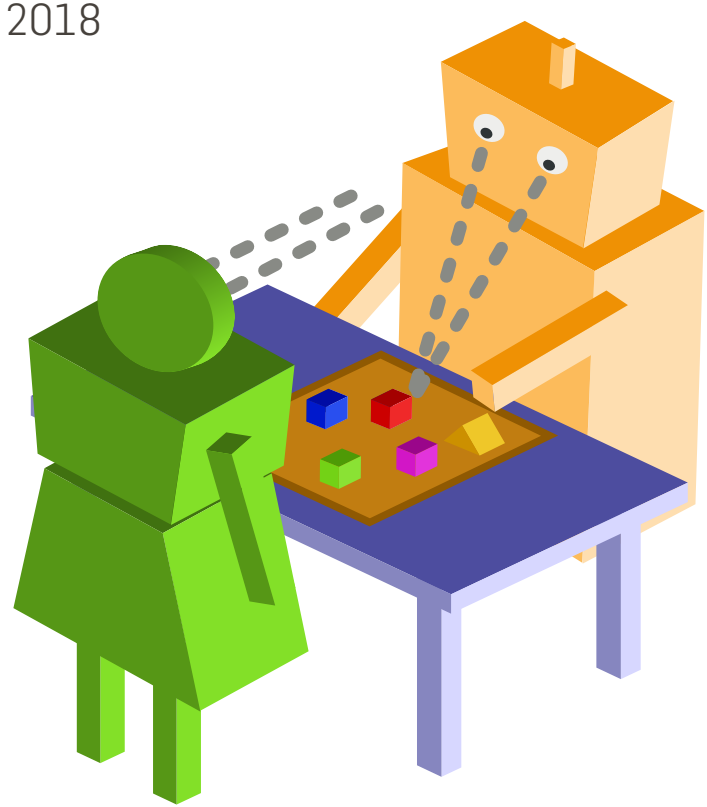
child-robot interaction for learning

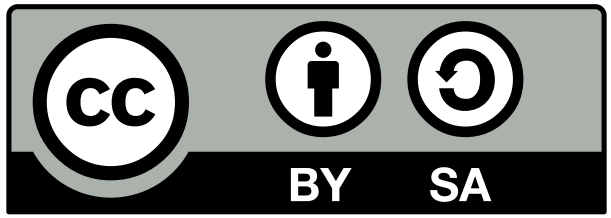
are we ready yet to push the classroom's door?

Symposium on Robots for Language Learning – 13 Dec. 2018



Séverin Lemaignan

Bristol Robotics Lab University of the West of England



You can download the sources of this presentation here:

github.com/severin-lemaignan/l2tor-symposium2018-technical-challenges-cri

Quick poll:

What is the greatest challenge that “child-robot interaction for learning” faces today?

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What is the greatest challenge that “child-robot interaction for learning” faces today?

Getting our robots accepted & used in schools, without us being around…?


Experimental set-up

open, underspecified situations
complex social dynamics
rich semantics
interplay of socio-cognitive functions
(and ideally, a bit of actual learning)


What about some maths now?
Scottie
SCOTTIE classroom!
Yeah, yeah...
Let's frame it bit


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Yeah, yeah...


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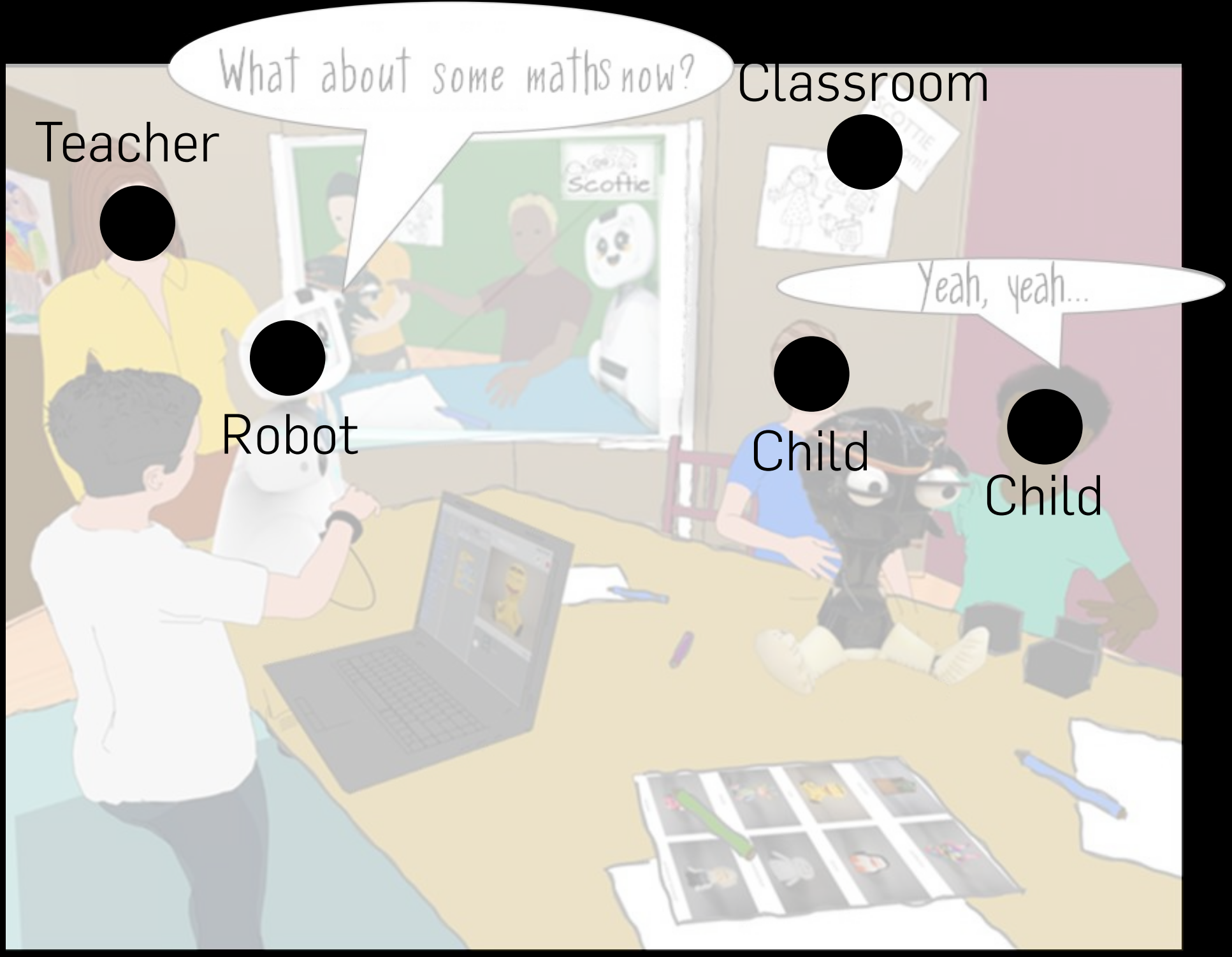
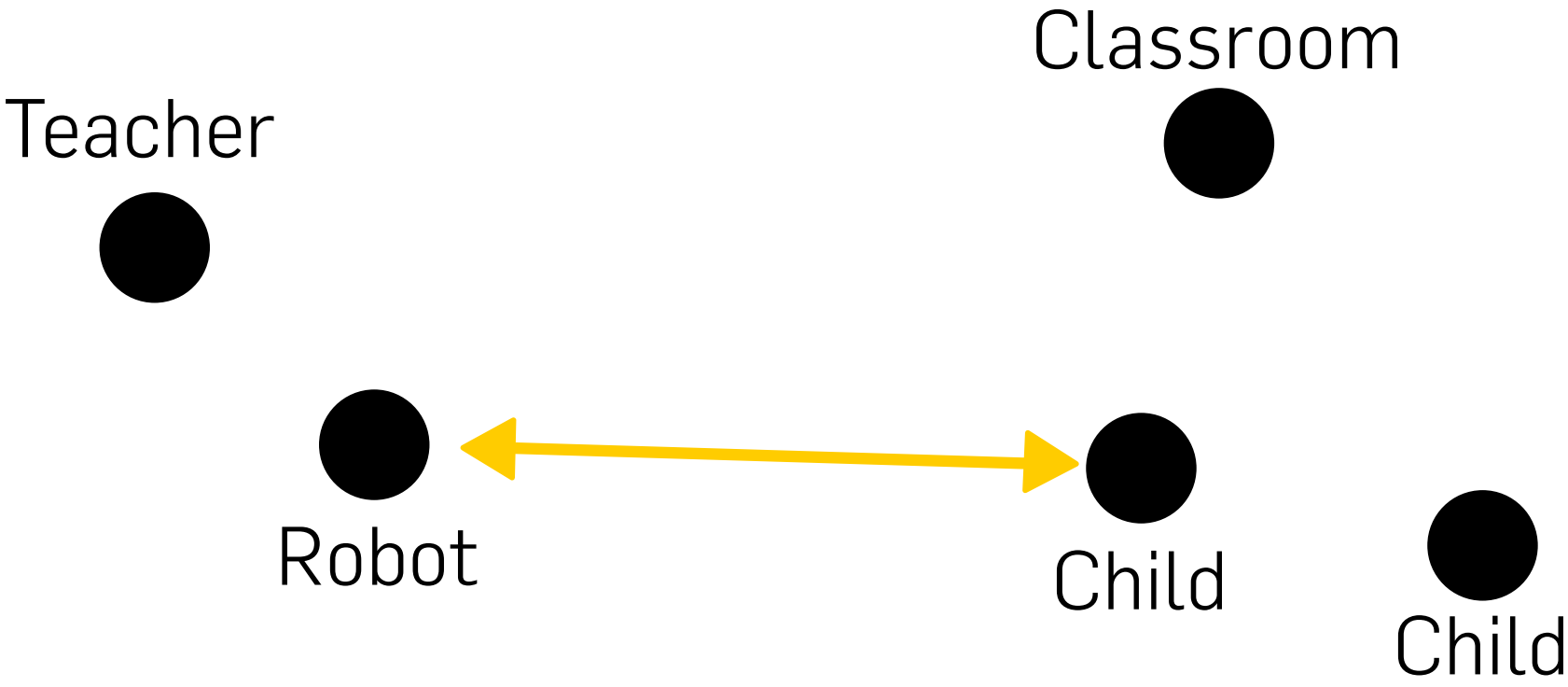
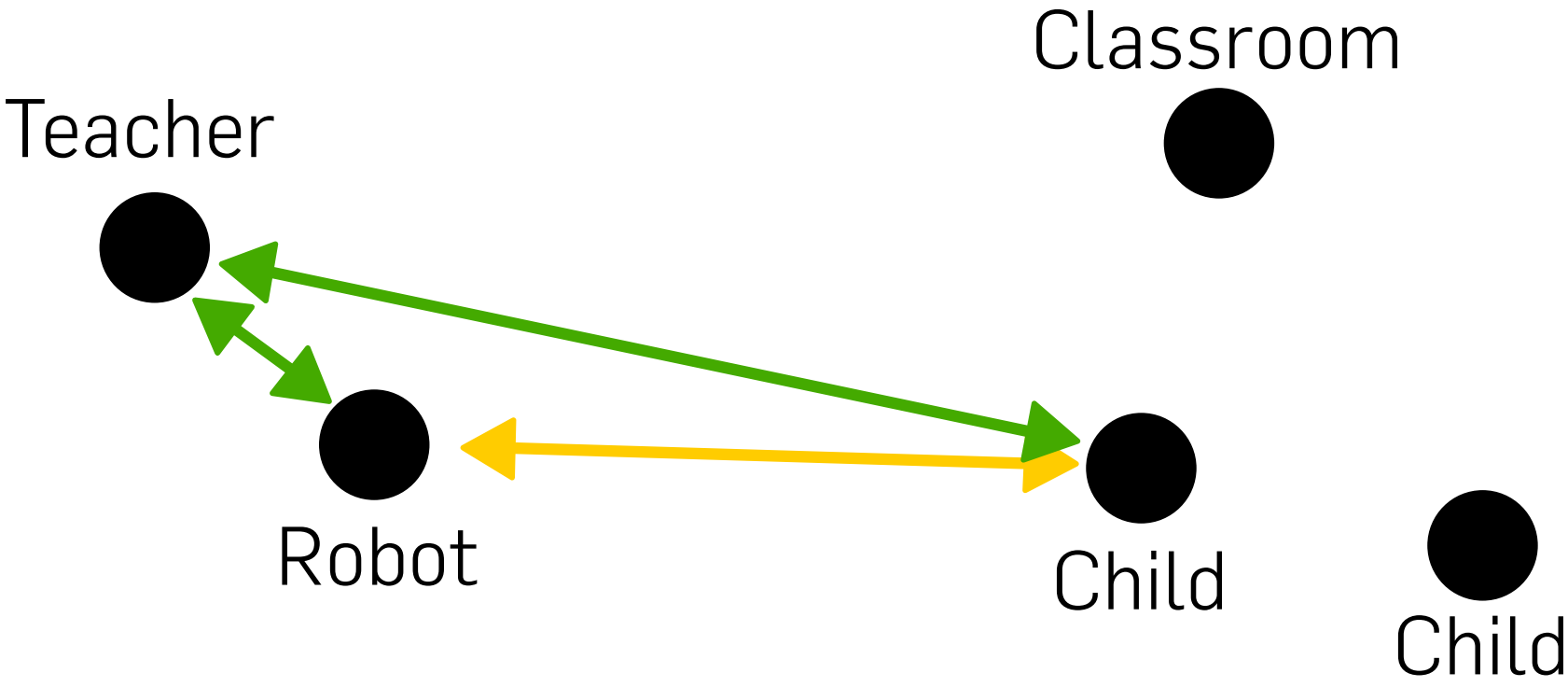

