ACTING WITH OBJECTS, INTERACTING WITH OTHERS

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OVERVIEW

- **Framework:** observation of OBJECTS (AFFORDANCES) and of OTHERS (e.g., effectors) as well as of WORDS activates a SIMULATION of an action / interaction
- **SIMULATION: OBJECTS**
  - ✓ Multiple affordances and simulation
- **SIMULATION: HANDS**
  - ✓ Hand primes and size-posture compatibility
  - ✓ Hand primes and perspective
  - ✓ Hand primes and categorization in children
  - ✓ Hand primes and categorization in older people
- **SIMULATION: WORDS AND SENTENCES**
  - ✓ Simulation sensitive to the effector
  - ✓ Simulation sensitive to emotional valence
  - ✓ Simulation sensitive to properties such as weight
  - ✓ Limits of embodied theories and Word As Tools

FRAMEWORK: EMBODIED AND GROUNDED COGNITION

Traditional view:

Action

Cognition

Perception

- Perception and action peripheral
- Sequential relationship between perception and action
- Perception does not vary depending on the motor response (oculomotor, manual etc.)

Embodied and grounded cognition

- Cognition “grounded” in sensorimotor processes.

SIMULATION

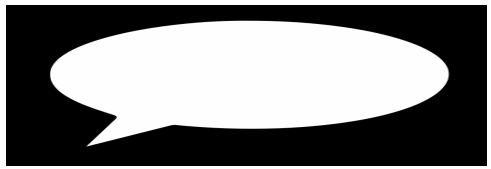
- Simulation (Barsalou, 1999; Decety & Grezes, 2006; Gallese, 2007; 2009)

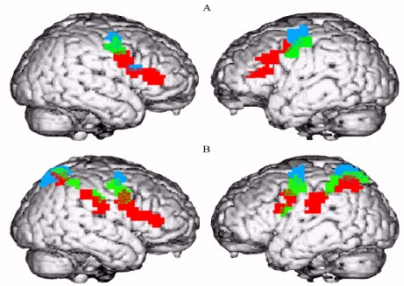
- "offline recruitment of the neural networks involved in specific operations such as perceiving and acting" (Jeannerod, 2007)

  E.g., while observing objects *canonical neurons system

  E.g., while observing others *mirror neurons system

  (motor resonance)



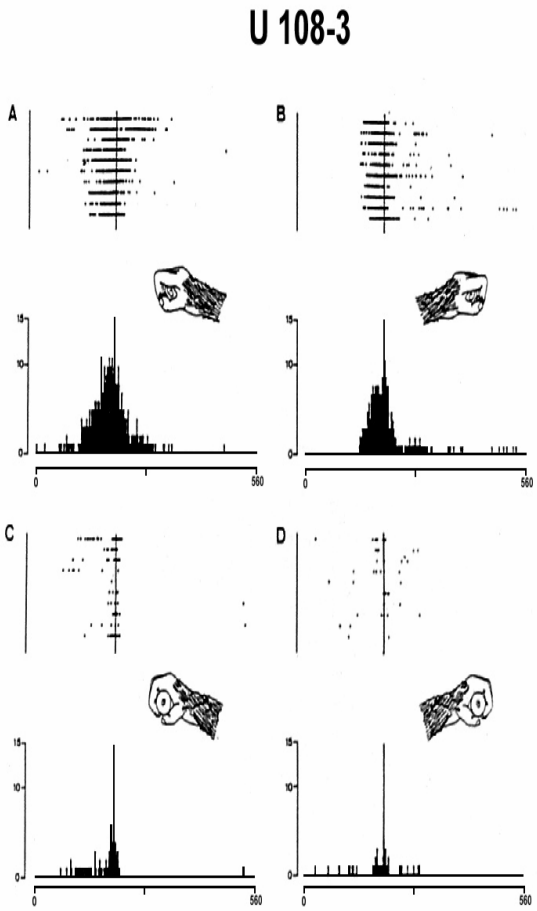


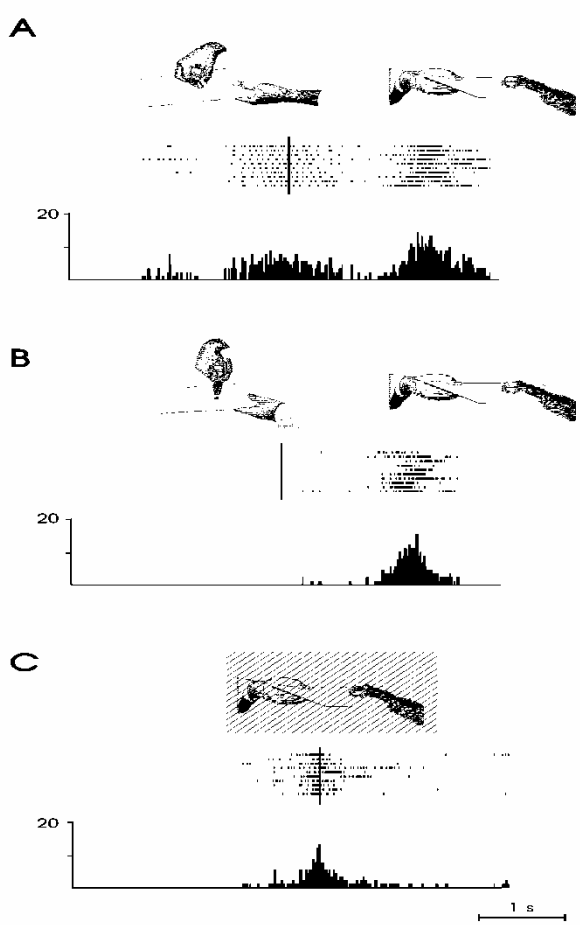
Buccino_et al, 2001

But simulating is not doing:

- ✖ Weaker activation
- ✖ Simultaneous activation of a "blocking" mechanism;
- ✖ No movement, thus no sensory feedback.

NEURAL BASIS: CANONICAL AND MIRROR NEURONS





Rizzolatti & Craighero, 2004

OBSERVING OTHERS AND SIMULATION

- Ideomotor theories; theory of event coding (TEC): the **similarity between the seen stimuli and the performed actions** facilitates processing of the seen stimuli (Prinz, 1990; Hommel et al., 2001).

- Resonance, mirror system activation.
  - E.g., Grezes et al.,2004: observation of our own actions produced faster activation of the parietal pre-motor areas than observation of others' actions.
  - E.g., Flach et al., 2003: hand clapping.
  - E.g., Calvo Merino et al, 2005, 2006: greater motor resonance when watching movements performed by dancers of the same gender.

OBSERVING OBJECTS AND SIMULATION

- Object concepts as **simulators** (Barsalou, 1999), as patterns of potential actions (Glenberg, 1997).
- Function = activating on-line **simulations** that support interaction with objects, even when there is no specific task-requirement. E.g., seeing an orange -> activation of a specific grasp configuration

- Embodied and grounded cognition. Object concepts are:
  - "Grounded" in sensorimotor processes, not arbitrary (Barsalou, 2008)
  - Multimodal, not amodal (Gallese & Lakoff, 2005)
  - Dynamical: they vary depending on context, goals etc.

OBSERVING OBJECTS AND SIMULATION

Seeing manipulable objects activates motor information:

- Neural evidence (review in Martin, 2007)
  - specific brain areas for manipulable and non-manipulable objects (Martin et al., 1996; Gerlach et al., 2002; Kellenbach et al., 2003)
  - specific brain areas for tools (left premotor areas) (e.g., Chao & Martin, 2000; Grafton et al., 1997)
  - role of the canonical neuron system (CNS) in representing knowledge of graspable objects (e.g., Taira et al., 1990; Fagg & Arbib, 1998; Raos et al., 2005).

