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**WITH  
PLYMOUTH  
UNIVERSITY**



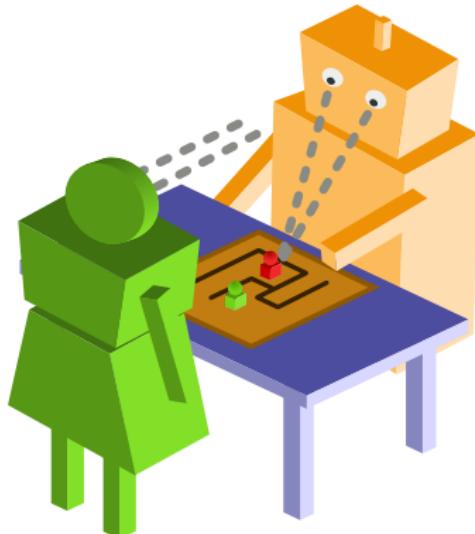
# Of Cognition and Social Robots

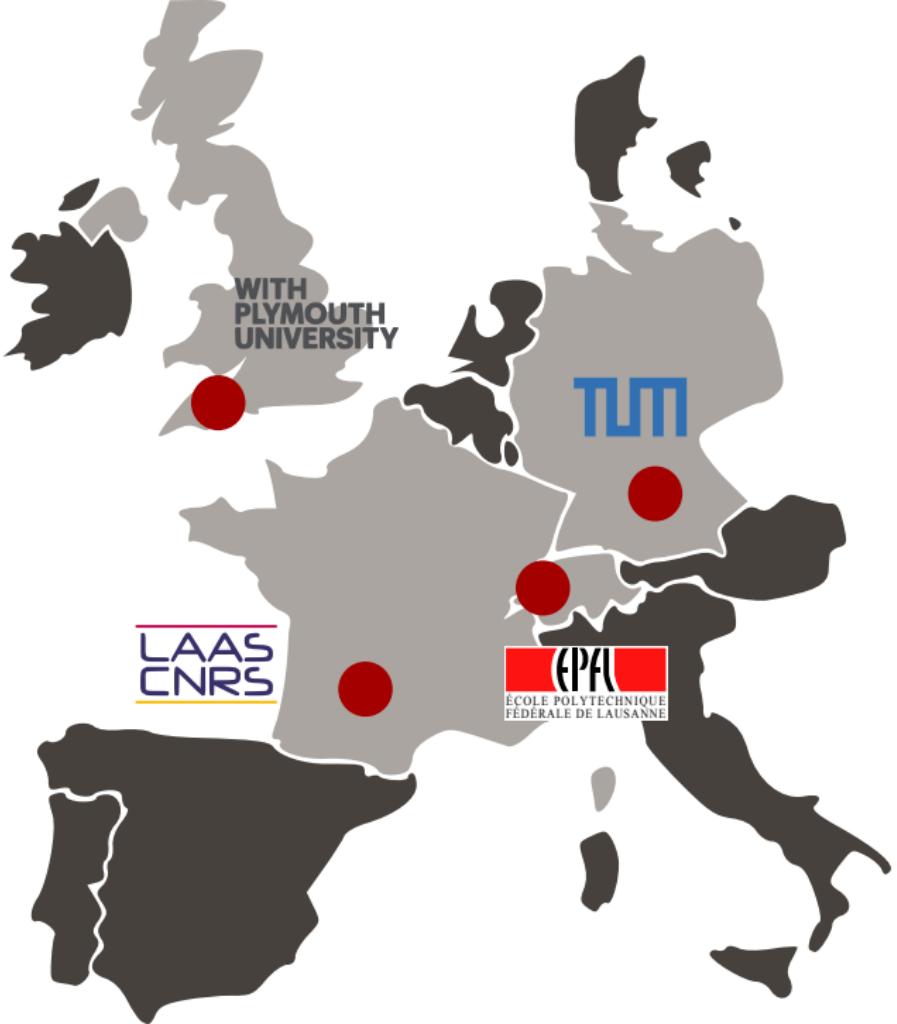
## Is “Social Cognition” in HRI just a buzz word?

Bristol Robotics Lab – **May 11, 2016**

Séverin Lemaignan

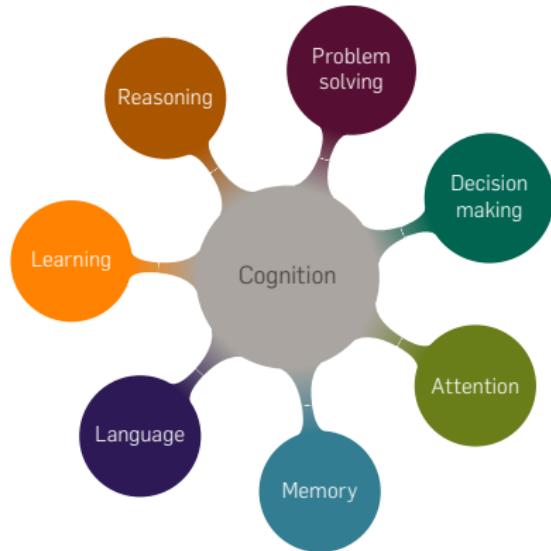
Centre for Robotics and Neural Systems  
**Plymouth University**

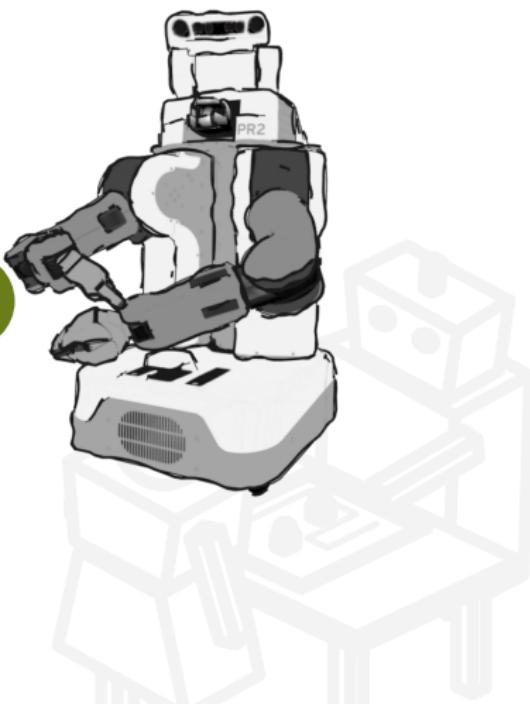


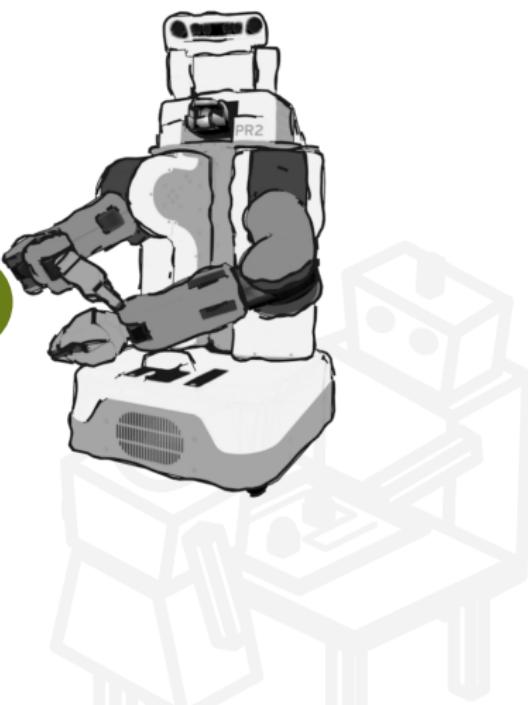
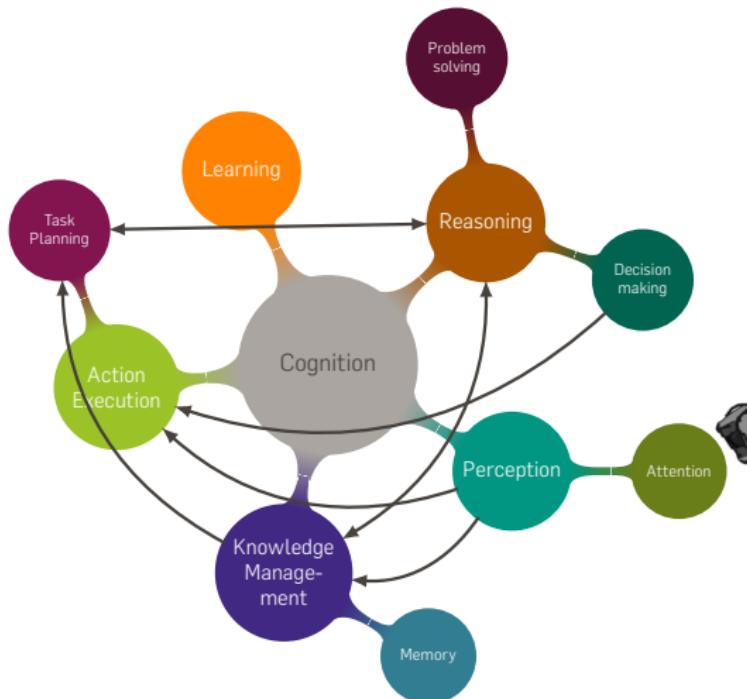


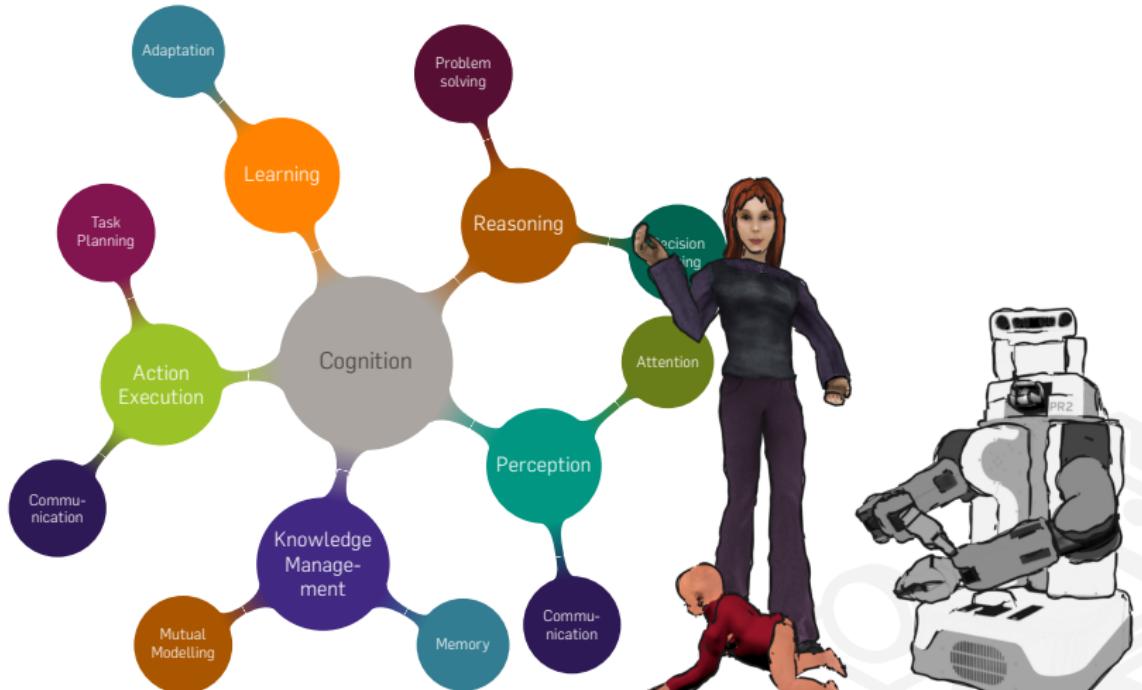
“Cognition is a group of mental processes that includes **attention**, **memory**, producing and understanding **language**, **learning**, **reasoning**, **problem solving**, and **decision making**.”







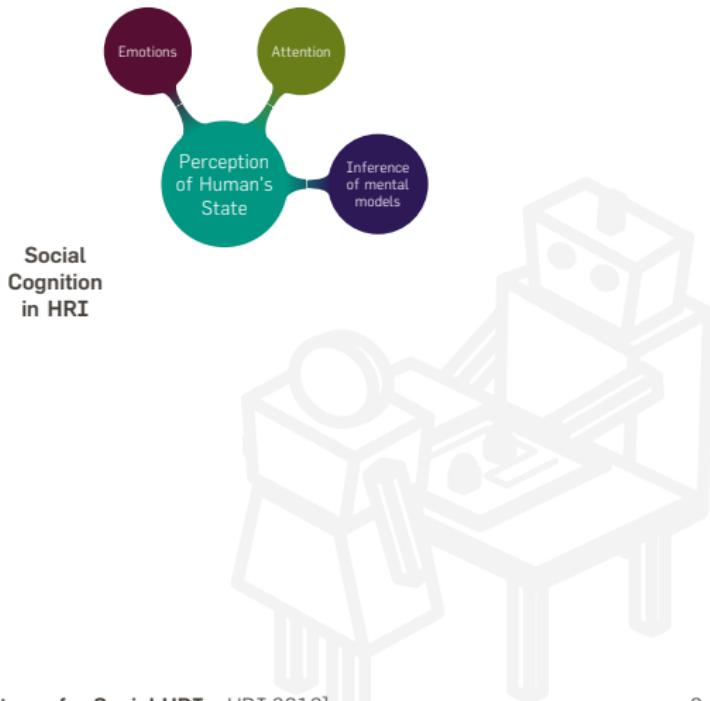








# FUNCTIONS FOR SOCIAL COGNITION





# FUNCTIONS FOR SOCIAL COGNITION





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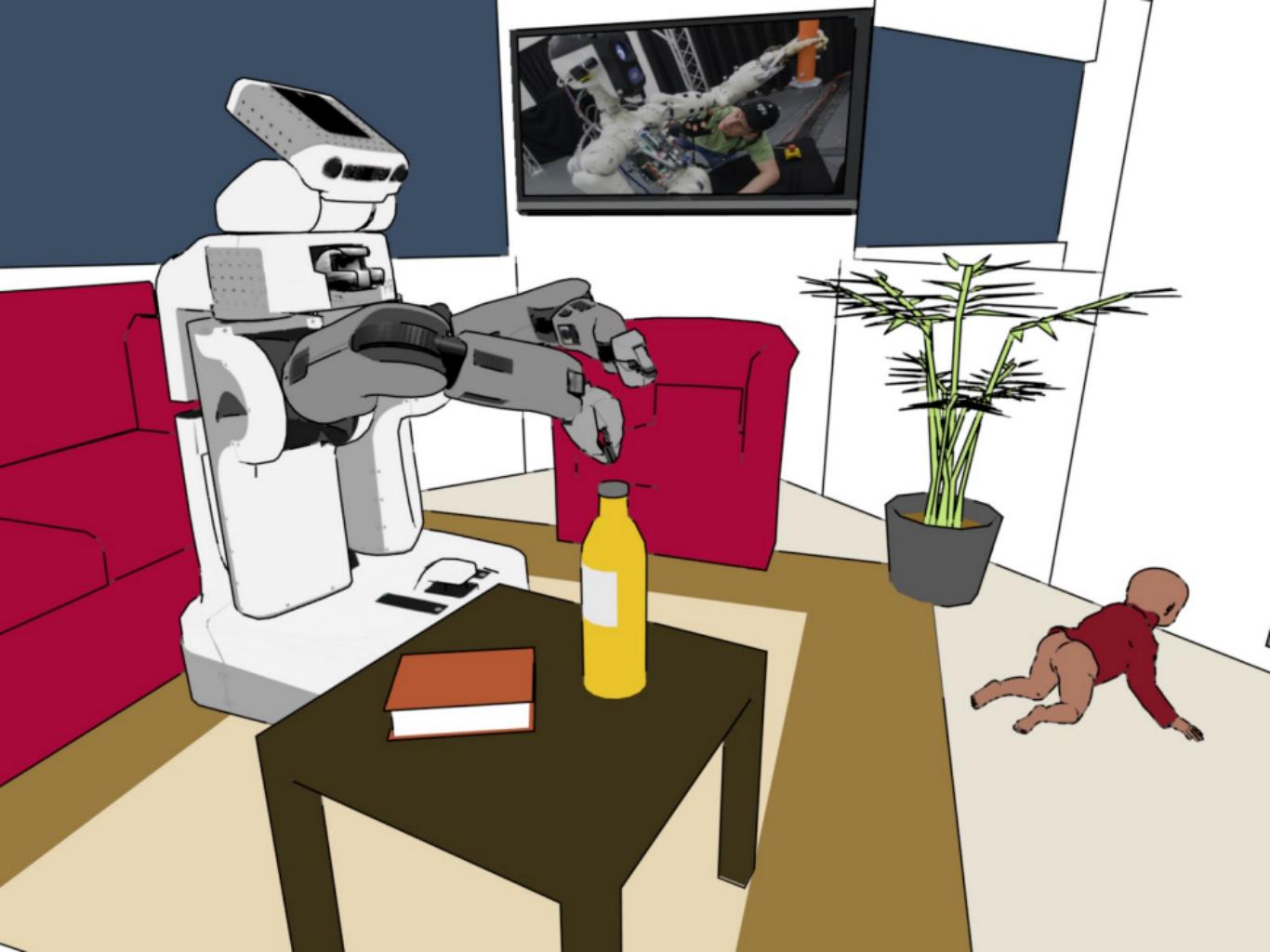