What about some maths now?
Classroom
Teacher
Yeah, yeah...
Robot
Child
Child


Classroom
Teacher
Robot
Child
Child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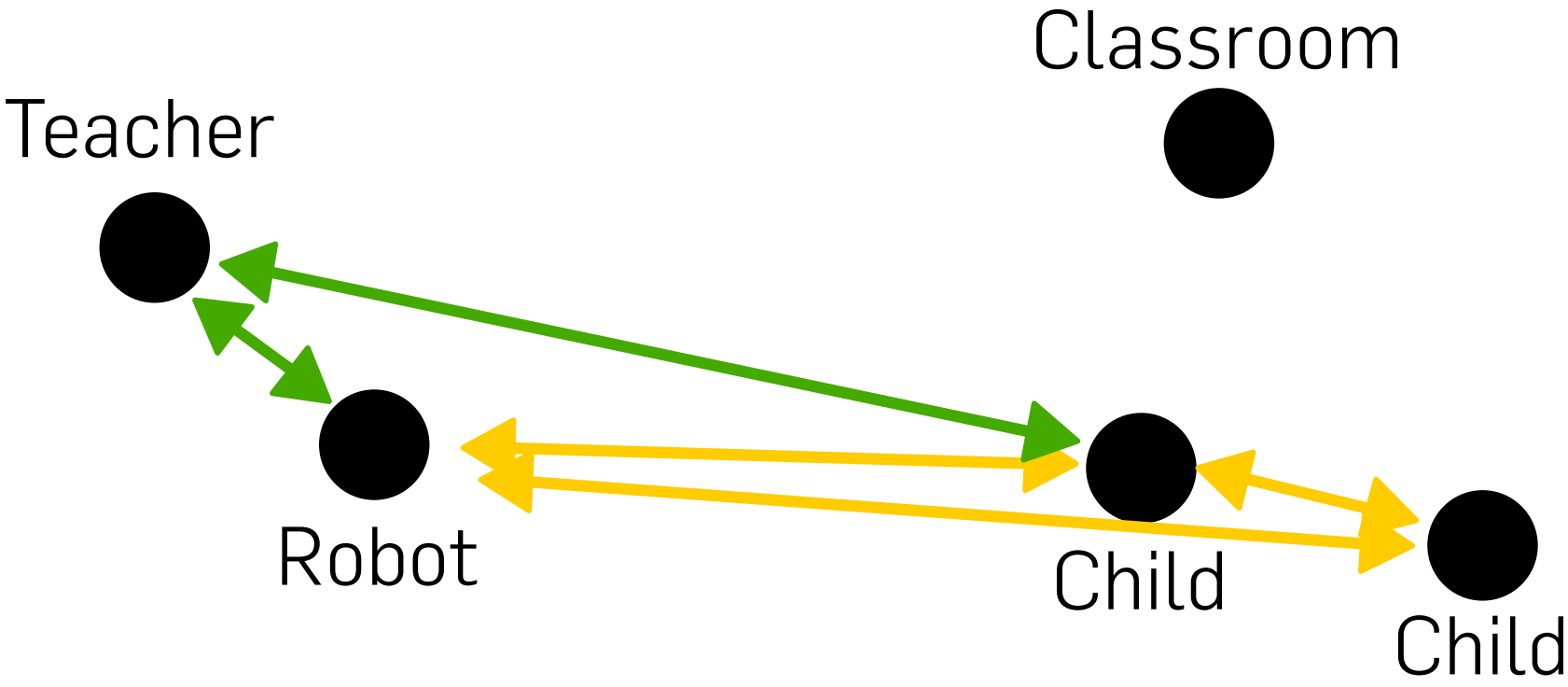
Classroom
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Child
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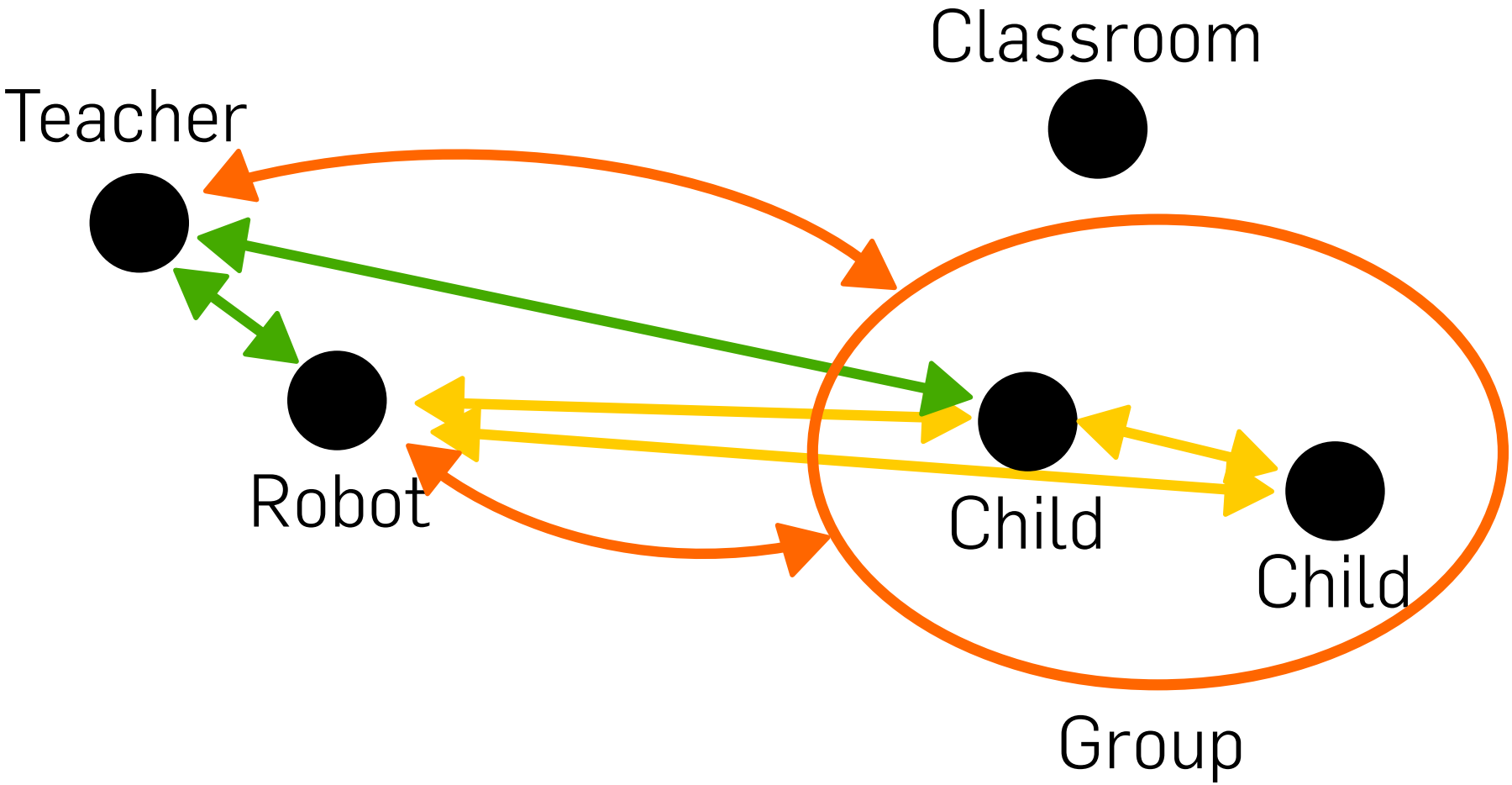
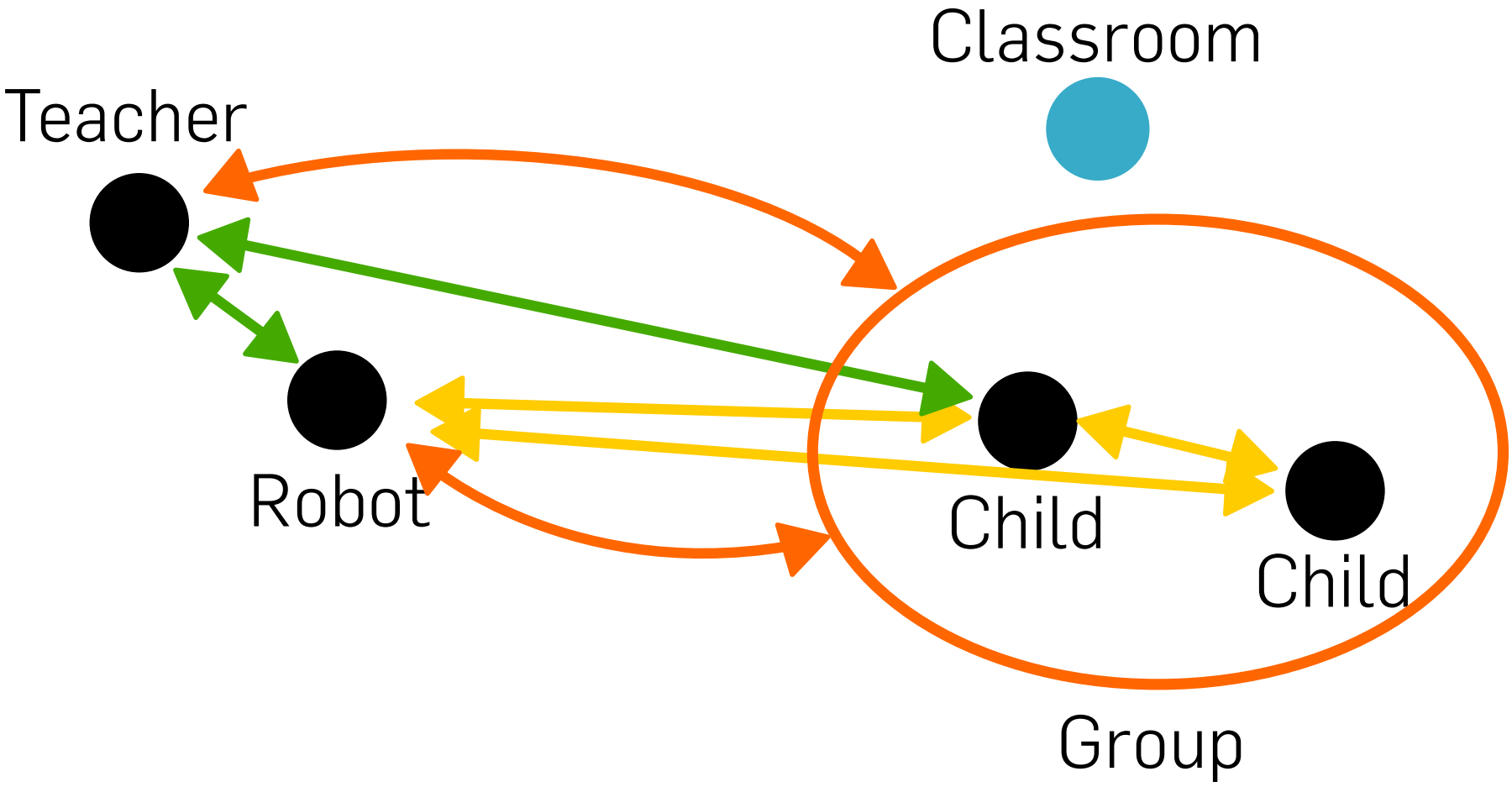
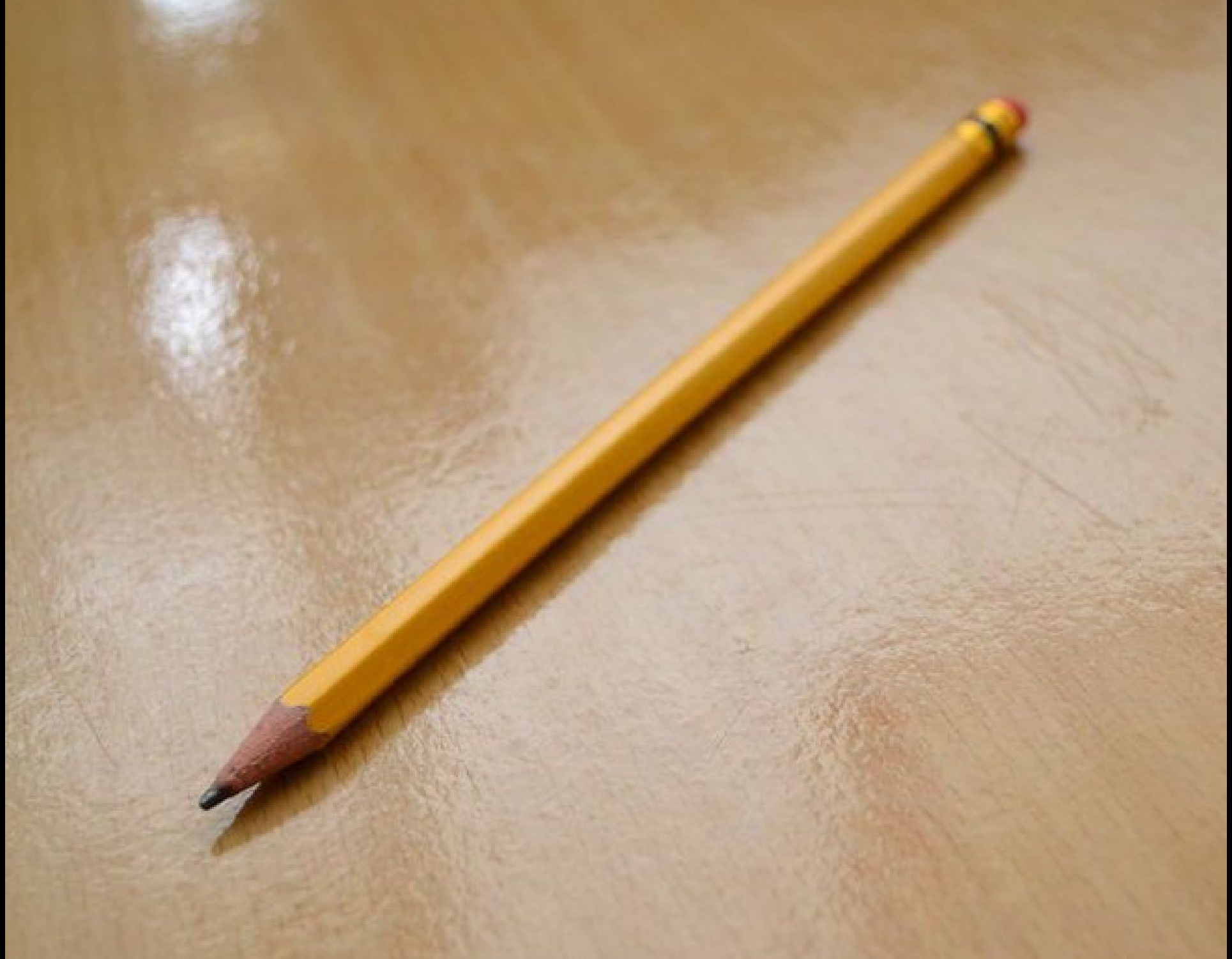

Classroom
Teacher
Robot
Child
Child
Group


Classroom
Teacher
Robot
Child
Child
Group

THE CLASSROOM

What is the most effective learning tool in a classroom?



WHY THAT?

- **ubiquitous**: a pervasive yet unremarkable tool that blend into the daily learning routine; has to be trustworthy (i.e. reliable), readily replaceable (i.e. cheap, no affective bonding), intuitive (i.e. few simple affordances)

WHY THAT?

- **ubiquitous**: a pervasive yet unremarkable tool that blend into the daily learning routine; has to be trustworthy (i.e. reliable), readily replaceable (i.e. cheap, no affective bonding), intuitive (i.e. few simple affordances)
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- **effective**: to gain broad acceptance in a classroom, a tool must critically represent a net educative gain and must not incur higher workload for the teacher

Pens and paper are pervasive...


WORDMANIA
English
PRONOUNS CHART
PERFORMANCE LAND
...what about robots?

What does it look like to build a pen-like robot?

DESIGN PRINCIPLES FOR THE CLASSROOM

- **ubiquitous**: a pervasive yet unremarkable tool that blend into the daily learning routine; has to be trustworthy (i.e. reliable), readily replaceable (i.e. cheap, no affective bonding), intuitive (i.e. few simple affordances)

[Özgür, Lemaignan et al. **Cellulo: Versatile Handheld Robots for Education** – HRI 2017]

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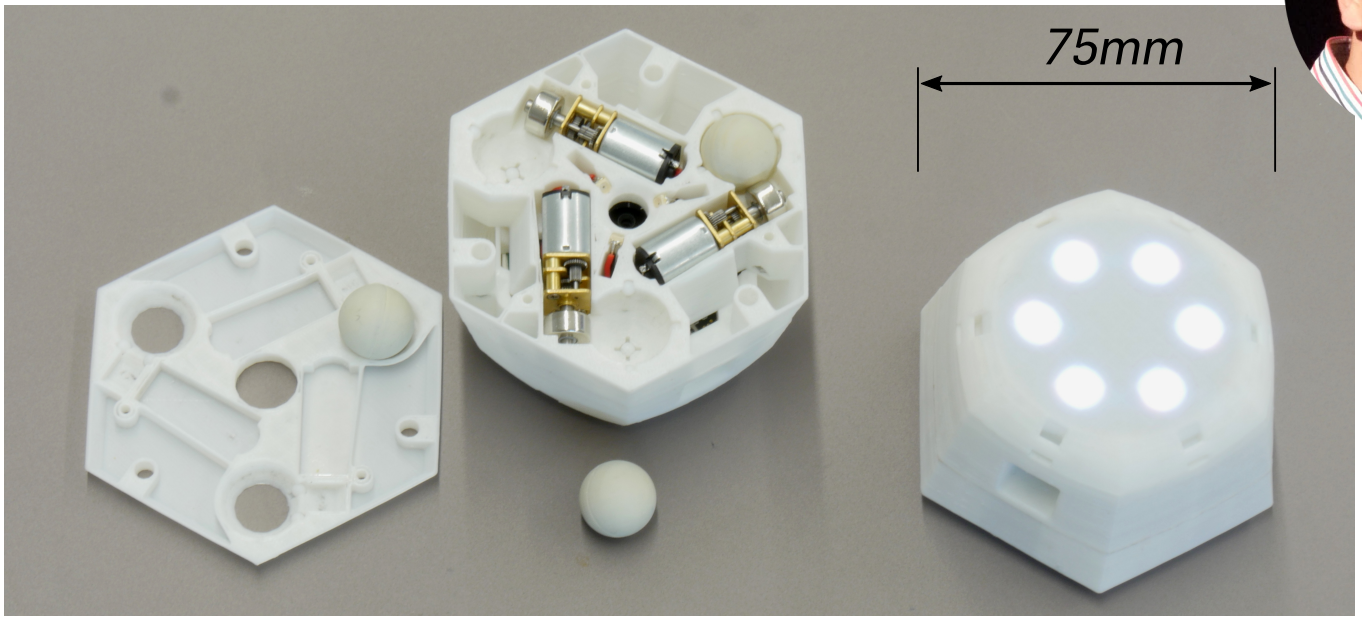
English
PRONOUNS CHART
PERFORMANCE LAND
WORDMANIA

