SENSORIMOTOR TRANSFORMATIONS: IMPLICATIONS FOR OBJECTS AND AFFORDANCES

anna m. borghi[1,2]

1 Department of Psychology, University of Bologna

2 Institute of Science and Technology of Cognition, CNR, Rome

annamaria.borghi@unibo.it

Web-site: http://laral.istc,cnr.it/borghi

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OVERVIEW

- Framework: 2 lines of research: observation of others and of objects (affordances) activates a simulation
- Multiple affordances and simulation
- Hand primes and compatibility effects
- Hand primes and categorization in children
- Hand primes and perspective
- Hand primes and words
- Hand primes and categorization in older people

OBSERVING OTHERS AND SIMULATION

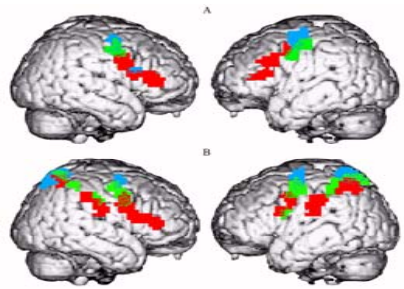
- Simulation (Barsalou, 1999; Decety & Grezes, 2006; Gallese, 2007; 2009)

- "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.

OBSERVING OTHERS AND SIMULATION

- Common coding theory; theory of event coding (TEC): perceptual contents and action plans are coded in a common representational map. therefore, 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; Tipper et al., 2007, Yoon & Humphreys, 2005; Tucker & Ellis, 1998, 2001, 2004)

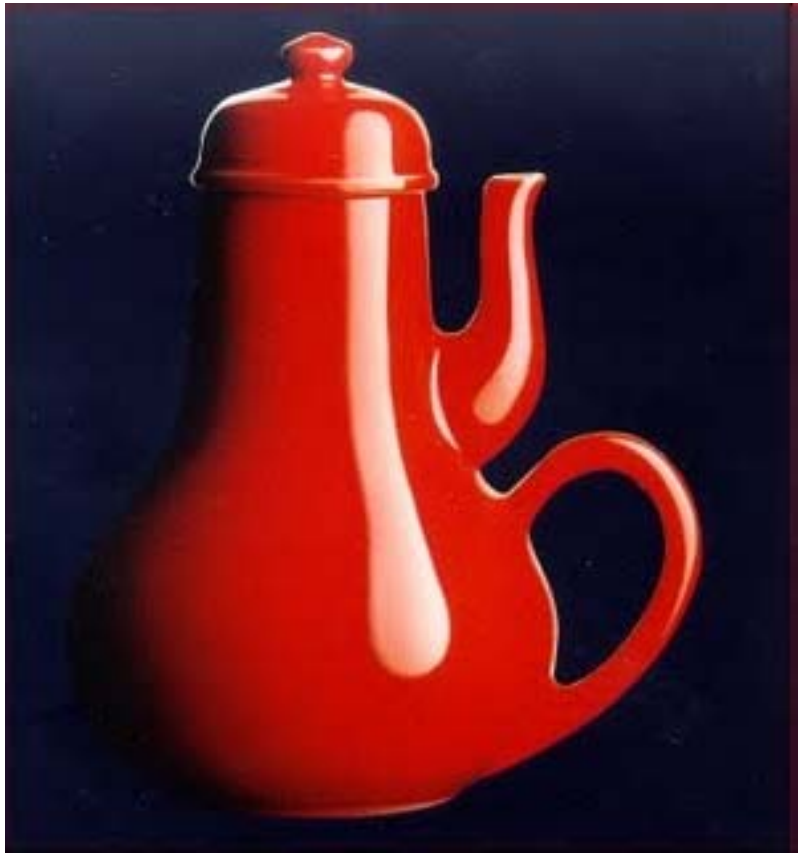
OBJECTS AND AFFORDANCES

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.

AFFORDANCES OF WHAT?



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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?

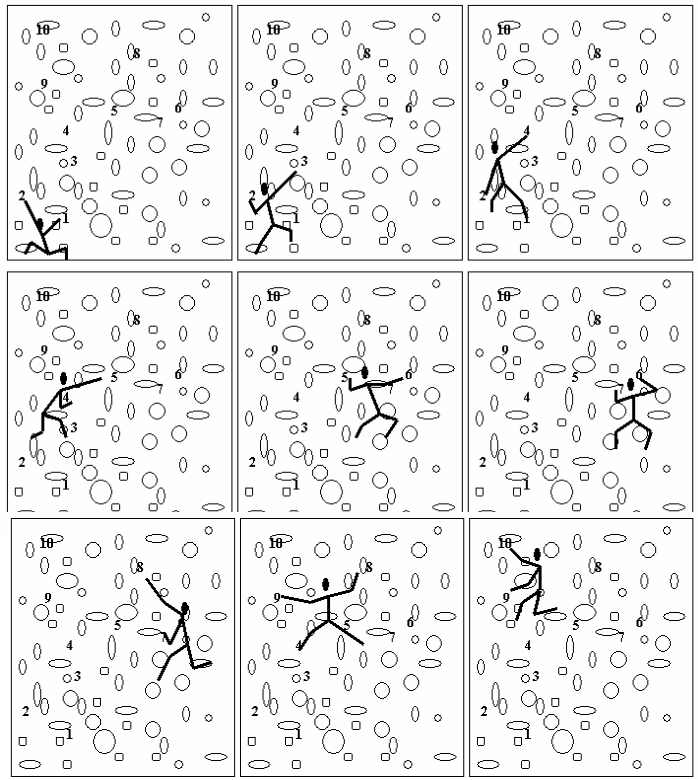
Pezzulo, Barca, Lamberti-Bocconi & Borghi, submitted