- Behavioral evidence
  - Studies on affordances and on compatibility effects (e.g., Bub et al., 2003, 2008; Ellis et al., 2007; Tipper et al., 2007, Yoon & Humphreys, 2005; Tucker & Ellis, 1998, 2001, 2004)

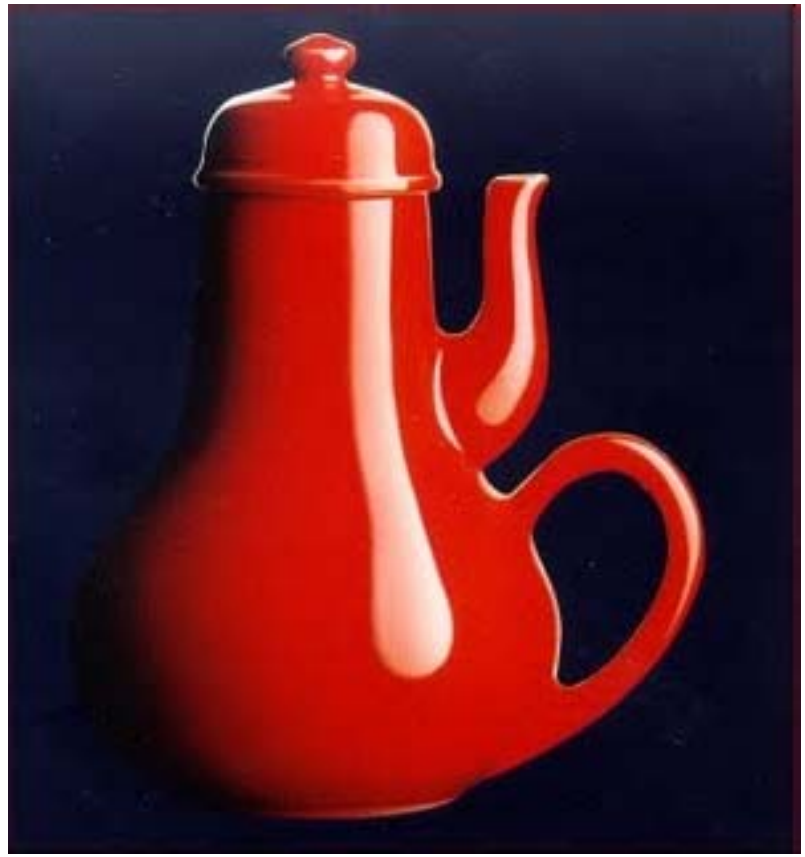
OBJECTS AND AFFORDANCES

Concept of **affordance** (Gibson, 1979).
The environment offers itself to the subject.
E.g., apple

- Affordances concern BOTH perception and action
- Affordances are both subjective and objective
- Affordances refer both to the world and to the individuals
- Affordances are variable

Ellis & Tucker (2000): **micro-affordances:** brain assemblies that are the product of the conjoining, in the brain, of visual stimuli and action responses.

DIFFERENT KINDS OF AFFORDANCES.....



Norman,

STABLE AND VARIABLE AFFORDANCES

Affordances can be:

- "stable" / permanent – based on long-term visuomotor associations. E.g., size.
- "temporary"/variable – based on online visual information. E.g., current orientation of an object.

- No dichotomy
- Working hypothesis: stable affordances part of object representation? Stable affordances represented in the ventral system (or dorso-ventral), variable affordances in the dorsal (or dorso-dorsal)? (in development, EU project ROSSI)

Borghi & Riggio, 2009, Brain Research

Menz, Borghi, Buccino & Binkofski, in prep.

MULTIPLE AFFORDANCES AND MOTOR SIMULATION

- Specificity of rock climbing: affordance observation during training

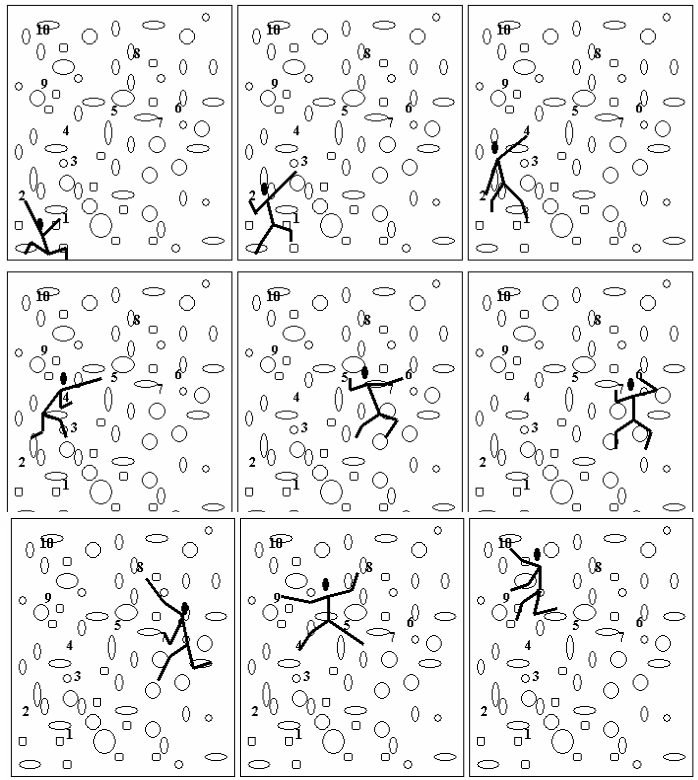
MULTIPLE AFFORDANCES AND MOTOR SIMULATION

- Majority of studies on affordances: single affordances – here: multiple holds on a climbing wall
- Role of motor competence for affordance activation?
- Effects of motor simulation on recall?

Pezzulo, Barca, Lamberti-Bocconi & Borghi, under review

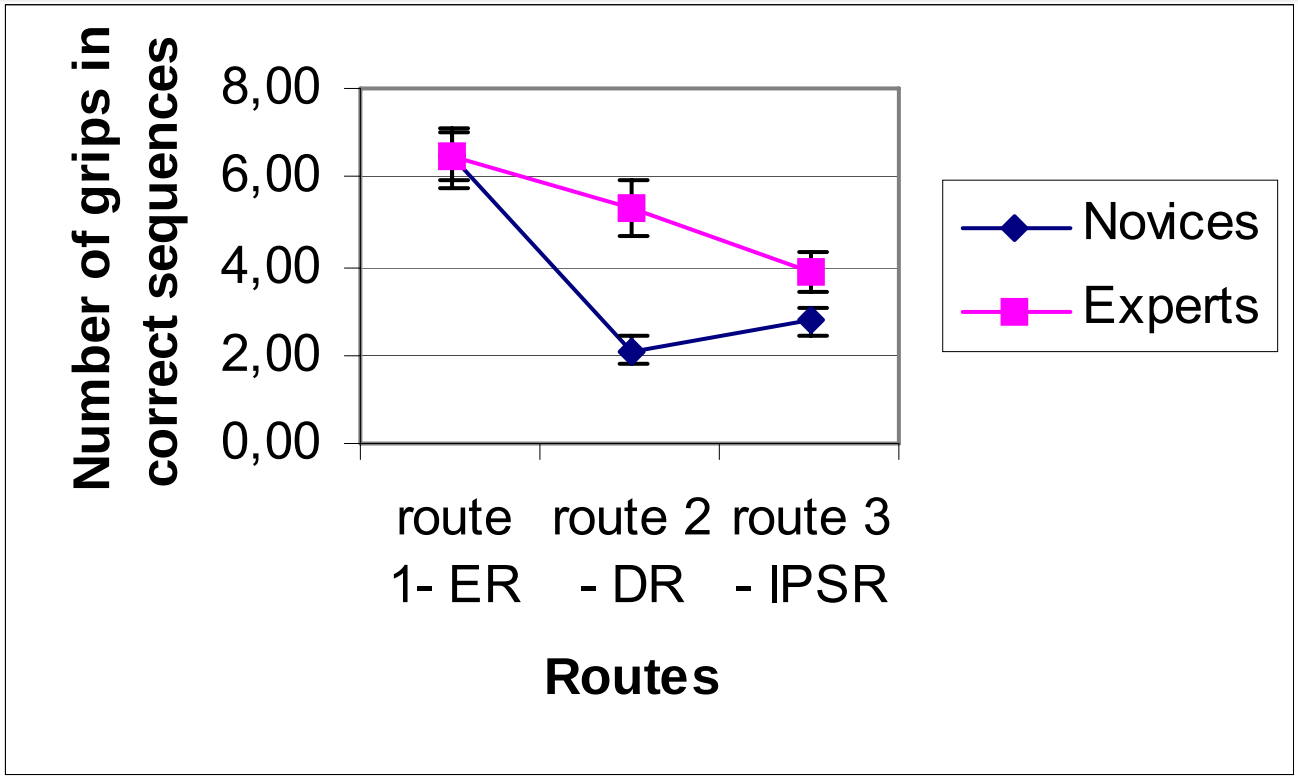
MULTIPLE AFFORDANCES AND MOTOR SIMULATION: PROCEDURE

- Participants: experts and novices rock climbers
- 3 routes: easy, difficult, impossible but perceptually salient
- Procedure: routes are shown by the trainer, then participants have to mark the sequence of holds on a sheet.



Sample sequence of 9 movements composing a climbing route

MULTIPLE AFFORDANCES AND MOTOR SIMULATION: RESULTS



- Easy route: no difference experts – novices
- Impossible Percept. Salient Route: no difference experts – novices
- Difficult Route: experts much better than novices

MOTOR simulation, better recall not based on perceptually salient patterns

MULTIPLE AFFORDANCES AND MOTOR SIMULATION: DISCUSSION

- motor simulation activated by multiple affordances
- simulation as '**affordance calculus**', not response to a sequence of individual affordances. earlier affordances determine the next affordances, and 'goal' holds determine what holds are affordances retrospectively
- simulation **related to motor competence of climbers**: capability to hold small holds, but also to simulate sequences of complex actions.