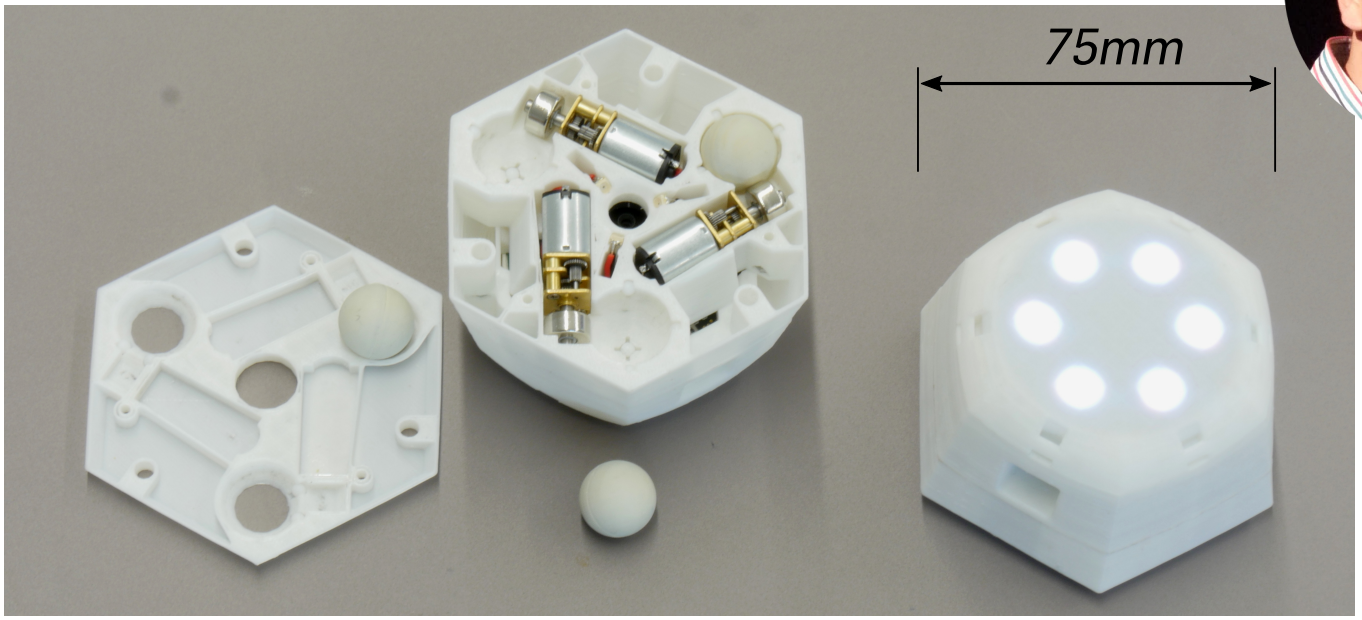

WORDMANIA
English
PRONOUNS CHART
PERFORMANCE LAND
NUMBERS

CELLULO: HARDWARE

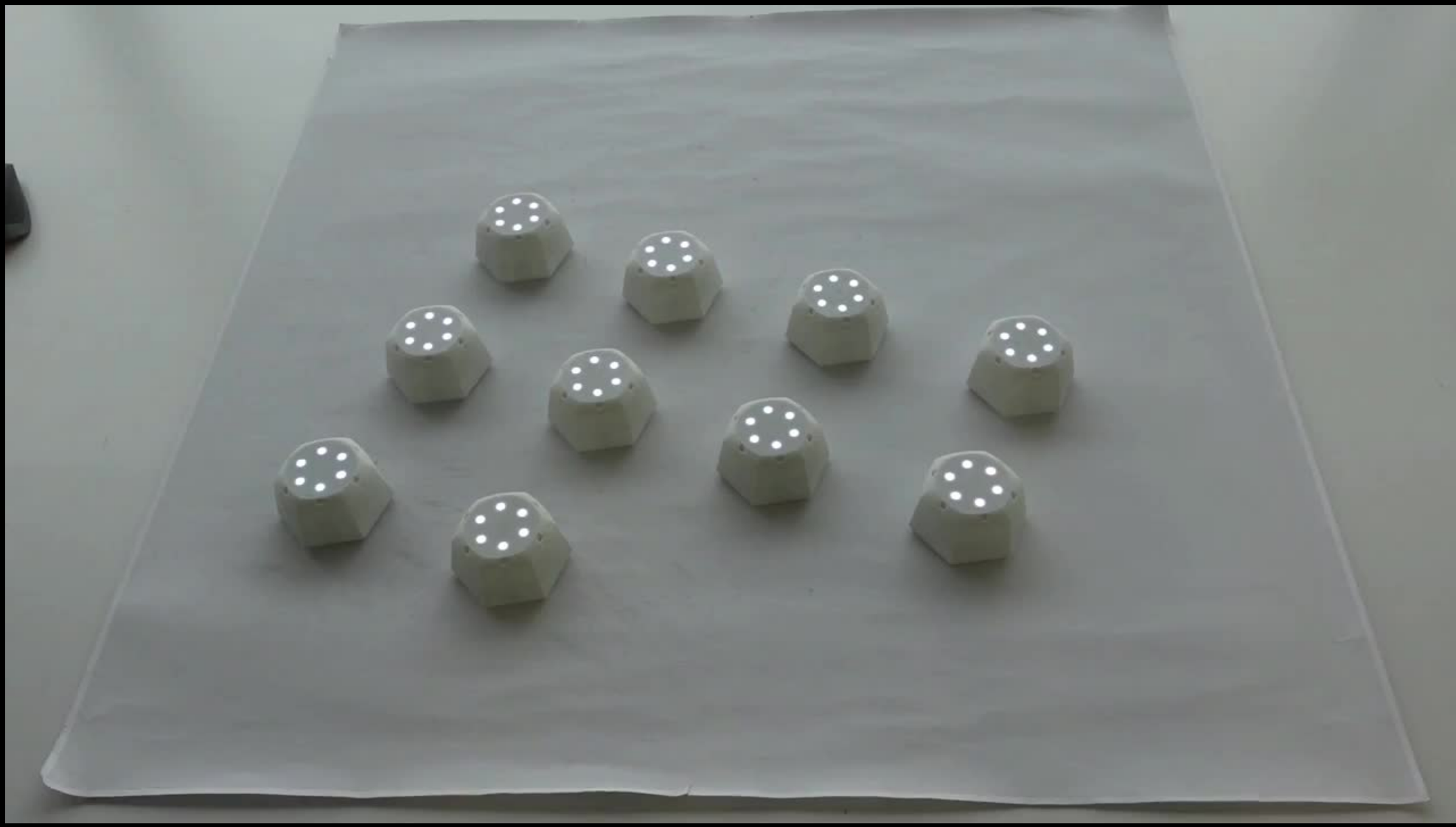


- Holonomic motion
- Sub-mm absolute localisation (no external hardware)
- Haptic feedback + tactile RGB LED buttons
- Bluetooth

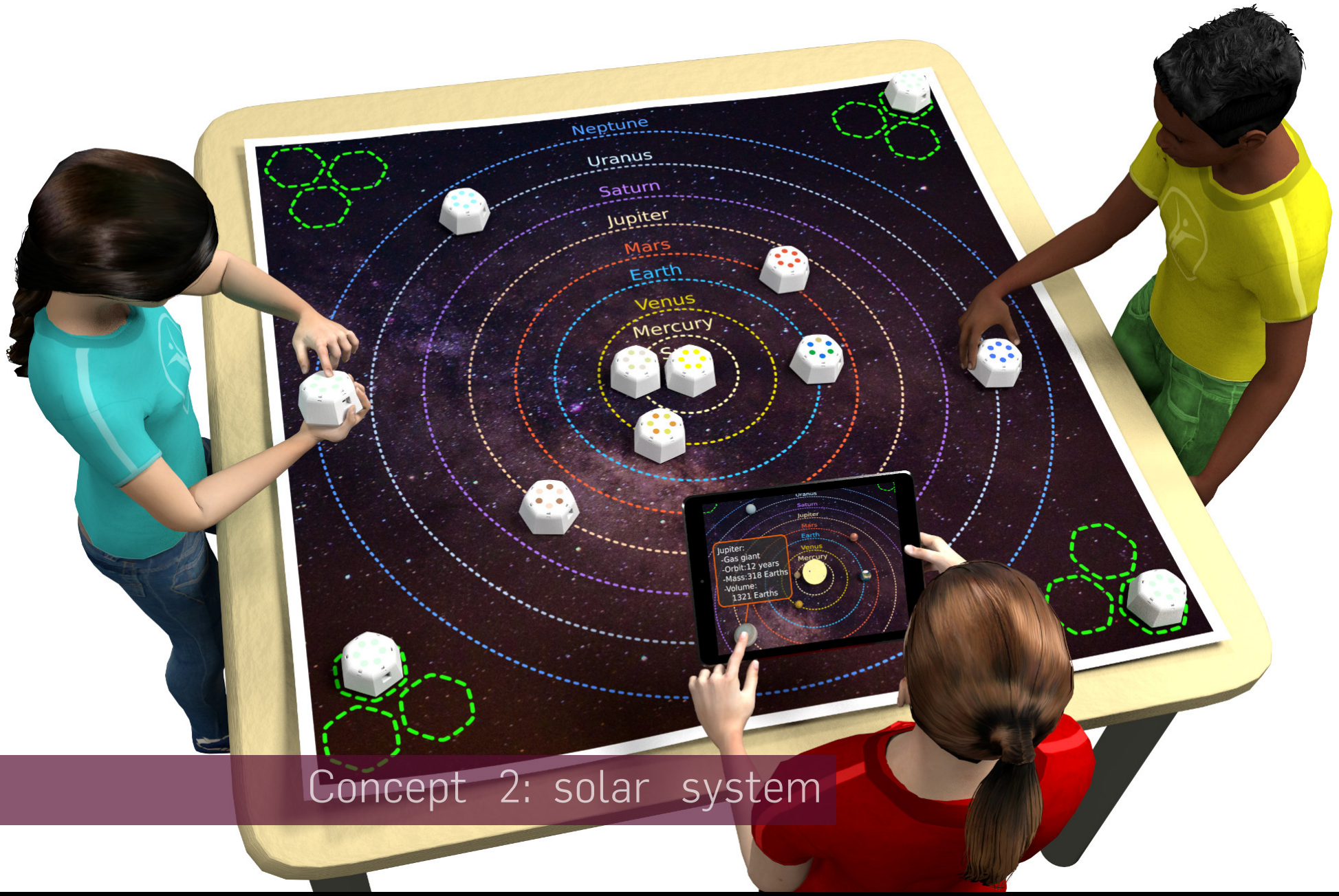
CELLULO: HARDWARE



- Holonomic motion
- Sub-mm absolute localisation (no external hardware)
- Haptic feedback + tactile RGB LED buttons
- Bluetooth
- Affordable (prototype: €125)