MULTIPLE AFFORDANCES AND MOTOR SIMULATION

- Specificity of rock climbing: simulation elicited by affordance observation

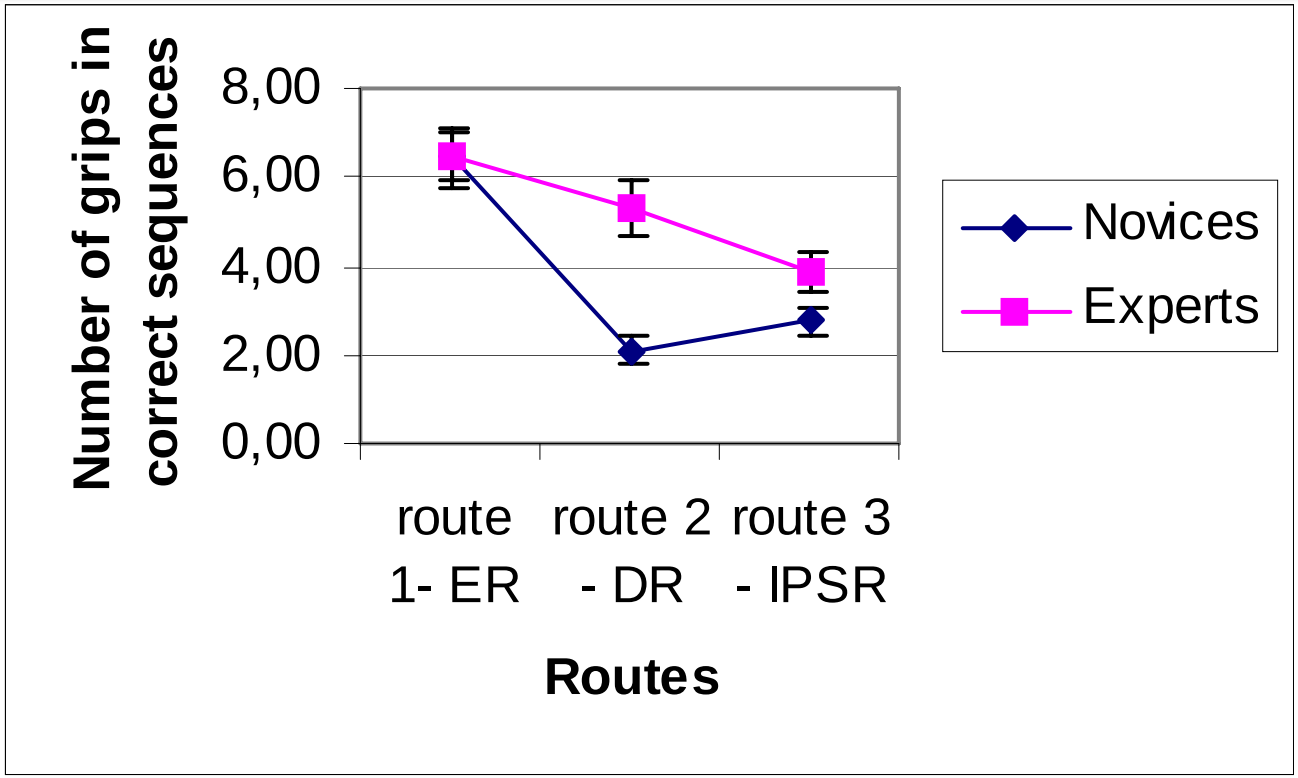
MULTIPLE AFFORDANCES AND MOTOR SIMULATION: PROCEDURE

- 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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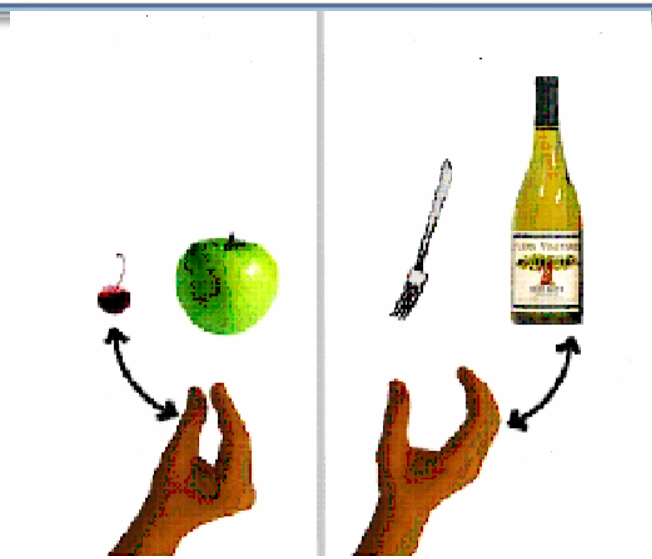
AFFORDANCES AND COMPATIBILITY EFFECT: SIZE

Intrinsic properties: SIZE
Tucker & Ellis, 2001, 2004

- **Task**: categorization of small and larger objects in NATURAL and ARTIFACTS. Response mimicking a precision or a power grip



- **Results:** compatibility effects between the object size (not relevant to the task) and the kind of grip used to respond.
- **Explanation:** seeing an object activates motor information and potentiates affordances related to past experiences with that object.

HAND PRIMES AND GRIP COMPATIBILITY

T&E: seeing objects activates **affordances, but movement 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)

Borghi, Bonfiglioli, Lugli, Ricciardelli, Rubichi, & Nicoletti, 2005; 2007

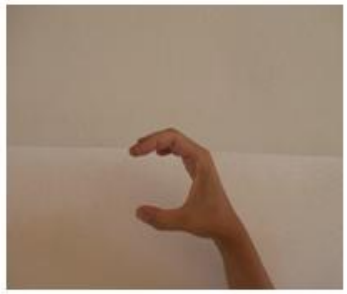
HAND PRIMES AND GRIP COMPATIBILITY: PROCEDURE

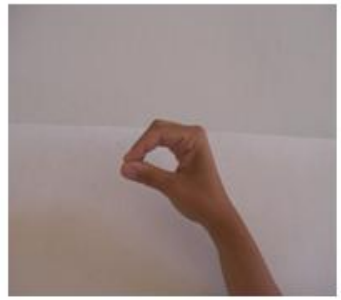
500 ms

+

600 ms

Visual prime (power, precision)





catch-trial

No answer

Target-object (power, precision)

Until response

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

HAND PRIMES AND GRIP COMPATIBILITY: PREDICTIONS

If visual objects activate motor information,

- **Natural objects** should be **faster than artifacts**, because the latter activate both action and function information (on the difference action-function e.g., Boronat et al. 2005, Buxbaum et al., 2000, Creem & Proffitt, 2001)

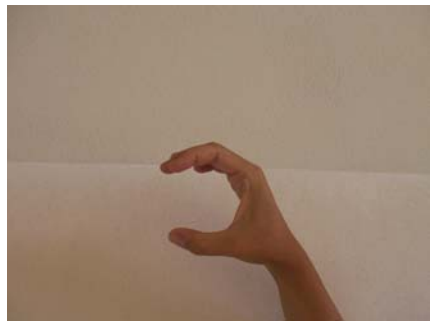
- Target-objects graspable with a **power grip** should be processed **faster** than target-objects graspable with a precision grip, as in real life the processes underlying the implementation of a precision grip are more complex and time consuming than those required for a power grip.

HAND PRIMES AND GRIP COMPATIBILITY: PREDICTIONS

If a specific motor program (an action simulation) is activated by the prime, then

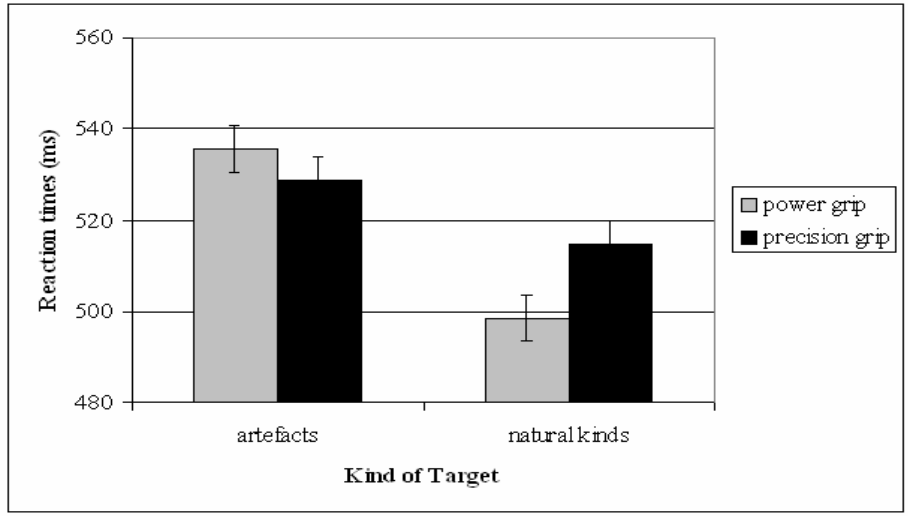
- ☺ a **compatibility effect** between the hand posture of the prime and the size of the target-object should be found

- ☺ the neural substrate underlying the action simulation driven by the hand postures could be the “mirror neuron system”.