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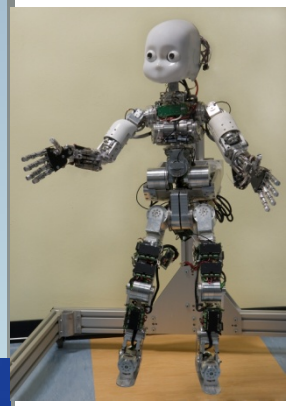
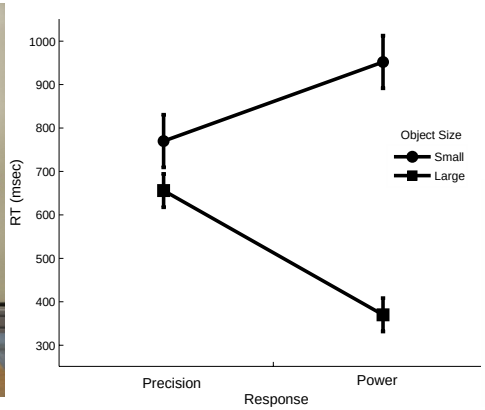
AFFORDANCES AND COMPATIBILITY EFFECTS

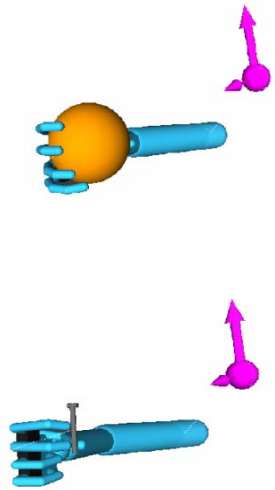
Tucker & Ellis, 2001, 2004

- **Task:** categorization of objects into NATURAL and ARTEFACTS.
- **Results**: compatibility effect between the kind of grip and the object size.

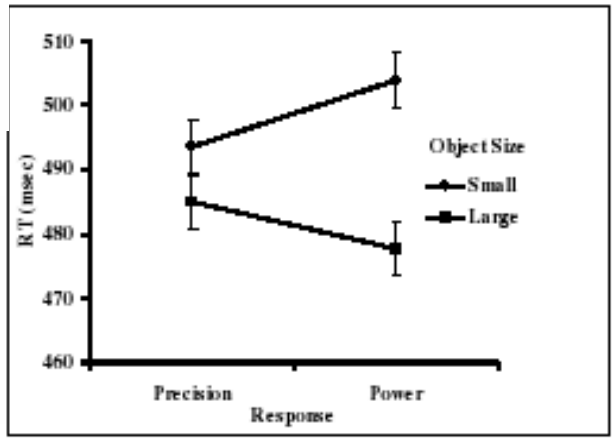
Model







Experiment



iCub Robot

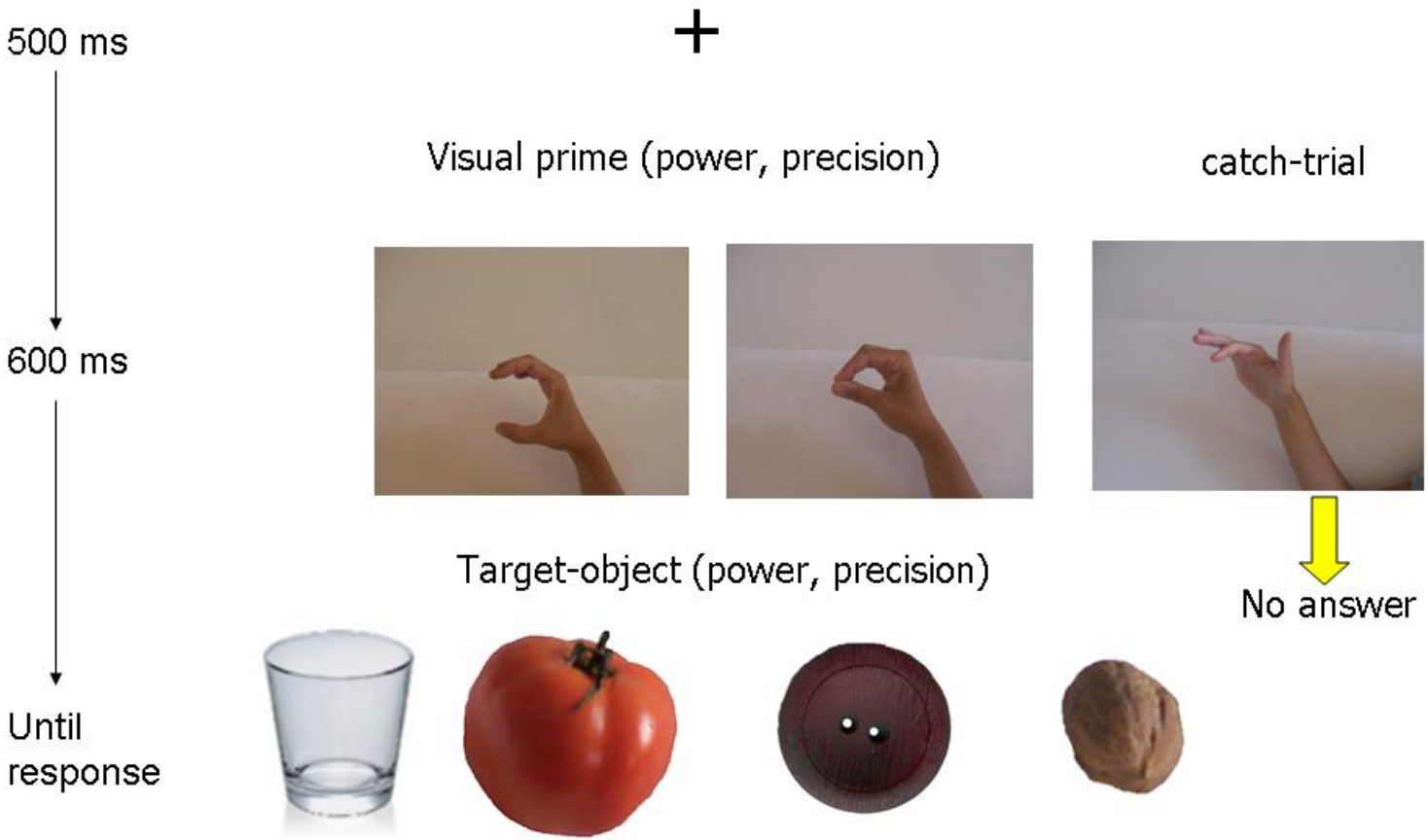
Caligiore, Borghi, Parisi, Baldassarre, 2009; under review

HAND PRIMES AND GRIP COMPATIBILITY

T&E: seeing objects activates **affordances**, but the movement is relevant to the task. Do hand primes evoke specific motor program with objects **when the movement is not relevant to the task?**

- **Task**: **categorization** task– simple key pressure on the keyboard to decide whether objects were artifacts or natural objects (movement not relevant to the task)
- **Prime**: photo of a hand - precision vs. power posture evoking manipulation, not function (Buxbaum et al., 2003)
- **Target**: photos of manipulable objects (graspable either with a precision or with a power grip)