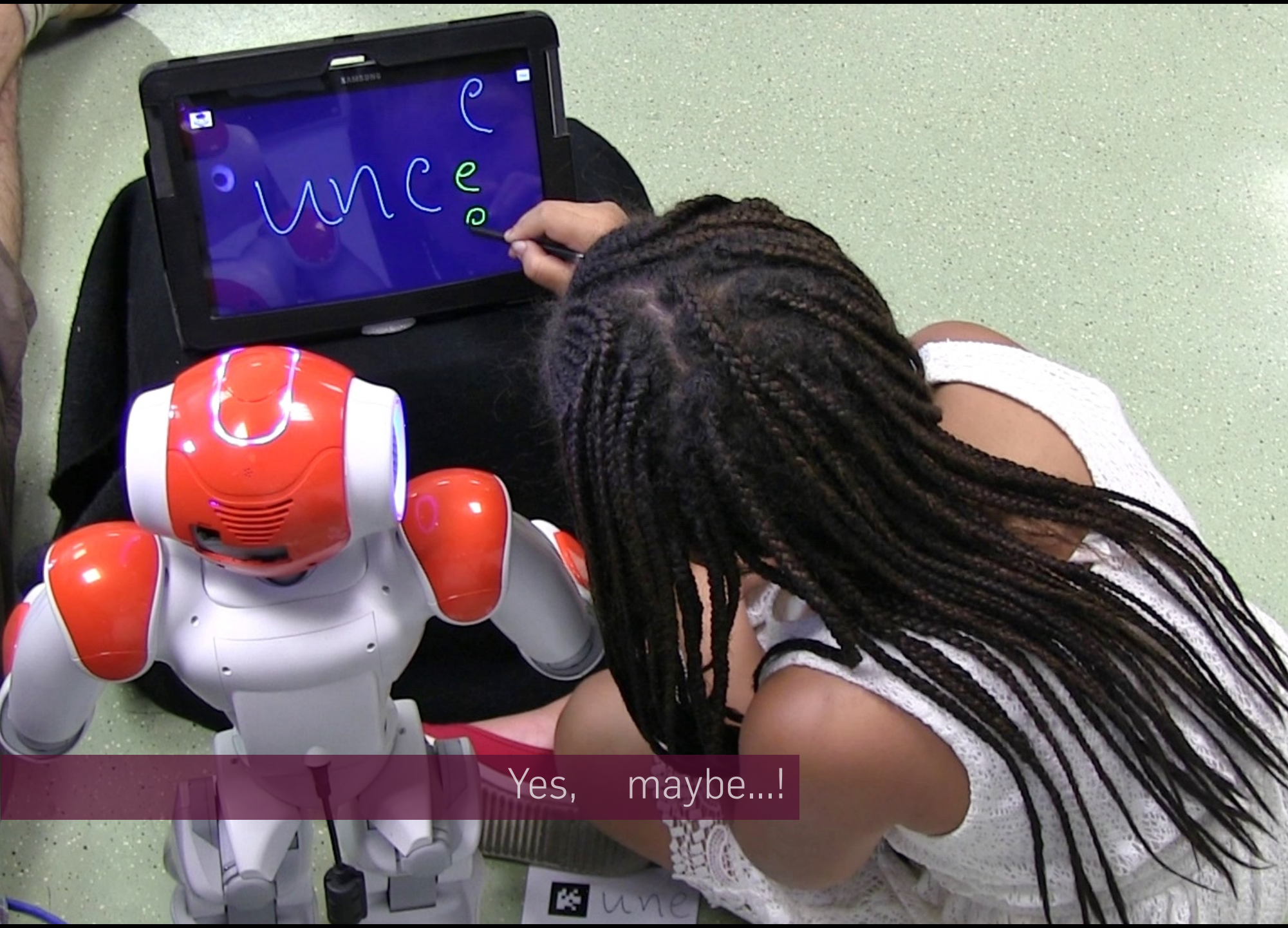

$O_2 + 2H_2 = 2H_2O$
Reactor
Reactor 1
Chemistry Lab
Concept 1: chemistry



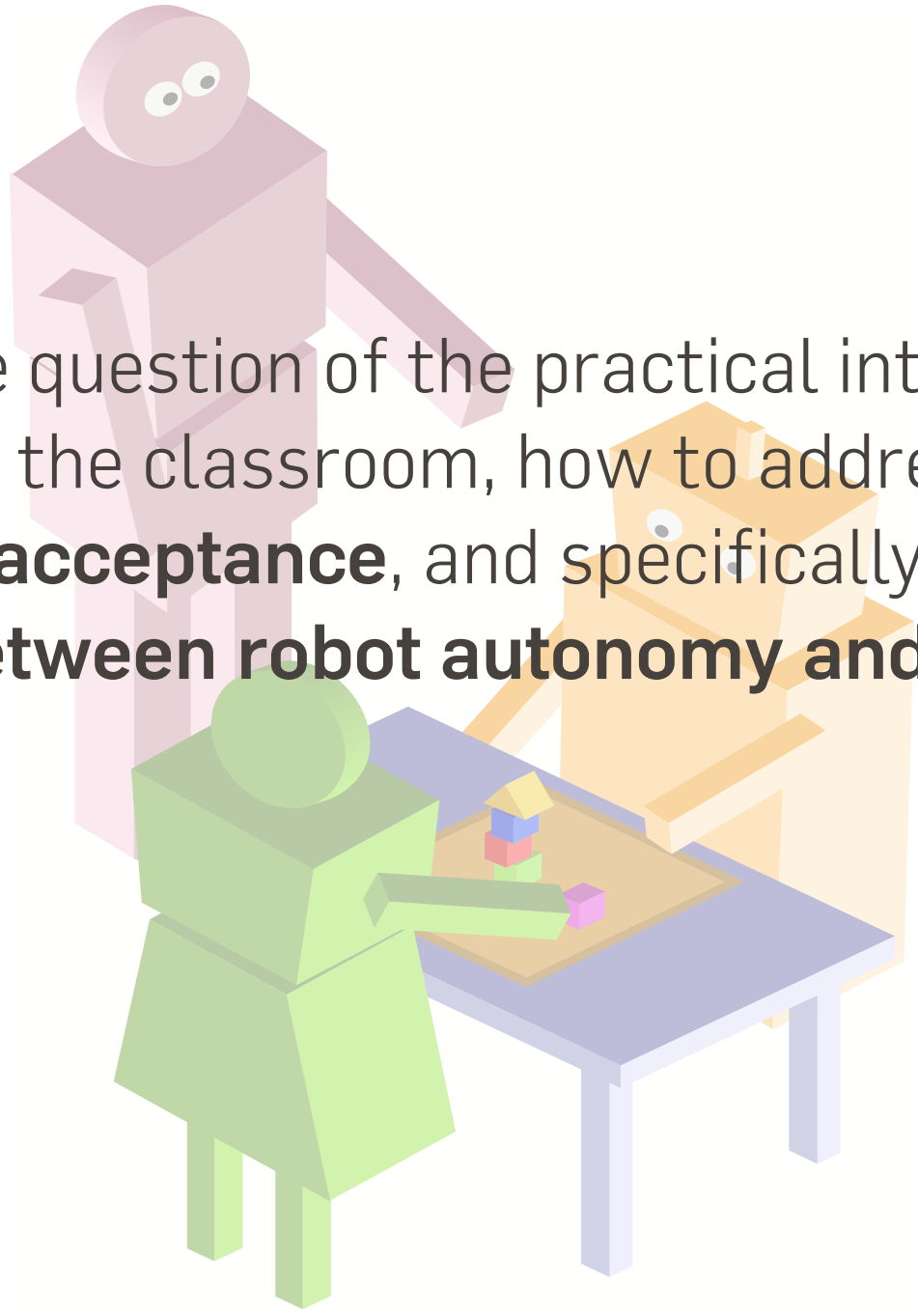
Concept 2: solar system

If a “pen-like” robot is actually doable,

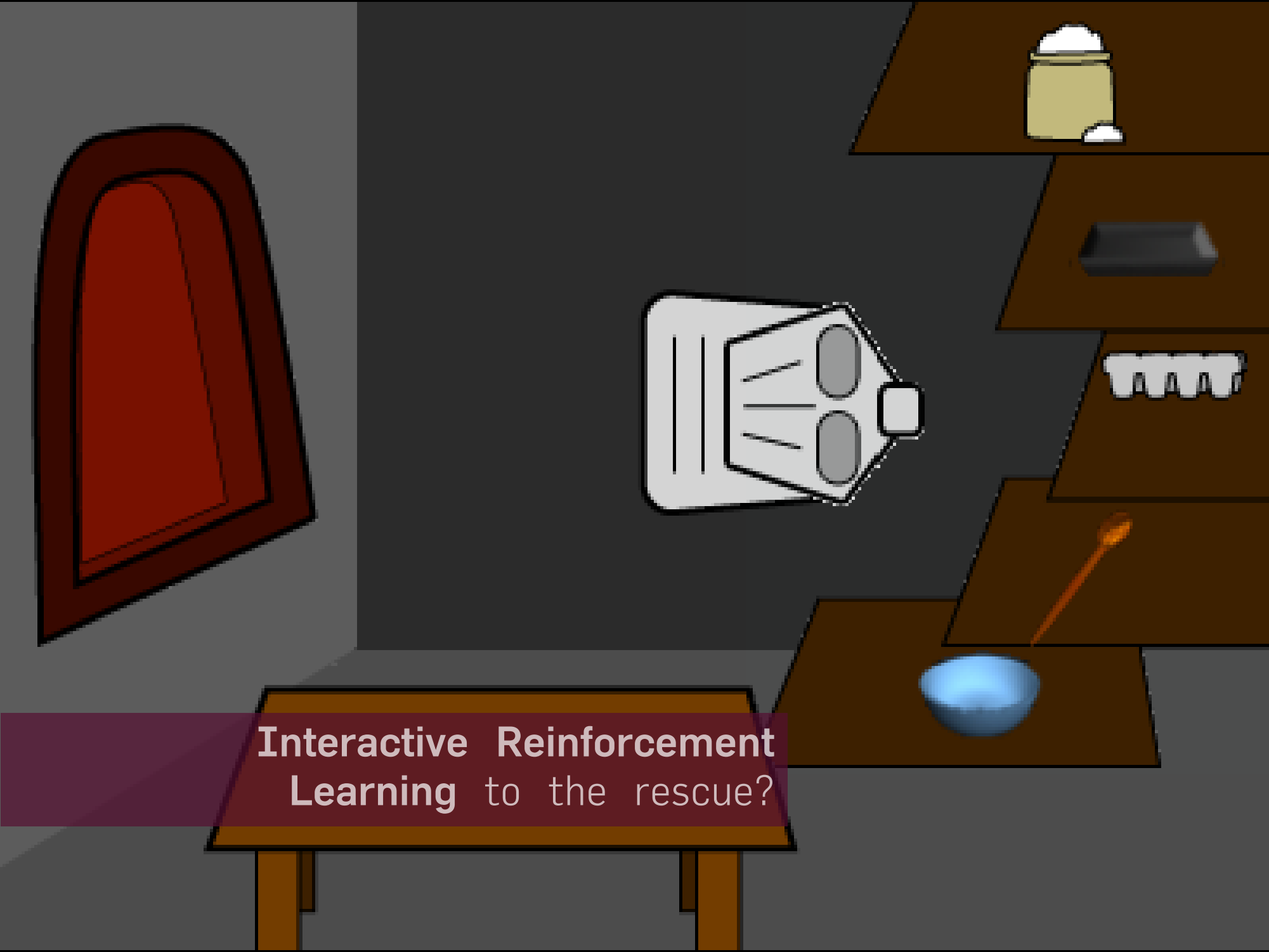
...are social robots relevant at all...?


une
Yes, maybe...!

THE TEACHER



Beyond the question of the practical integration of robots into the classroom, how to address **teachers' acceptance**, and specifically, the **tension between robot autonomy and teacher control**?


Interactive Reinforcement
Learning to the rescue?

AUTONOMOUS ROBOT, YET TEACHER IN THE LOOP?

To be relevant to us, we need:

- a real robot

AUTONOMOUS ROBOT, YET TEACHER IN THE LOOP?

To be relevant to us, we need:

- a real robot
- a real interaction (...with a human!)

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To be relevant to us, we need:

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- a real interaction (...with a human!)
- a continuous interaction

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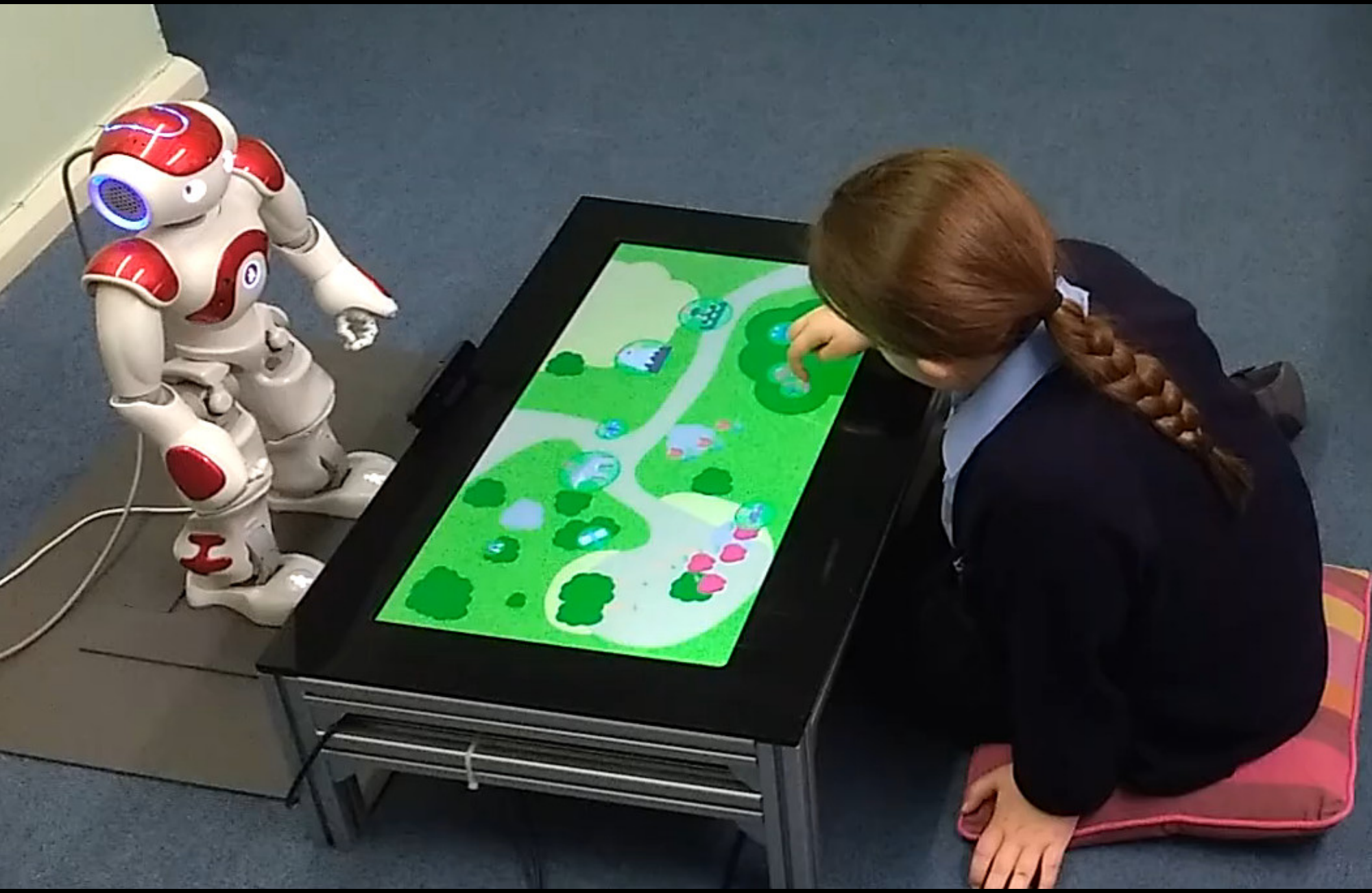
- a realistic task (large state vector & action space)

AUTONOMOUS ROBOT, YET TEACHER IN THE LOOP?

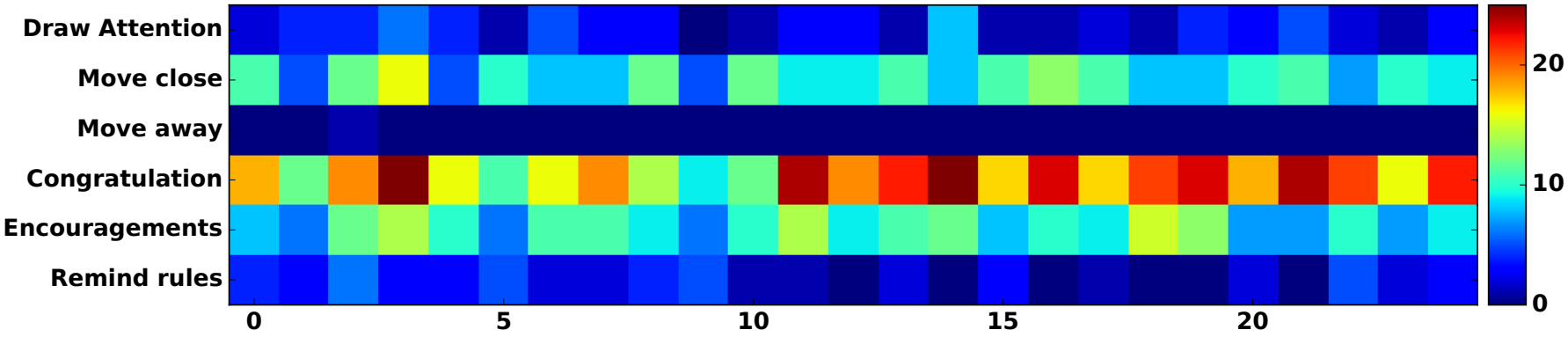
To be relevant to us, we need:

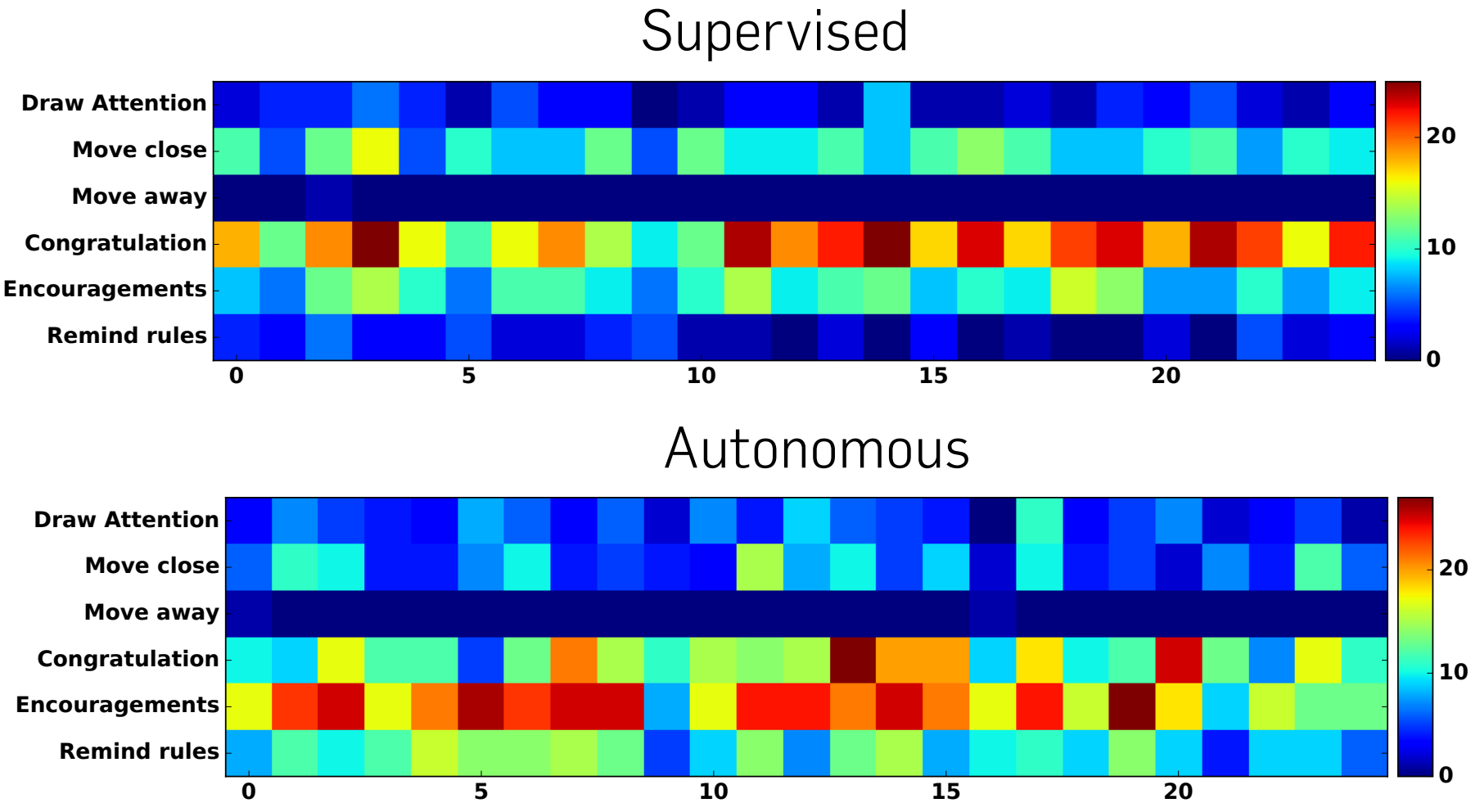
- a real robot
- a real interaction (...with a human!)
- a continuous interaction
- a realistic task (large state vector & action space)
- also including social behaviours & social dynamics




|state| = 210 |action_space| = 655

Supervised


Draw Attention
Move close
Move away
Congratulation
Encouragements
Remind rules
0
5
10
15
20
20
10
0