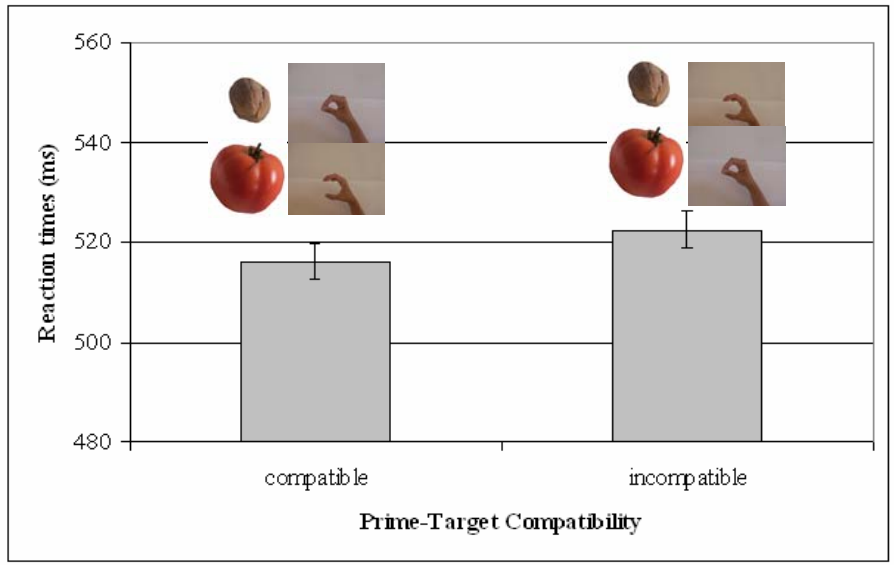


HAND PRIMES AND GRIP COMPATIBILITY: RESULTS

- 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

- Seeing photographs of objects activated information regarding how to manipulate and use them (**HOW and WHAT FOR**). 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 functional knowledge**. Consistent with studies that show that action and function knowledge do not overlap (e.g., Boronat et al. 2005)

- Possible alternative explanation: perceptual effect of size (Kosslyn, 1976). But:
  - Why should this effect be limited to natural objects?

HAND PRIMES AND GRIP COMPATIBILITY: DISCUSSION

- The visual primes alone were not sufficient to induce "motor resonance" behaviour in participants. Participants **did not automatically use their body to 'simulate' other persons' actions** (Fischer et al, 2003; 2005). Evidence in line with our results: Klatzky et al., 1989; Bub et al., 2003.

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 → Common coding theory.

Vainio, Symes, Ellis, Tucker & Ottoboni (2008) replicated the prime-target compatibility effect using dynamic hand primes (videos), without any motor preparation. But differences> the hand did not disappear, not real prime

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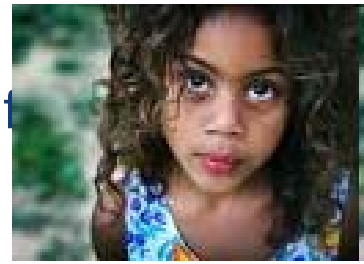
HAND PRIMES AND CATEGORIZATION IN CHILDREN

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. ot
  (precision vs. power posture)

- **Target**: photos of manipulable objects, natural kinds and artefacts

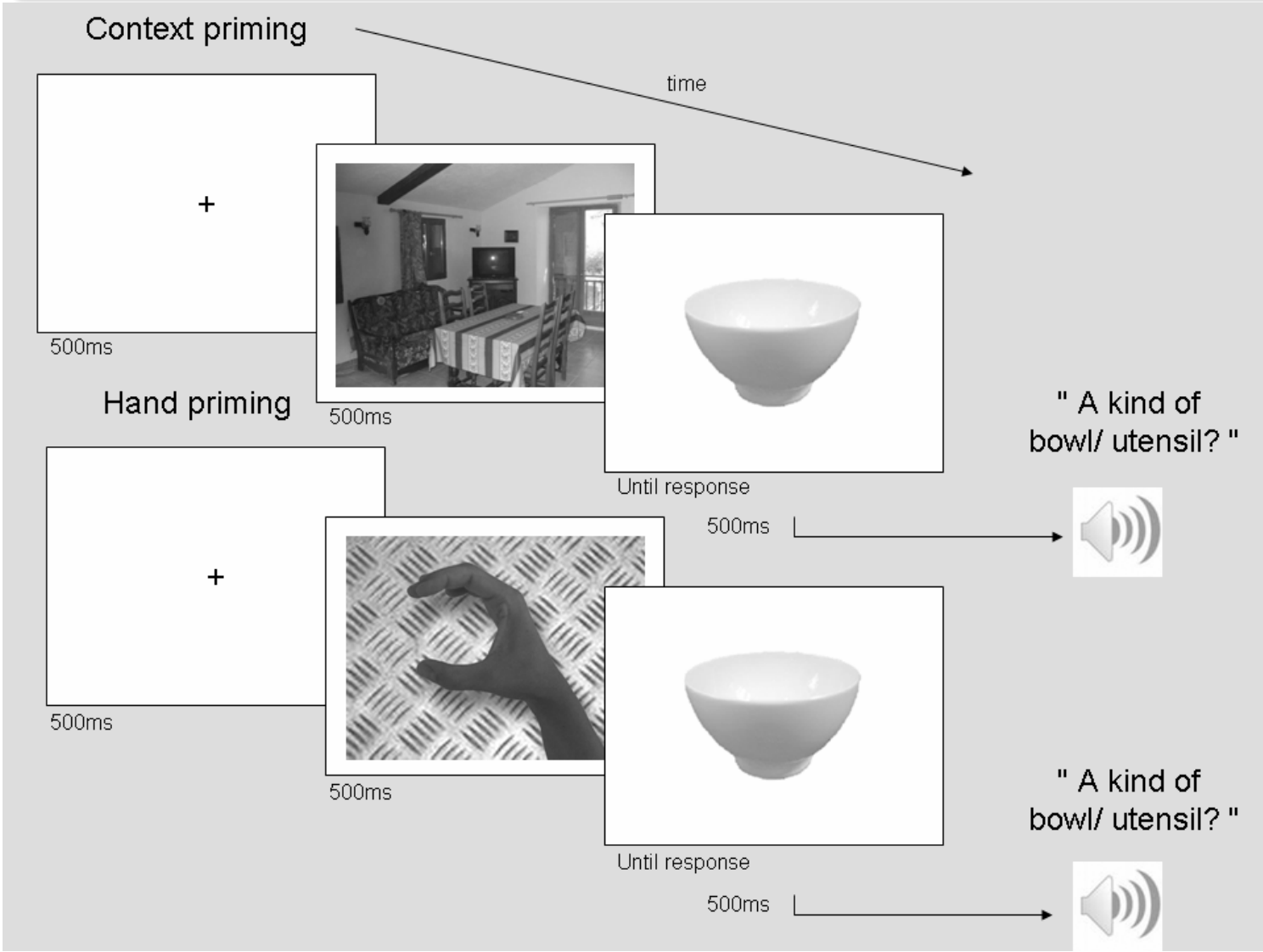
- **Task**: Basic-level task : « a kind of bowl? »