# OVERVIEW

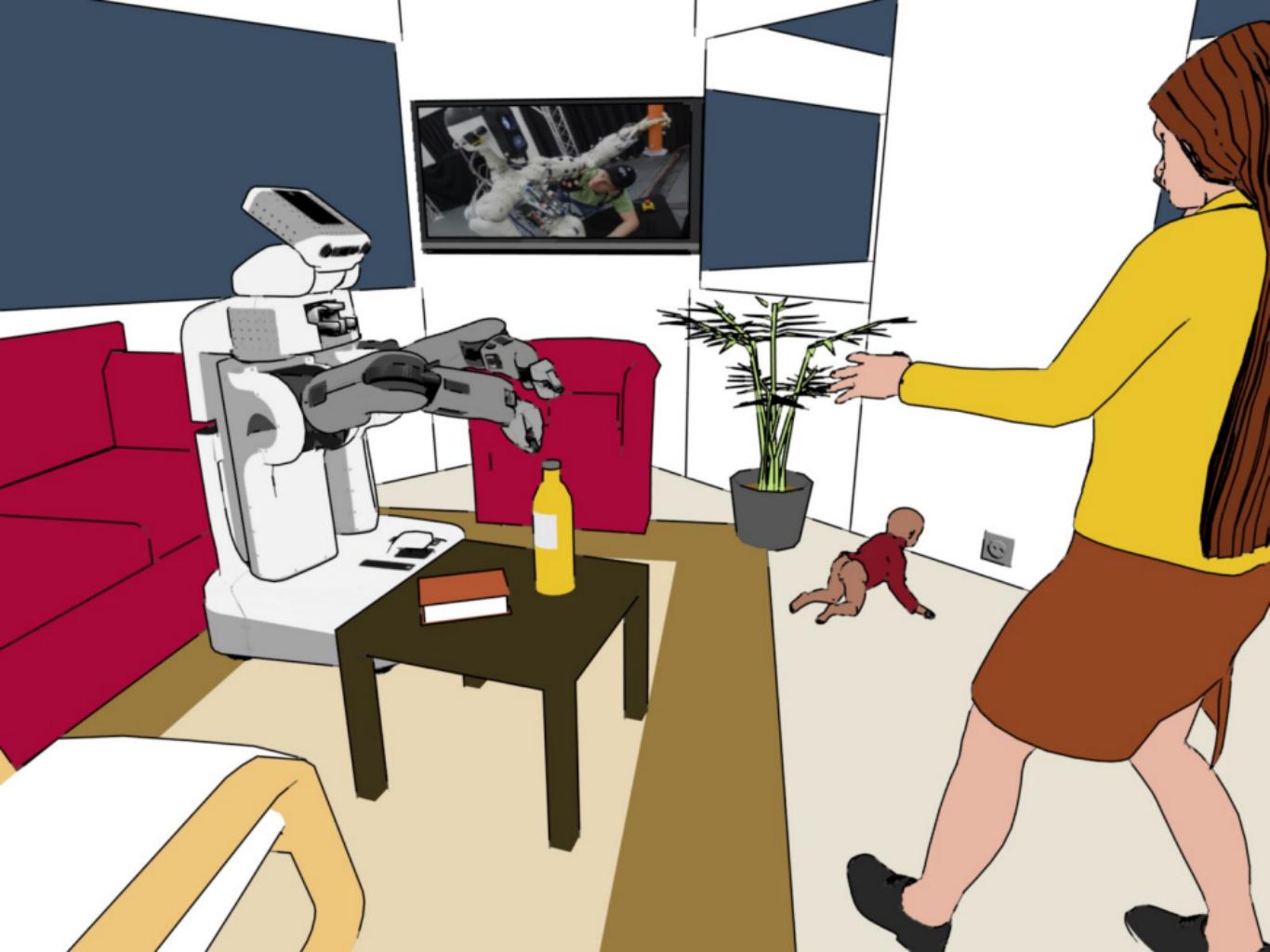
1. The Robot's (Symbolic) World
2. Adding the Human to the Equation
3. Are you still with me?
4. A Summary and Some Ideas

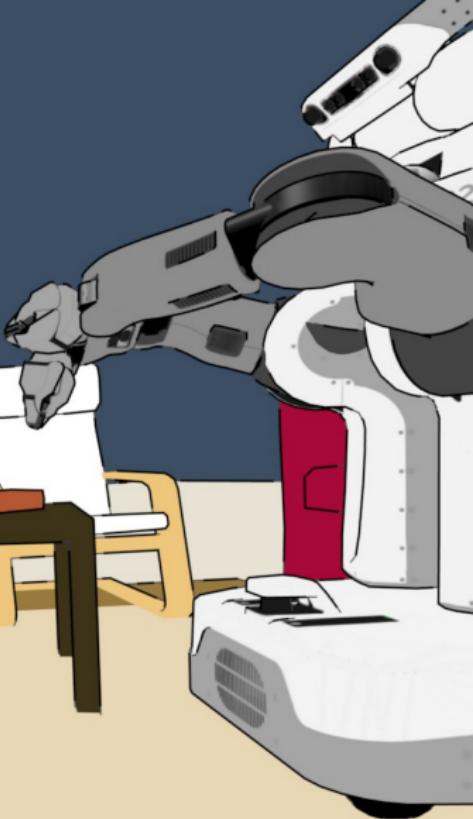
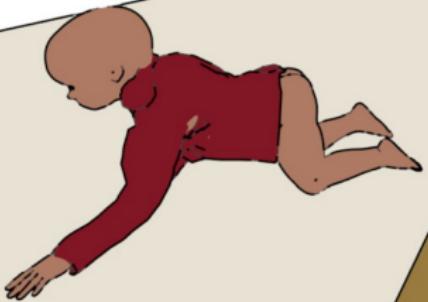


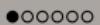
# THE ROBOT'S (SYMBOLIC) WORLD



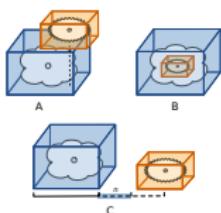
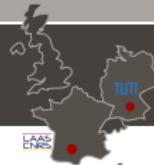
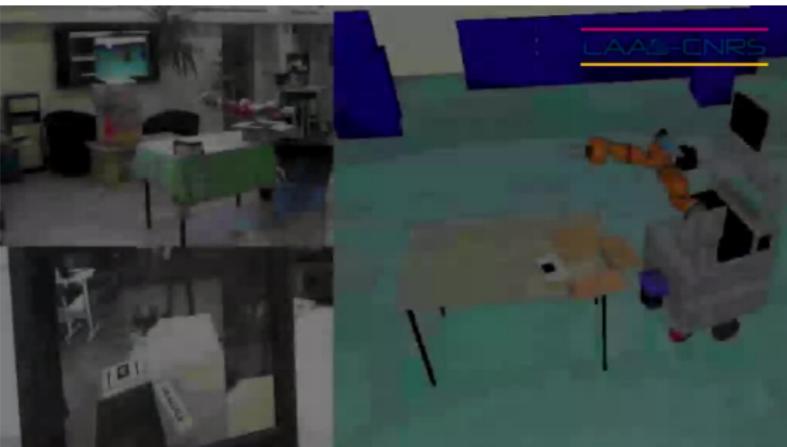




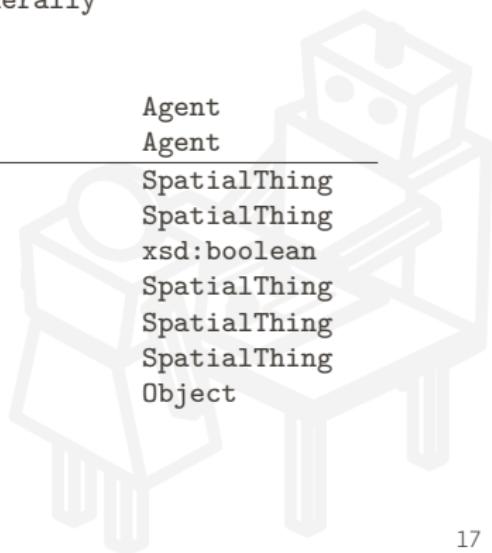




## SITUATION ASSESSMENT

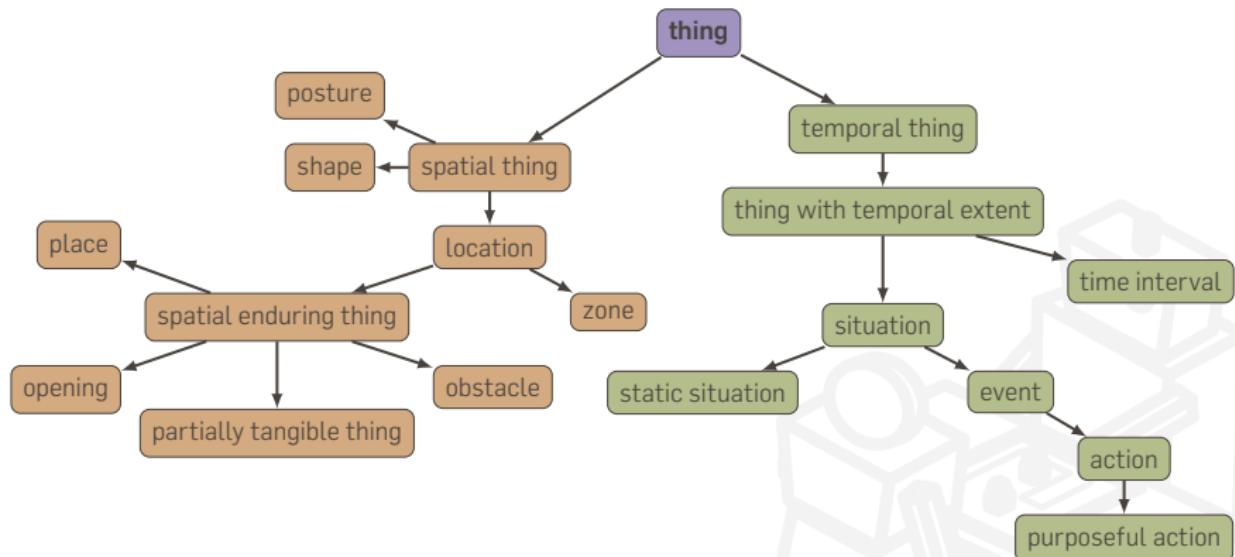


Subject	Predicate	Object
Location	$\text{isAt} \equiv \text{cyc:objectFoundInLocation}$ $\rightarrow \text{isOn} \equiv \text{cyc:above\_Touching}$ $\rightarrow \text{isIn}$ $\rightarrow \text{isNextTo}$	Location
Location	$\text{isAbove} \equiv \text{cyc:above-Generally}$	Location
Location	$\text{isBelow}$	Location
Location	$\text{hasRelativePosition}$ $\rightarrow \text{behind} \equiv \text{cyc:behind-Generally}$ $\rightarrow \text{inFrontOf} \equiv \text{cyc:inFrontOf-Generally}$ $\rightarrow \text{leftOf}$ $\rightarrow \text{rightOf}$	Location
Object	$\text{cyc:farFrom}$	Agent
Object	$\text{cyc:near}$	Agent
Agent	$\text{looksAt}$	SpatialThing
Agent	$\text{sees}$	SpatialThing
SpatialThing	$\text{isInFieldOfView}$	xsd:boolean
Agent	$\text{pointsAt} \equiv \text{cyc:pointingToward}$	SpatialThing
Agent	$\text{focusesOn}$	SpatialThing
Agent	$\text{seesWithHeadMovement}$	SpatialThing
Agent	$\text{canReach}$	Object



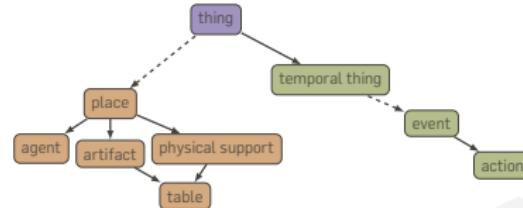
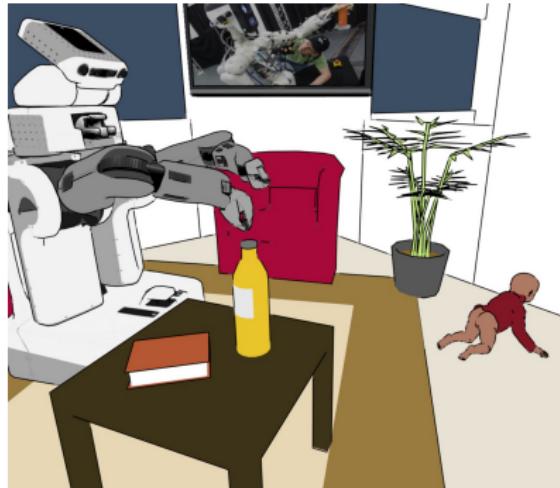


# FROM SPATIAL MODEL TO SYMBOLIC MODEL



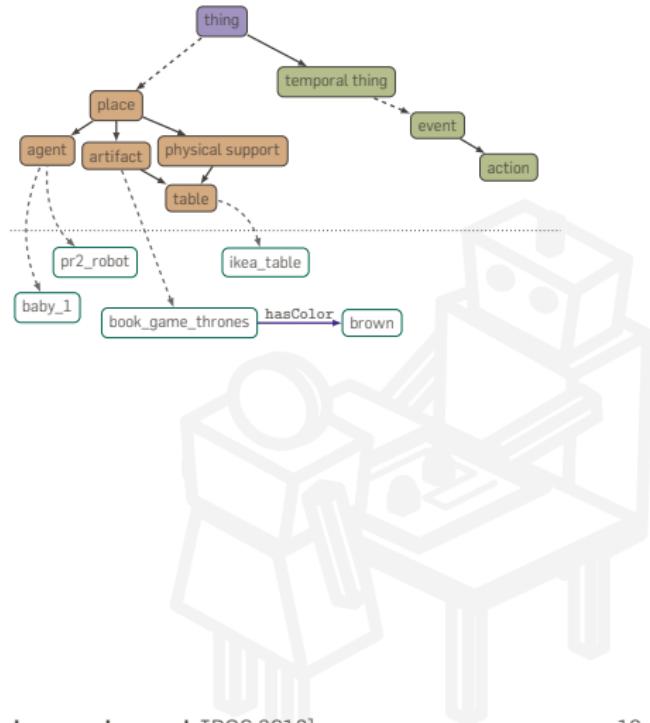
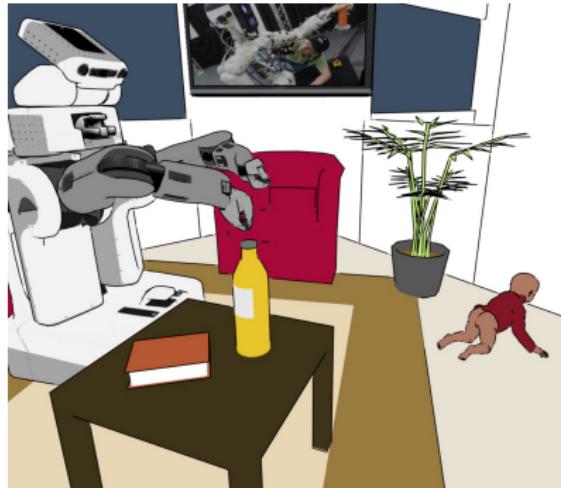


# ONLINE INSTANTIATION



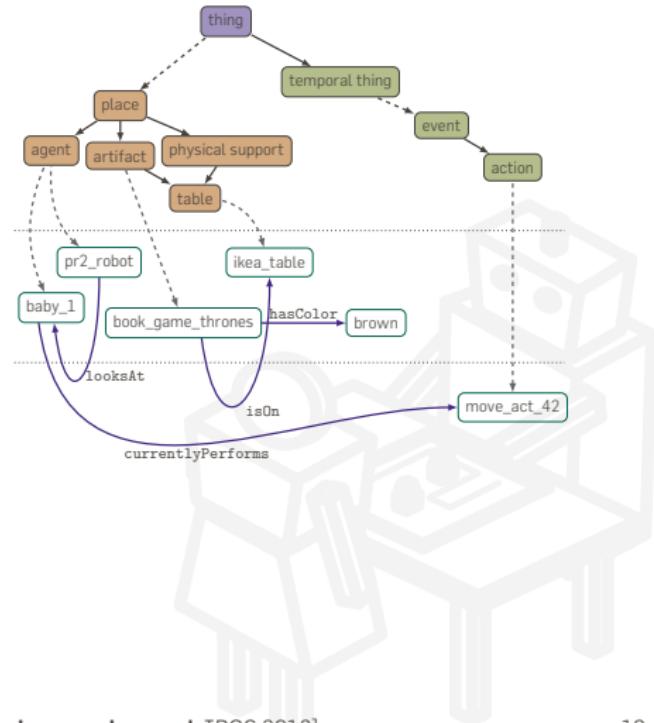
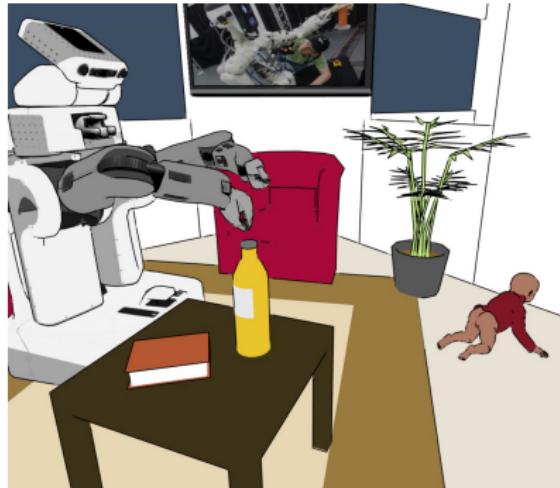


# ONLINE INSTANTIATION





# ONLINE INSTANTIATION





# DIALOGUE GROUNDING

I keep the natural language processing part for the questions, but:

"Give me the book on the table"





# DIALOGUE GROUNDING

I keep the natural language processing part for the questions, but:

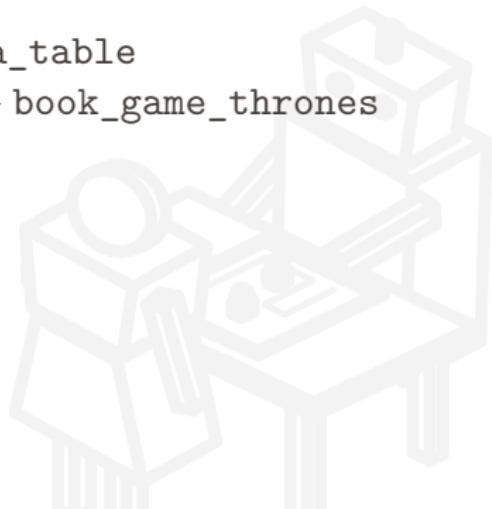
"Give me the book on the table"



me → baby\_1

find(?obj type table) → ikea\_table

find(?obj type book, ?obj isOn ikea\_table) → book\_game\_thrones





# DIALOGUE GROUNDING

I keep the natural language processing part for the questions, but:

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find(?obj type book, ?obj isOn ikea\_table) → book\_game\_thrones



baby\_1 desires give\_act\_1,

give\_act\_1 type Give,

give\_act\_1 performedBy myself,

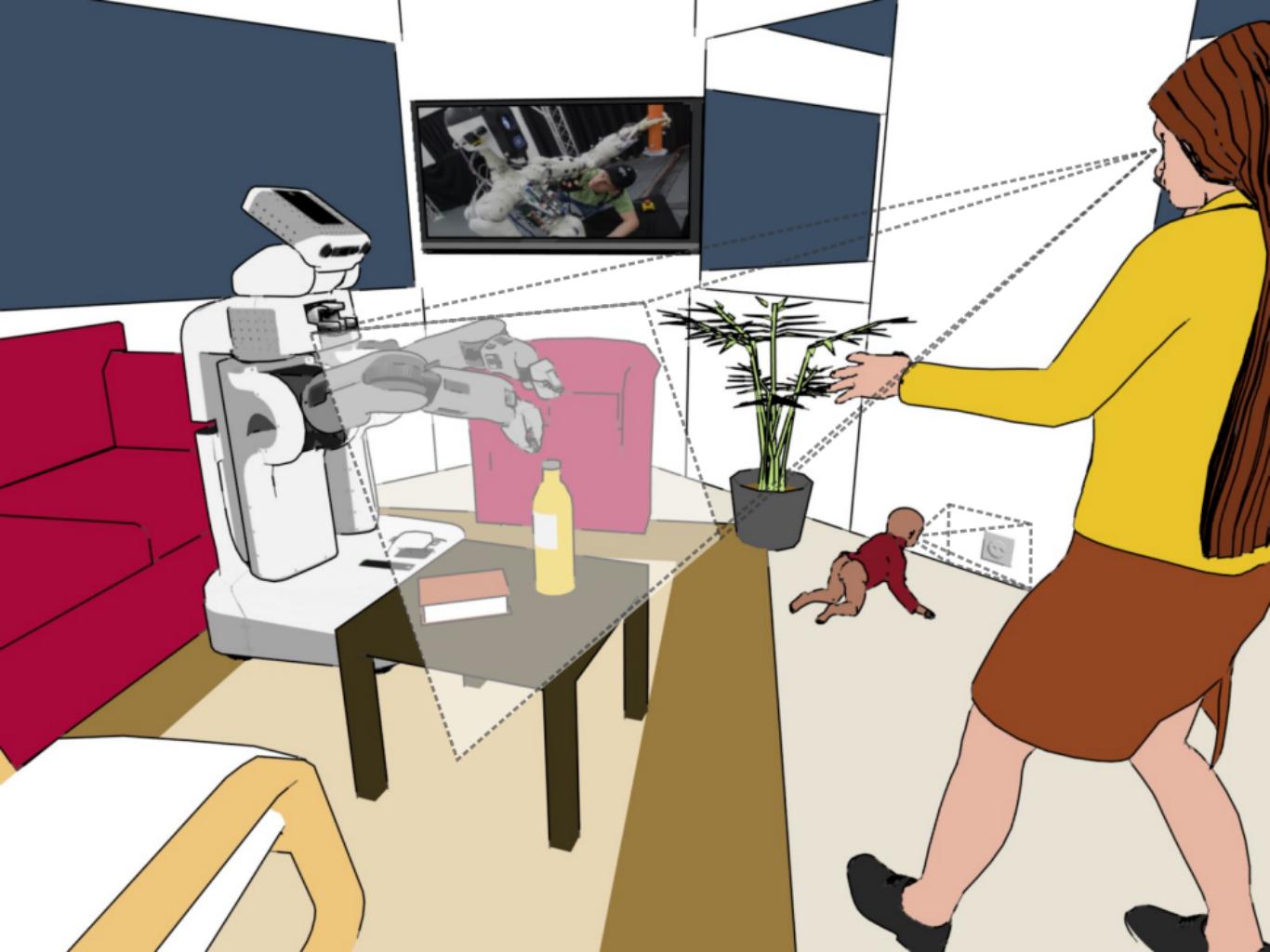
give\_act\_1 actsOnObject book\_game\_thrones,

give\_act\_1 receivedBy baby\_1

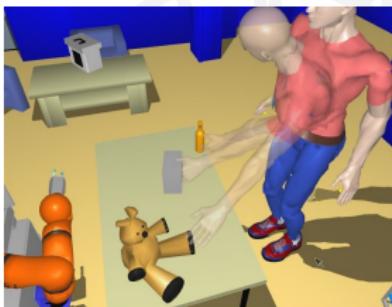
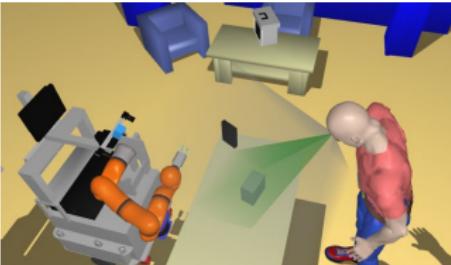
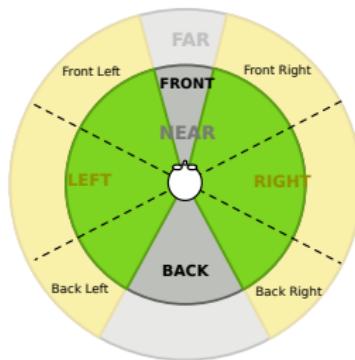
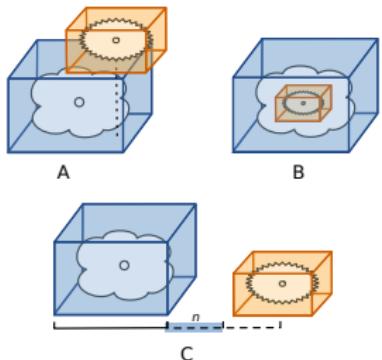
LAAS-CNRS



ADDING THE HUMAN TO THE EQUATION

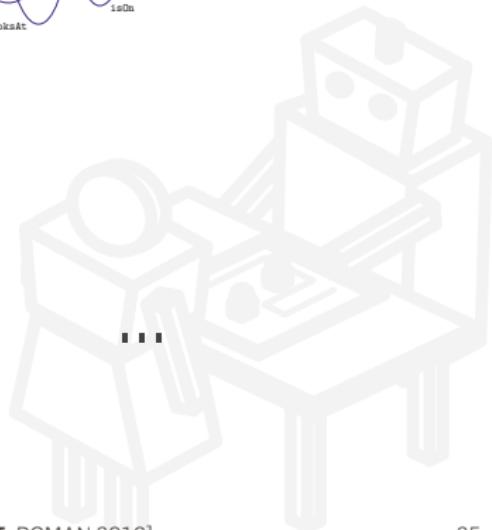
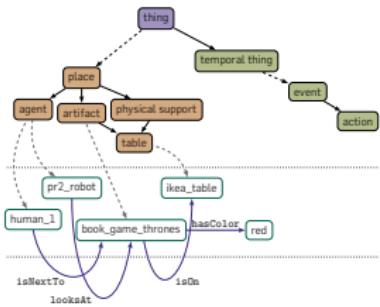
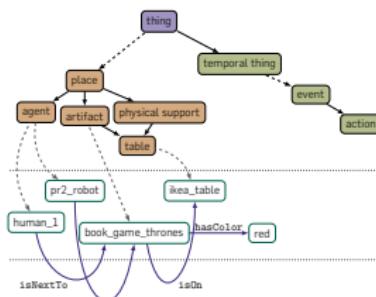
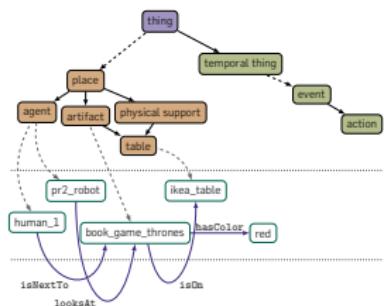


# VISUAL PERSPECTIVE TAKING





# MULTIPLE SYMBOLIC MODELS

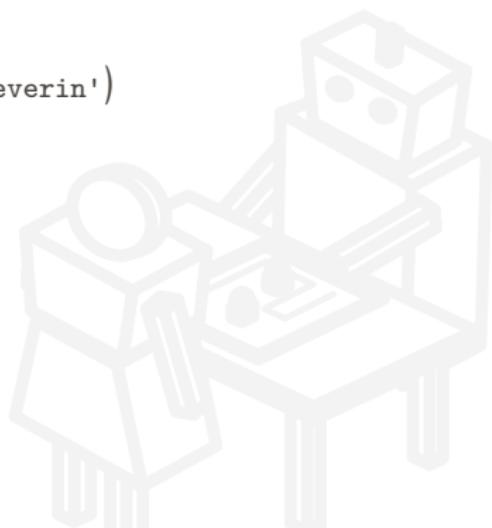




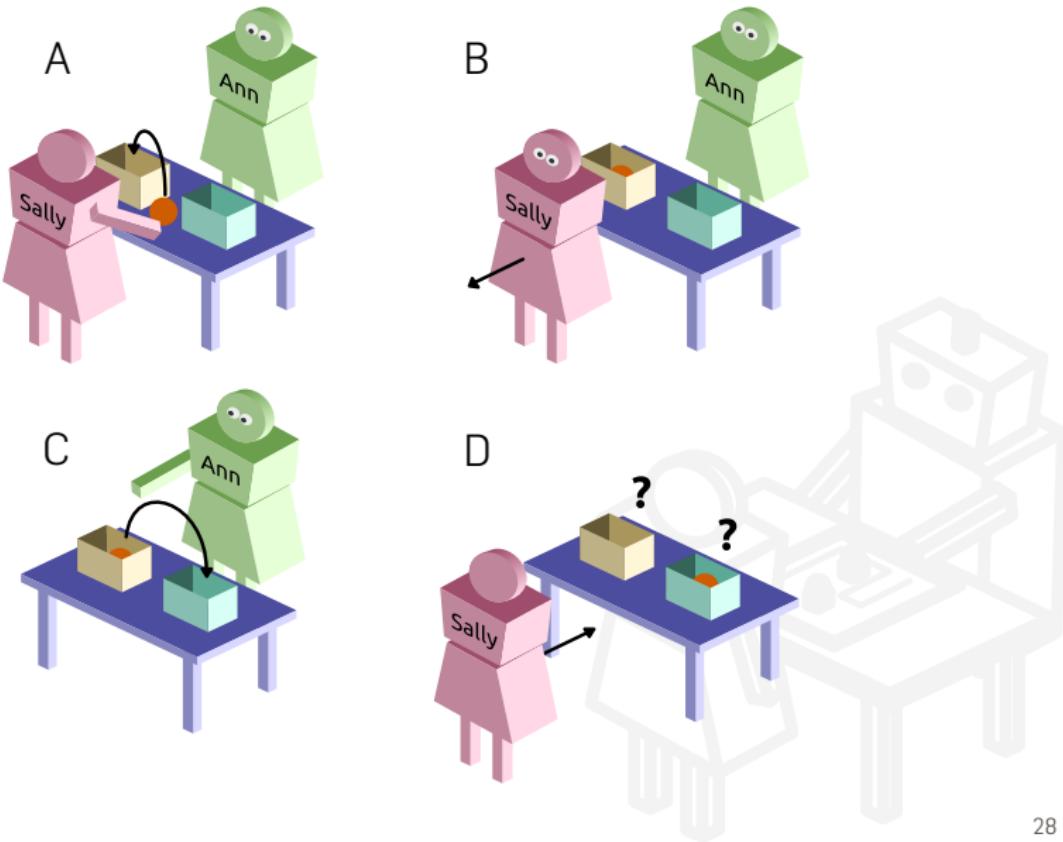
"Give me the can!"



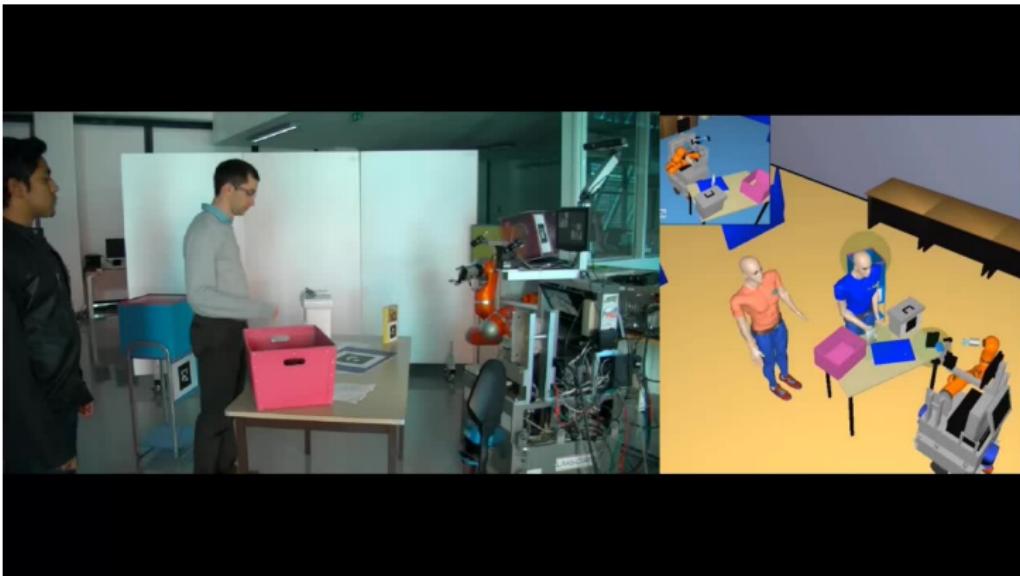
find(?obj type Can, model='severin')

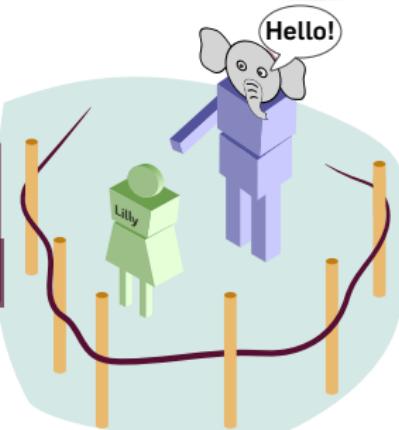
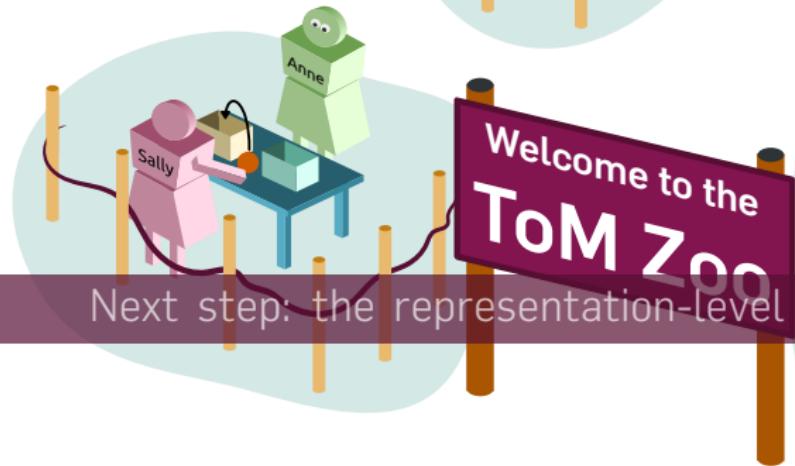
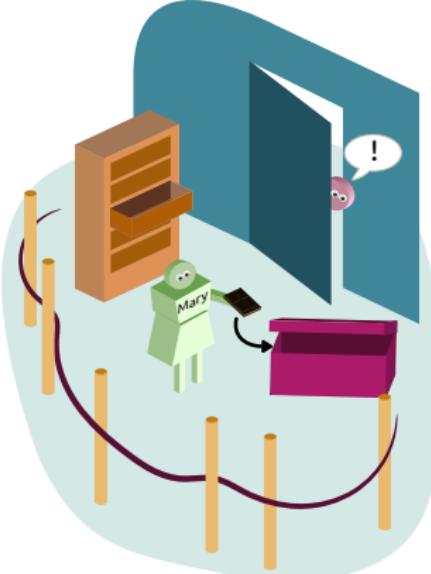
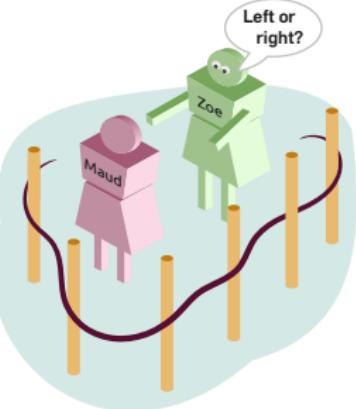
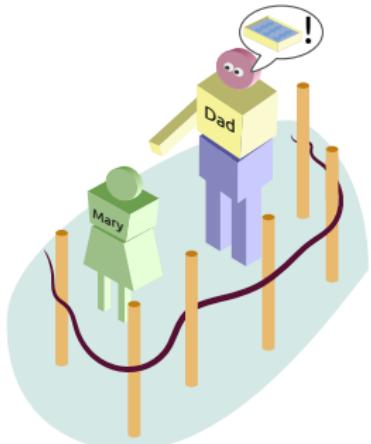


# THE FALSE-BELIEF EXPERIMENT



# THE FALSE-BELIEF EXPERIMENT



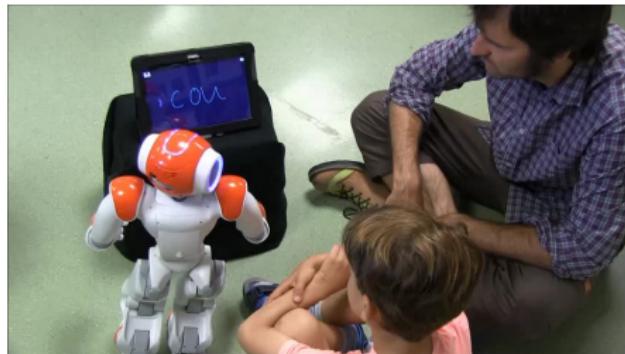


Mind modelling is **mutual**

We can take advantage of it in HRI at fundamental levels



# COGNITIVE ENGAGEMENT AND META-COGNITION





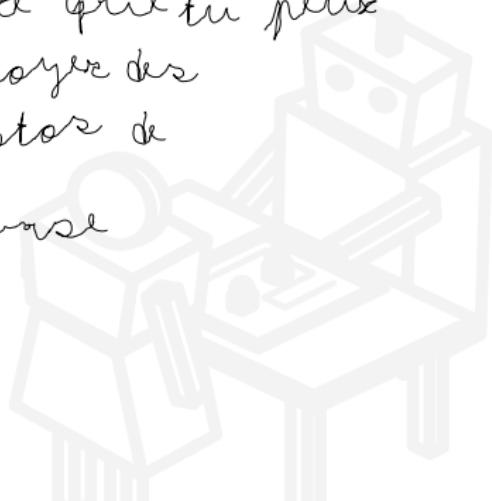
salut mimi  
nous persons  
que c'est un  
corps  
est que que tu peu  
croire des  
photos de  
la lise