HAND PRIMES AND GRIP COMPATIBILITY: PROCEDURE

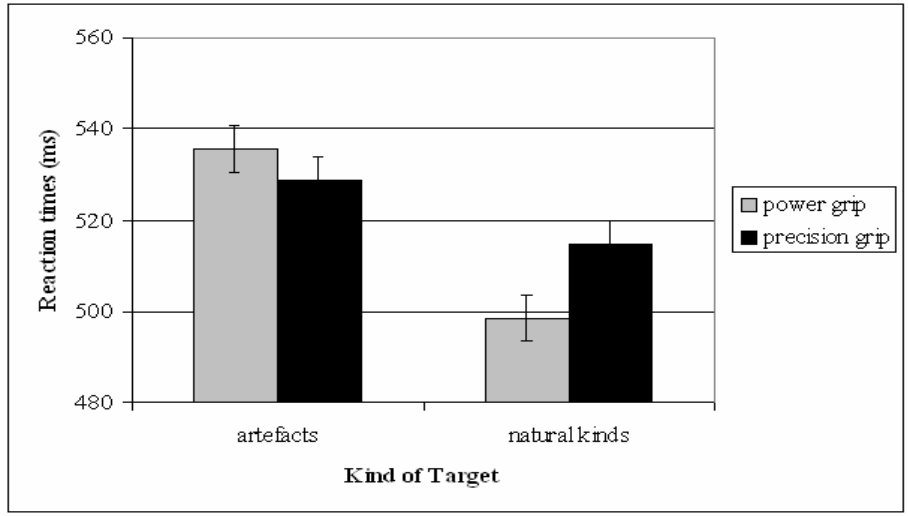


Categorization task: Artefact or natural object? Key pressure to respond

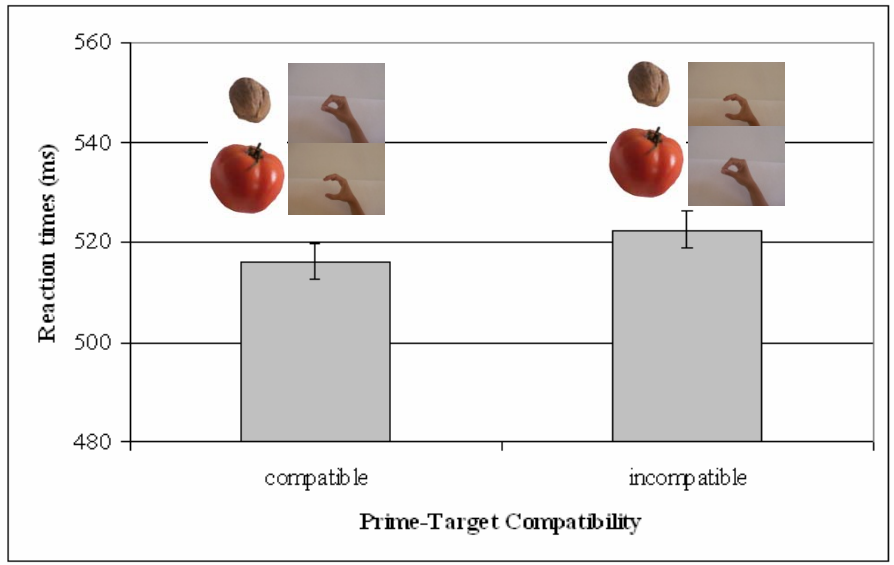
Borghi, Bonfiglioli, Lugli, Ricciardelli, Rubichi, & Nicoletti, Neuroscience Letters, 2007

HAND PRIMES AND GRIP COMPATIBILITY: RESULTS

- Natural objects graspable with a power grip faster than artifacts: activation of manipulability?



- Compatibility effect, but only if the experiment was preceded by a training phase in which participants were required to reproduce with both hands the hand gestures later shown as primes.



HAND PRIMES AND GRIP COMPATIBILITY: DISCUSSION

- Advantage of natural objects graspable with a power grip over the other object types. Explanation: natural objects induced a simpler simulation of **action (grip) but not function**. Manipulation and function do not overlap (e.g., Boronat et al., 2005)

- Visual primes alone were not sufficient to induce "motor resonance". Participants **did not automatically use their body to 'simulate' other persons' actions** (Fischer et al, 2003; 2005).

  Motor training could have led participants to match their own actions with the actions they saw, thus becoming sensitive to the different motor programs triggered by the two primes : TEC theory.

Vainio, Symes, Ellis, Tucker & Ottoboni (2008) found the prime-target compatibility effect using dynamic hand primes (videos), without any motor preparation.

HAND PRIMES AND PERSPECTIVE

- Aim: verify whether the **similarity** between the execution modalities of the **perceived and the performed action** can facilitate action recognition.

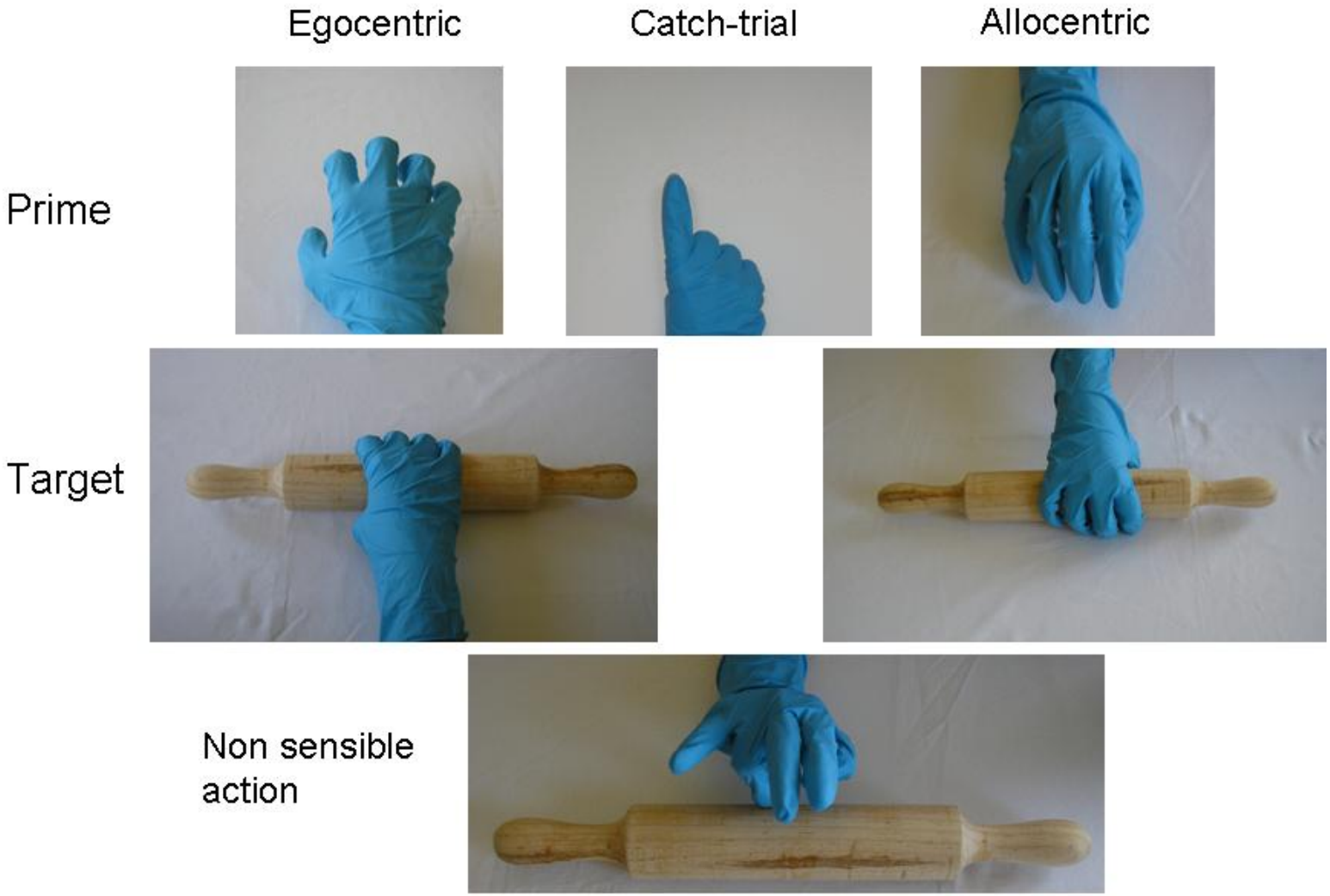
Manipulation of

- the **perspective** (egocentric and non-egocentric) of a visually presented hand interacting with an object

- the **morphological similarity** between the seen hand and the responding hand (half of the participants wore a glove, the hand primes were displayed with a glove).

Bruzzo, Borghi & Ghirlanda, Neuroscience Letters, 2009

HAND PRIMES AND PERSPECTIVE: PROCEDURE

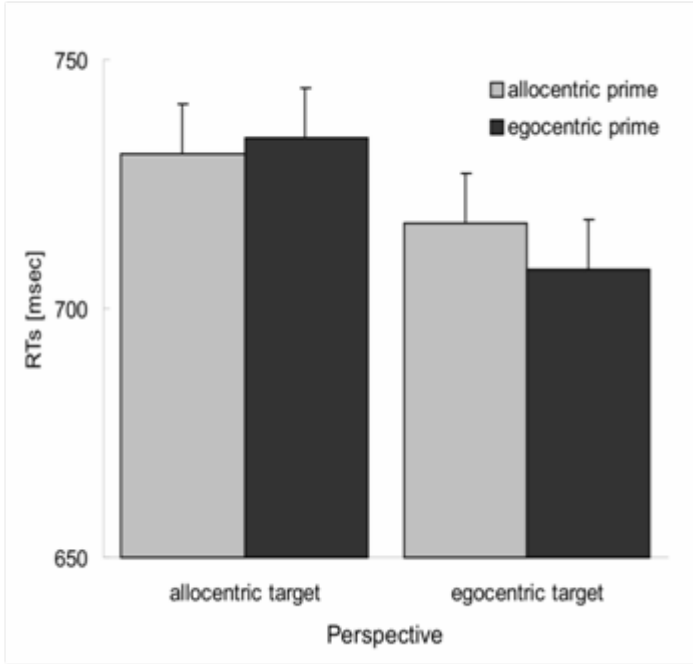


HAND PRIMES AND PERSPECTIVE: PREDICTIONS

- compatibility effect between the hand and the hand-object perspective.
- advantage of the ego- over the non-egocentric perspective due to the increase in similarity between the perceived and the performed action.
- the presence of the glove should improve performance due to the inferred visuotactile similarity between the seen stimulus (the hand wearing a glove) and our own body part (our own hand wearing a glove): the best performance should be found when participants wore a glove and saw the hand interacting with the object in an egocentric perspective.