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

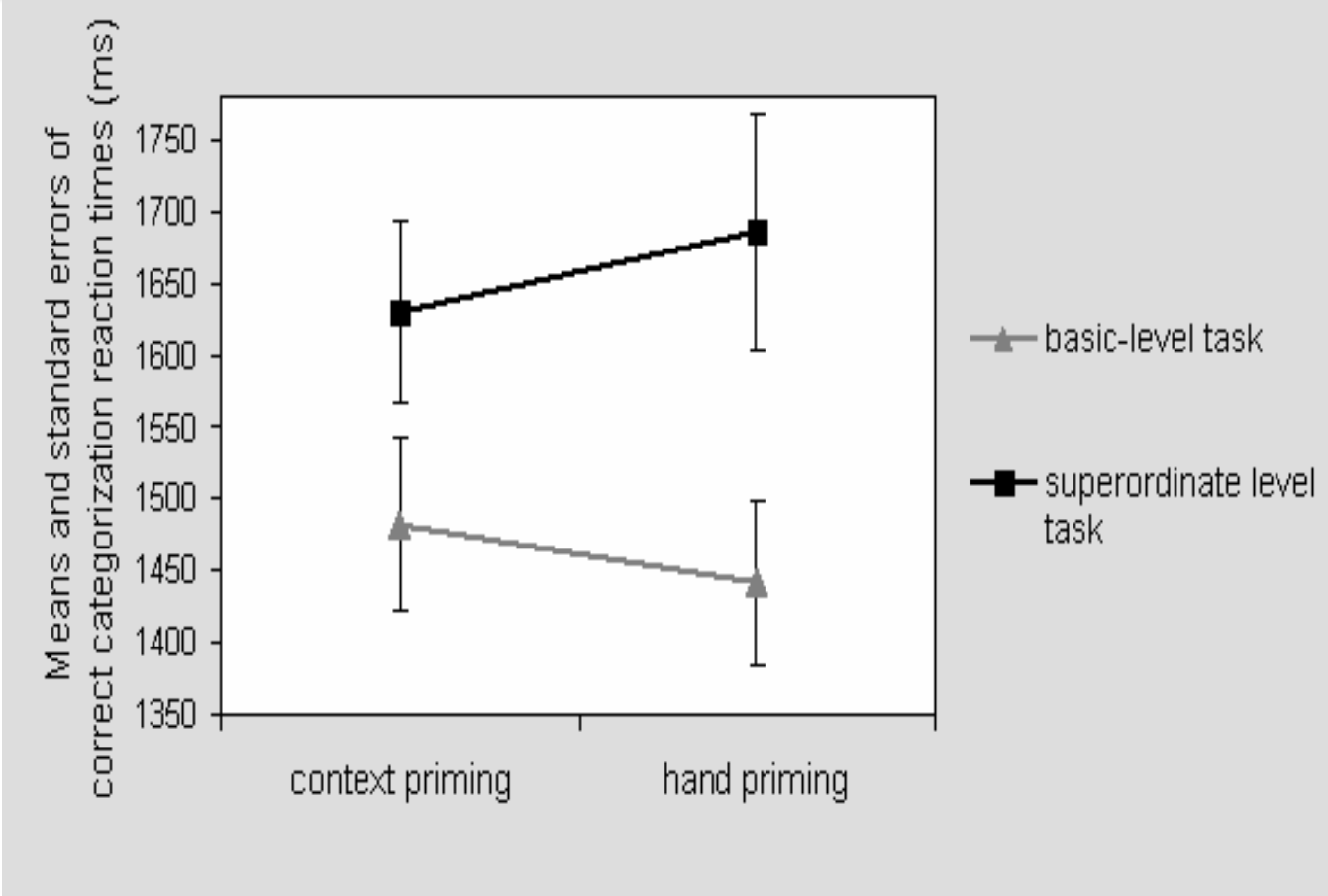
- **Participants**: 7-year-olds, 9-year-olds, adults

Kalénine, Bonthoux & Borghi, 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)?