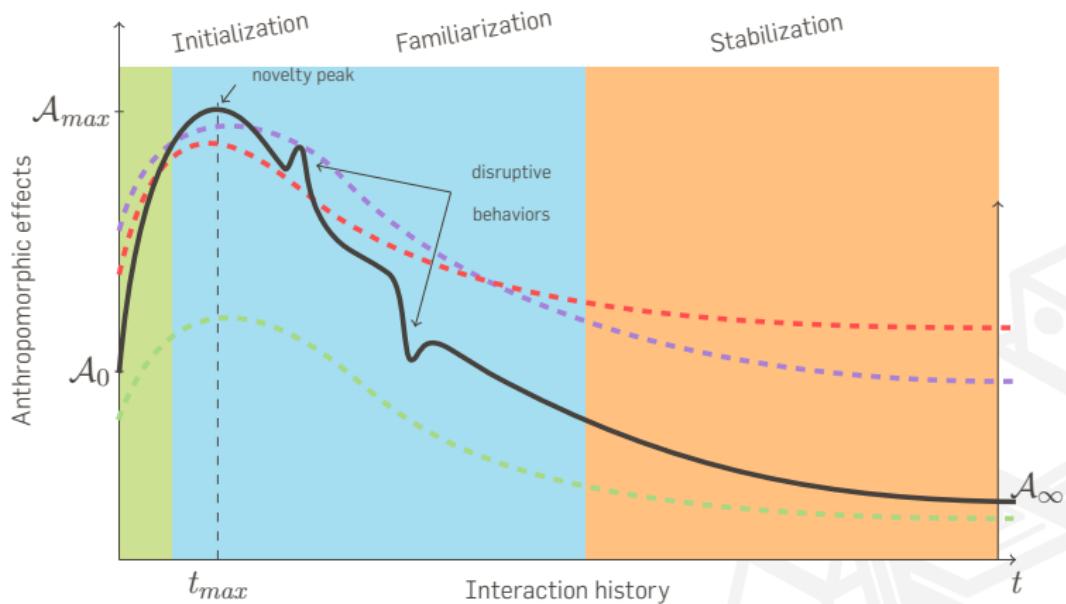
salut mimi  
nous persons  
que c'est un  
corps  
est à que tu peux  
croire des  
photos de  
la base

salut mimi  
nous persons  
que c'est un  
corps  
est à que tu peux  
envoyer des  
photos de  
la base



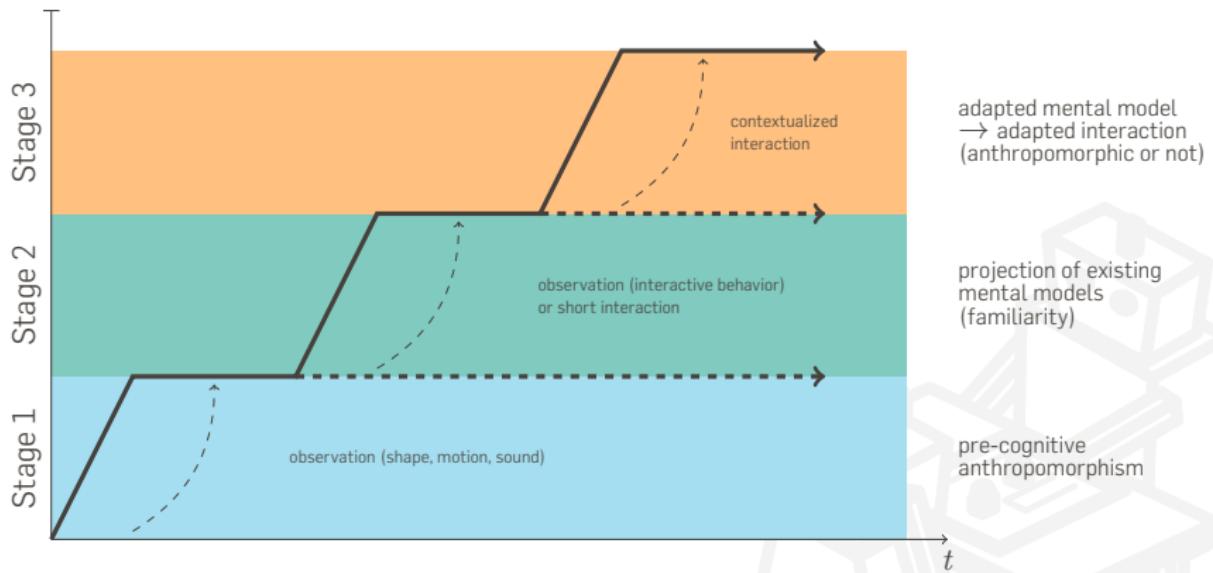
ARE YOU STILL WITH ME?

# HOW DO WE PERCEIVE ROBOT OVER TIME?

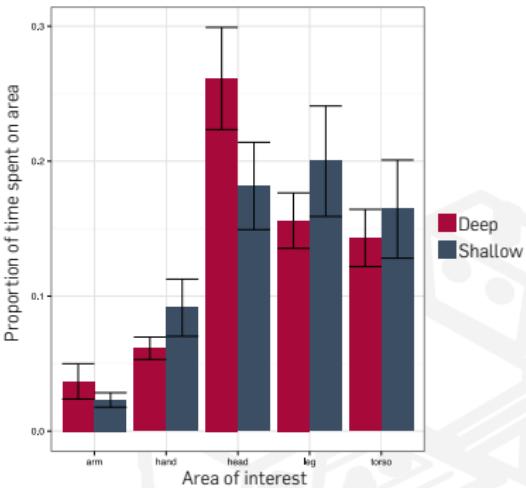




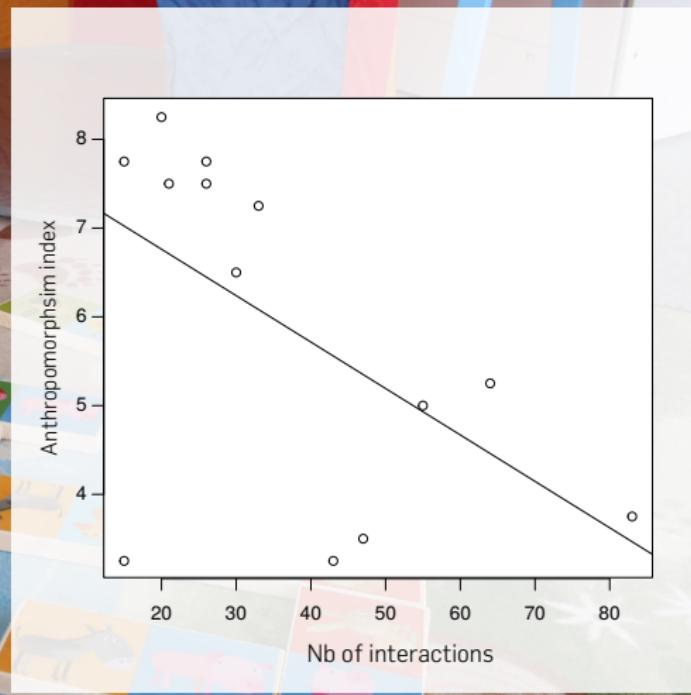
# COGNITIVE INTERPRETATION?



# COGNITIVE CONTEXT AND ANTHROPOMORPHISM



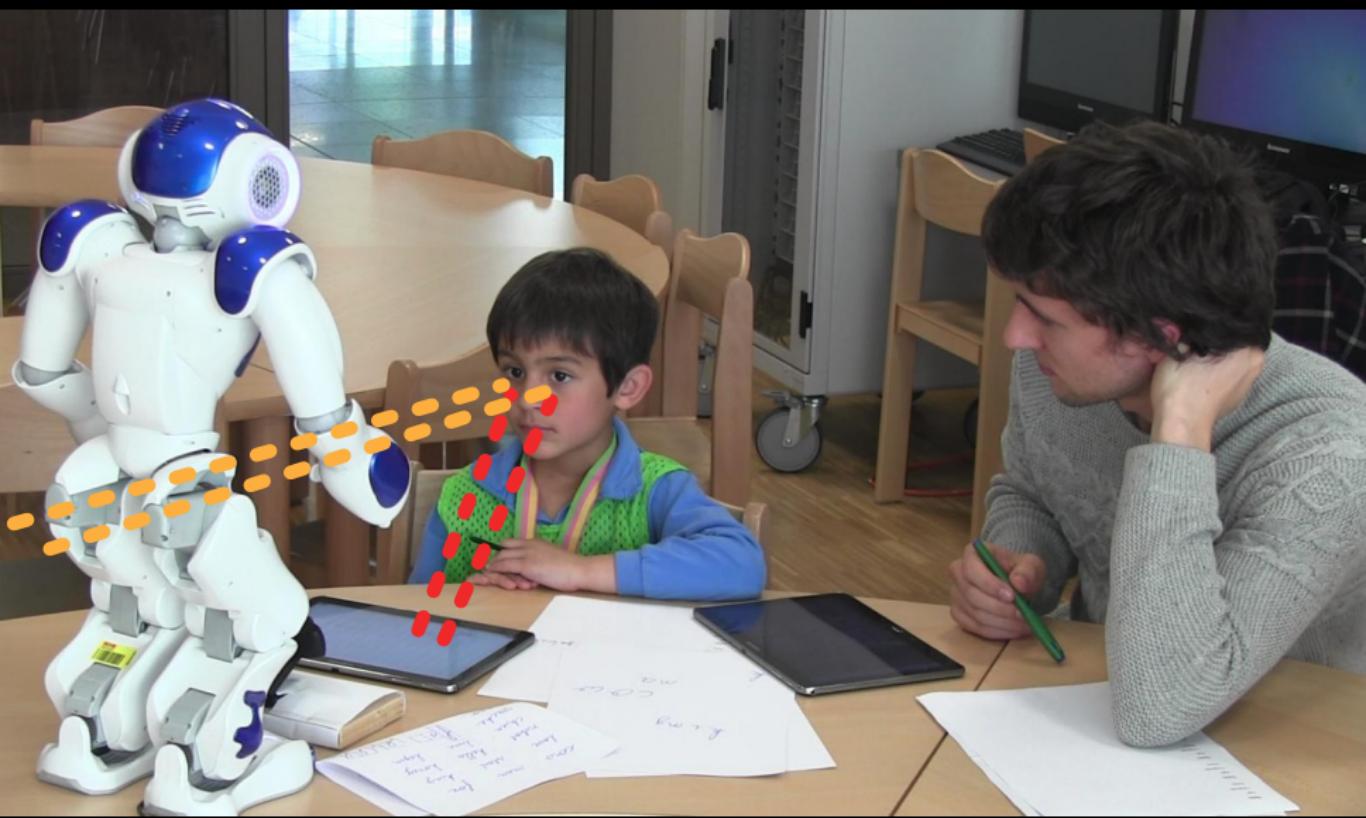
# ANTHROPOMORPHISM != ENGAGEMENT

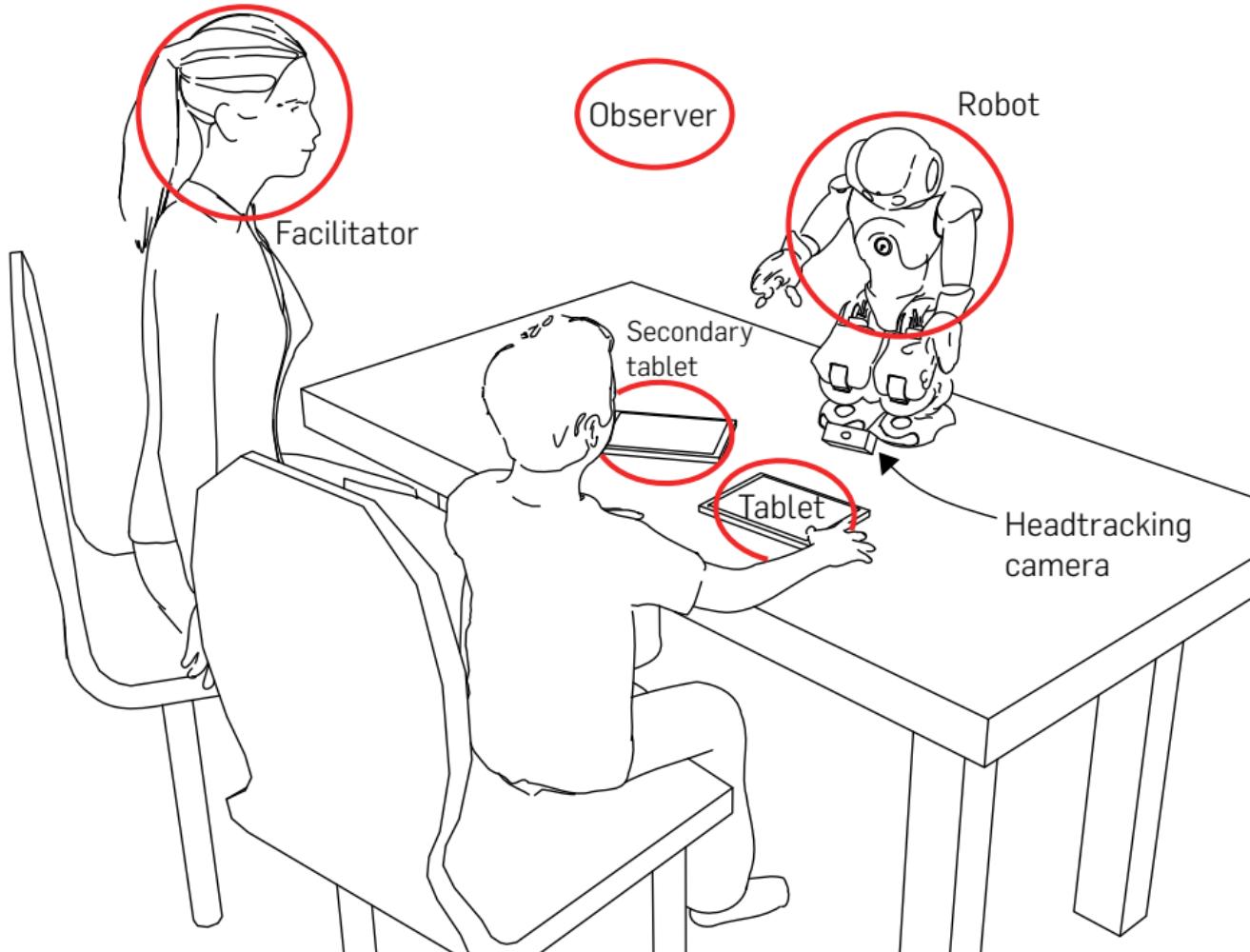


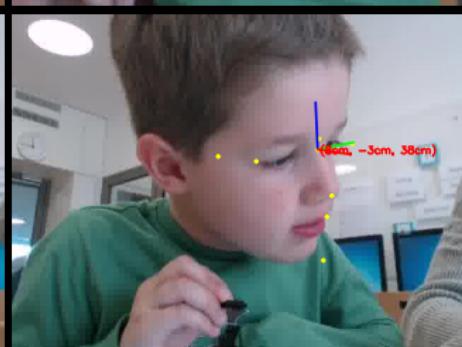
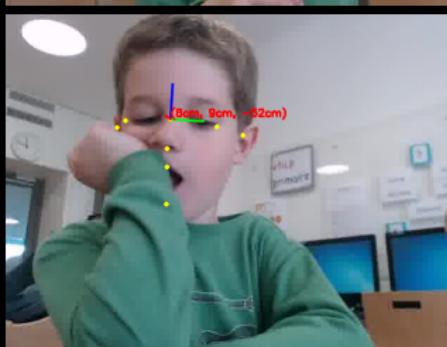
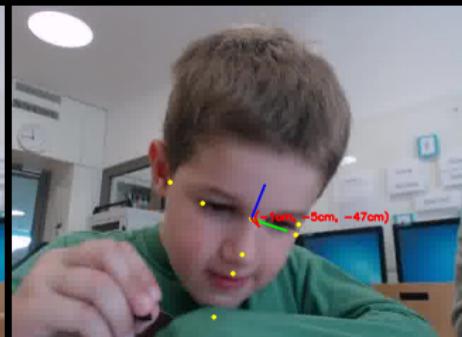
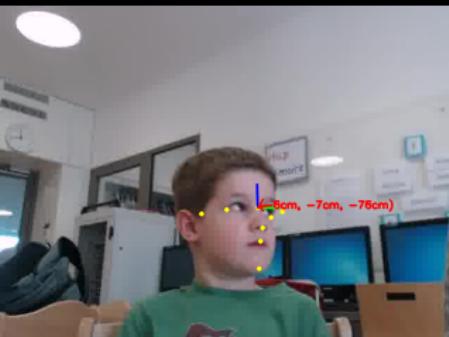
Can we make the assessment of engagement **practical?**





