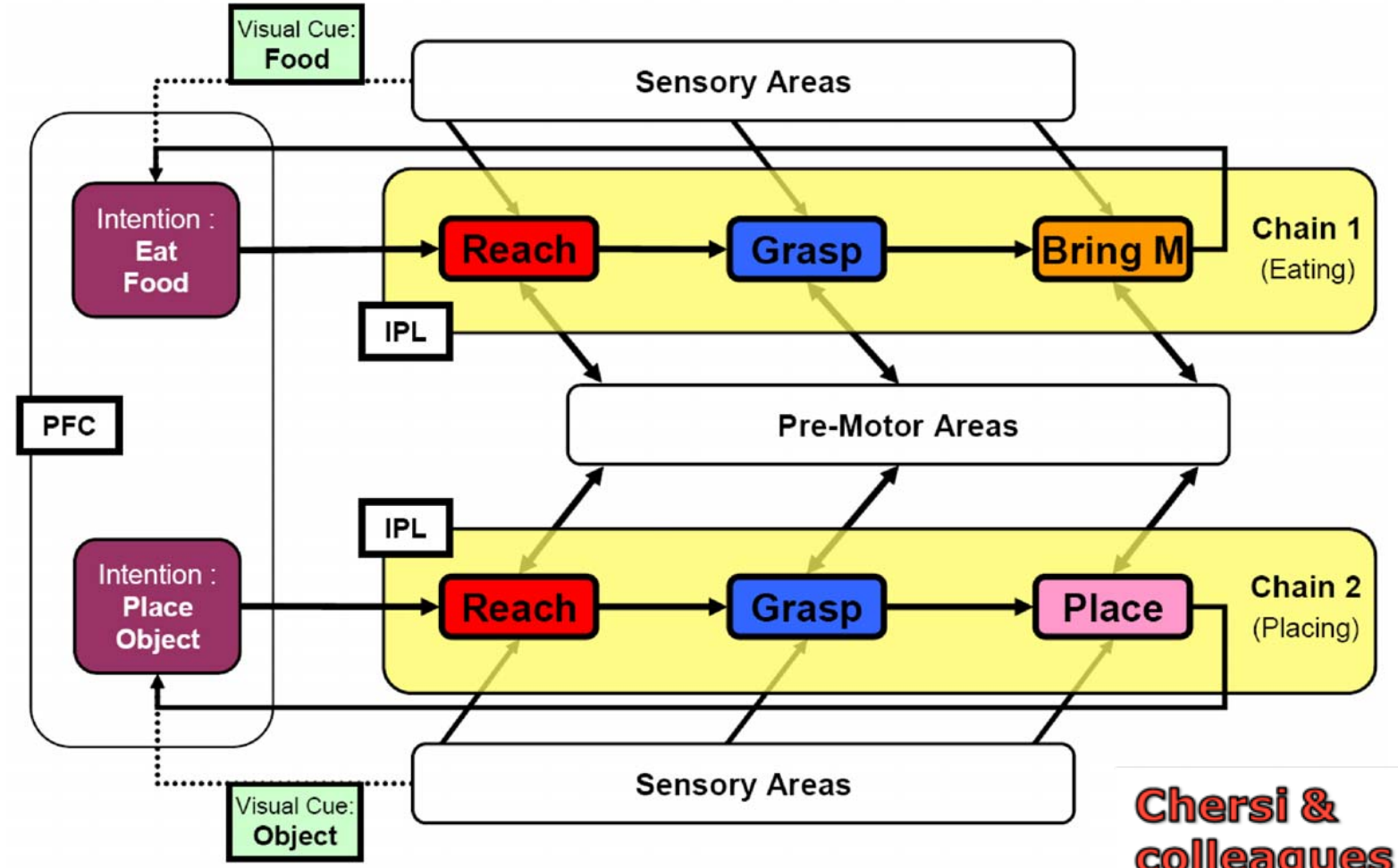
Meta-Analysis I (Lübeck)



Meta-Analysis II (Lübeck)



The Chain model



Chain model – pros & cons

- More detailed, biologically plausible model
  - addresses action generation & recognition
  - it models the experimentally observed specificity of MNs (Fogassi et al, 2005)
- But lacking some features
  - not addressing language & affordances
  - no account of the genesis of the system, in particular the learning of new actions

Summary so far

- **MNS2** provides realistic overall connectivity between regions involved in the mirror neuron system
- The **Chain model** provides a more detailed model of mirror neurons themselves, but lacks some features
- Our model should combine the MNS2 model and an augmented Chain model

Current and future work

- Modifying the chain model to
  - reflect the effects of language on the mirror neuron system
    - Chersi, Thill, Borghi & Ziemke, in prep
  - be able to learn and adapt to new actions
    - Hemeren, Thill, Duran & Ziemke, in prep
  - take into account affordances
    - modelling affordance processing in the Anteriour Parietal Lobe

Chain model and language

- Original model does not explicitly take language into account
- Current work focuses on extending the model to reproduce experimentally observed effects of language processing on motor programs
  - e.g. Borghi & Scorolli, 2009; Boulenger et al, 2006
  - requires minimal modifications to the model - most important is that neural structures activated during language comprehension are partially reused during action execution
    - experimentally observed in the monkey PMC (Coude et al, submitted)

Language and motor chains

- Language understanding = embodied mental simulation? (e.g. Gallese, 2008)
- Behavioral experiments illustrate role of motor cortex in language, but with conflicting results
  - interference vs. facilitation
- Our hypothesis: timing differences
- Extended chain model with (weakly) overlapping chains