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HAND PRIMES AND PERSPECTIVE

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

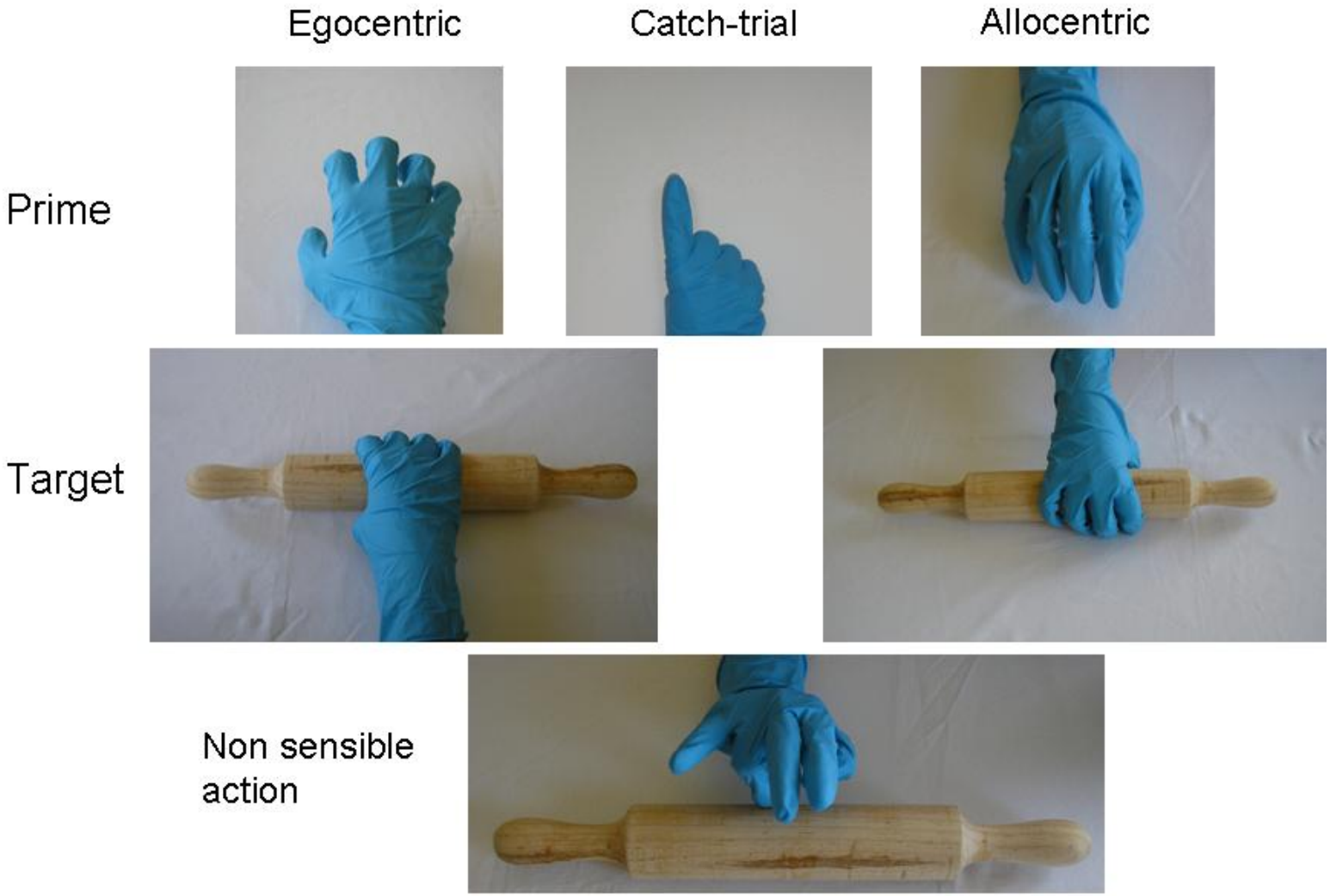
Manipulation of

- 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, 2008

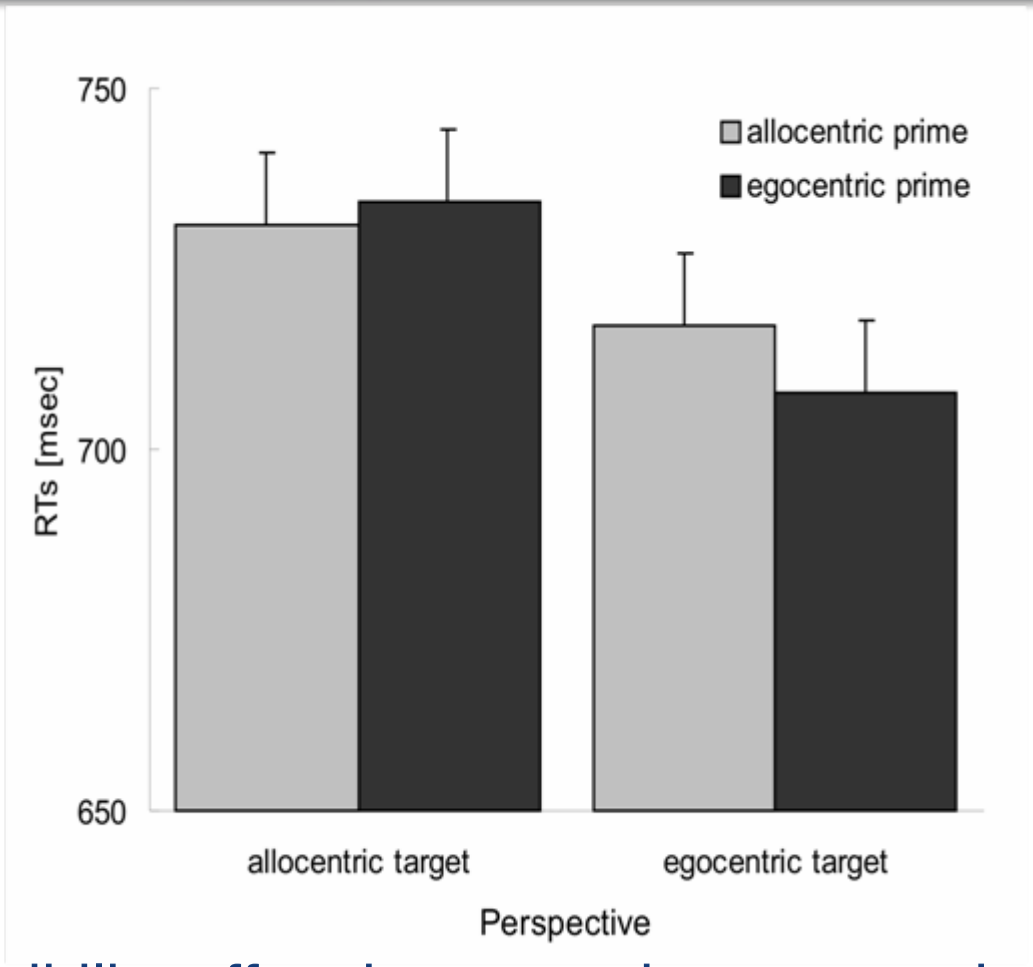
HAND PRIMES AND PERSPECTIVE: PROCEDURE



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

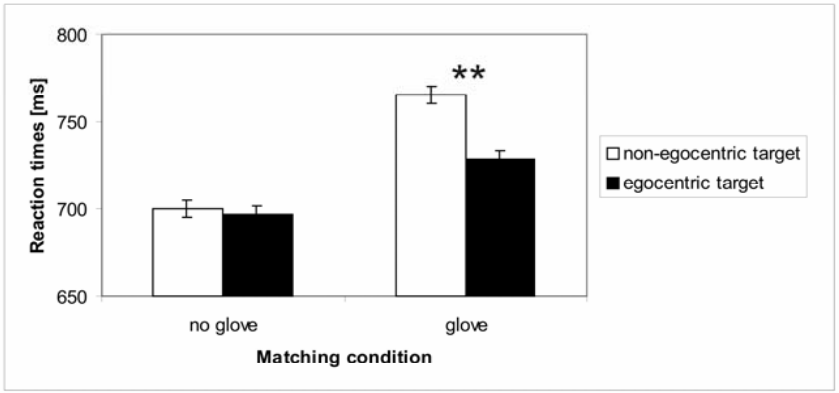


- compatibility effect between the perspective of Prime and Target: fastest responses with egocentric prime followed by egocentric target.

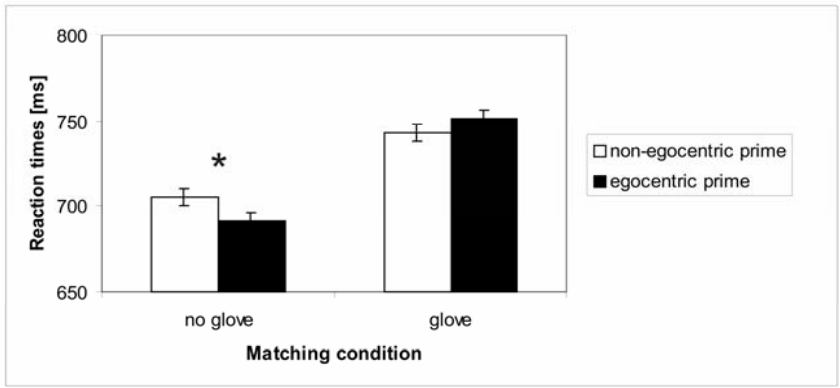
HAND PRIMES AND PERSPECTIVE: RESULTS

Fig.2

A



B



- Interaction Target perspective and Glove: egocentric targets are processed faster than non-egocentric ones when participants wear gloves (similarity with the hand they see)
- Why effect present with the target? Because the hand and the object interact
- Thus: simulation facilitated in case of similarity between our own hand and the seen hand (same perspective, same glove)

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HAND PRIMES AND TARGET-WORDS: THE ROLE OF ANIMACY

- **Aim:** verify with a priming paradigm whether entities characterized by autonomous movement activate different actions from objects characterized by non autonomous movement.