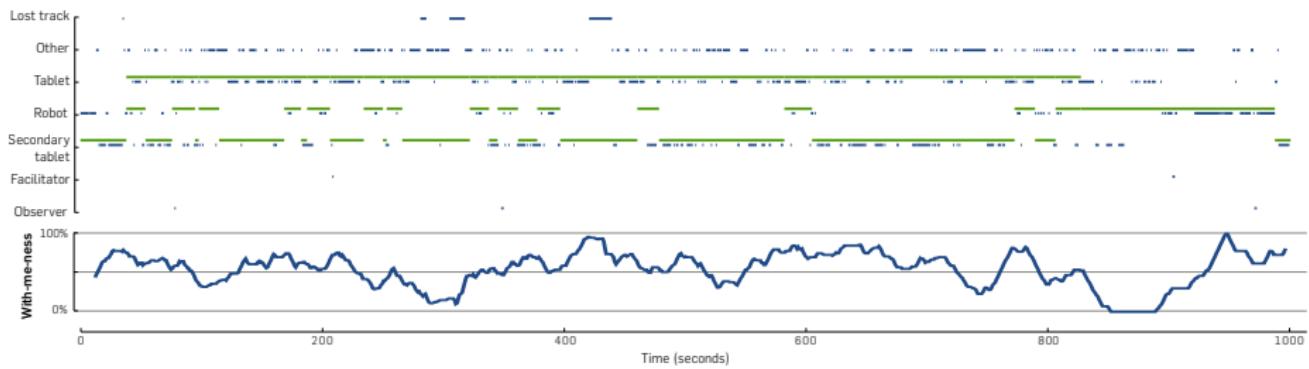






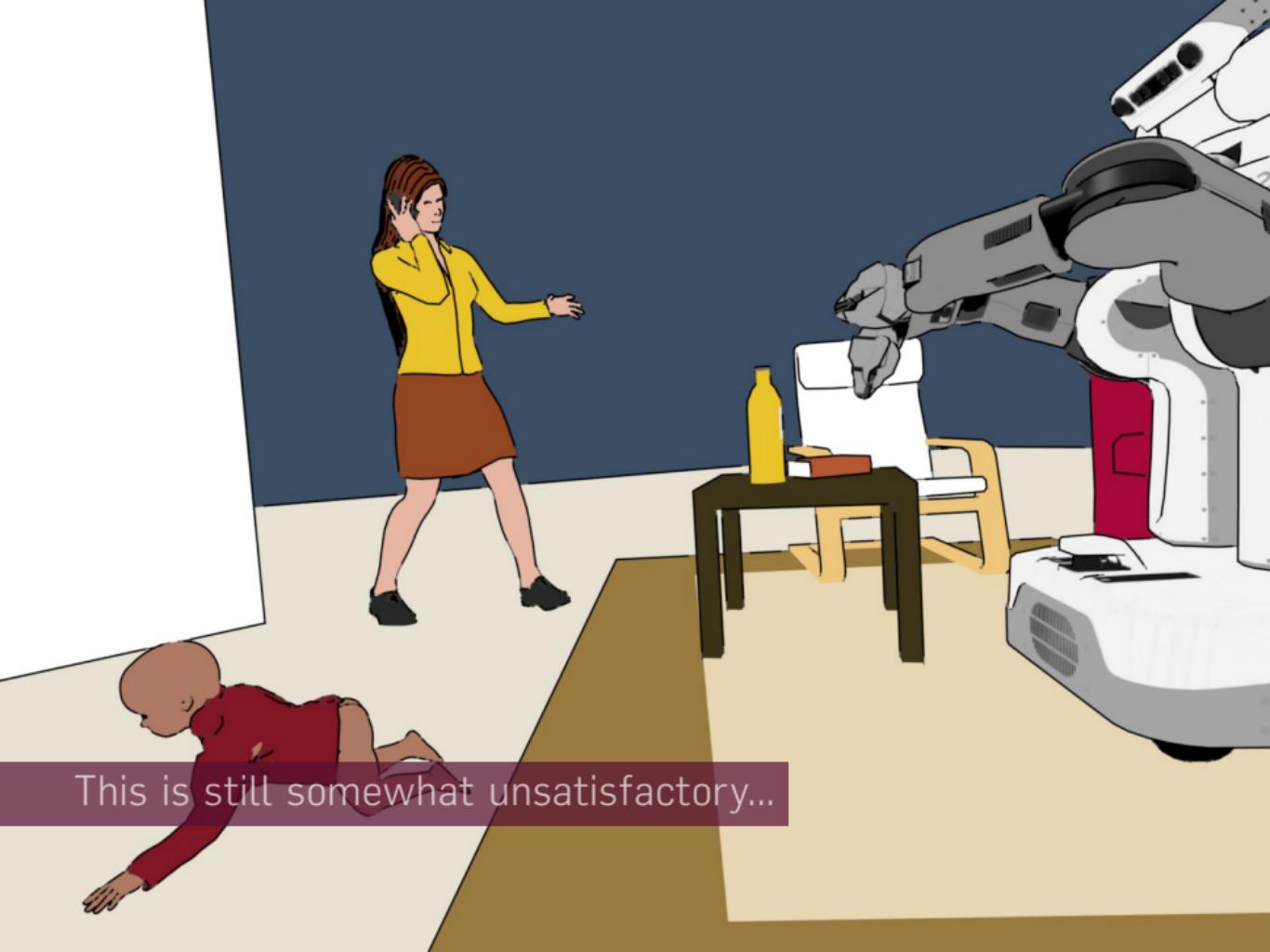


# WITH-ME-NESS



# A SUMMARY AND SOME IDEAS



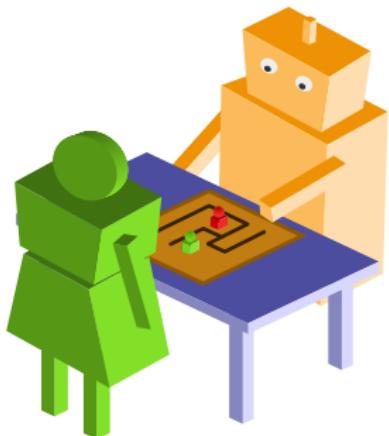


This is still somewhat unsatisfactory...

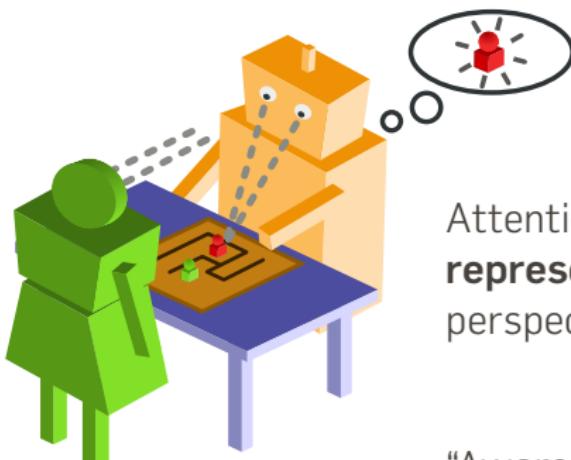
**Let's play a game!**



# ATTENTION, AWARENESS, ALIGNMENT



# ATTENTION, AWARENESS, ALIGNMENT

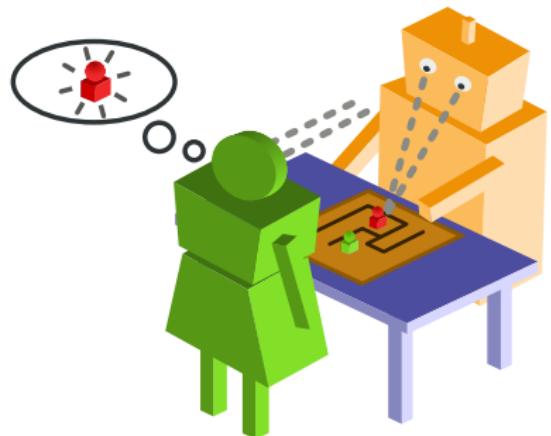


Attention is more about  
**representation** than visual  
perspective

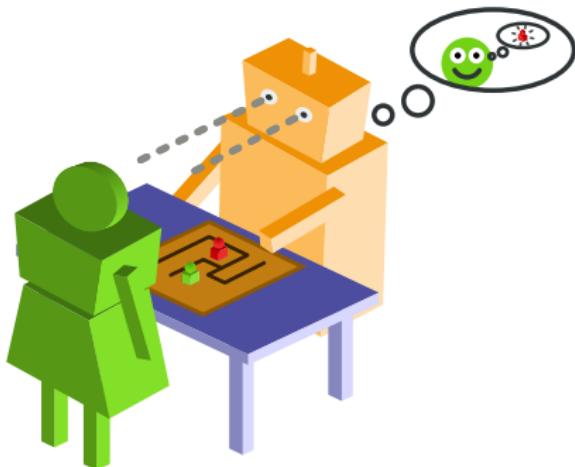
“Awareness is a construct that  
represents the attentional  
state of a brain”

[Graziano **Consciousness and the Social  
Brain – 2013**]

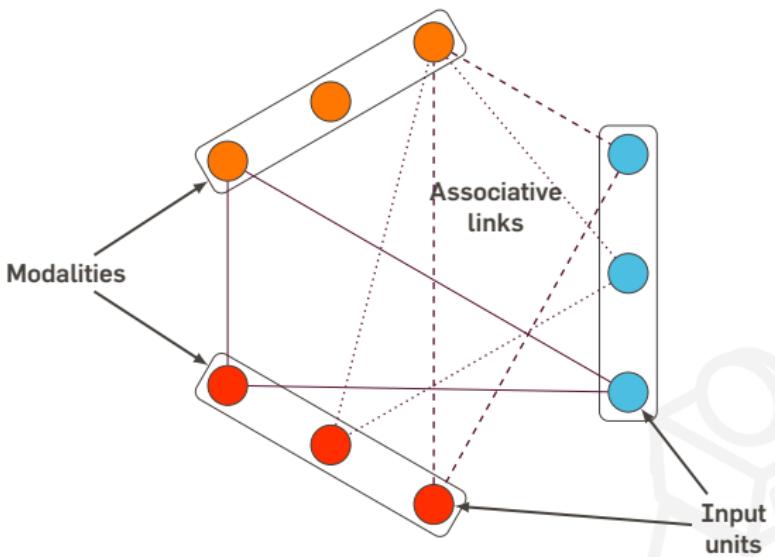
# ATTENTION, AWARENESS, ALIGNMENT



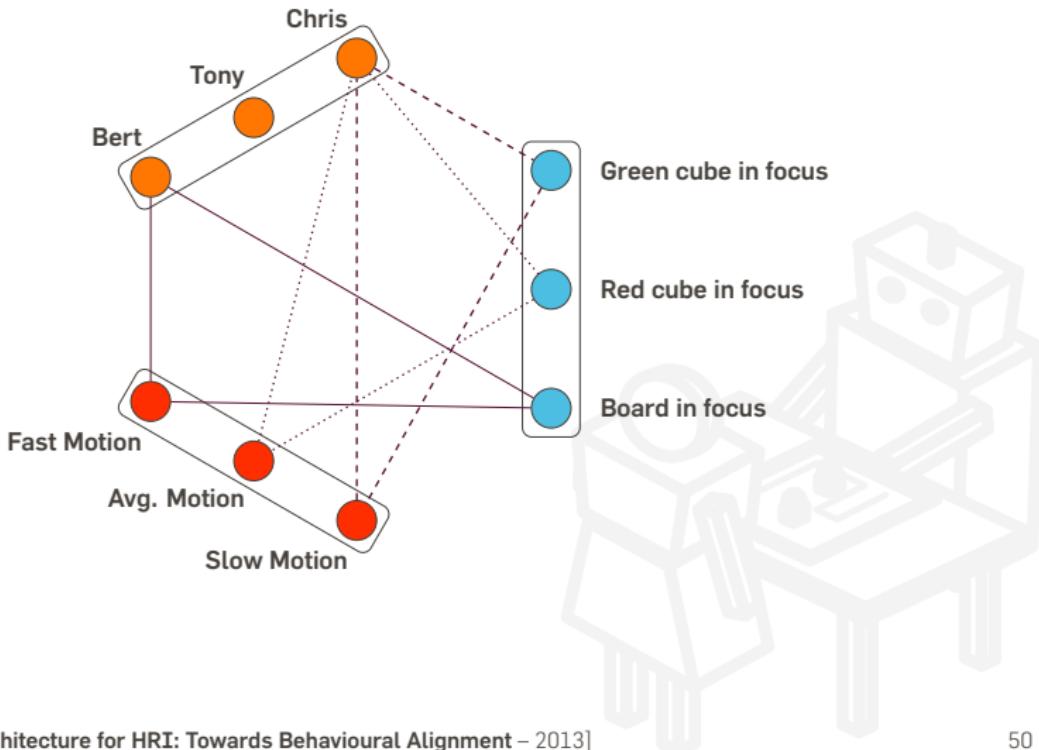
# ATTENTION, AWARENESS, ALIGNMENT



# ASSOCIATIVE MEMORY



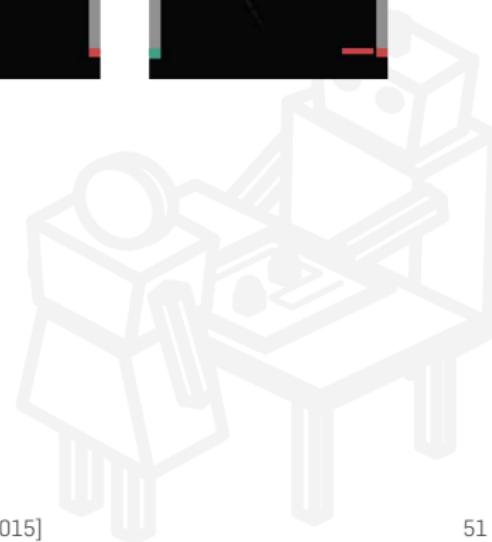
# ASSOCIATIVE MEMORY



# LEARNING COMPLEX BEHAVIOURS



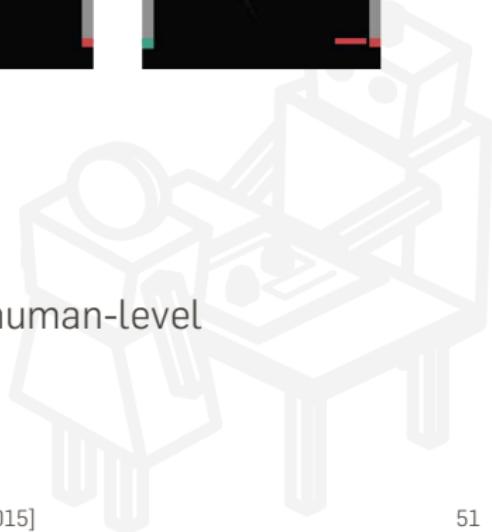
- Inputs: raw screen image + score
- from the outside, looks like planning



# LEARNING COMPLEX BEHAVIOURS



- Inputs: raw screen image + score
- from the outside, looks like planning
- ~~1.000.000~~ **500** games to play a good human-level



# LEARNING COMPLEX BEHAVIOURS



- Inputs: raw screen image + score
- from the outside, looks like planning
- ~~1.000.000~~ **500** games to play a good human-level

Could we also learn social dynamics?

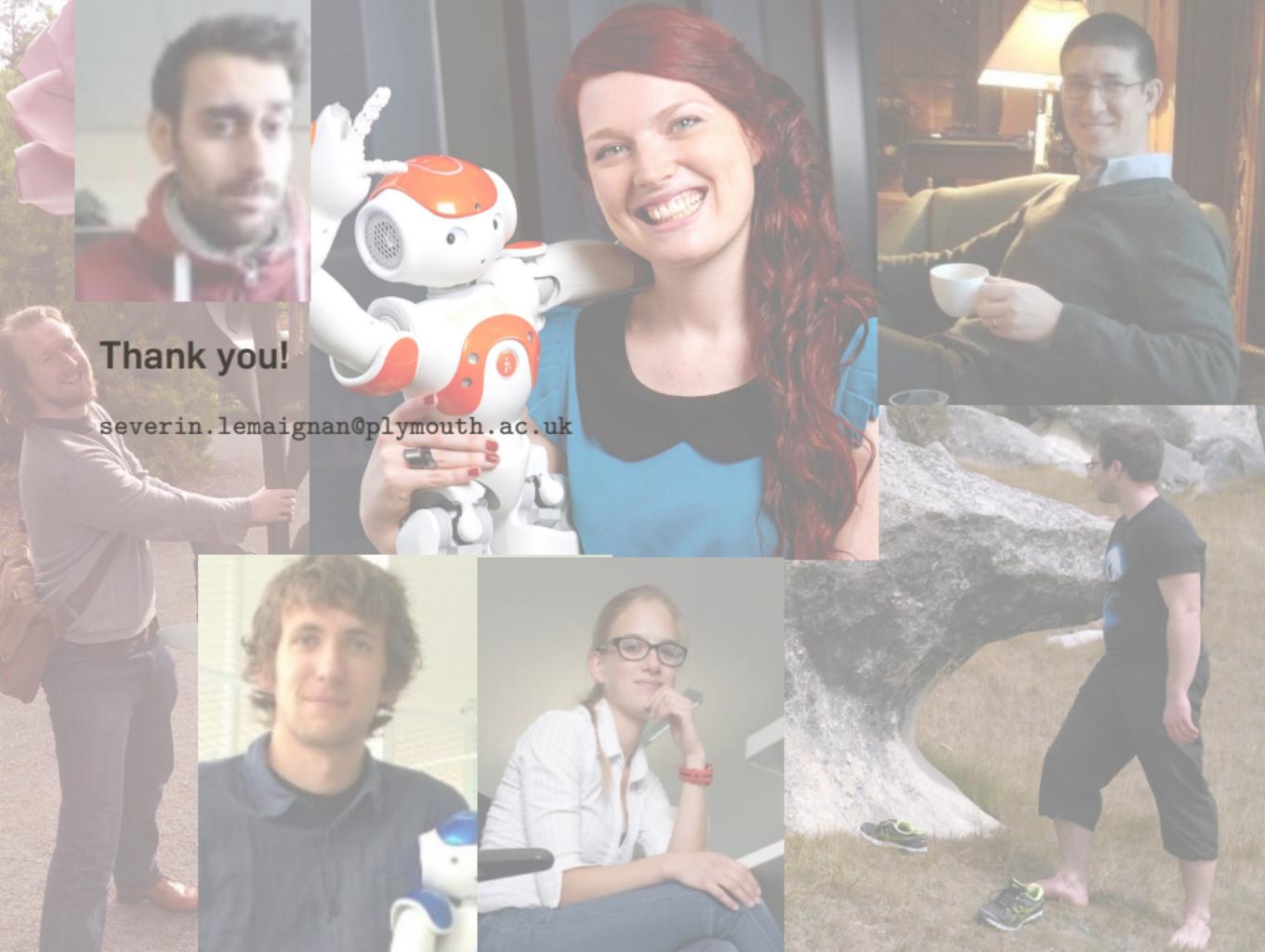
**Four main themes: studies, technical developments, theories and methods, design**

**Deadline: Septembre 5**

**Most selective conference of the field!**

**Unconventional research/methodologies: alt.HRI!**





Thank you!

[severin.lemaignan@plymouth.ac.uk](mailto:severin.lemaignan@plymouth.ac.uk)