Learning new primitives (1)

- In the original chain model, actions are represented as chains of *motor primitives*
  - How are such primitives formed?
    - i.e. how are observed complex actions segmented into motor primitives
  - Machine learning approaches exist, some even learning online (e.g. Kulic et al 2008)
    - but these are not necessarily biologically or cognitively plausible

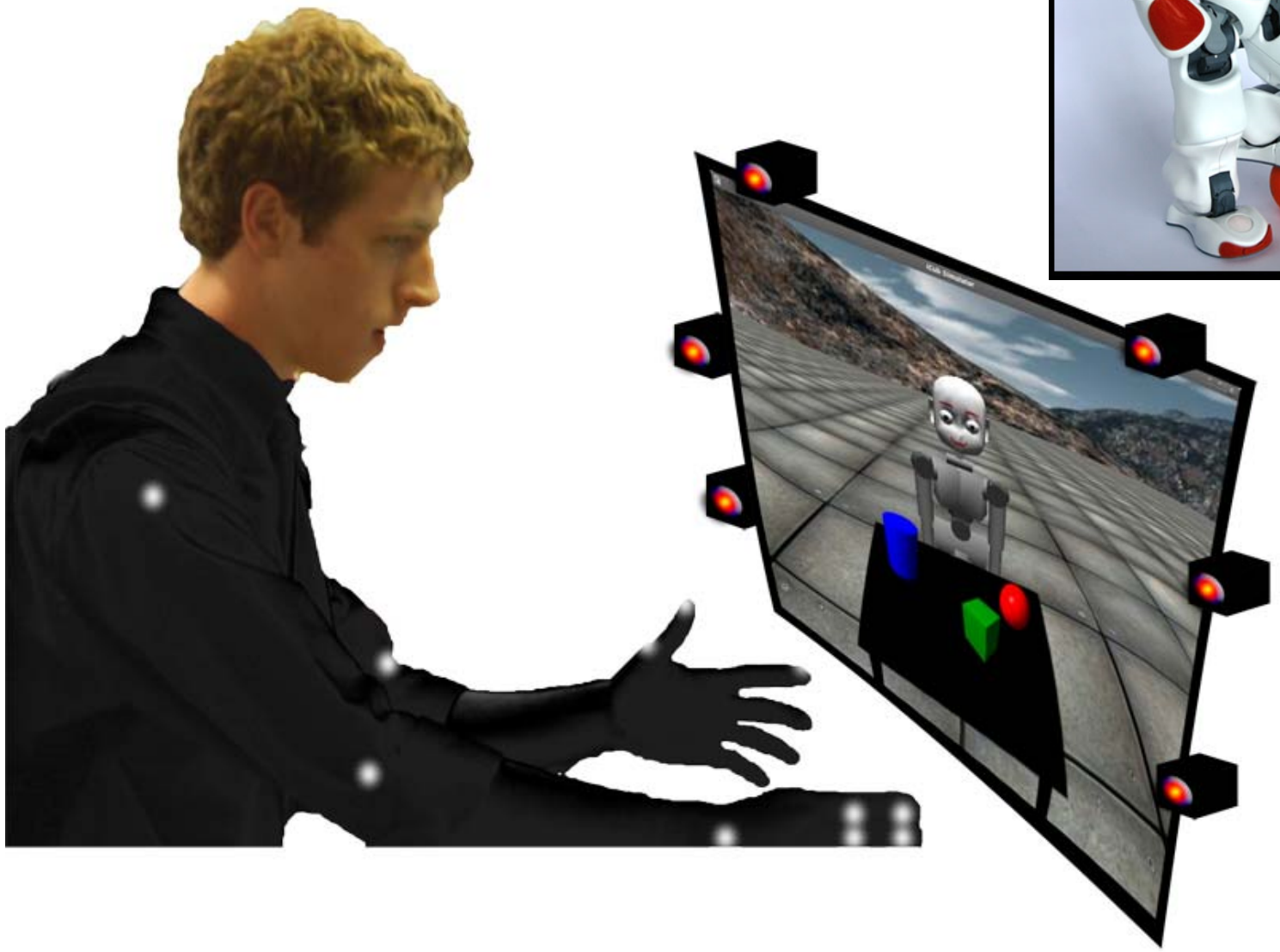
Learning new primitives (2)

- Motion segmentation in humans
  - Which primitives are formed?
  - Why and how?
- Knowledge gained can be used to
  - explain how the motor primitives can be organised in the mirror neuron system
  - form a first step towards an adaptive version of the Chain model

Learning new primitives (3)

- Motion capture of complex movements
  - can ask human participants to segment recorded movements
  - can also use recorded data in training/ verifying robotic implementation of the mirror neuron system
  - using a ShapeHand data glove system

ROSSI



COGNITIVE SYSTEMS ROBOTICS

SEVENTH FRAMEWORK PROGRAMME

Summary

- Our lab's main aim in ROSSI is a detailed computational model of the mirror neuron circuit
- We have identified a suitable initial model and necessary modifications
- We aim to demonstrate the final model in the interaction between a human and a simulated iCub humanoid robot

Details?

Chersi, Borghi, Thill & Ziemke (forthcoming). Sentence comprehension: Linking language to motor chains.

Menz, Jirak, Buccino. Borghi, Binkofski, Thill & Ziemke (forthcoming). Stable and variable affordances in the brain.

- Acknowledgements: Many of the ideas and illustrations used here come from various ROSSI partners.