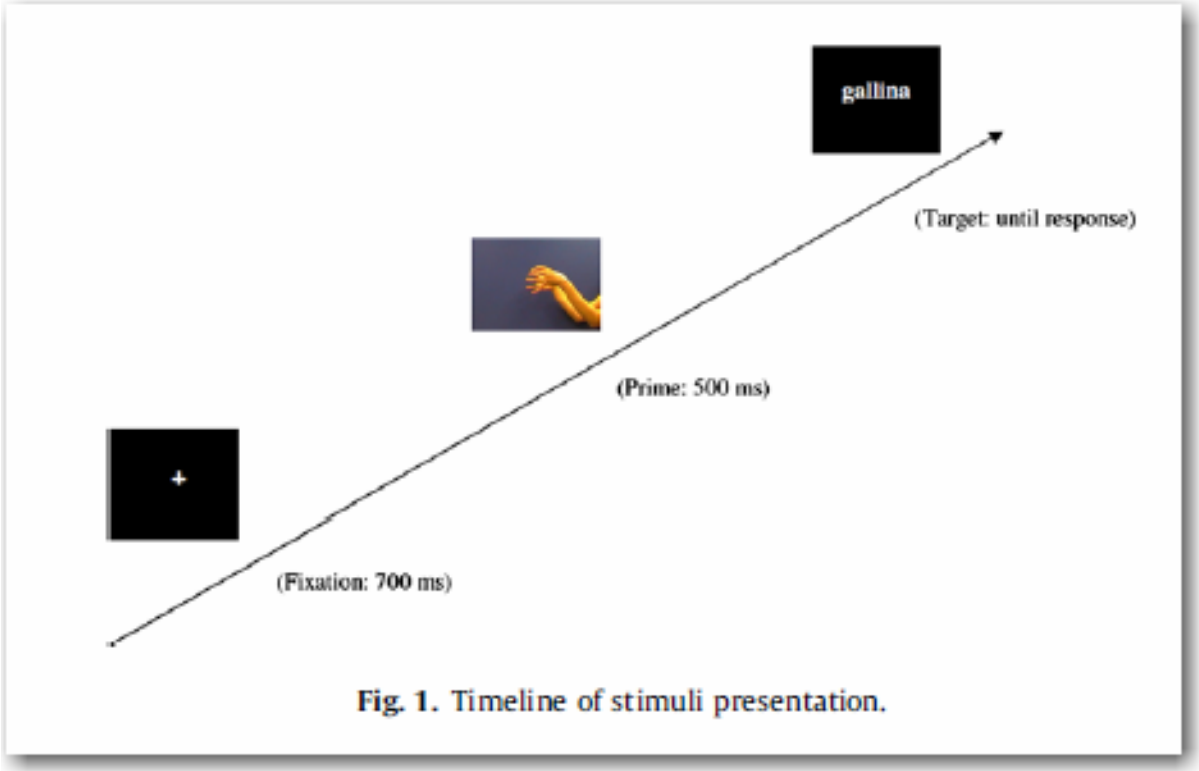
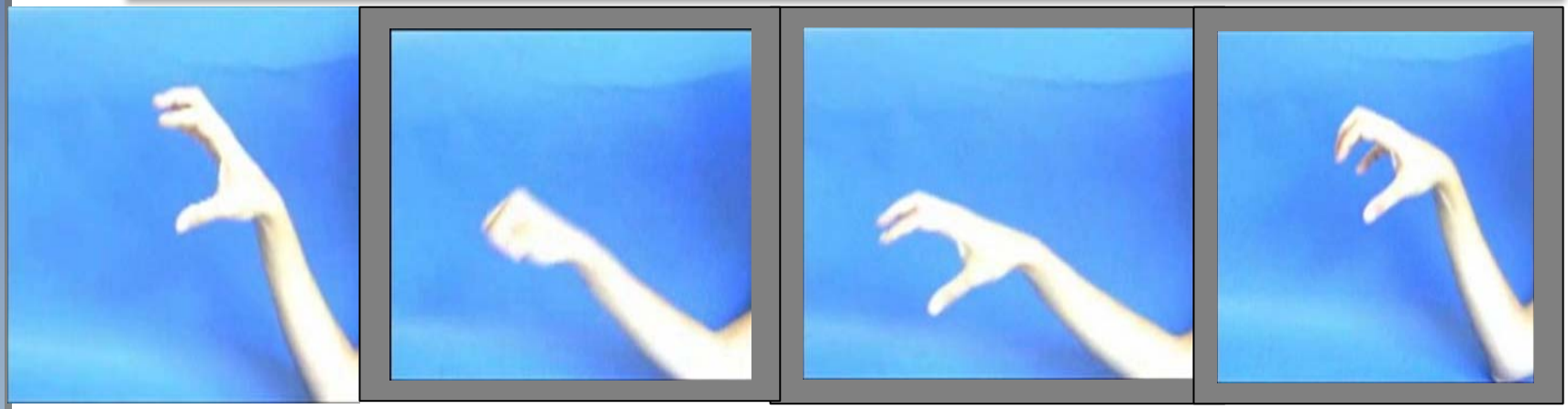


Fig. 1. Timeline of stimuli presentation.

Setti, Borghi & Tessari, 2009

HAND PRIMES AND PERSPECTIVE: RESULTS



ACTION MOTION MOTION+ACTION CATCH TRIAL

Hand primes: unimanual, bimanual

Hand primes: action (static grasping hand), motion (fist moving downward), motion+action (grasping hand moving downward), catchtrial (hand moving upward)

Targets: Words referring to animate vs. inanimate entities (e.g., cat, apple).

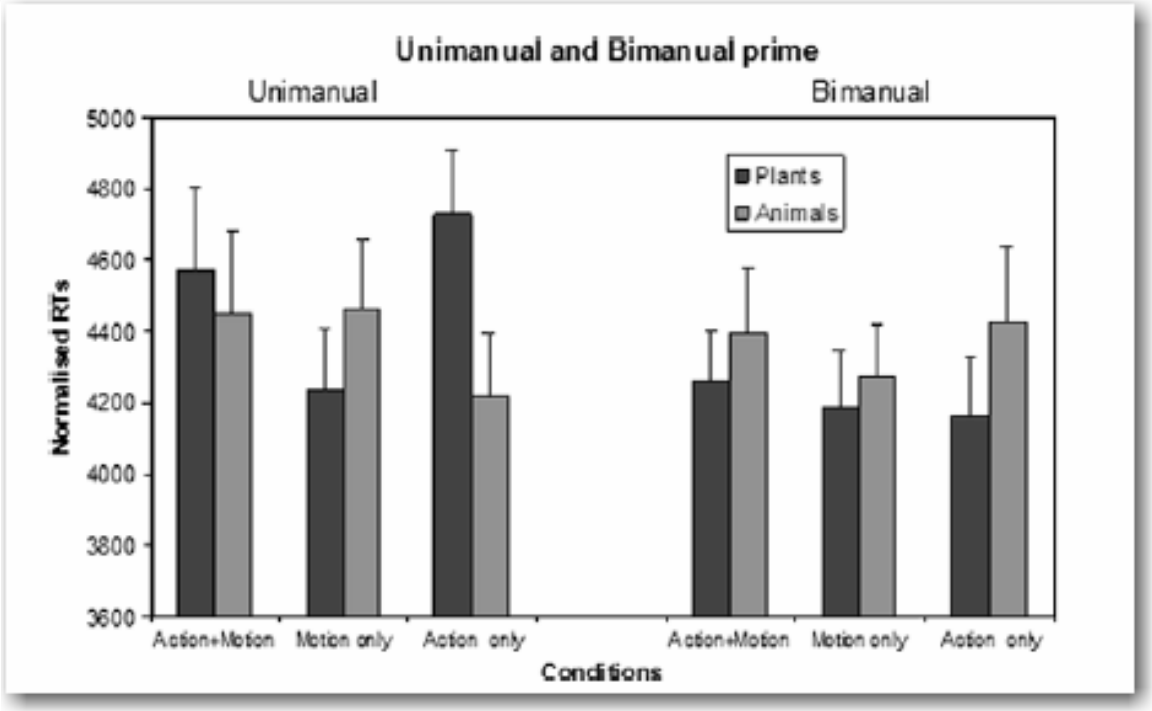
Task: animate or inanimate?

HAND PRIMES AND TARGET-WORDS: THE ROLE OF ANIMACY

- **Predictions:** Unimanual hand primes should affect processing of inanimate entities: these entities do not need to be grasped with both hands, because they do not move.
- Bimanual primes should primarily influence processing of animate entities, provided that these entities elicit motor resonance related to action.
- Different effect of grasping action and motion information on animate and inanimate entities?
- Words?

Setti, Borghi & Tessari, 2009

HAND PRIMES AND WORDS: RESULTS



- **Unimanual** condition: slower RTs in action&motion and action only with inanimate entities, animate entities with grasping action only. Interference of grasping actions with plants, of motion with animals. Why interference instead of facilitation? Words: more difficult integration.
- No difference when primes were bimanual.