## SUPPLEMENTARY MATERIAL

5. Mutual Modelling and Theory of Mind

6. Role of Unexpected Behaviours

7. More on CoWriter

8. Cognitive Architectures

9. Dialogue Grounding

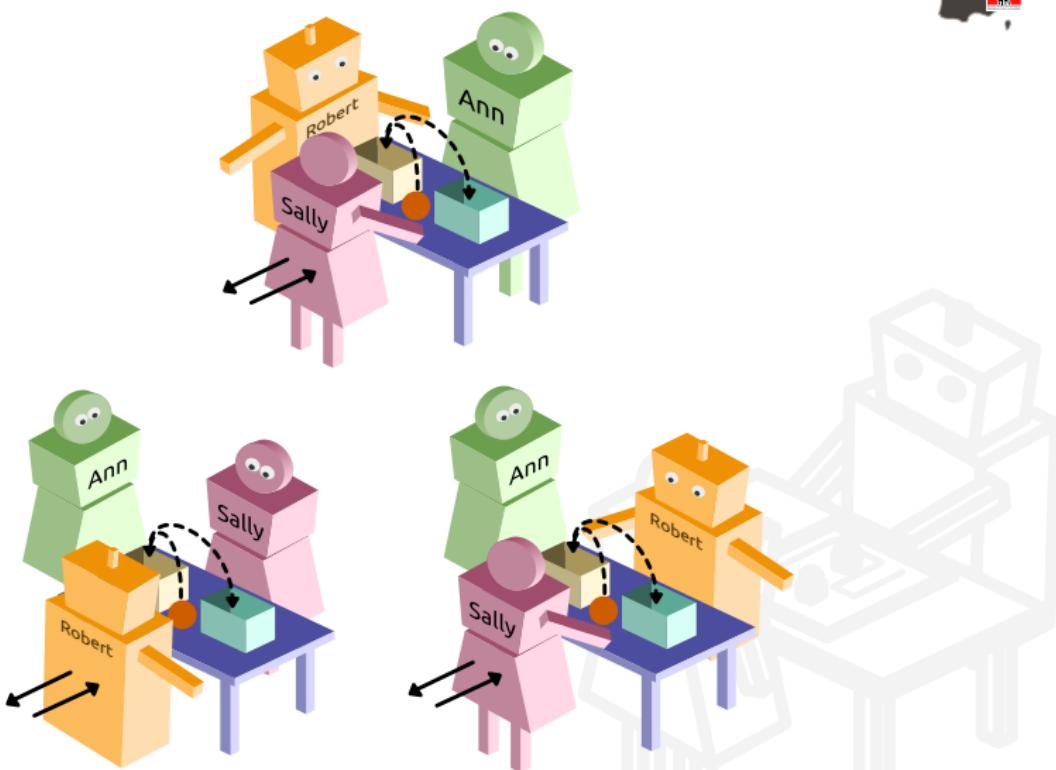
10. Human-aware Planning

11. Performing in Human Environments

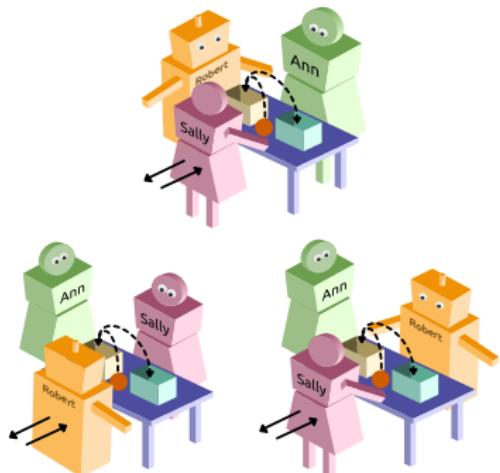


TOM

# THE FALSE-BELIEF EXPERIMENT, RELOADED

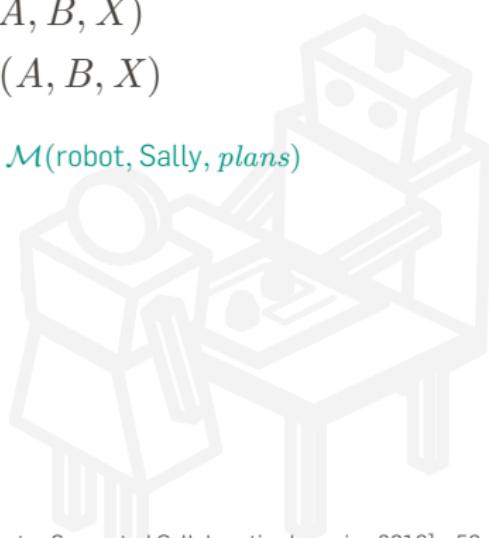


# THE FALSE-BELIEF EXPERIMENT, RELOADED



- $\mathcal{M}(A, B, X)$
- $\mathcal{M}^\circ(A, B, X)$

e.g.  $\mathcal{M}(\text{robot}, \text{Sally}, \text{plans})$



# THE FALSE-BELIEF EXPERIMENT, RELOADED

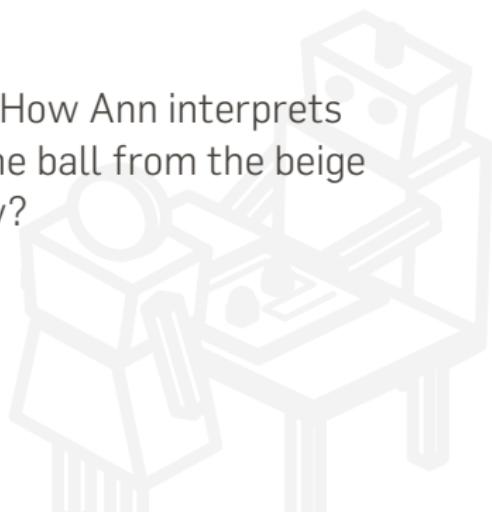


- **Robot is the observer**

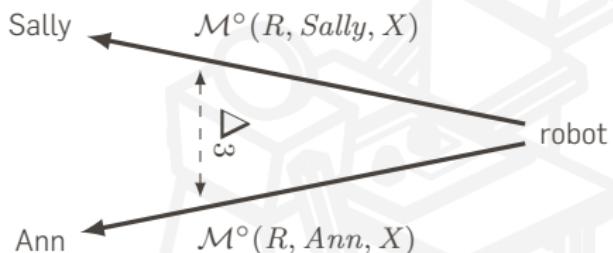
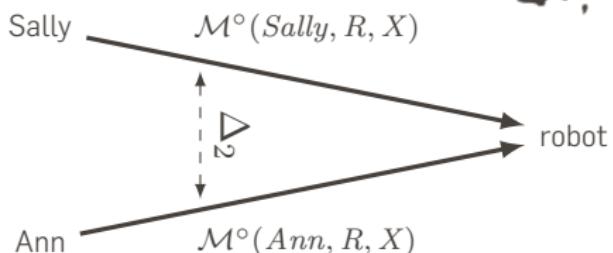
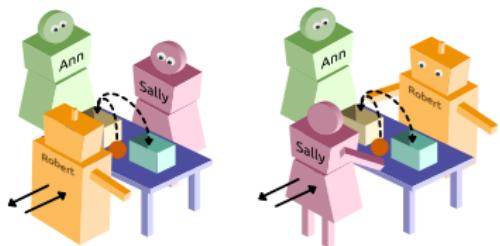
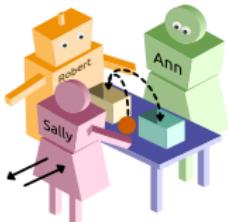
$\mathcal{M}^\circ(R, \text{Sally}|\text{Ann}, \text{plans})$ ? can the human verbalise it? i.e.  
 $\mathcal{M}(H, R, \mathcal{M}(R, H, \text{plans}))$ ?

- **Robot is an active participant**

$\mathcal{M}(H, R, \text{knowledge}|\text{plans}| \text{goals})$ ? i.e. How Ann interprets  
the behaviour of a robot who moves the ball from the beige  
box to the blue box while Sally is away?



# THE FALSE-BELIEF EXPERIMENT, RELOADED



# THE FALSE-BELIEF EXPERIMENT, RELOADED

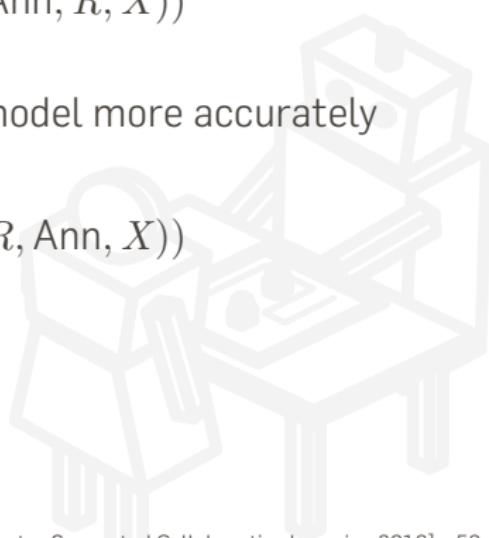


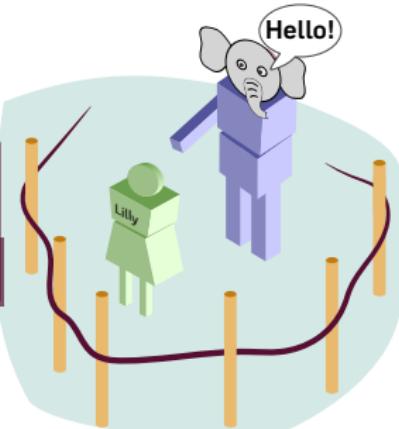
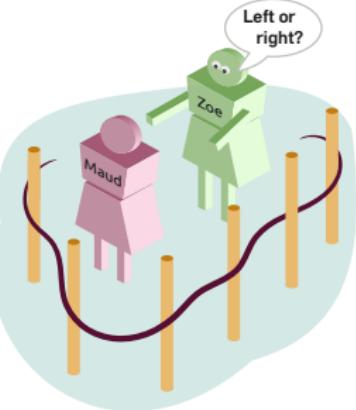
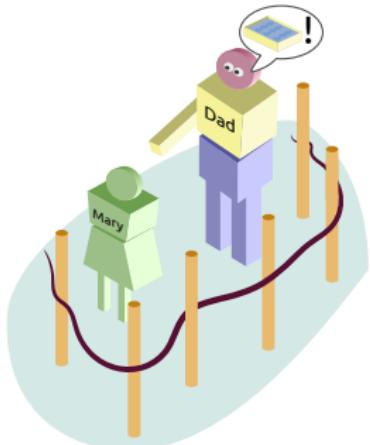
Do Sally and Ann have the same accuracy when modelling the robot?

$$\Delta_2 = \Delta(\mathcal{M}(\text{Sally}, R, X), \mathcal{M}(\text{Ann}, R, X))$$

Conversely, what may lead the robot to model more accurately  
Sally or Ann?

$$\Delta_3 = \Delta(\mathcal{M}(R, \text{Sally}, X), \mathcal{M}(R, \text{Ann}, X))$$







# SHOPPING LIST FOR HRI?

## Already in the HRI fridge

Instrumental gestures

Using person as tool

Talking about desires and emotions

Showing "active" sociability

Elicited structured play

## To buy...

Expressive gestures

Using person as receiver of information

Talking about beliefs and ideas

Showing "interactive" sociability

Spontaneous pretend play

# AUTISTIC ASSETS AND DEFICITS OBSERVED IN REAL LIFE



Assets	Deficits
Instrumental gestures	Expressive gestures
Using person as tool	Using person as receiver of information
Talking about desires and emotions	Talking about beliefs and ideas
Showing "active" sociability	Showing "interactive" sociability
Elicited structured play	Spontaneous pretend play

# UNEXPECTED BEHAVIOURS



# UNEXPECTED BEHAVIOURS

	Unplanned by the robot	Planned by the robot
Perceived as non- intentional	A	B
Perceived as intentional	C	D