Supervised
Draw Attention
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0
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Autonomous
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10
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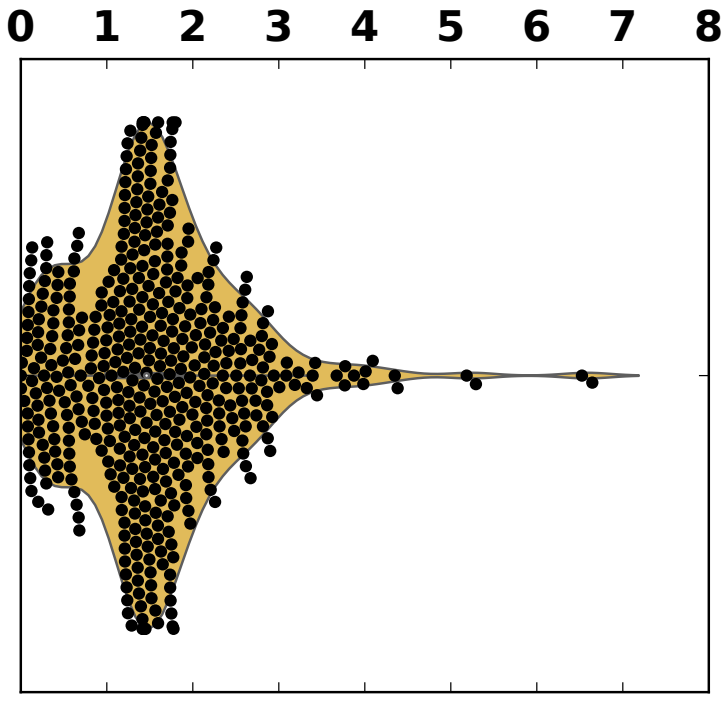
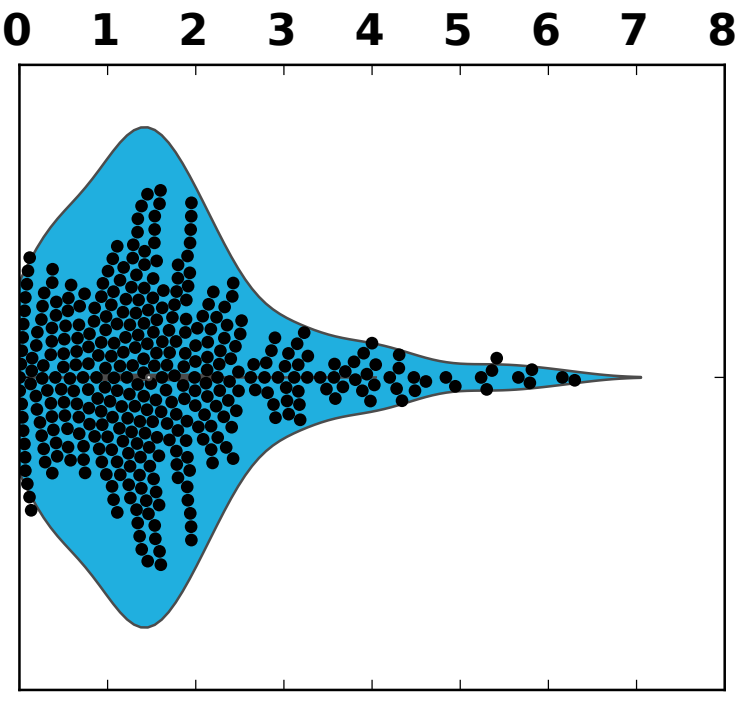
20
0
10
20

Time since eating event for each congratulation action (s)

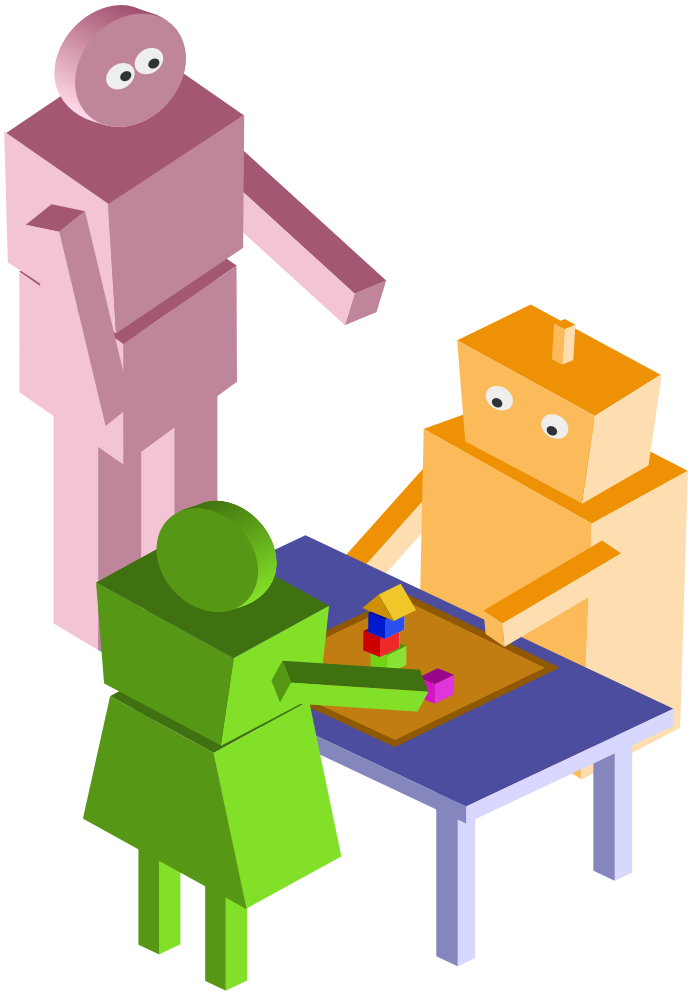


supervised



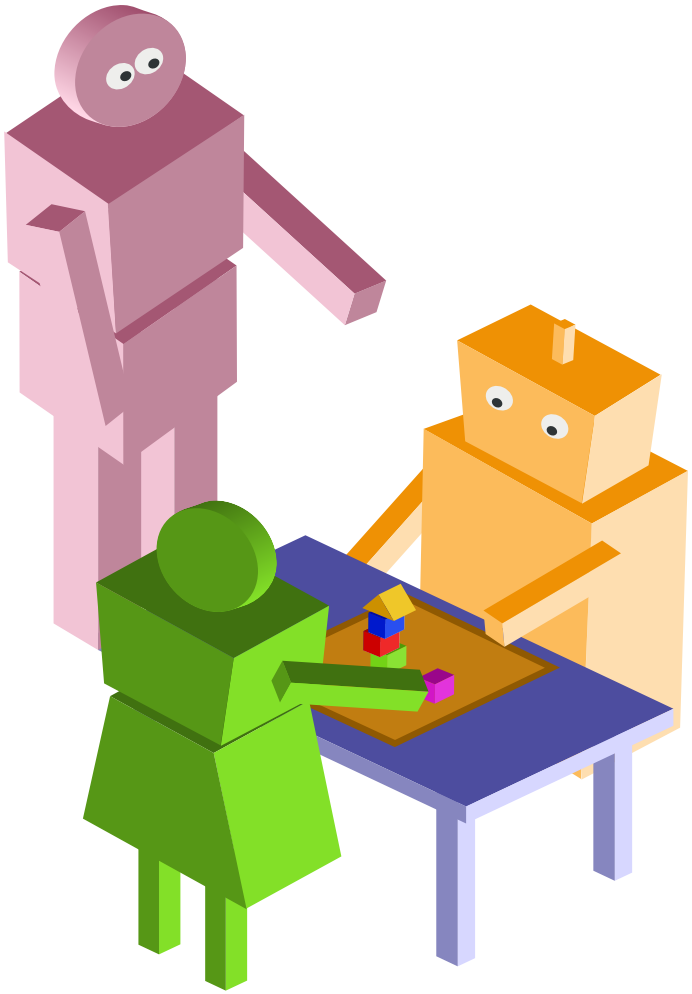
autonomous

WHAT DOES THAT MEANS FOR THE TEACHER?



- **Progressively transferring autonomy** demonstrably works in non-trivial tutoring scenarios
- (it also learns some elements of **social behaviours** and **social timing**)

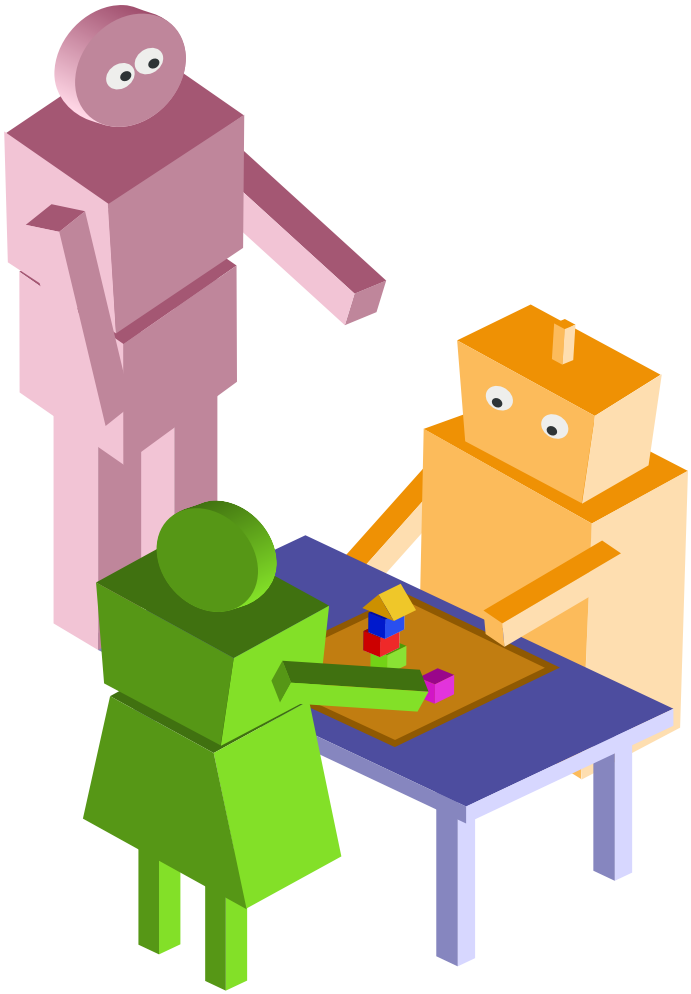
WHAT DOES THAT MEANS FOR THE TEACHER?



Key properties:

- **progressive autonomy** yet **transparency** of the behaviour;
- **observability** and possibility to **take over**;
- because the training takes place in-situ, the robot behaviours are **co-constructed** by the teacher and the child

WHAT DOES THAT MEANS FOR THE TEACHER?



Yet:

- Design of the input state tricky and largely task dependent;
- What about more complex social behaviours?
- Nothing yet on group dynamics

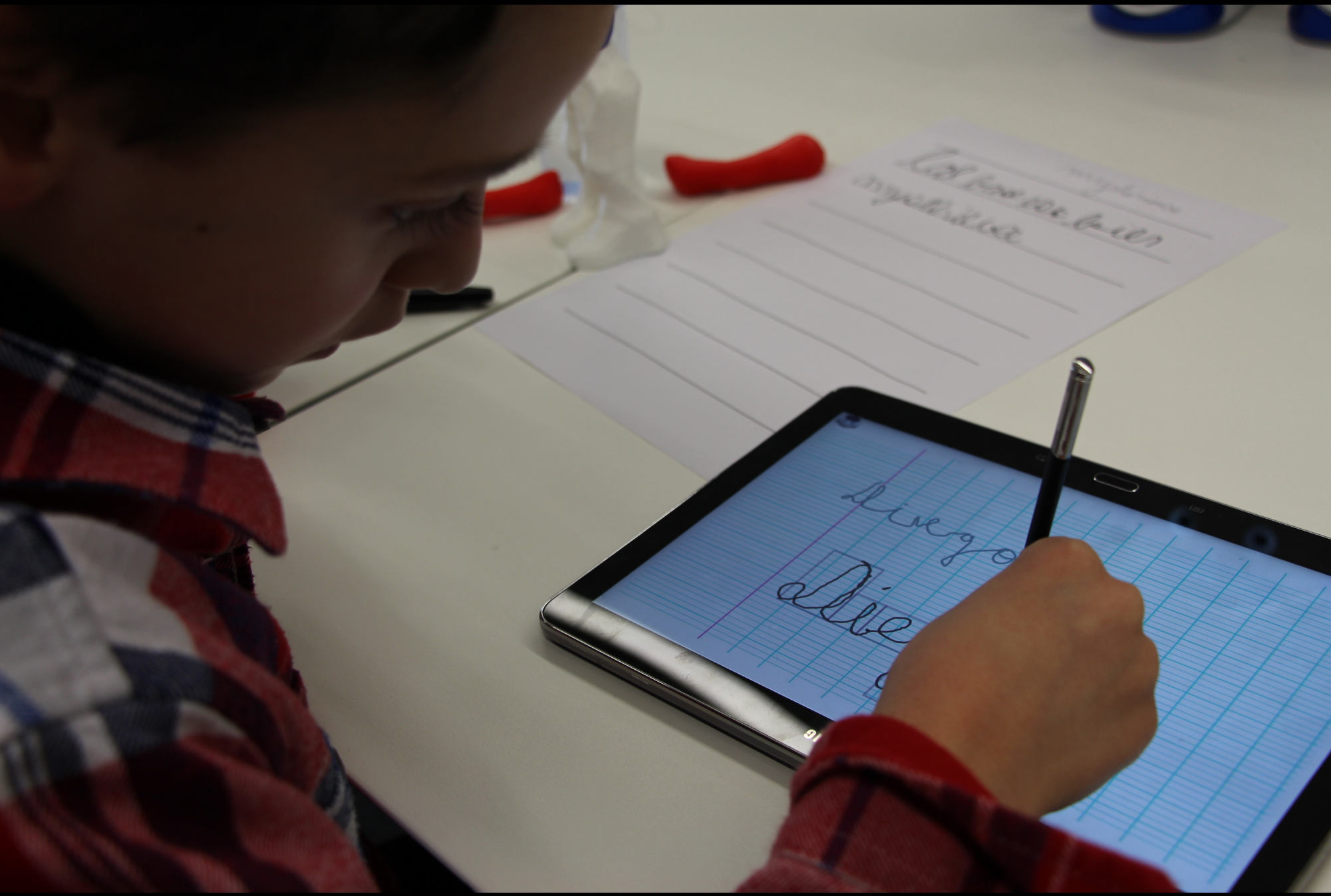
THE CHILDREN: THE CHALLENGE OF "DOING TOGETHER"

SOCIAL OR NOT SOCIAL?

SOCIAL OR NOT SOCIAL?

Tool?

Peer/tutor?



THE COWRITER PROJECT

Can we address children' hand-writing impairments with robots?

[Lemaignan et al. **Learning by Teaching a Robot: The Case of Handwriting** – Robotics and Automation Magazine 2016]

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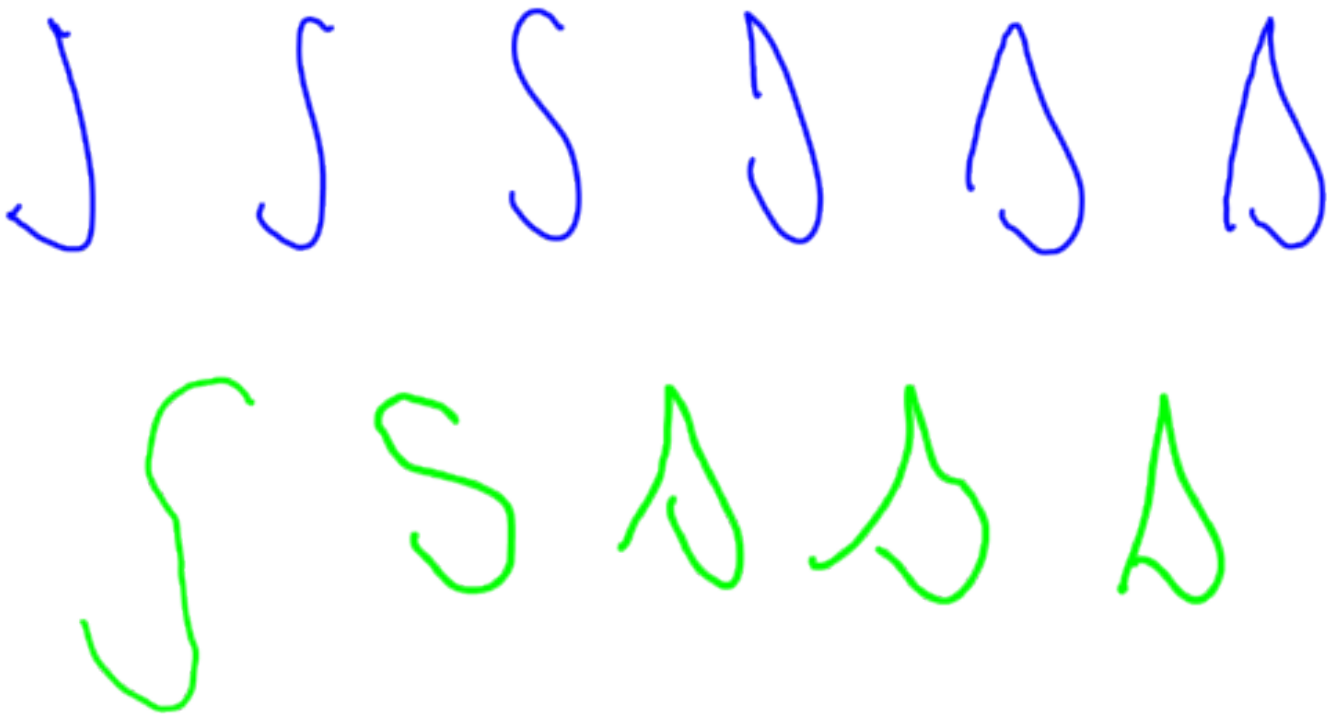
Can we address children' hand-writing impairments with robots?