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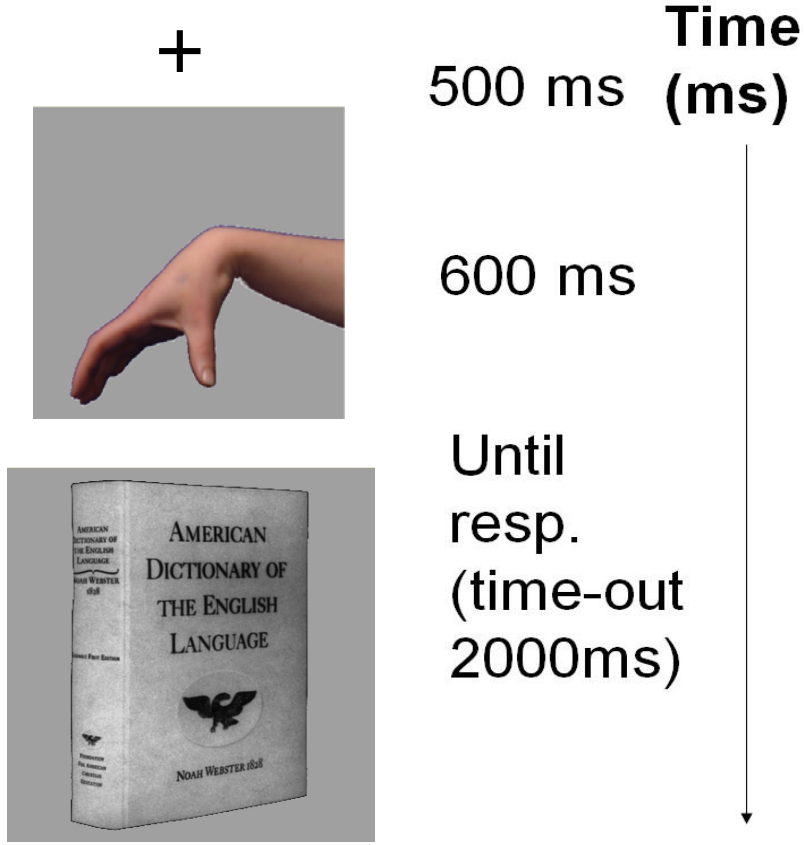
HAND PRIMES AND CATEGORIZATION IN OLDER PEOPLE

- 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

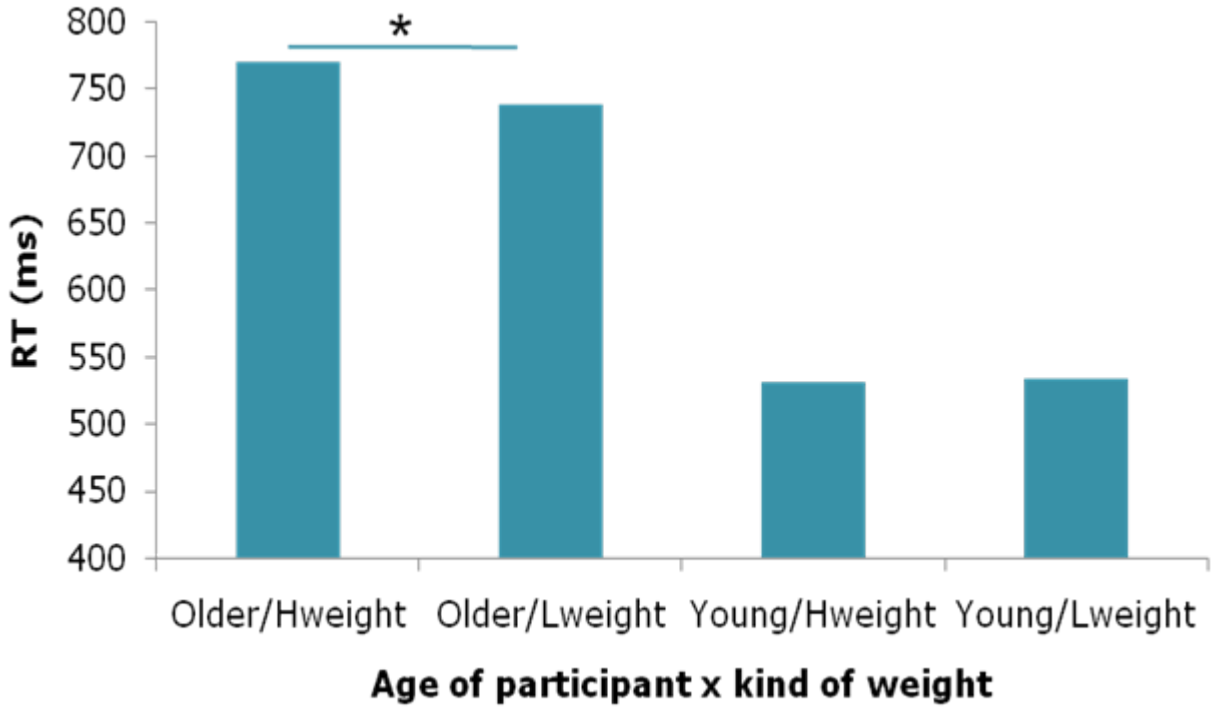
- Hand prime: same or different sex of the participant (Male vs. Female); Same or different age (Older, Younger) or neutral (Glove)
- Light object vs. Heavy object
- Participants: males and females, younger and older



HAND PRIMES AND CATEGORIZATION IN OLDER PEOPLE: RESULTS

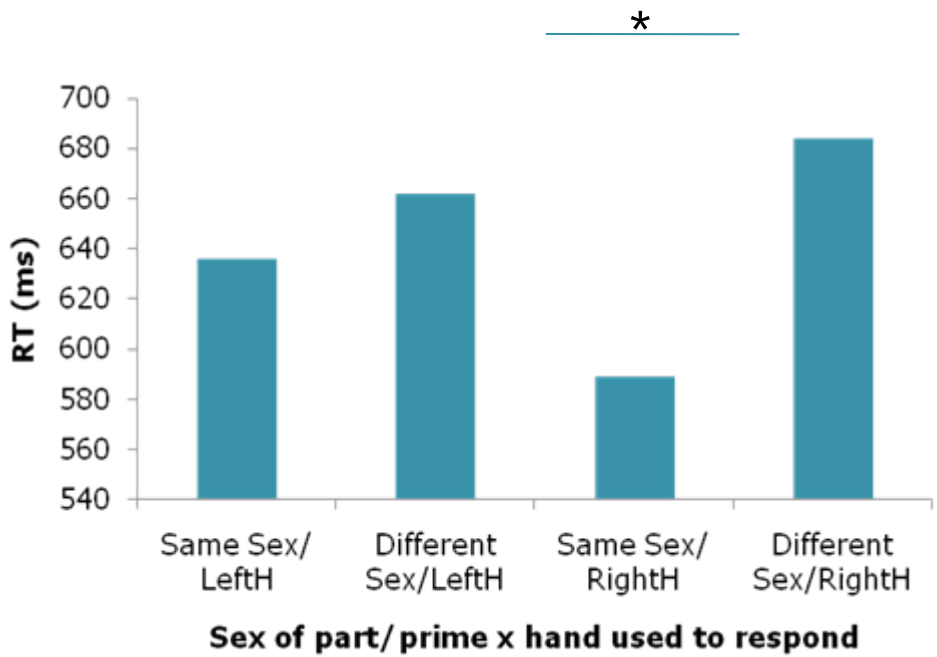
Participants: 58 older adults (no history of psychiatric or neurological illness), 52 younger adults

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.



SUMMARY AND OPEN ISSUES

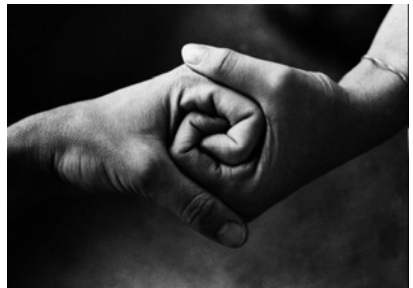
- Observation of objects (affordances) and of others' hands potentially interacting with objects activates an embodied simulation
- Objects: the simulation is activated not only by single but also by multiple objects (e.g., holds for climbers) and it influences both online processing and memory
- Objects: differences between artefacts and natural objects suggest that a different simulation is linked to object manipulation vs. use

SUMMARY AND OPEN ISSUES

- 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 and age reveal.