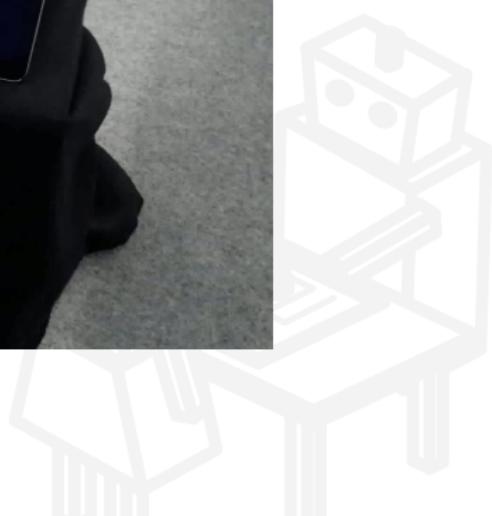


COWRITER



# COWRITER DETAILS

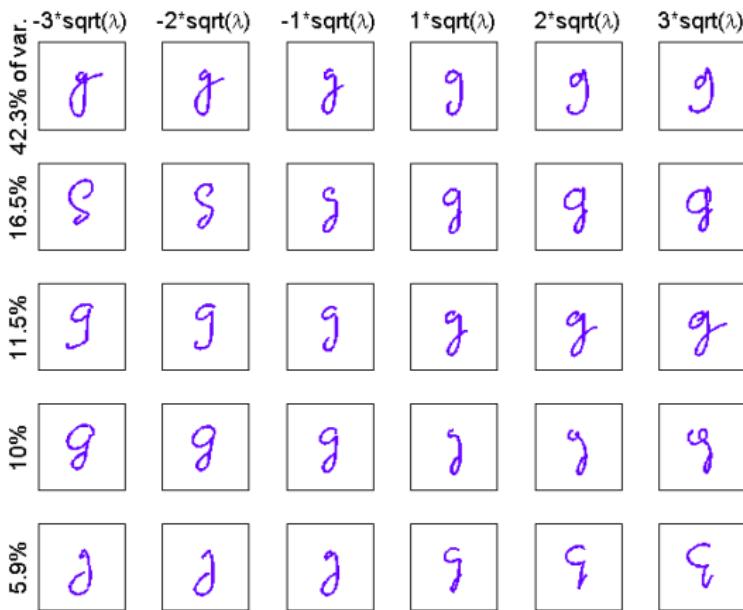
## CoWriter: Learning by Teaching



# COWRITER DETAILS



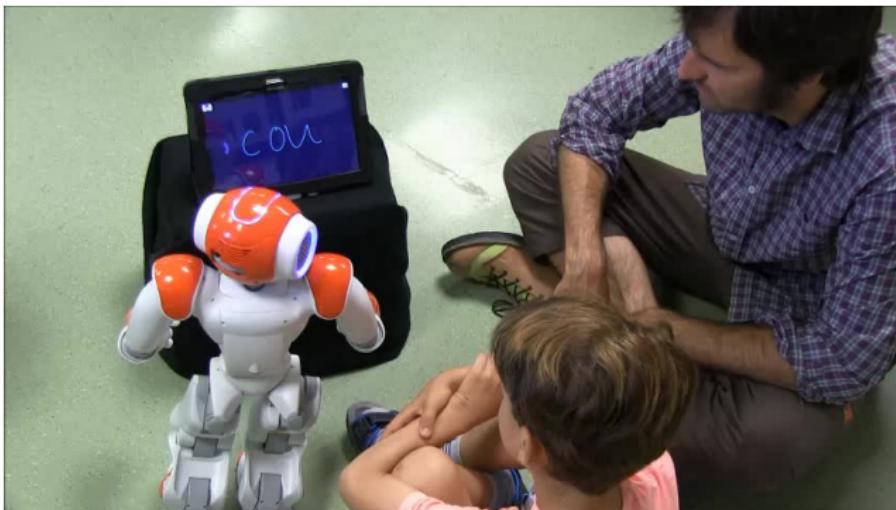
## CoWriter: Learning by Teaching

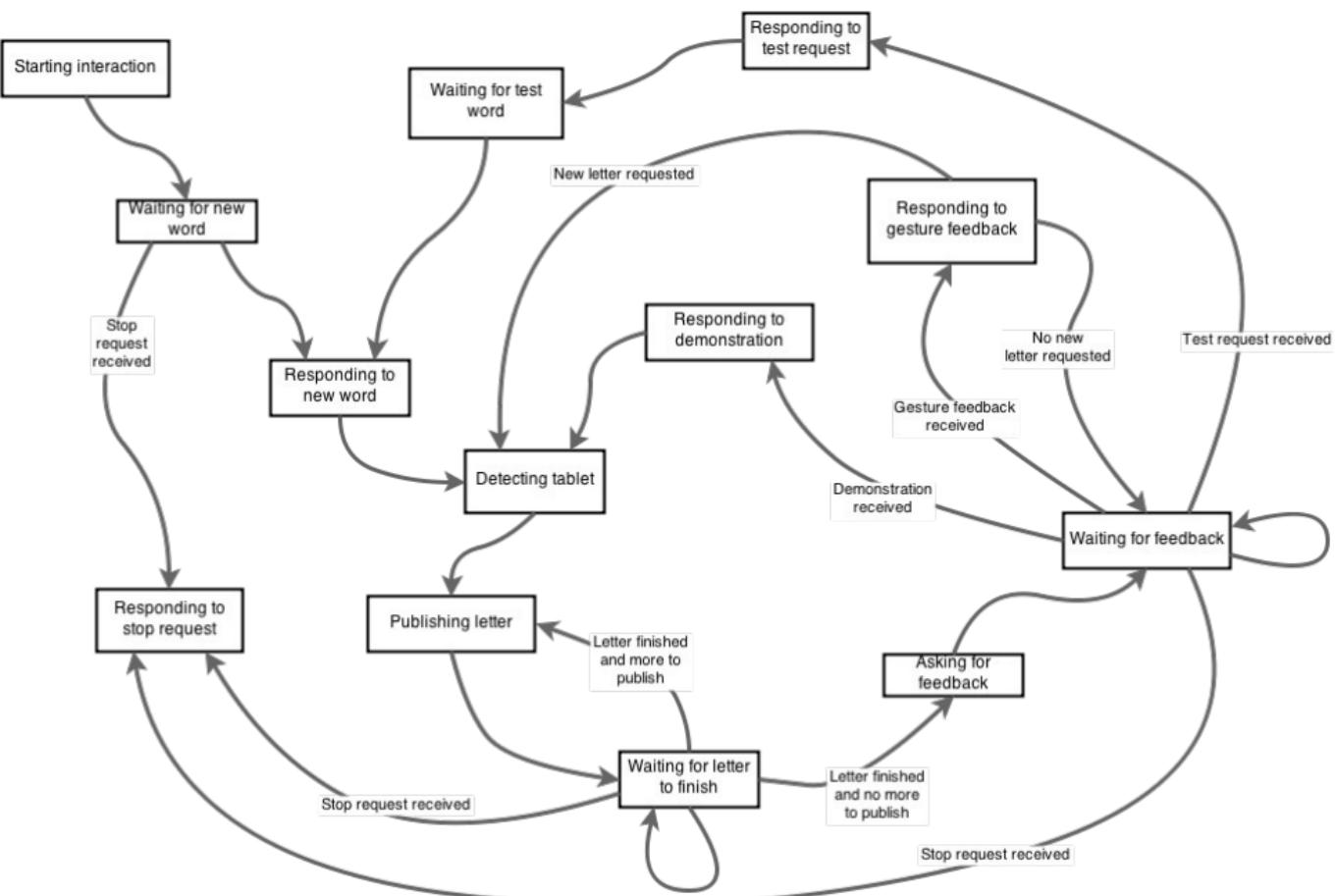


# COWRITER DETAILS



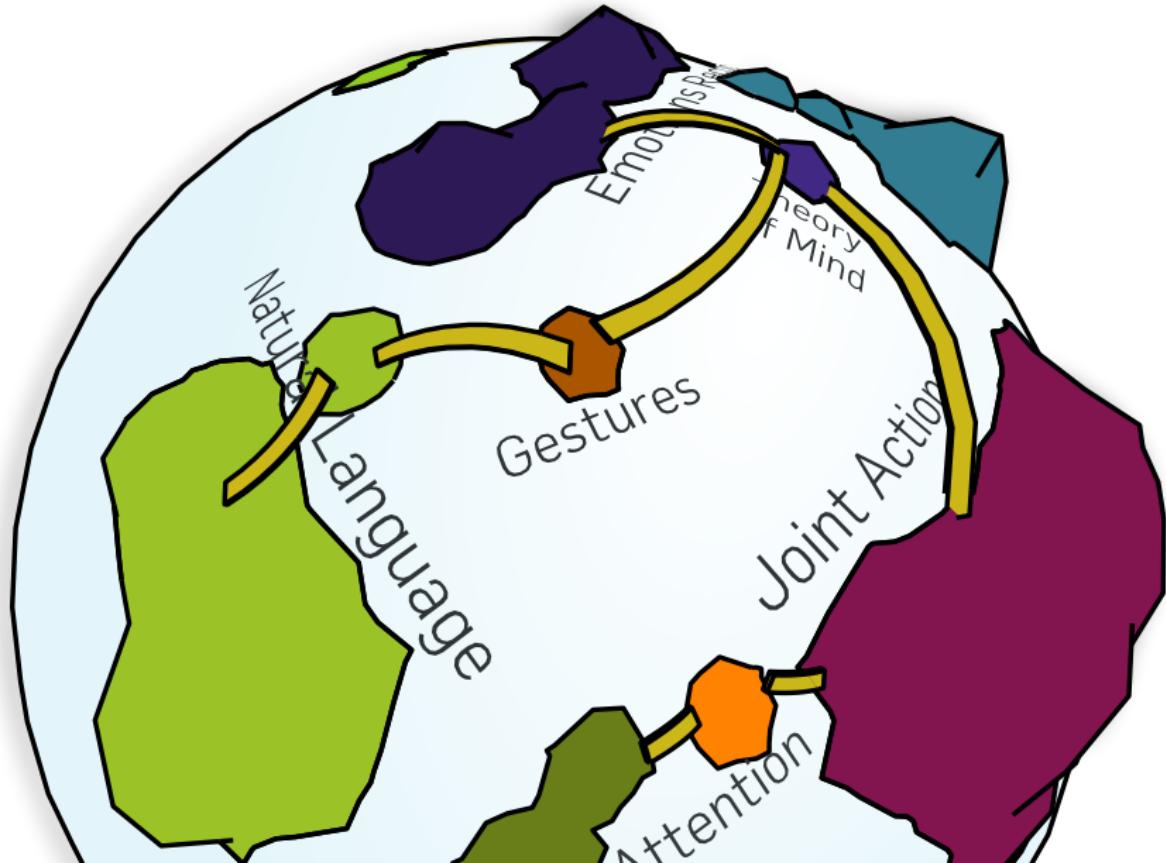
## CoWriter: Learning by Teaching

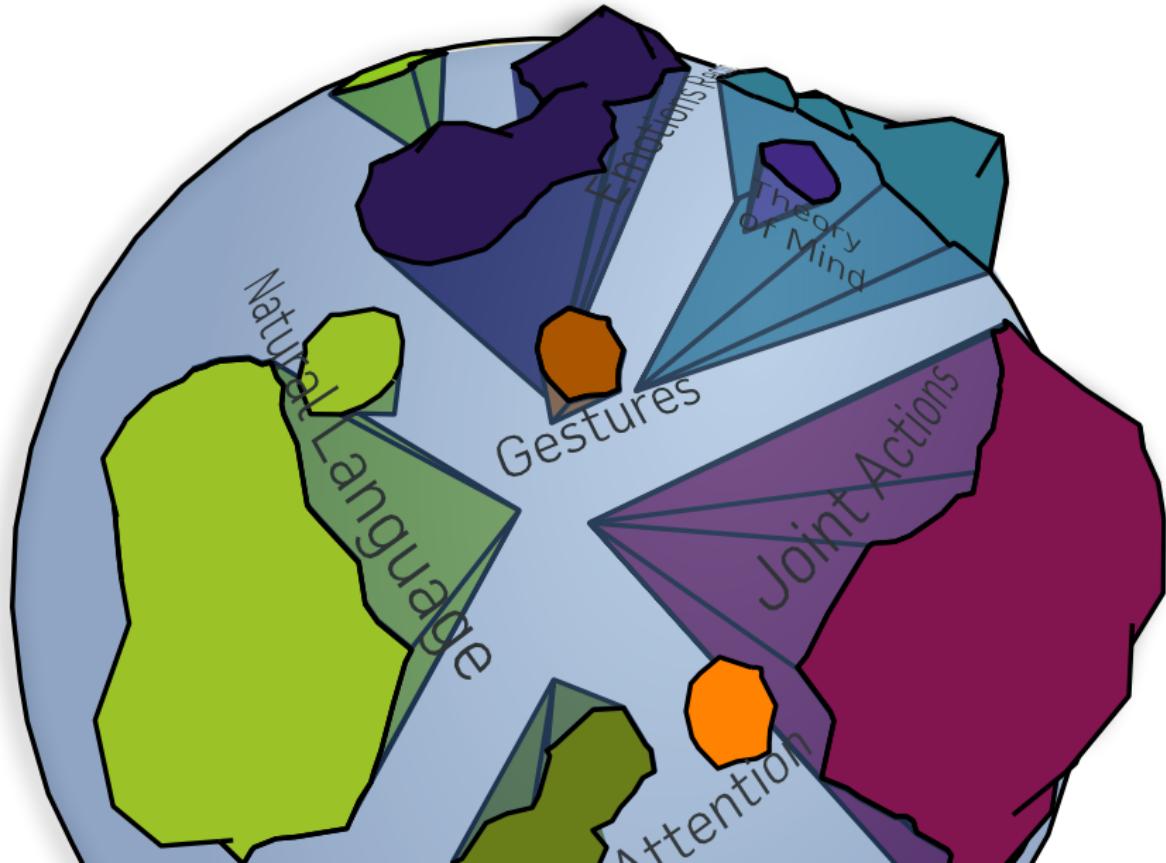


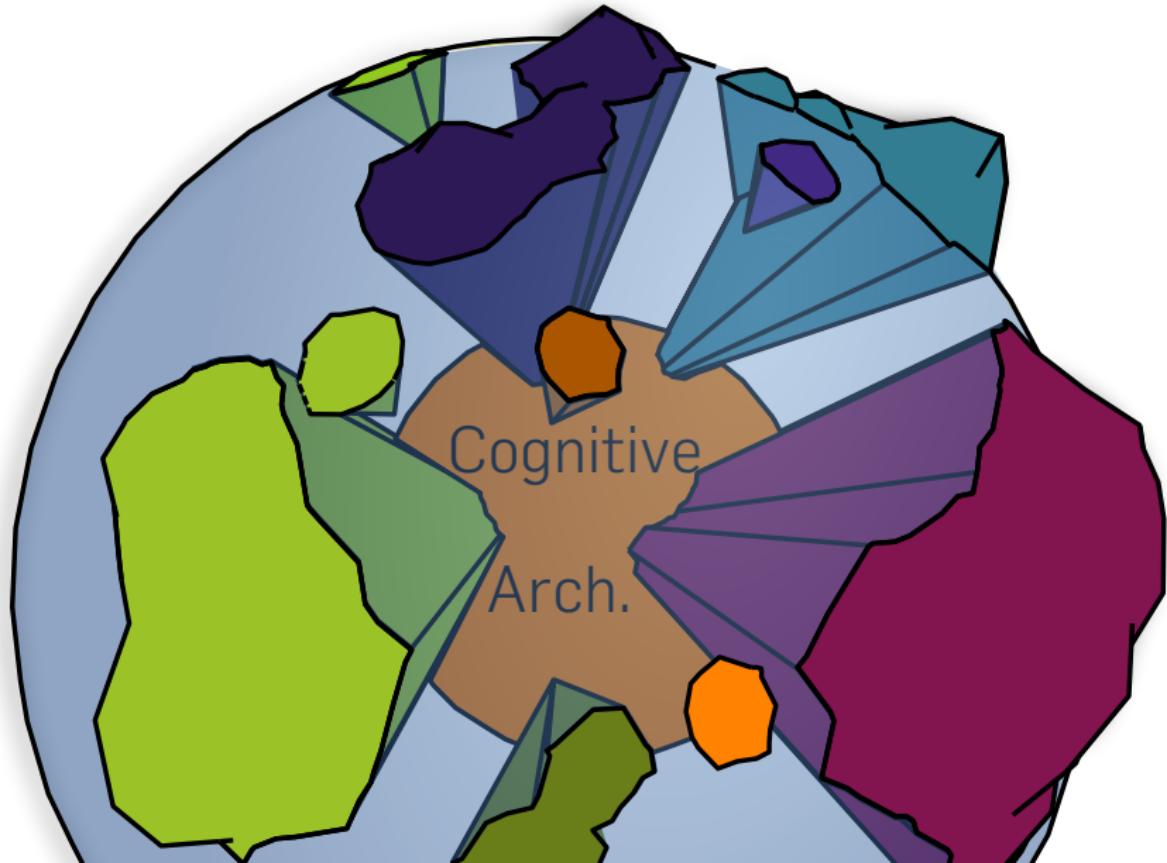


COGARCH





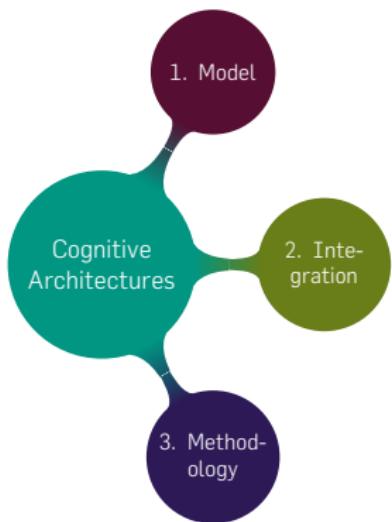




Cognitive

Arch.

# COGNITIVE ARCHITECTURES FOR SOCIAL HRI



## 1. Models of Human Cognition

- Modelling (aspects of) human cognition
- Subsequent application to robots

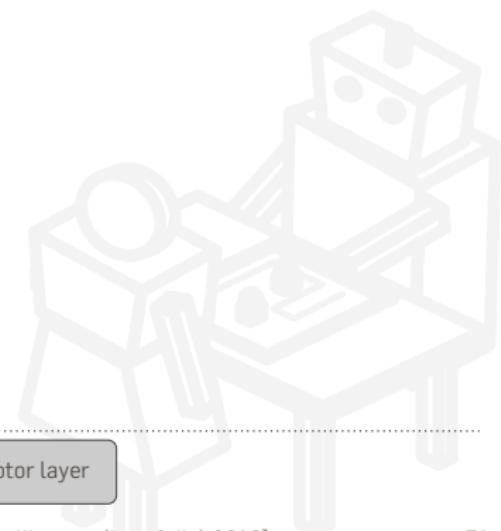
## 2. Technical Integration

- Define required functionality of robots
- Implement algorithms (etc) necessary

## 3. A Methodology

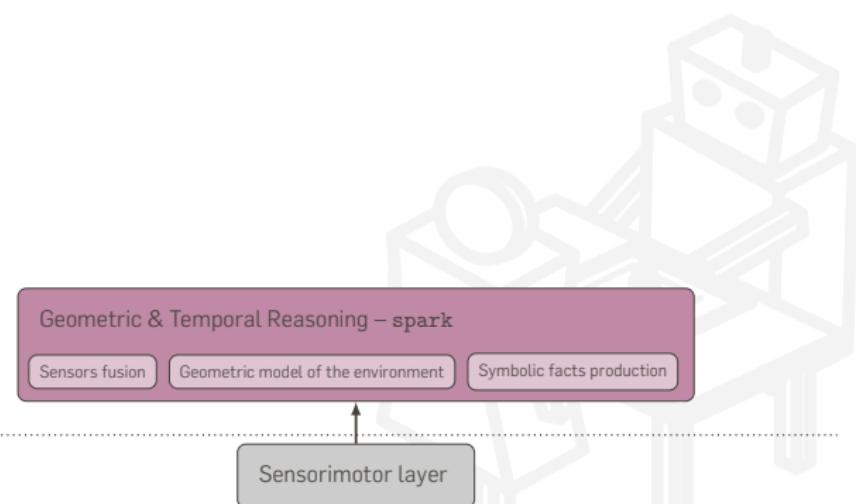
- Formalising assumptions
- Integrating knowledge from multiple disciplines
- Iteratively updating architecture

# FROM "TECHNICAL INTEGRATION"...

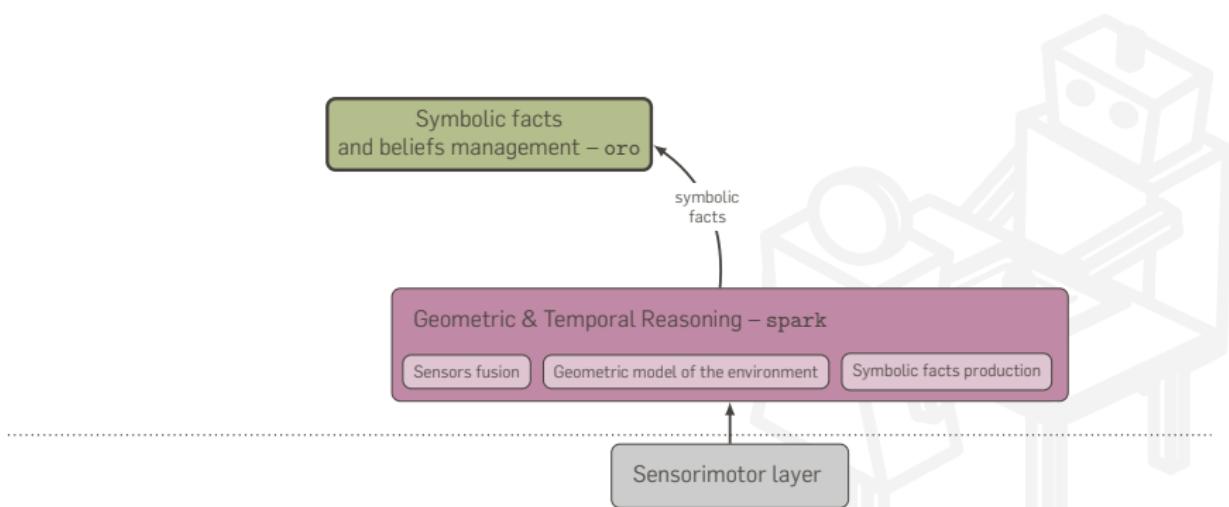




# FROM "TECHNICAL INTEGRATION"...

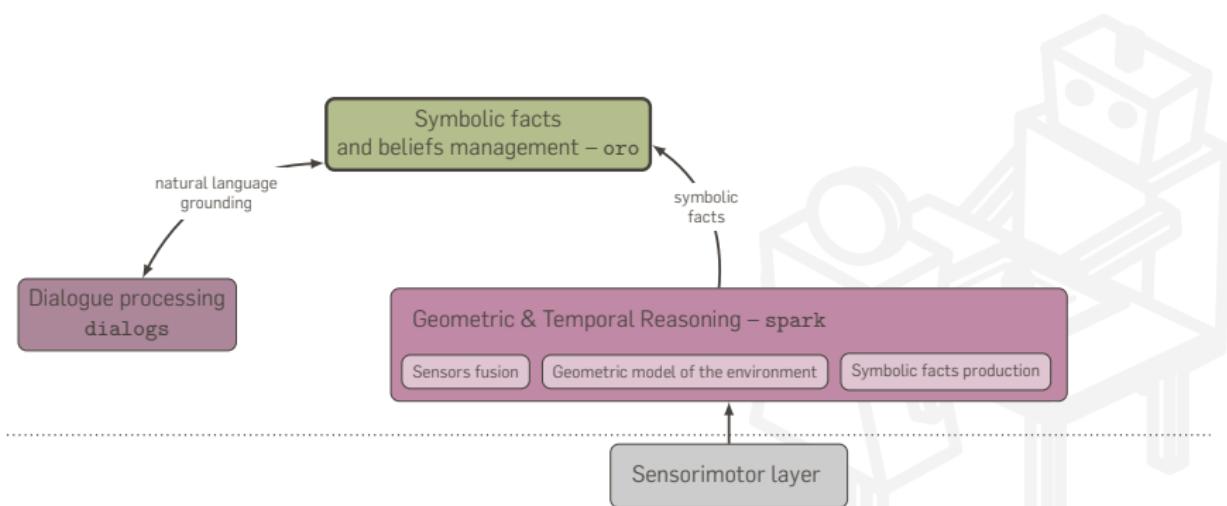


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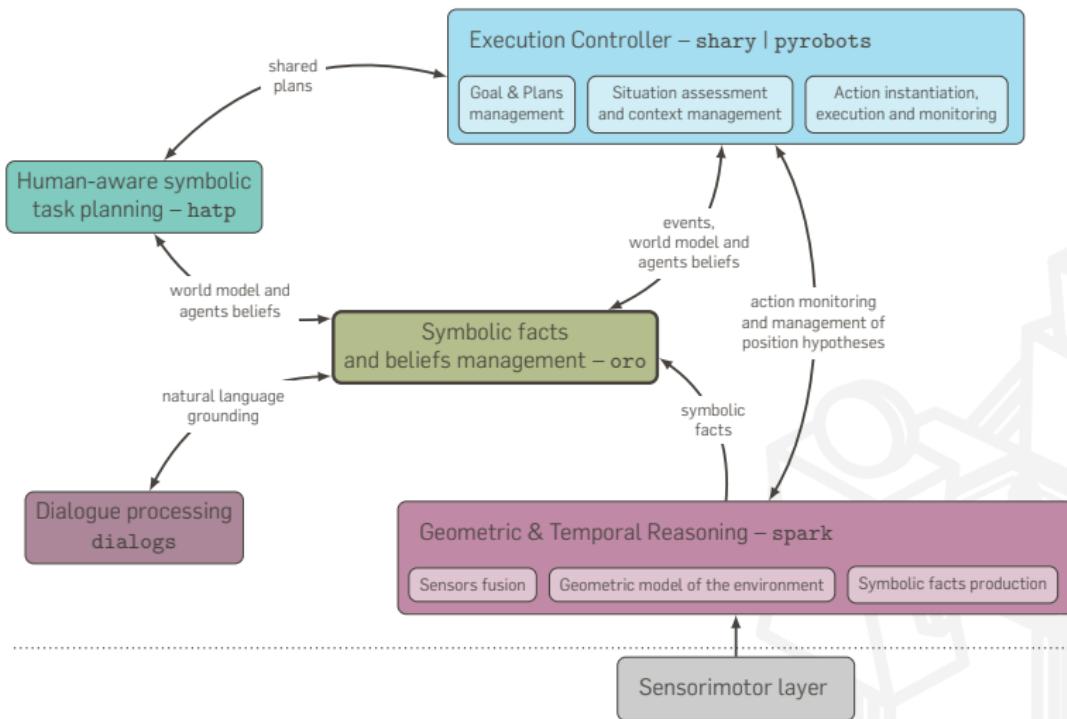


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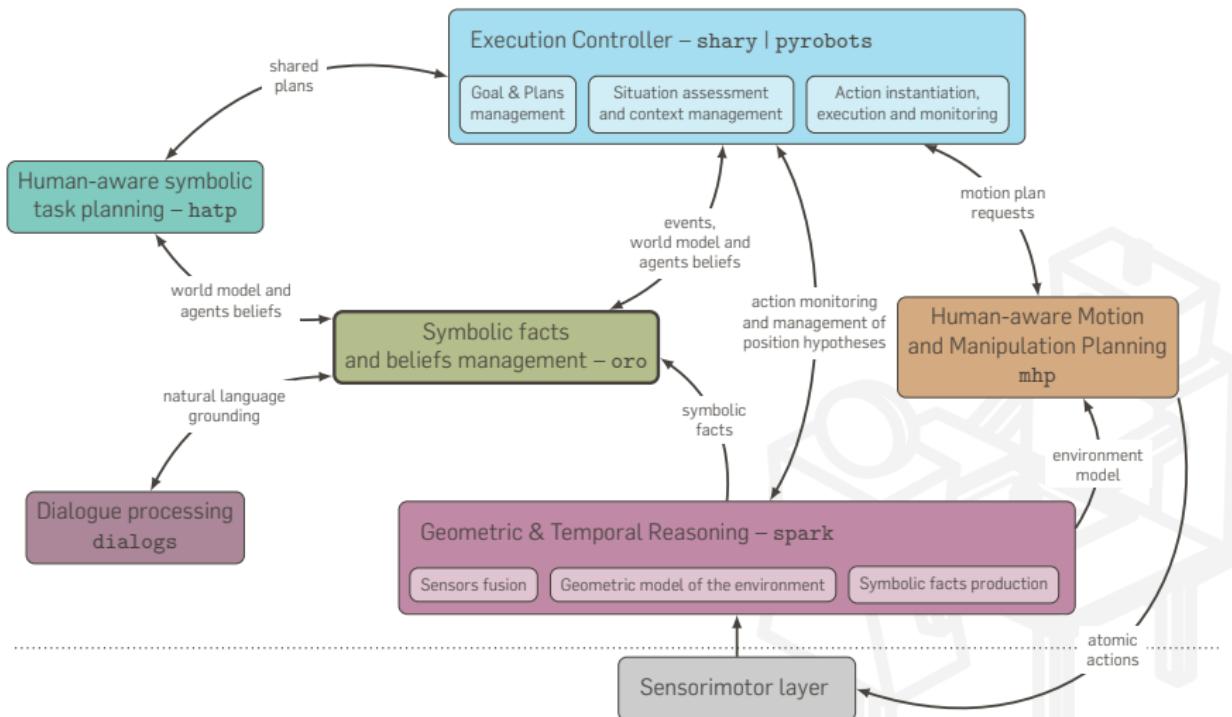