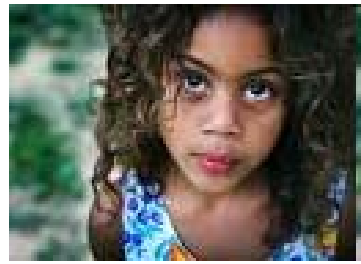
HAND PRIMES AND PERSPECTIVE: RESULTS

- compatibility effect between the perspective of Prime and Target: fastest responses with egocentric prime followed by egocentric target.
- Interaction Target perspective and Glove: egocentric targets are processed faster than non-egocentric ones when participants wear gloves (similarity with the hand they see)
- Thus: **simulation facilitated** in case of **similarity** between our own hand and the seen hand (same perspective, same glove)



HAND PRIMES AND CATEGORIZATION IN CHILDREN

AIM: assess the effect of action and context priming on superordinate (e.g., bowl) and basic-level (e.g., utensil) categorization of manipulable objects during development



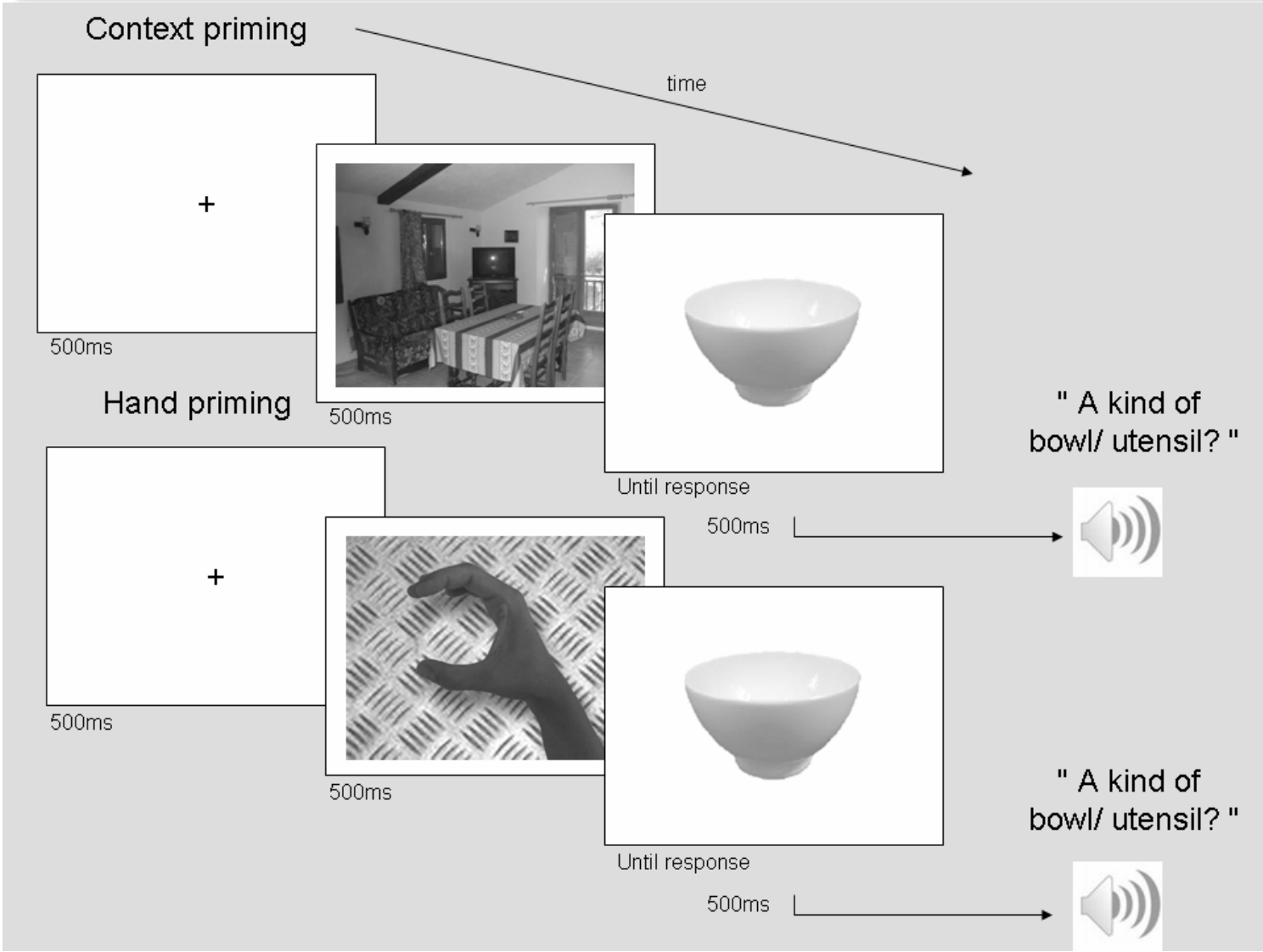
- **Prime**: photo of a scene (inside, outside) vs. of a hand (precision vs. power posture)
- **Target**: photos of manipulable objects, natural kinds and artefacts
- **Task**: Basic-level task : « a kind of bowl? »

vs. superordinate-level task « a kind of utensil? »

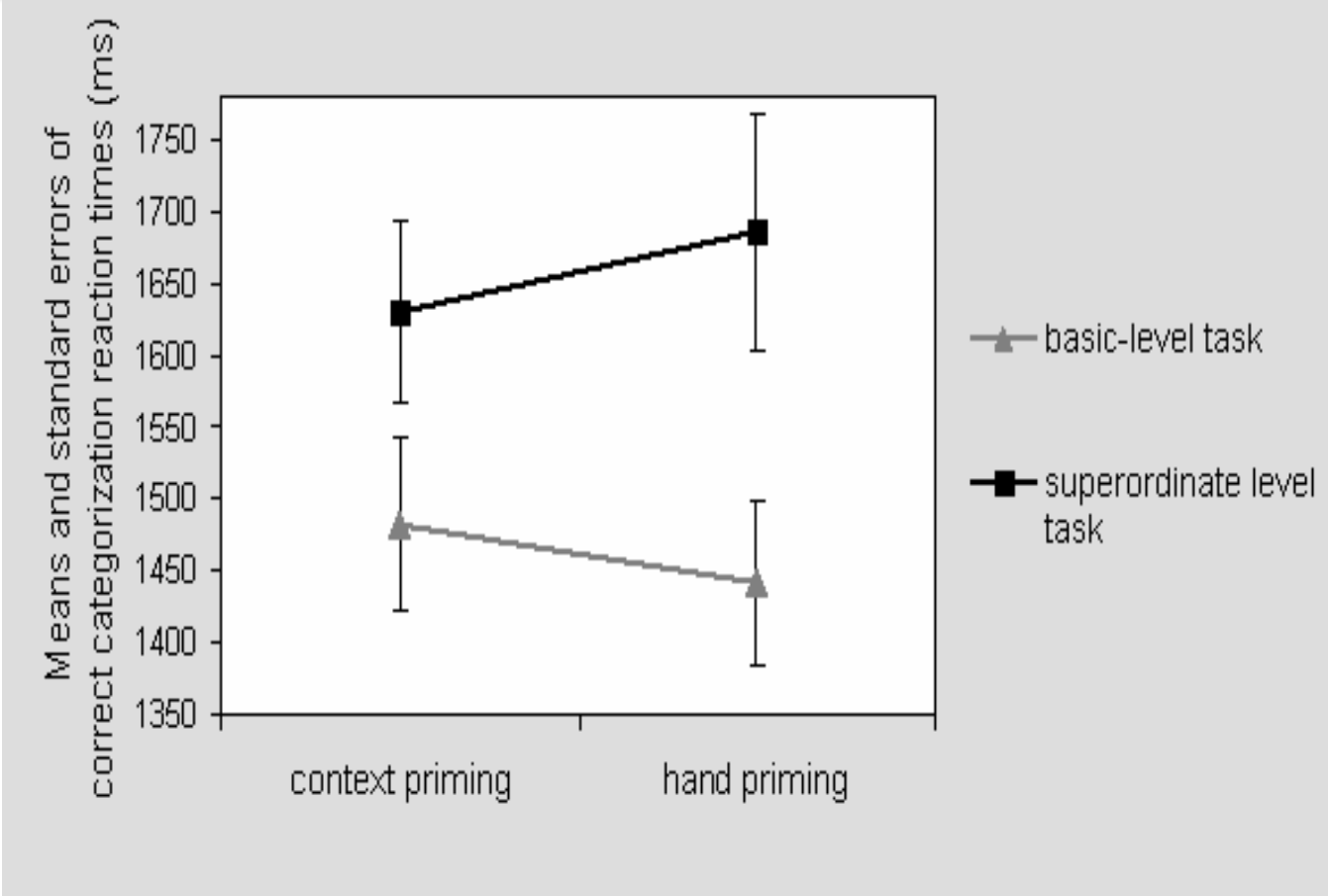
- **Participants**: 7-year-olds, 9-year-olds, adults

Kalénine, Bonthoux & Borghi, British J. of Developm. Psychol., 2009

HAND PRIMES AND CATEGORIZATION IN CHILDREN: PROCEDURE



HAND PRIMES AND CATEGORIZATION IN CHILDREN: RESULTS



- advantage of the basic over the superordinate task greater in the hand priming than in the context priming condition, irrespective of age.