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Milena Anelli, Valentina Bazzarin, Giulia Baroni, Daniele Caligiore, Claudia Gianelli, Pierre Jacquet, Laura Freina, Stefano Ghirlanda, Roberto Nicoletti, Luisa Lugli, Domenico Parisi, Antonello Pellicano, Claudia Scorolli, Alessia Tessari

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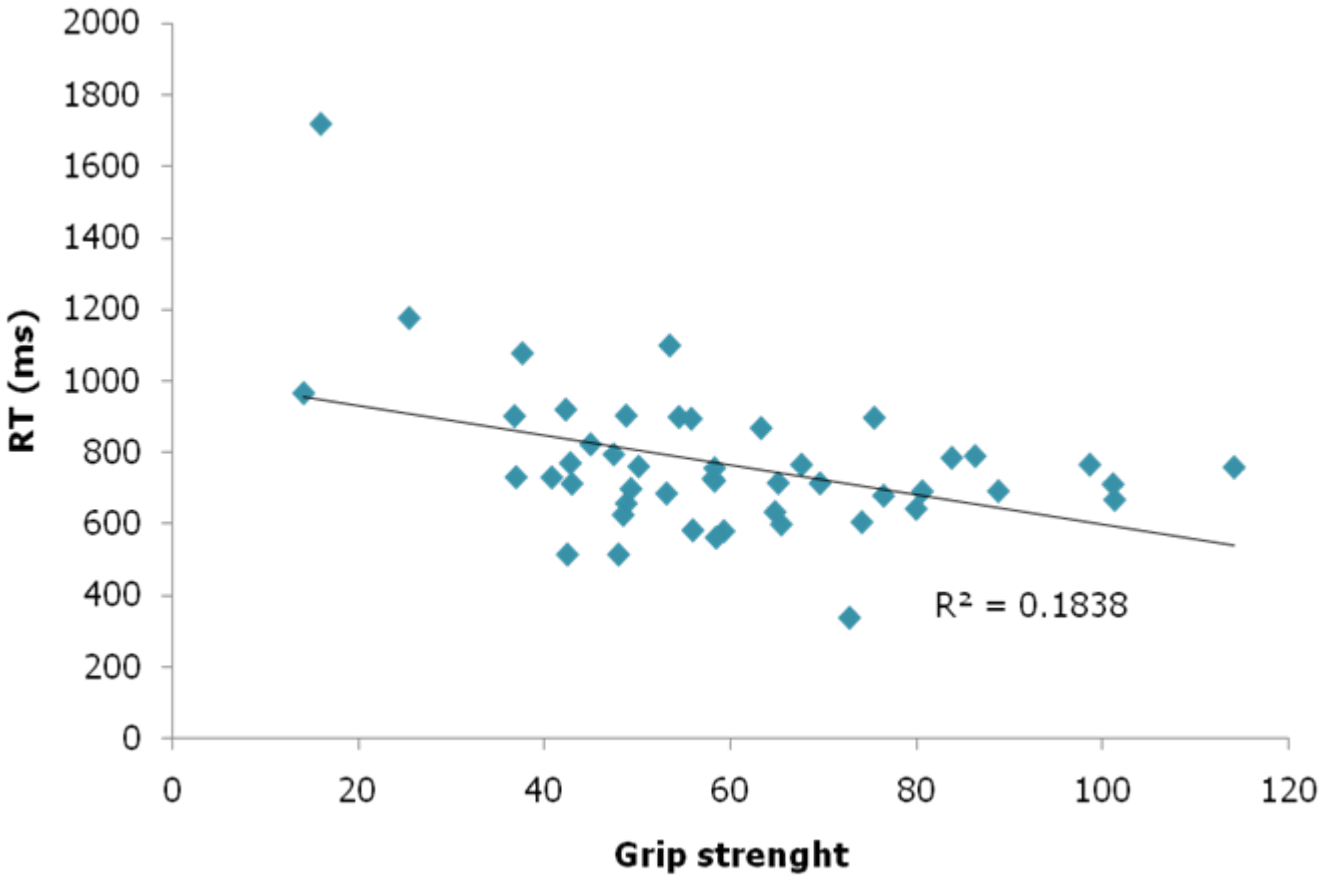
COGNITIVE SYSTEMS ROBOTICS

SEVENTH FRAMEWORK PROGRAMME

GRIP STRENGTH AND RTS

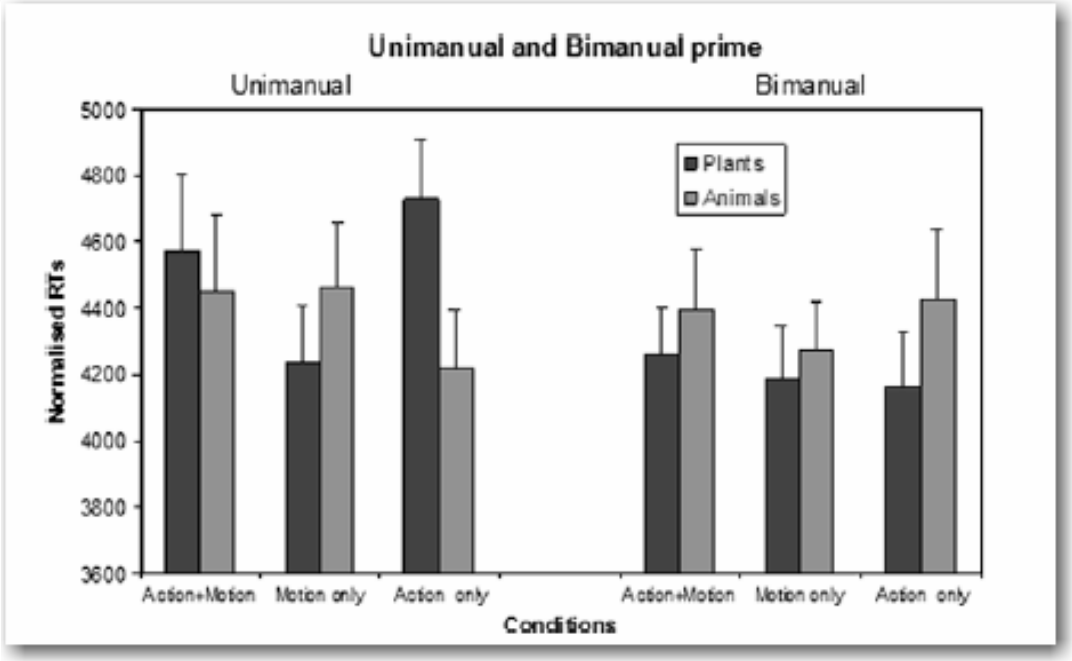
NoAction Young Light condition RTS and grip



Additional slides

- Comparing the results on RTs and accuracy for animal targets with bi-manual primes, a speed-accuracy trade-off appeared as animal targets paired with bimanual 'Action+Motion' primes were responded to faster leading to a higher number of errors than in the other conditions. Therefore, a further analysis taking into account the speed-accuracy trade-off was deemed necessary.
- Response times were divided by the proportion of correct responses (Chan, Merrifield, & Spence, 2005; Townsend, & Ashby, 1978) and entered in an ANOVA with Type of Prime as a between participants factor and Condition and Type of Target as within participants factors (same as above).

HAND PRIMES AND WORDS: RESULTS



- Unimanual condition: targets referring to plants when preceded both by 'Motion+Action' and 'Action only' primes compared to the 'Motion only' condition. Plants in the unimanual 'Motion+Action' and 'Action only' condition also differed from animal targets in the unimanual 'Action only' condition. **Interference for action with animals, for motion with plants?** No significant difference was found when primes were bimanual.