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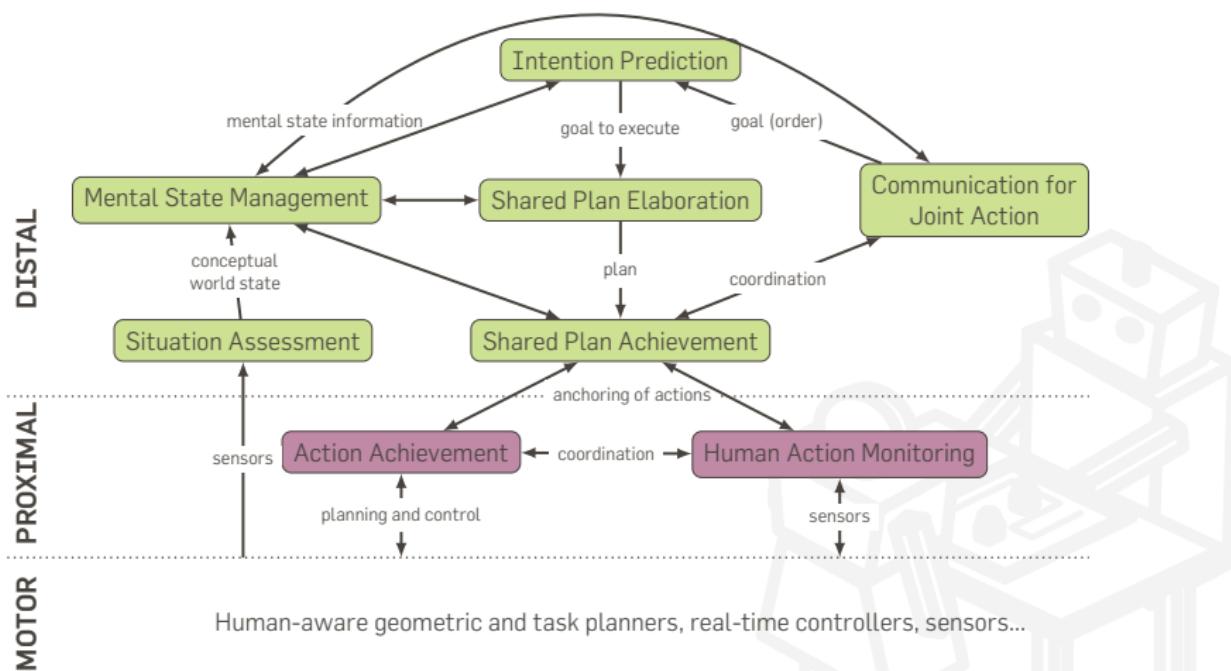




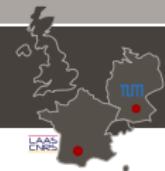
# FROM "TECHNICAL INTEGRATION"...



# ...TO “MODELING OF HUMAN COGNITION”...



DIALOGUE

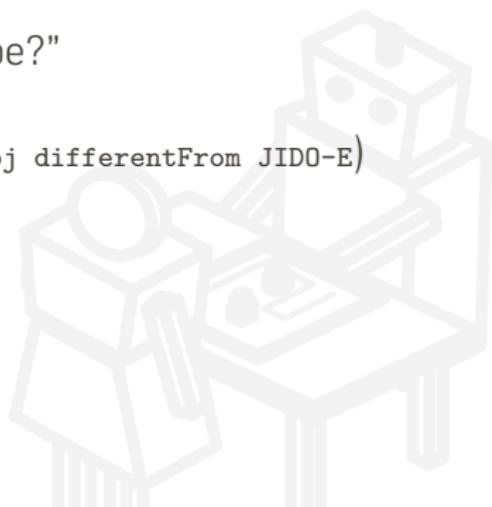


# DIALOGUE GROUNDING

"Where is the other tape?"

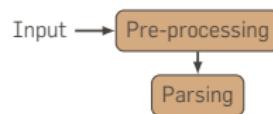


find(?obj isAt ?loc, ?obj type VideoTape, ?obj differentFrom JIDO-E)



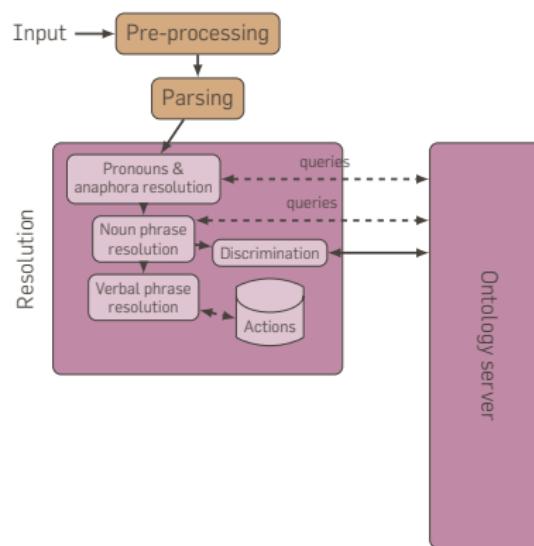


# DIALOGUE GROUNDING

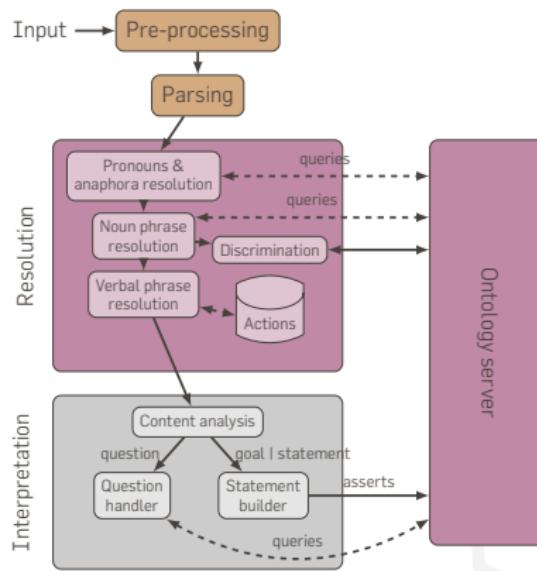




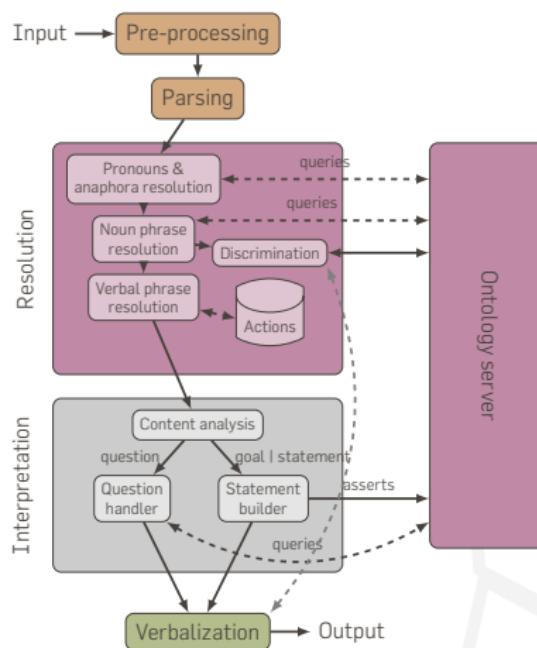
# DIALOGUE GROUNDING



# DIALOGUE GROUNDING



# DIALOGUE GROUNDING



# DIALOGUE GROUNDING



"Give me the book on the table"





# DIALOGUE GROUNDING

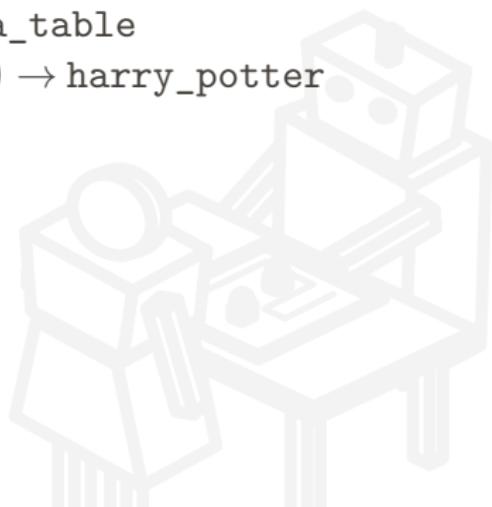
"Give me the book on the table"



`me → baby_1`

`find(?obj type table) → ikea_table`

`find(?obj type book, ?obj isOn ikea_table) → harry_potter`





# DIALOGUE GROUNDING

"Give me the book on the table"



`me → baby_1`

`find(?obj type table) → ikea_table`

`find(?obj type book, ?obj isOn ikea_table) → harry_potter`



`baby_1 desires action1,`

`action1 type Give,`

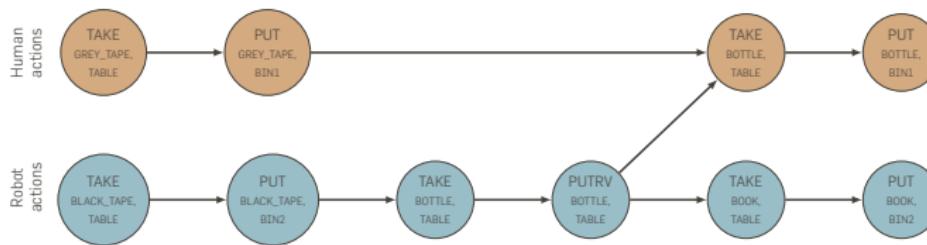
`action1 performedBy myself,`

`action1 actsOnObject harry_potter,`

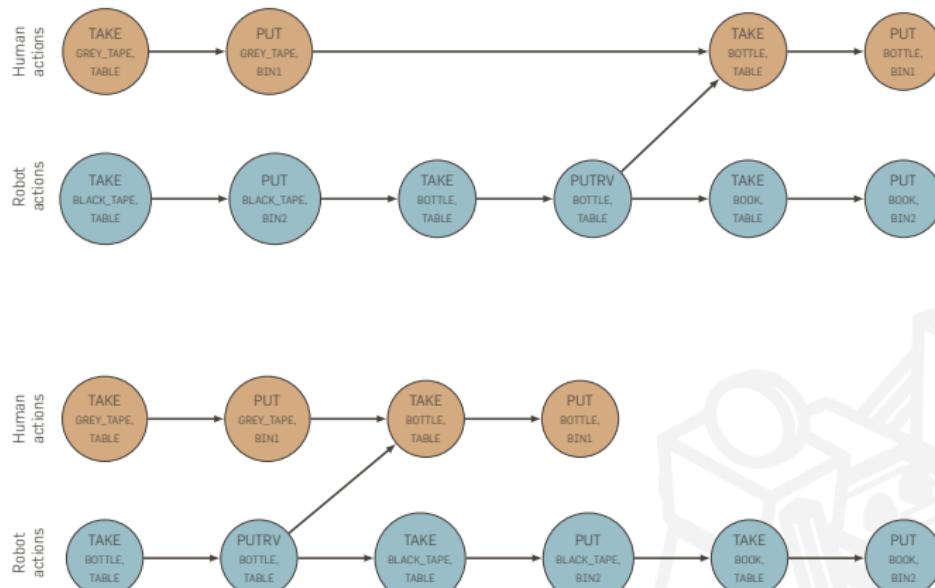
`action1 receivedBy baby_1`

# PLANNING

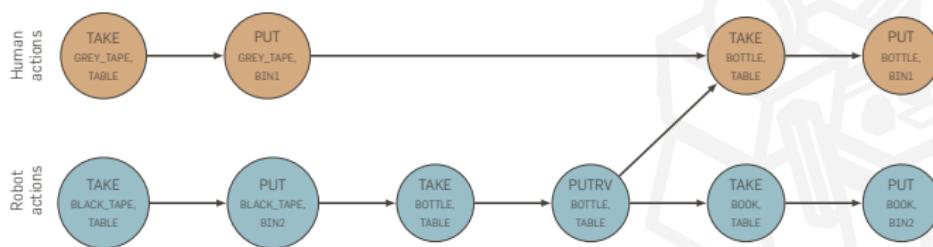
# PLANNING FOR THE HUMAN



# PLANNING FOR THE HUMAN



# PLANNING FOR THE HUMAN





LAAS-CNRS

ACTING

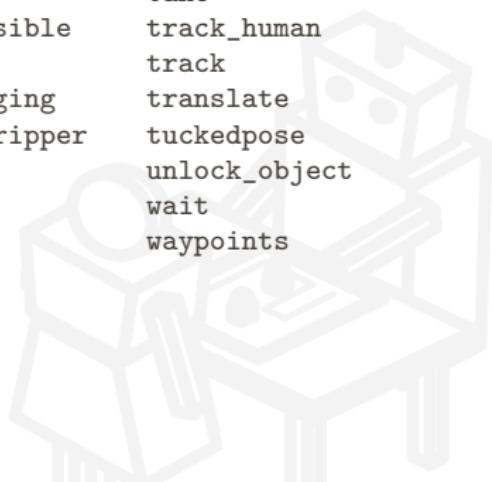


LAAS-CNRS

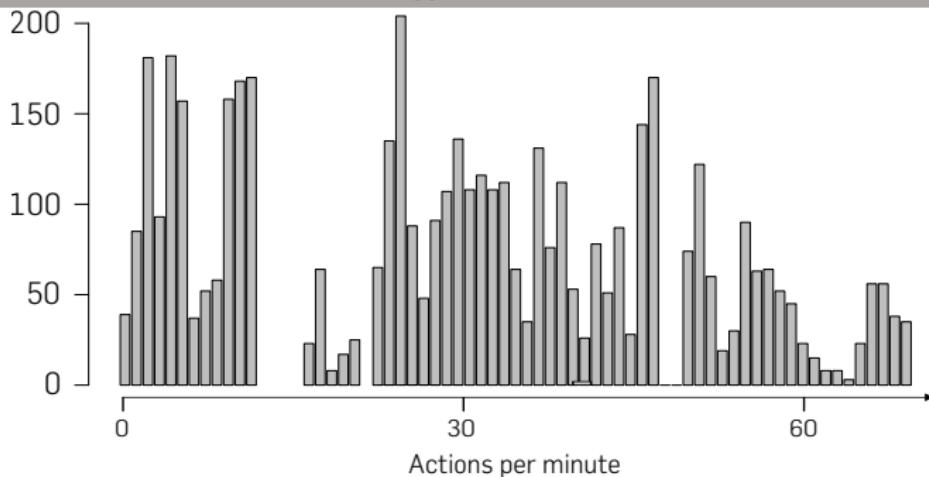
3



amit_give	follow	manipose	setup_scenario
arms_against_torso	glance_to	move_head	show
attachobject	goto	movearm	slow_arms_swinging
basicgive	grab_gripper	moveclose	sorry
basicgrab	grab	open_gripper	speed_arms_swinging
basictake	gym	pick	sweep_look
basket	handover	place_agent	sweep
cancel_follow	handsup_folded	place_object	switch_cameras
cancel_track	handsup_folded2	pointsat	take
cancel	handsup_folded3	put_accessible	track_human
carry	handsup	put	track
close_gripper	hide	rarm_swinging	translate
configure_grippers	idle	release_gripper	tuckedpose
detect_and_grab	init	release	unlock_object
detect	larm_swinging	restpose	wait
disabledevileye	lock_object	rotate	waypoints
display	look_at_ros	satisfied	
dock	look_at_xyz	say	
enabledevileye	look_at	setpose	
extractpose	looksat	settorso	







lightbar  
 on\_toy\_added  
 move  
 background\_blink  
 undock  
 pulse\_row  
 blink  
 on\_lolette  
 placeeyes

on\_bumped  
 up\_down\_row  
 wakeup  
 look\_at\_caresses  
 on\_toy\_removed  
 sneak\_in  
 on\_lolette\_removed  
 fall\_asleep  
 look\_at\_lolette

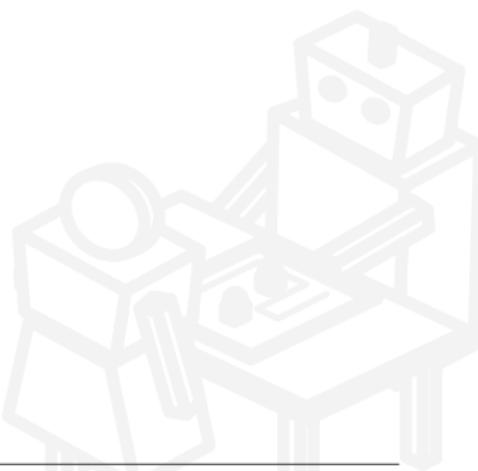
active\_wait  
 closeeyes  
 lightpattern  
 turn  
 idle  
 playsound  
 blush

PYROBOTS

---

```
1  from robots import GenericRobot
2  from robots.concurrency import action, ActionCancelled
3  from robots.resources import Resource, lock
4
5  class MyRobot(GenericRobot):
6      # ... state + lowlevel action
7
8  WHEELS = Resource("wheels")
9
10 @clock(WHEELS)
11 @action
12 def move_forward(robot):
13     target = [1.0, 0., 0., "base_link"]
14
15     try:
16         robot.goto(target)
17
18         while(robot.dist_to(target) > 0.1):
19             robot.sleep(0.5)
20
21     except ActionCancelled:
22         robot.stop()
```

---



---

```
1 with MyRobot() as robot:
2
3     robot.whenever("my_bumper", True).do(move_forward)
4
5     try:
6         while True:
7             time.sleep(0.5)
8     except KeyboardInterrupt:
9         pass
```

---