HAND PRIMES AND CATEGORIZATION IN CHILDREN: DISCUSSION

- irrespective of age, **contextual cues** help more to access **superordinate-level concepts** than action cues: this reduces the basic-level superiority.

- **action information** is more efficient to process a **single exemplar** than a collection of exemplars. Explanation: context works as glue that links specific actions experienced with different object exemplars and facilitates superordinate object categorization(Murphy & Wisniewsky, 1989; Borghi, Caramelli & Setti, 2005) .

- Open issue: does the context mainly refer to visual information (Bar, 2004) or may the context also convey motor information, considering that it could afford potential actions (Iacoboni et al., 2005)?

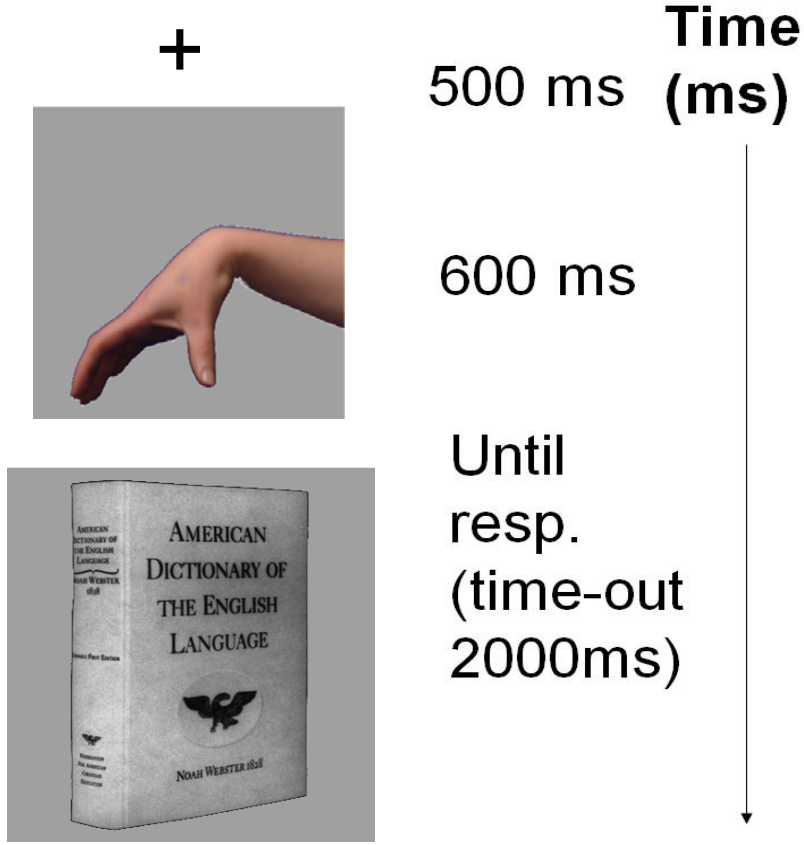
HAND PRIMES AND CATEGORIZATION IN OLDER PEOPLE

- Aim: verify whether seeing heavy vs. light objects elicits a motor simulation and whether this simulation differs in younger and older people
- Aim: verify whether the **similarity** between the hand prime's characteristics and the characteristics of participants' hands can facilitate action simulation (gender, age).

Setti, Burke, Liuzza, Kenny, Borghi, Newell, in prep.

HAND PRIMES AND CATEGORIZATION IN OLDER PEOPLE

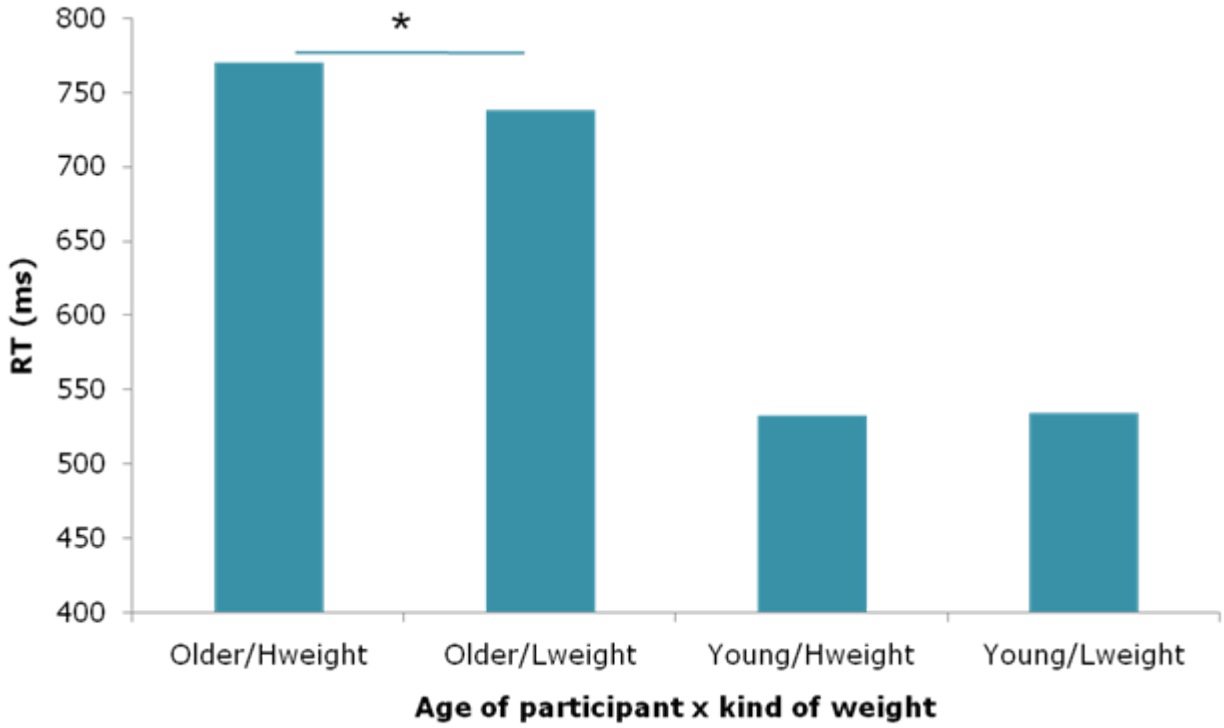
- Hand prime: same or different sex of the participant (Male vs. Female); Same or different age (Older, Younger) or neutral (Glove)
- Light object vs. Heavy object
- Participants: males and females, younger and older



HAND PRIMES AND CATEGORIZATION IN OLDER PEOPLE: RESULTS

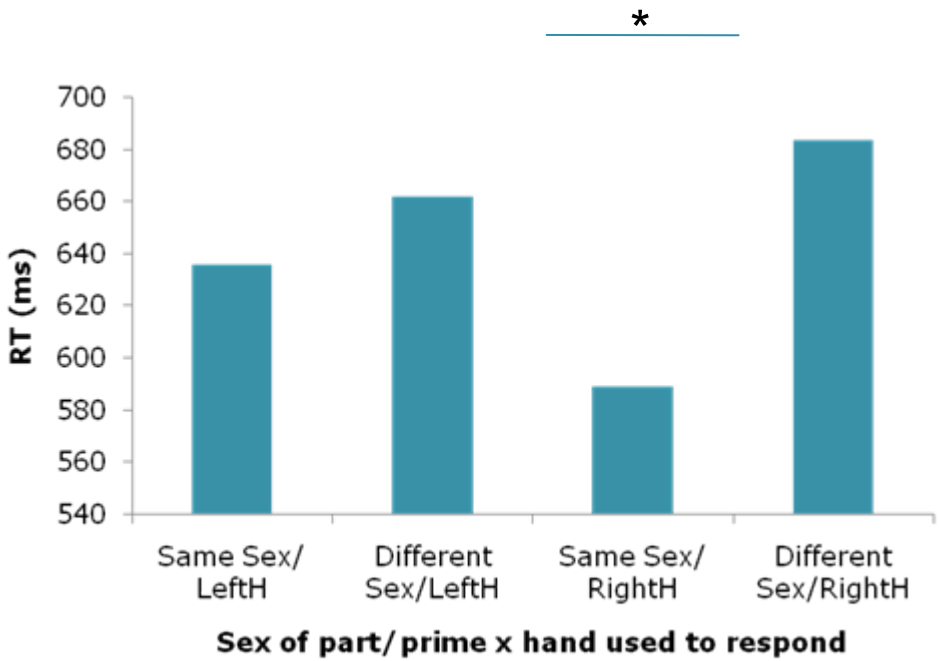
Participants: 58 older adults (no history of psychiatric or neurological illness), 52 younger adults

only OLDER respond slower to heavy weight with their NON dominant hand, no difference for younger. This suggests that they simulate lifting the objects and that this simulation is modulated by participants' age.