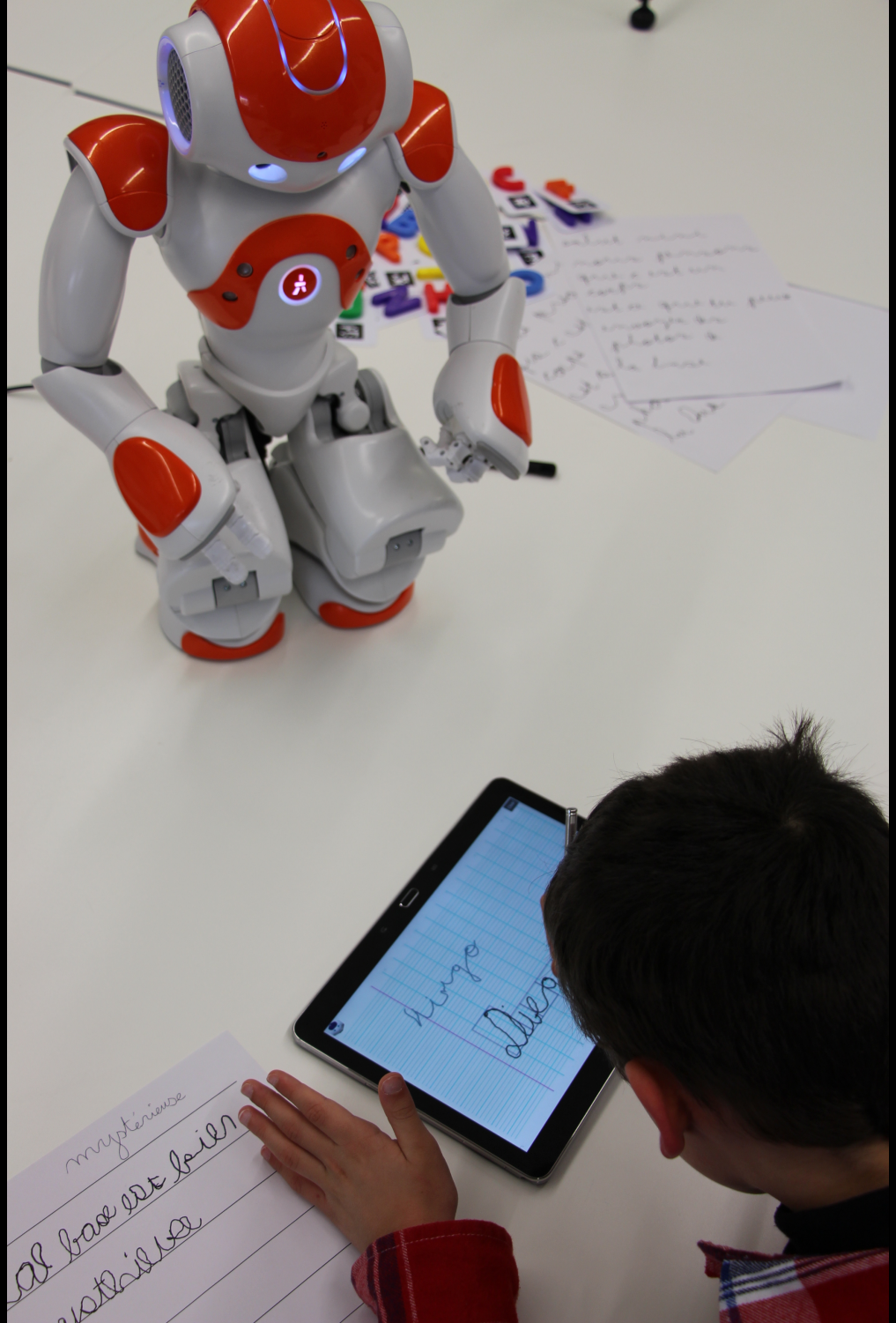
- Robots do not know how to write!
- Learning by Teaching
- (nice side-effect: we can adapt to each child and each disabilities)

[Lemaignan et al. **Learning by Teaching a Robot: The Case of Handwriting** – Robotics and Automation Magazine 2016]

LEARNING FROM DEMONSTRATION



[Hood, Lemaignan et al. **When Children Teach a Robot to Write: An Autonomous Teachable Humanoid [...]** – HRI 2015]


mystérieuse

BEFORE – AFTER

salut mimi
nous pensons
que c est un
corps
est ce que tu peux
envoyer des
photos de
la Lune

BEFORE – AFTER

salut mimi
nous pensons
que c est un
corps
est ce que tu peux
envoyer des
photos de
la Duse

salut mimi
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que c est un
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photos de
la base

BEFORE – AFTER

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WHAT ROLE DOES THE ROBOT PLAY HERE?

- The robot as 'cognitive agent' is key here (Protégé effect, metacognition)
- (note: a tool for the teacher vs a social agent for the child!)
- Could we replace it by someone else? Not easily. Have we just invented an original role for the robot?

But this is turn by turn!

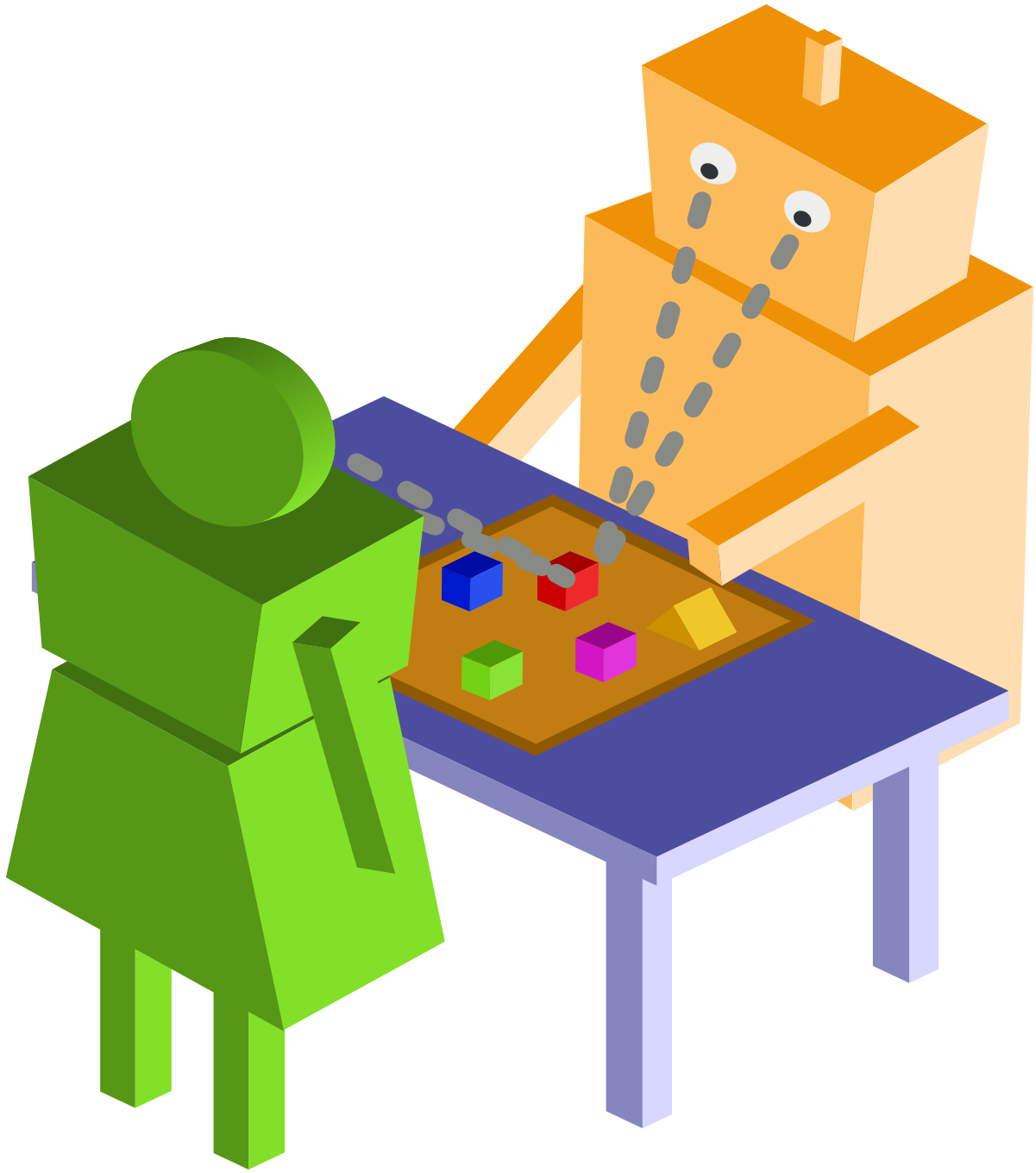
What about less structured, “messy” interactions?

But this is turn by turn!

What about less structured, “messy” interactions?

...we are not yet very good at modelling real-world social dynamics...

Joint action offers nevertheless a possible framework to reason about it.



MODEL-BASED JOINT ACTION

1. establish a joint goal
2. plan for the robot
3. plan for the human in order to build a set of priors
4. execute the robot plan
5. monitor progress of the partner towards the goal

[Lemaignan et al. **Artificial Cognition for Social Human-Robot Interaction: An Implementation** Artificial Intelligence 2017]

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...hard ones, though:

- *how to communicate/agree on goals & plans?*
- *what about the human's own plans?*
- *monitoring/recognising error situations*
- *what to do when we're going 'off track'?*
- *...*

[Lemaignan et al. **Artificial Cognition for Social Human-Robot Interaction: An Implementation** Artificial Intelligence 2017]

WE CAN DO A BIT ALREADY

[Lemaignan et al. **Artificial Cognition for Social Human-Robot Interaction: An Implementation** – Artificial Intelligence 2017]

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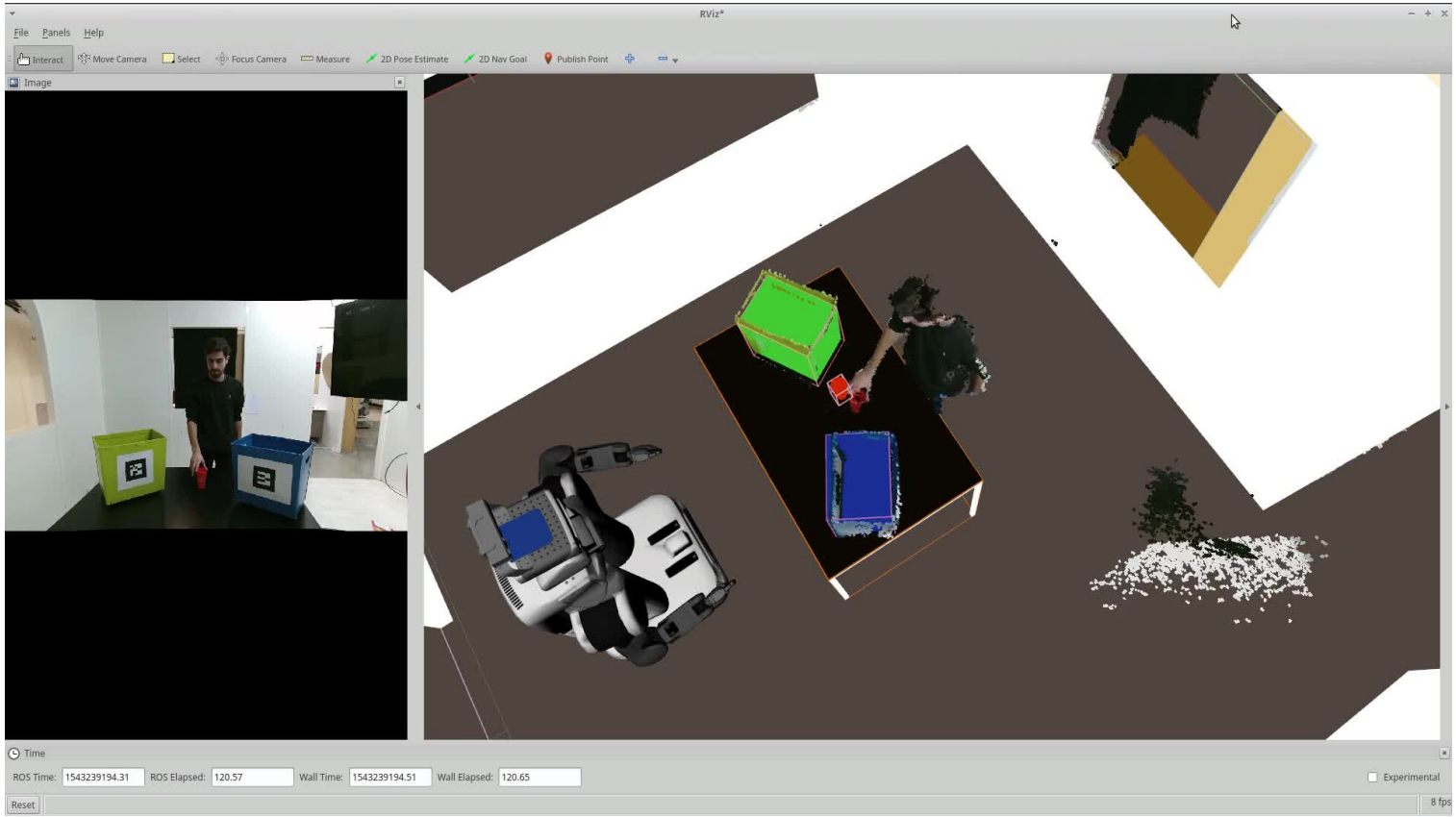

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HOW DO HUMANS PERFORM TASKS TOGETHER?

Collaborating is a costly socio-cognitive activity.

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...which is closely related to: **be lazy**

First, go for the simple – if possibly ambiguous – actions; and, if really needed, repair

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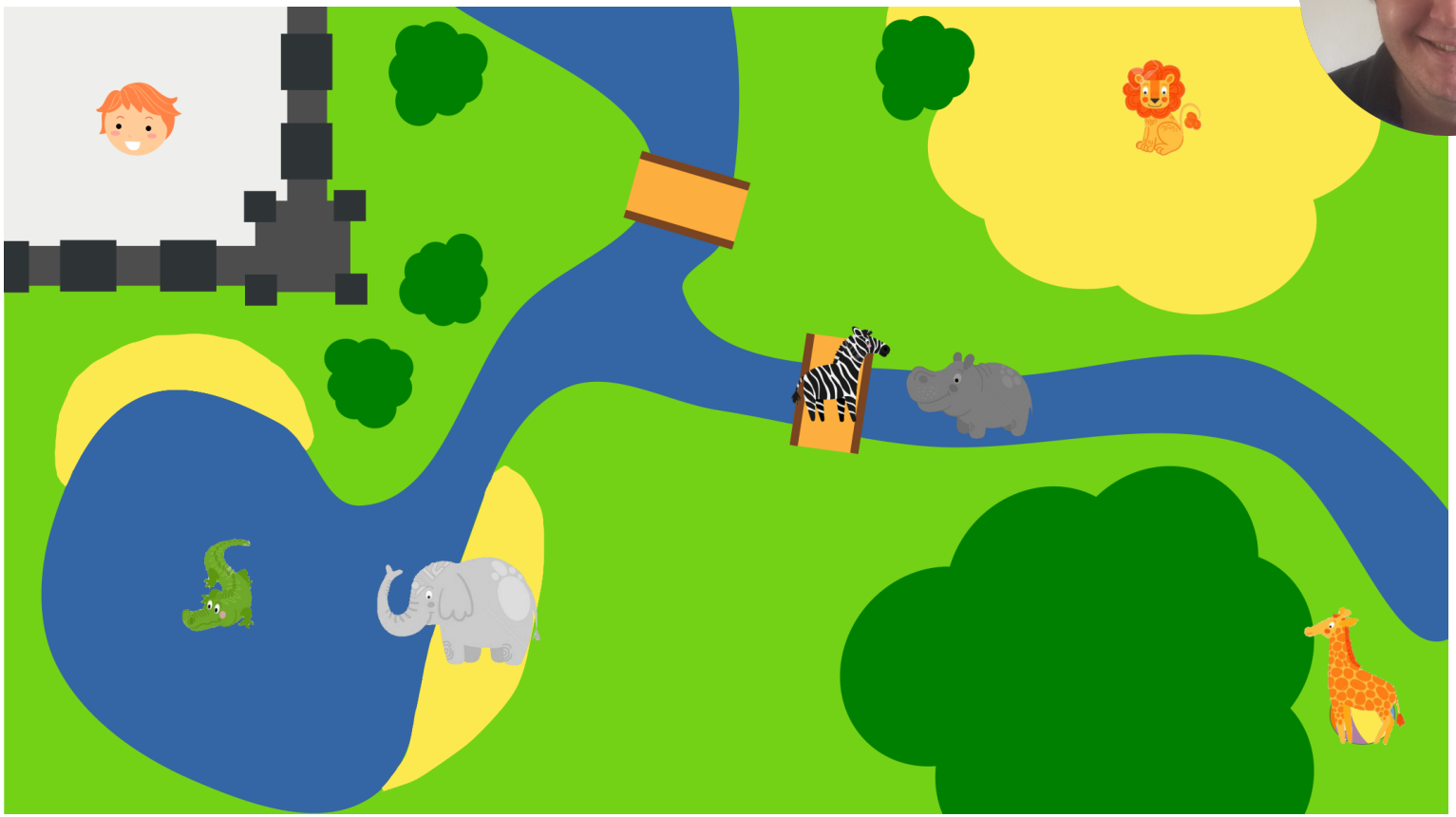
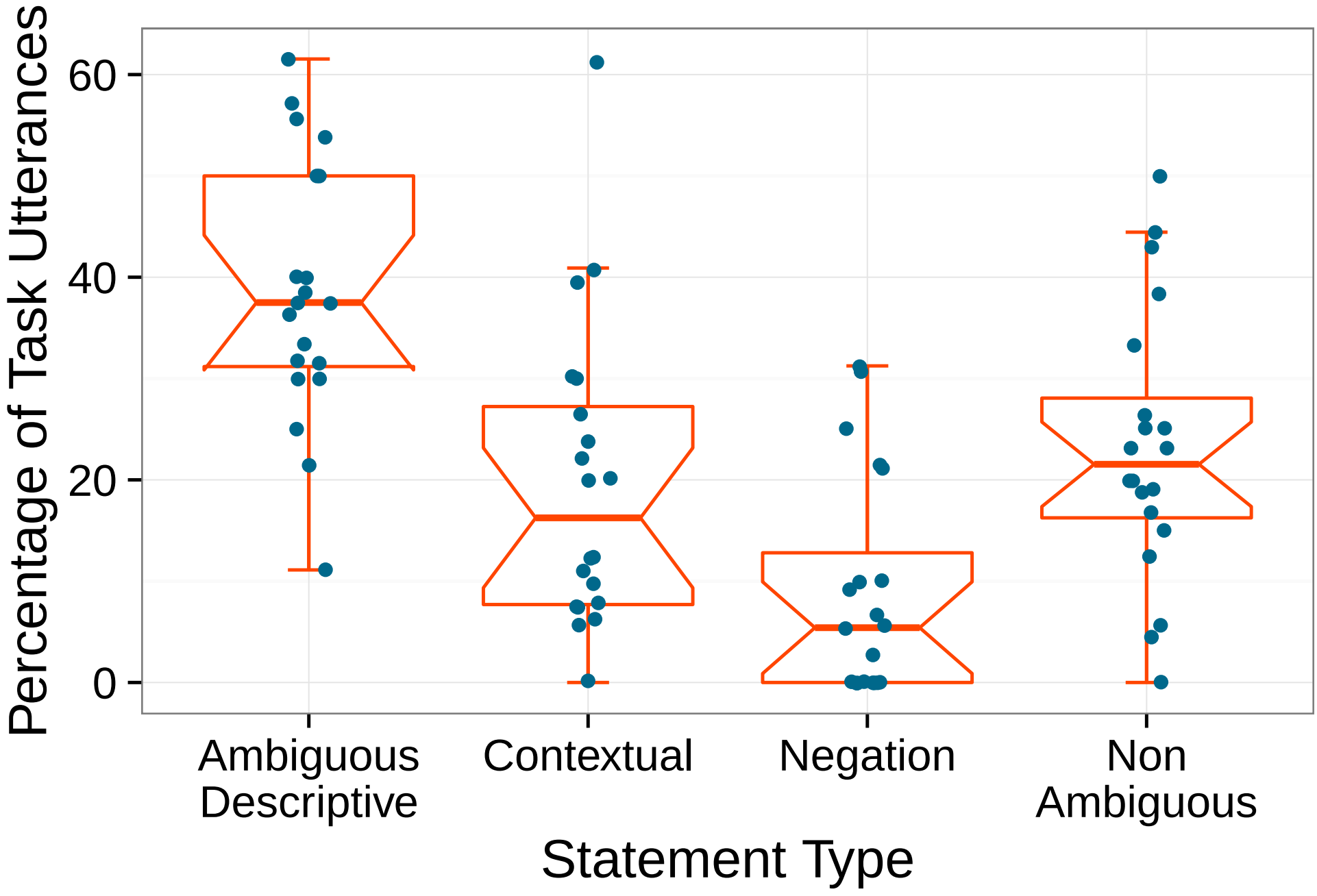
What does "be lazy" mean for robots?

ONE EXAMPLE: GROUNDING OF SPATIAL LANGUAGE



Ambiguities arise easily when describing spatial scenes.

How do we solve them?


Percentage of Task Utterances
60
40
20
0
Ambiguous Descriptive
Contextual
Negation
Non Ambiguous
Statement Type

SURFACE ALIGNMENT; GROUNDING CRITERION

Psycholinguistics provides a lot of the foundational work on these questions.

- ***Communication is a dynamic social process***: the partner often to signal missing/misunderstood informations

[Clark and Wilkes-Gibbs, ***Referring as a collaborative process***, Cognition 1986
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SURFACE ALIGNMENT; GROUNDING CRITERION

Psycholinguistics provides a lot of the foundational work on these questions.

- ***Communication is a dynamic social process***: the partner often to signal missing/misunderstood informations
- Repairing is generally less costly than avoiding ambiguities in the first place

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SURFACE ALIGNMENT; GROUNDING CRITERION

Psycholinguistics provides a lot of the foundational work on these questions.

- ***Communication is a dynamic social process***: the partner often to signal missing/misunderstood informations
- Repairing is generally less costly than avoiding ambiguities in the first place
- You only ever need to reach the ***grounding criterion***, ie ***enough*** mutual understanding for the task

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- $\Rightarrow$ we typically only reach ***partial (or surface) alignment*** – full alignment is usually not required

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IN SOCIAL HUMAN-ROBOT INTERACTION

Well studied in communication (cf back-channeling)

Can we expand this line of thought to sHRI in general?

Most of our social and behavioural alignment comes from sub-conscious social mechanisms:

- entrainment (coupling),
- mimicry,
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- ...and others

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- ...and others

Can we model & generate them?

THE PROBLEM

- These mechanisms are unfortunately often ill-defined, and particularly difficult to turn into equations (or controllers, in our case)
- no close-form equation of social interactions $\Rightarrow$ data-driven approaches?

TOWARDS THE DATA-DRIVEN STUDY OF SOCIAL DYNAMICS

DATA!

If we want to use machine learning, we need data (relevant to child-robot interactions in a learning environment).

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- open, underspecified situations
- natural interactions
- rich semantics
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...a task that exhibits:

- complex social dynamics
- open, underspecified situations
- natural interactions
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- interplay of many socio-cognitive functions

while being...

- reproducible/replicable experimental procedure
- clear quantitative metrics
- practical

FREE PLAY

"Just play! Enjoy yourselves!"

- **rich set of cognitive and social dynamics**; importance of motivation/drive; **uncertain and unexpected situations**
- what is the right action policy? Focus instead on the **social policy**

FREE PLAY

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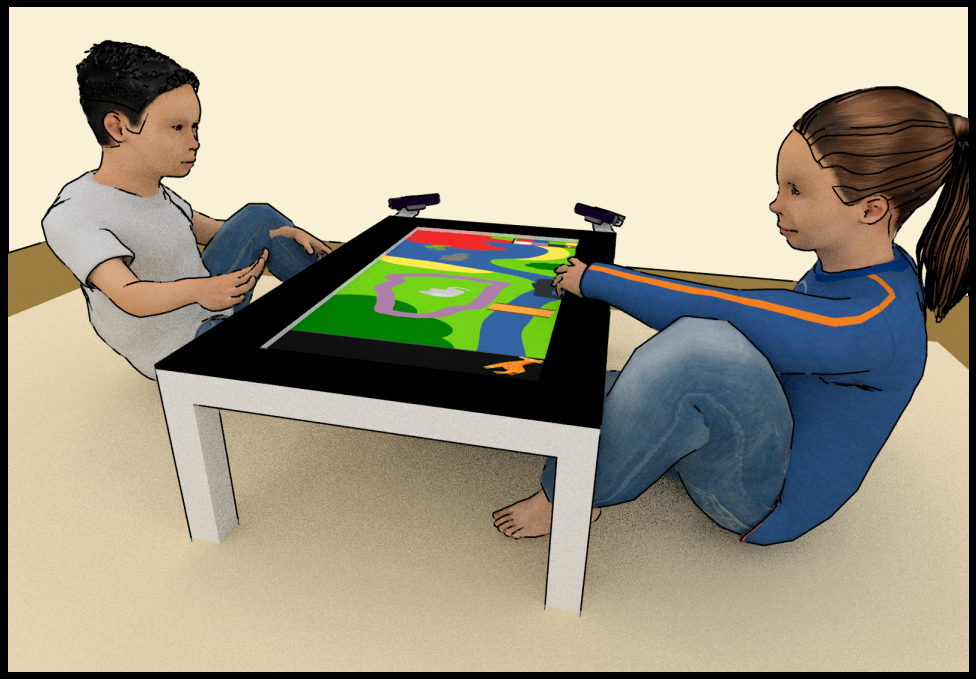
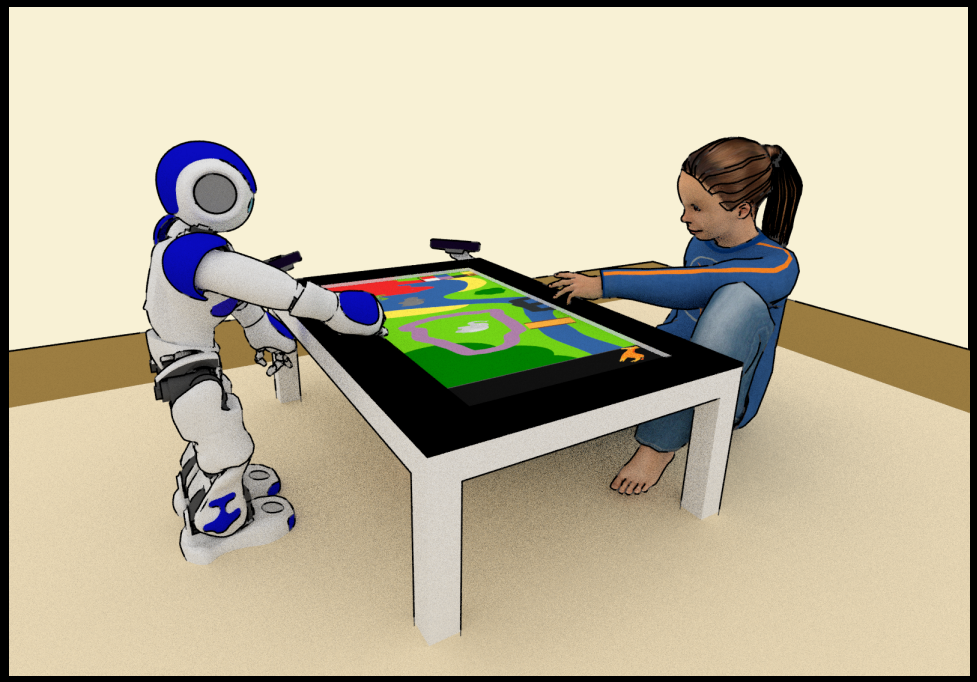
- focus on children
- with a little bit of scaffolding & framing





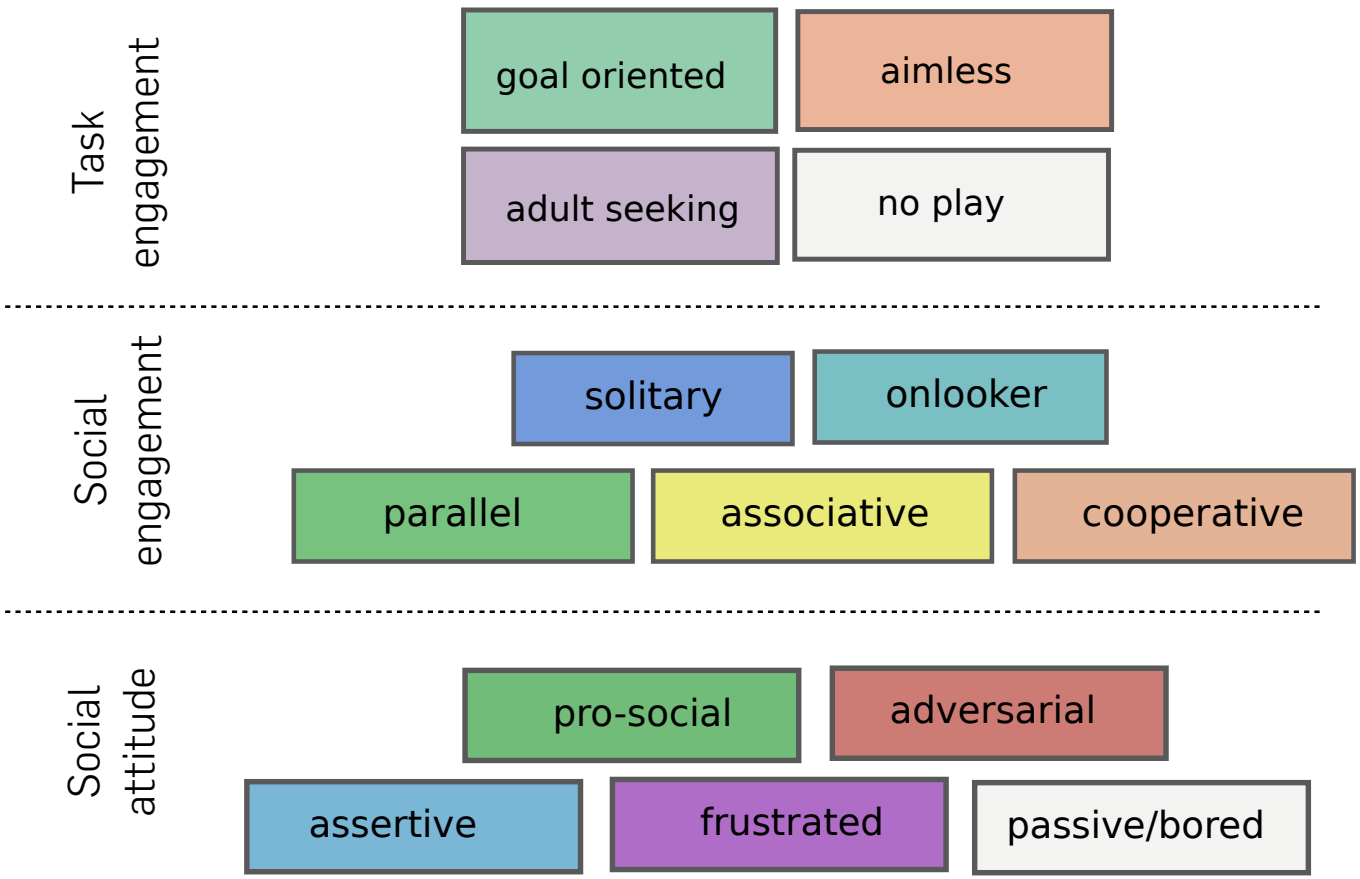
THE PINSORO DATASET

- 120 children, 4 to 8 years old
- 75 interactions
  - 90 children playing with another child,
  - 30 playing with a robot
- About 45h+ of recordings; 2M+ frames; ≈ 2TB
- average duration of freeplay interactions: 24min in child-child condition; 19min in child-robot condition