HAND PRIMES AND CATEGORIZATION IN OLDER PEOPLE: RESULTS

both OLDER and YOUNGER show an effect of overlapping between participants' sex and hand prime sex on dominant hand. Same gender primes facilitate simulation of object lifting, in particular with the dominant hand.



HAND PRIMES AND CATEGORIZATION IN OLDER PEOPLE

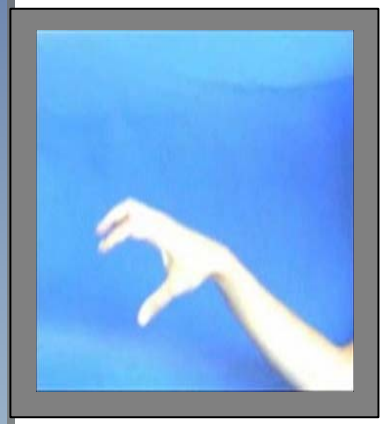
- Why effect of gender compatibility, but not of age compatibility?

Possible causes:

- Reduced perceptual differences
- No change of the body schema

What would happen with a kid's hand?

OTHER STUDIES WITH HAND PRIMES



APPLE

Prime:
dynamic / static hand,
either grasping / moving hand,
unimanual/bimanual.

Target:
words referring to self-moving vs non self-moving entities (e.g., cat, apple)

With unimanual prime **interference**:
grasping with words referring to **inanimate objects**, **movement** with **animate objects**.

Interference instead of facilitation: because of words?

Setti, Borghi, Tessari, Brain & Cognition, 2009

SUMMARY SO FAR

- Observation of **objects (affordances) and of others' hands** potentially interacting with objects activates an embodied simulation

- Objects: the simulation is activated not only by single but also by **multiple objects** (e.g., holds for climbers) and it influences both **online processing and memory**

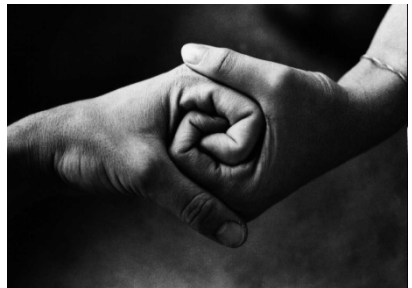
- Objects: differences between artefacts and natural objects suggest that a different simulation is linked to **object manipulation vs. use**

SUMMARY SO FAR

- Hands and objects: seeing a hand potentially interacting with an object activates a **specific motor program**. It is unclear whether this activation is automatic.

- Hands: **hand primes** work better for **single exemplars** than for collections of exemplars
- Hands: they prime pictures and **words** as well

- Hands: the motor resonance process is modulated both by the characteristics of objects and by the **similarity between the visually perceived hand and the participant's hand**, as the effects of **perspective** and the effects of **gender** reveal.



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SIMULATION AND LANGUAGE COMPREHENSION

Language comprehension: **simulation** of the described action / situation. Neural basis: Canonical and Mirror Neuron System (Rizzolatti & Craighero, 2004; Gallese, 2009)

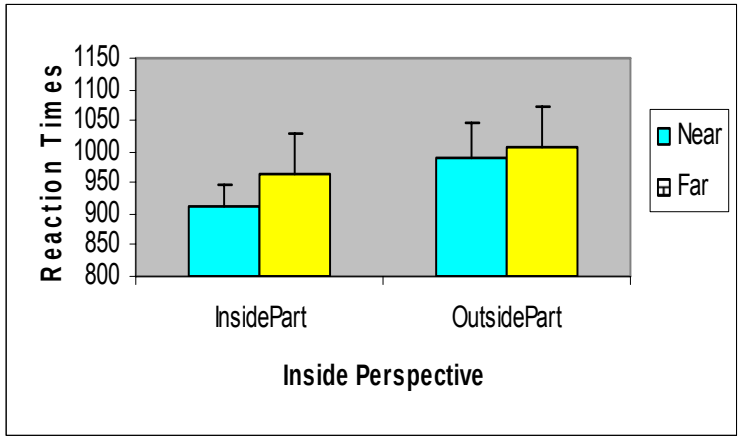
Behavioral, physiological, brain imaging evidence: somatotopic and early activation of motor and premotor cortices during language comprehension (reviews: Barsalou, 2008; Fischer & Zwaan, 2008; Martin, 2007; Pulverműller, 2005; Toni, de Lange, Noordzij, & Hagoort, 2008)

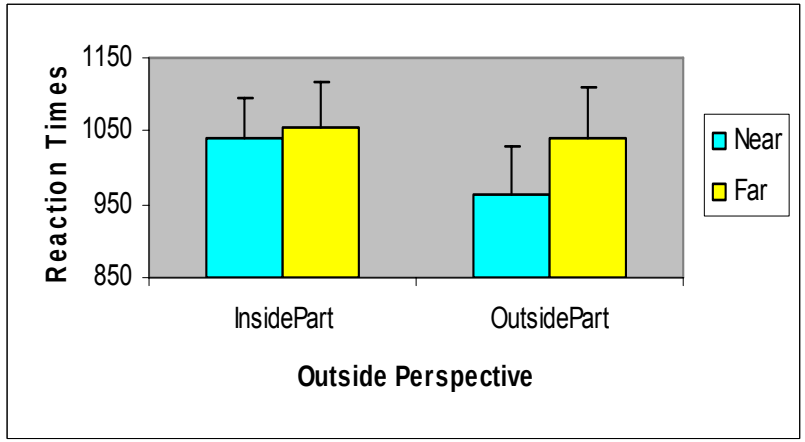
SIMULATION AND LANGUAGE COMPREHENSION: PARTS

Task: reading sentences – part verification

Variables: **Internal vs. External Actions, Internal vs. External Parts, Near vs. Far Parts**

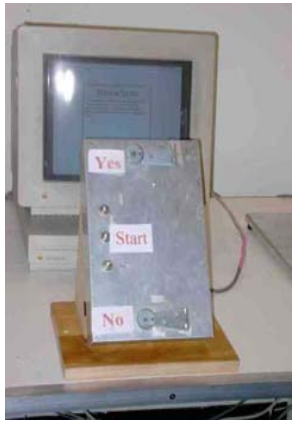
IA - You are driving a car – IPN - horn, IPF - back seat
EA - You are painting a car – EPN - trunk, EPF - exhaust pipe





Borghi, Kaschak & Glenberg, Memory & Cognition, 2004.

SIMULATION AND LANGUAGE COMPREHENSION: PARTS



Task: part verification task.

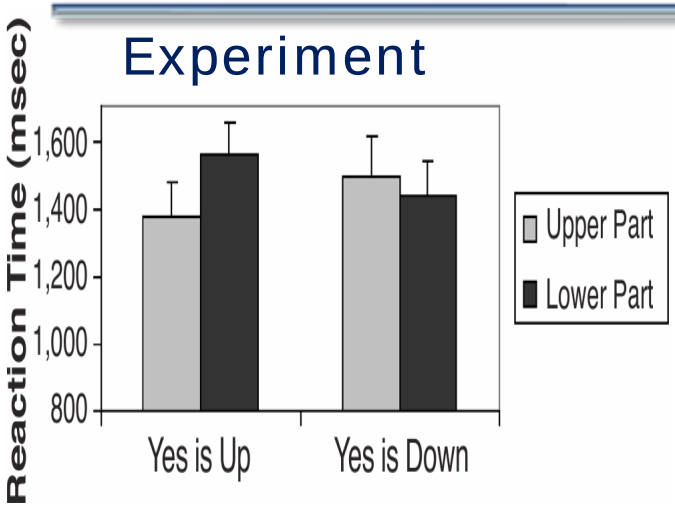
E.g. “There is a doll standing on the table in front of you”

“head” vs. “foot”

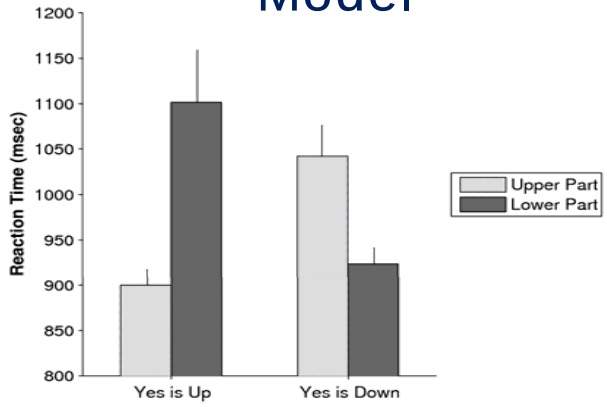
Movement upwards or downwards to respond.

Borghi, Kaschak & Glenberg, Memory & Cognition, 2004.

Experiment



Model



Replicated with a model: Caligiore, Borghi, Parisi & Baldassarre, under review

LANGUAGE COMPREHENSION AND ACTION

are actions encoded in terms of GOALS (Hommel et al., 2001)

or also (and to what extent) in proximal terms (e.g., which EFFECTOR do we use)? (e.g., Bach & Tipper, 2007)

Buccino, Riggio et al., 2005

Aziz-Zadeh & Damasio, 2008

Hauk, Johnsrude & Pulvermüller, 2004

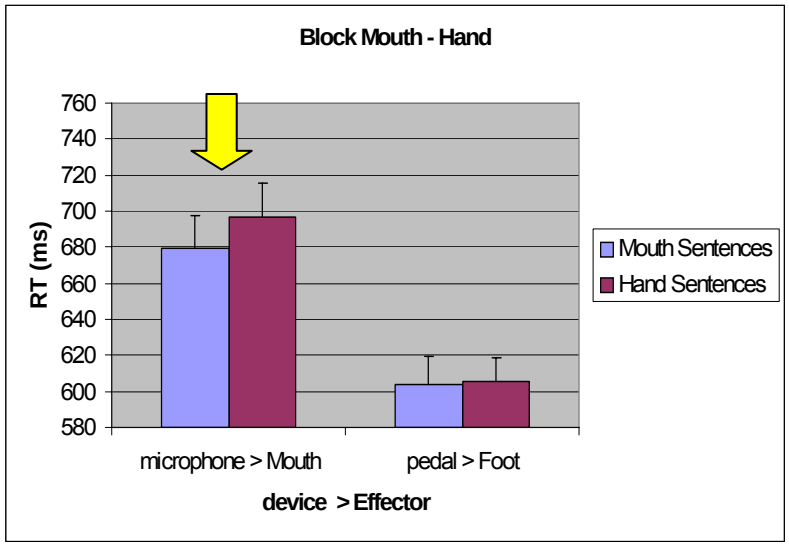
many others….

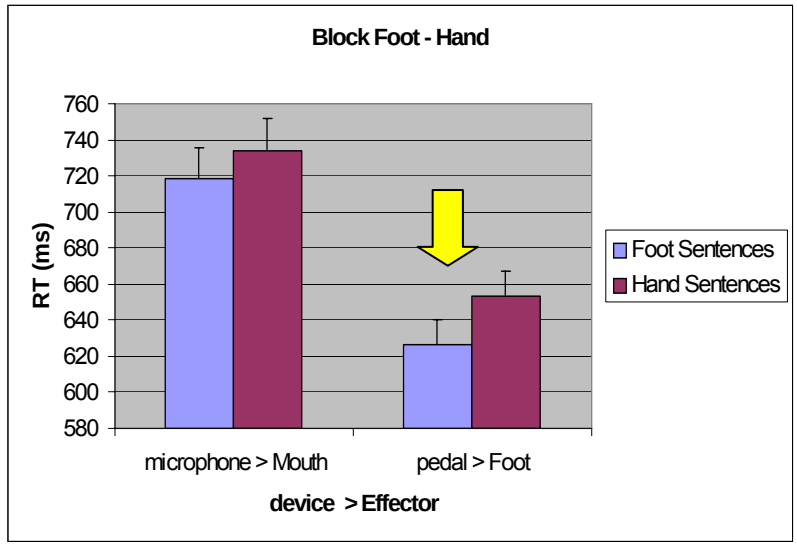
SIMULATION AND SENSITIVITY TO THE EFFECTORS

Task: evaluate sentence sensibility

(e.g., “kick / throw the ball” - “unwrap / suck the sweet”).

Results: facilitation when congruence between the effector implied by the sentence and effector used to respond (foot, mouth vs. hand as baseline)





Scorolli & Borghi, Brain Research, 2007,
Borghi & Scorolli, Human Movement Science, 2009.

SIMULATION AND WORD EMOTIONAL VALENCE

task: classify words as positive or negative.

focus not on the arm but on the hand posture.

2 conditions: open hand vs. hand holding a tennis ball.

results: with the empty, open hand, faster RTs when withdrawing negative objects from the body and approaching/reaching positive objects far from the body. When holding a tennis ball replication of results by Chen and Bargh (1999).

PosNear NegFar	PosFar NegNear
953	**836**

PosNear NegFar	PosFar NegNear
872	**949**

Freina, Baroni, Borghi & Nicoletti, *Memory and Cognition*, 2009

SIMULATION AND WORD EMOTIONAL VALENCE

Simulation sensitive also to the **specific posture of the hand** (clench-closed hand vs. palm-open hand; see Klatzky et al., 1987; Klatzky et al., 1989).

But relevance of the hand posture only **if it influences the** more general **action goal**, and induces the participant to assign a different meaning to the whole movement (Bekkering et al., 2000; Hommel, Müsseler, Aschersleben & Prinz, 2001)

Hand open: far positive (REACH), near negative

Hand holding something: near positive (KEEP), far negative

SIMULATION AND WORDS REFERRING TO WEIGHT

Task: participants listened to sentences referring to the lifting of light or of heavy objects (e.g., pill vs. chest).

Then they liften one of two boxes that were visually identical, but one was light and the other heavy.

Focus on the **kinematics of the initial lift** (rather than reaching), which is mostly shaped by proprioceptive features derived from weight that cannot be visually determined.

Results: participants were slower when the weight suggested by the sentence and the weight of the box corresponded.

Scorolli, Borghi & Glenberg, Experim. Brain Research, 2009

SUMMARY SO FAR

- The simulation run during language comprehension is quite detailed.
- It is sensitive to object properties:
  - ✓ Object spatial organization (parts)
  - ✓ Object weight (intrinsic properties)
- It is sensitive to action properties:
  - ✓ Effectors
  - ✓ Action goals
- It is sensitive to emotional and social aspects (modulated by action goals)

- But: limits of embodied and grounded theories of language comprehension

EMBODIED THEORIES AND LANGUAGE: LIMITS

Limits of embodied theories of language:

- 1. focus only on referential aspects.
  What about social aspects of language?
- 2. abstract words?

- Hypothesis: intending words as WAT, Words as Tools could help to solve both issues:
  - words acquired in a social context (Vygotskij, 1934),
  - words as actions (es. Austin, 1962; Clark, 1998; Wittgenstein, 2001)

Borghi & Cimatti, Proc. Cogsci, 2009; Borghi & Cimatti, in prep.

WAT AND DEVELOPMENT OF ABSTRACT WORDS

- E.g. word ball: the sensorimotor experience can precede the linguistic one

  embodied individual experience

- E.g. words freedom, justice, logics: linguistic experience helps us in collecting a variety of bodily states, internal and external experiences, etc.

  These states and experiences are recognized and categorized once they are named.

  embodied social experience

Not dichotomy!

"freedom"

WAT AND ABSTRACT WORDS: EVIDENCE IT ACCOUNTS FOR

- emotional aspects. Emotional aspects more frequent with abstract compared to concrete words (Vigliocco et al, 2009).
- Age of acquisition. Later acquisition of abstract compared to concrete words (McGhee-Bidlack, 1991).
- Modality of acquisition (MOA). MOA (Wauters et al., 2003): initial perceptual acquisition, then linguistic acquisition. But abstract words?
- Brain imaging. Left hemisphere areas are more active with abstract than with concrete words (e.g. Sabsevitz, Medler, Seidenberg, & Binder, 2005)

WAT AND ABSTRACT WORDS: EVIDENCE REQUIRED

- Cross-linguistic: the difference in language should influence more abstract than concrete words
- Developmental: acquisition of abstract words more mediated by language (MOA).
- Neural basis: all words should activate sensorimotor areas, abstract words should activate more linguistic and social-emotional areas

Behavioral work: Scorolli, Binkofski, Buccino, Riggio, Nicoletti, Borghi, submitted

WAT AND DEVELOPMENT OF THE "SENSE OF BODY"

- "body ownership", proprioceptive, fragmented
- Holistic sense of the body (agency") (Tsakiris et al., 2006, 2007)
- Use of tools: extension of our peripersonal space (Iriki et al., 2004; Maravita, 2004; Farne' et al., 2007).

PROPOSAL

- Hypothesis: beyond mirror neurons, social sense of our body: internal language (words "I", "mine")
- Hypothesis: WAT - words instruments that **modify** / enlarge our **peripersonal space**, similarly to real tools

Borghi & Cimatti, Neuropsychologia, in press

SUMMARY

- **Framework:** observation of OBJECTS (AFFORDANCES) and of OTHERS (e.g., effectors) as well as of WORDS activates a SIMULATION of an action / interaction
- **ACTING WITH OBJECTS - affordances**
  - ✓ Multiple affordances and simulation
- **OBSERVING OTHERS – hands**
  - ✓ Hand primes and size-posture compatibility
  - ✓ Hand primes and perspective
  - ✓ Hand primes and categorization in children
  - ✓ Hand primes and categorization in older people
- **INTERACTING WITH OTHERS – words**
  - ✓ Simulation sensitive to the effector
  - ✓ Simulation sensitive to emotional valence
  - ✓ Simulation sensitive to properties as weight
  - ✓ Word As Tools, WAT

Thanks!

EMbodied COgnition lab

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