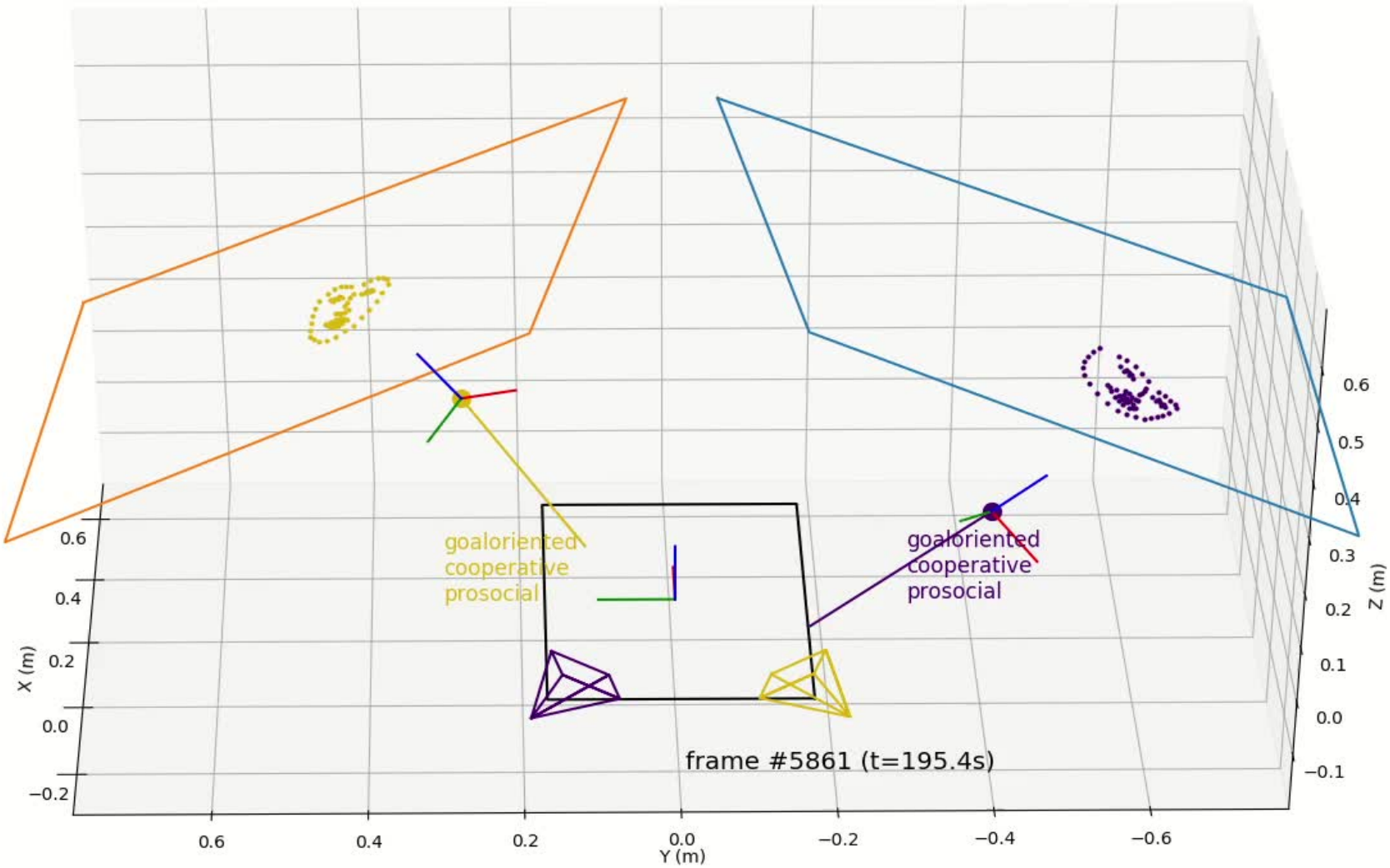
Large open dataset: **freeplay-sandbox.github.io**

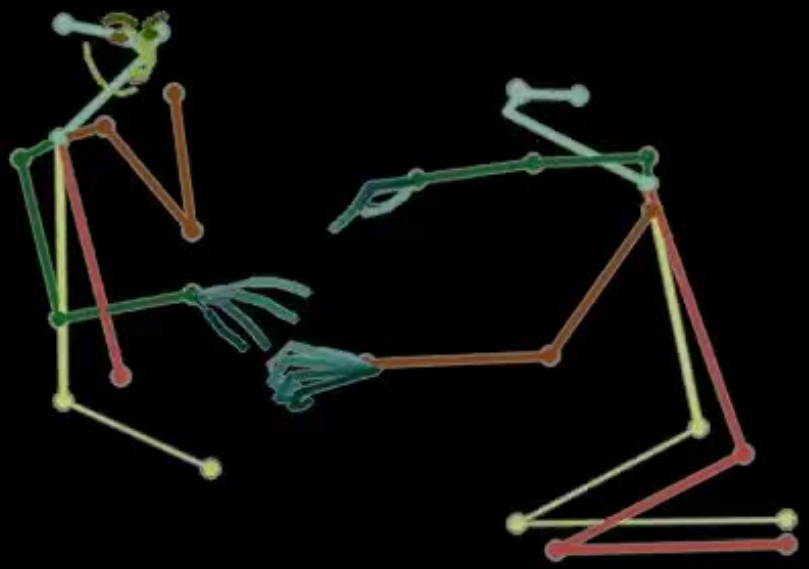
[Lemaignan et al. **The PInSoRo dataset: Supporting the data-driven study of child-child and child-robot social dynamics** PLOS One 2018]

13000+ ANNOTATIONS

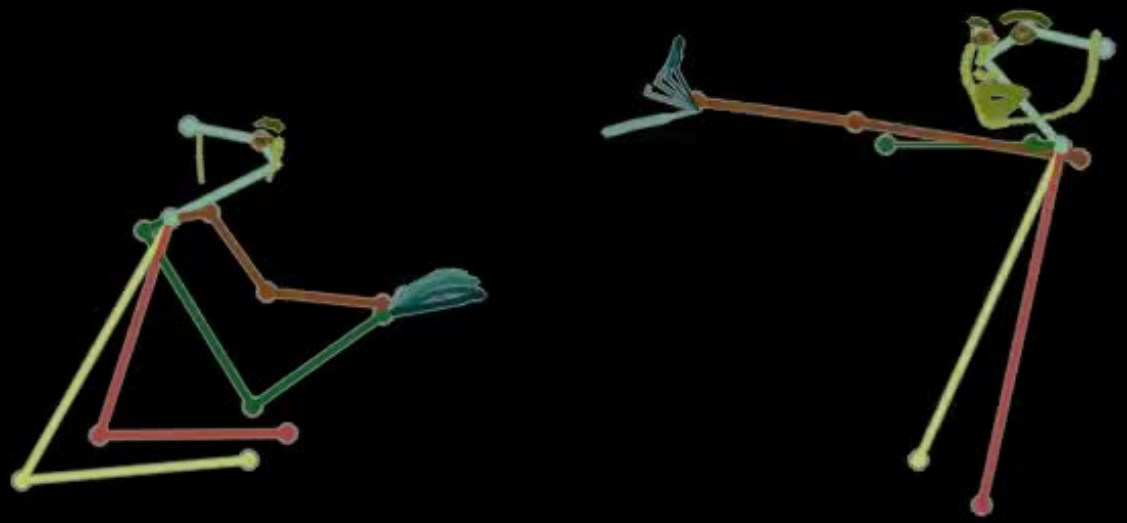



Attitude: passive
Social engag.: onlooker
Task engag.: no play
Attitude: passive
Social engag.: solitary
Task engag.: goal oriented


goaloriented
cooperative
prosocial
goaloriented
cooperative
prosocial
frame #5861 (t=195.4s)
X (m)
Y (m)
Z (m)
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
0.5
0.3
0.1
−0.1




Focused!
ILLUMINATED POLITICAL
& PHYSICAL




open me

ULTIMATELY...

Real-time identification by the robot of...

- the **task engagement**

  is my partner 'on task' or not?

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Social behaviours; Social dynamics: **generation as well!**

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- We can reduce the socio-cognitive cost of collaboration by relying as much as possible on **implicit (sub-conscious) social mechanisms**

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- The robot needs to learn to recognise and interpret those social cues, hidden within complex social dynamics (in real-time!)

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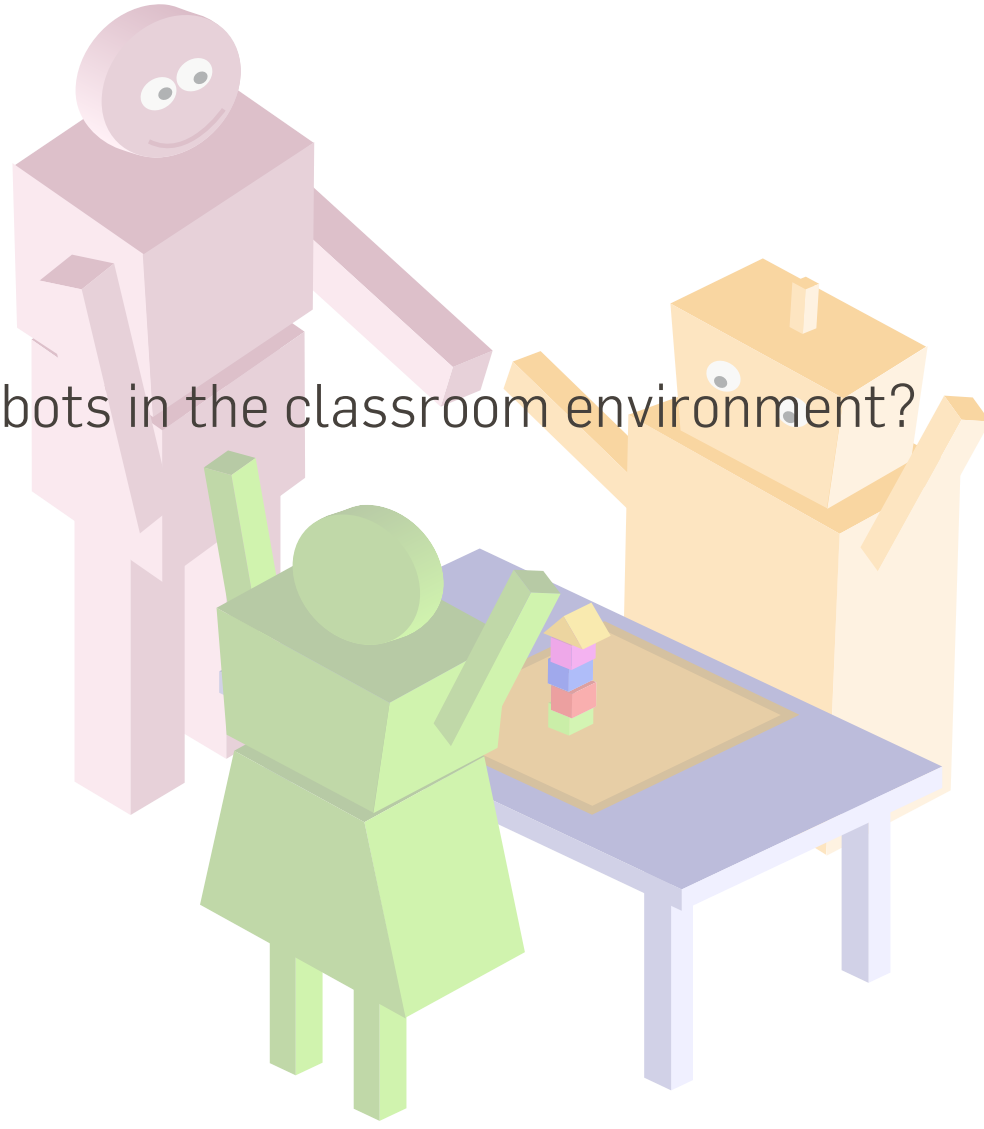
- (do not be scared of ambiguous/partially defined instructions/situations)
- The robot needs to learn to recognise and interpret those social cues, hidden within complex social dynamics (in real-time!)
- We have some raw material. Time to process it together!

In summary:

- Integration of ***social*** robots in the classroom environment?



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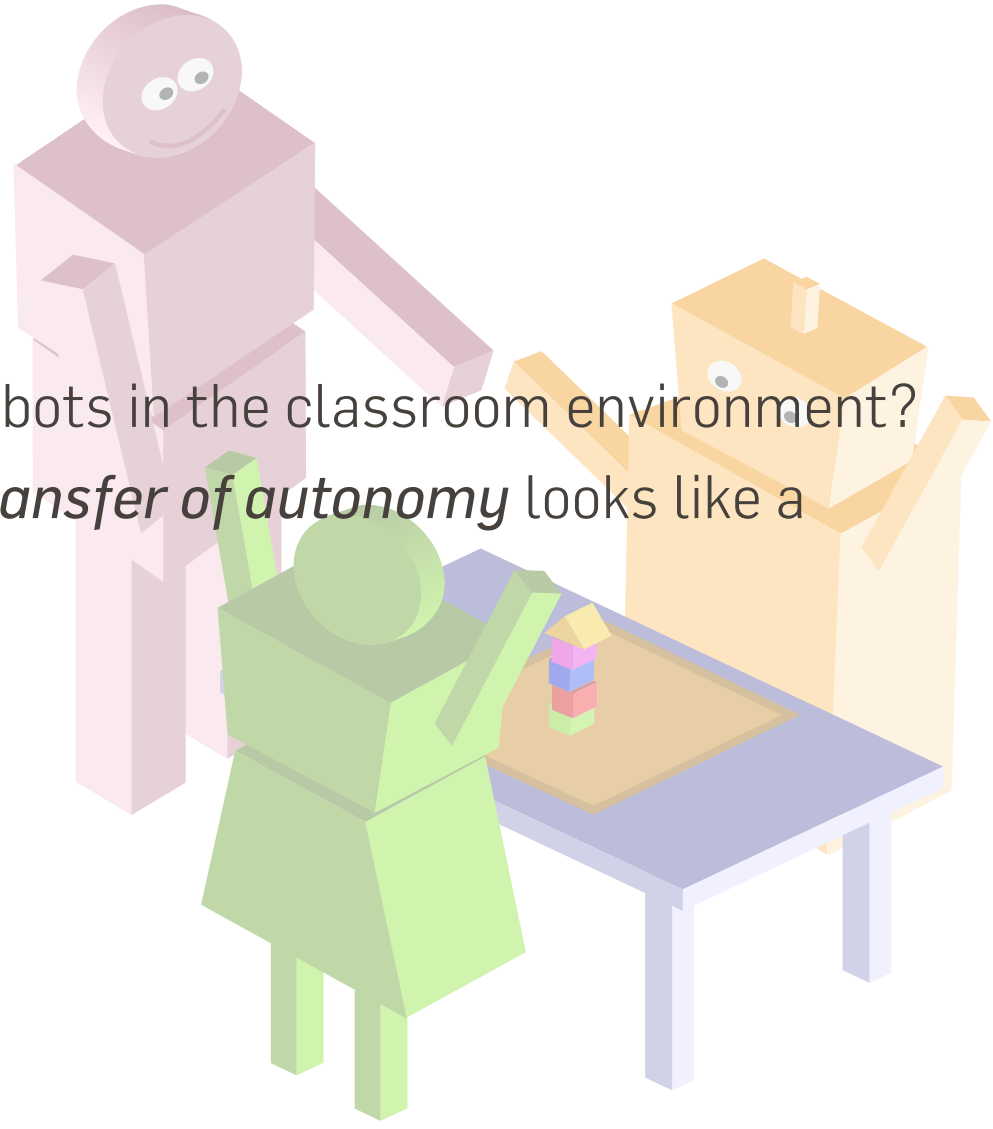

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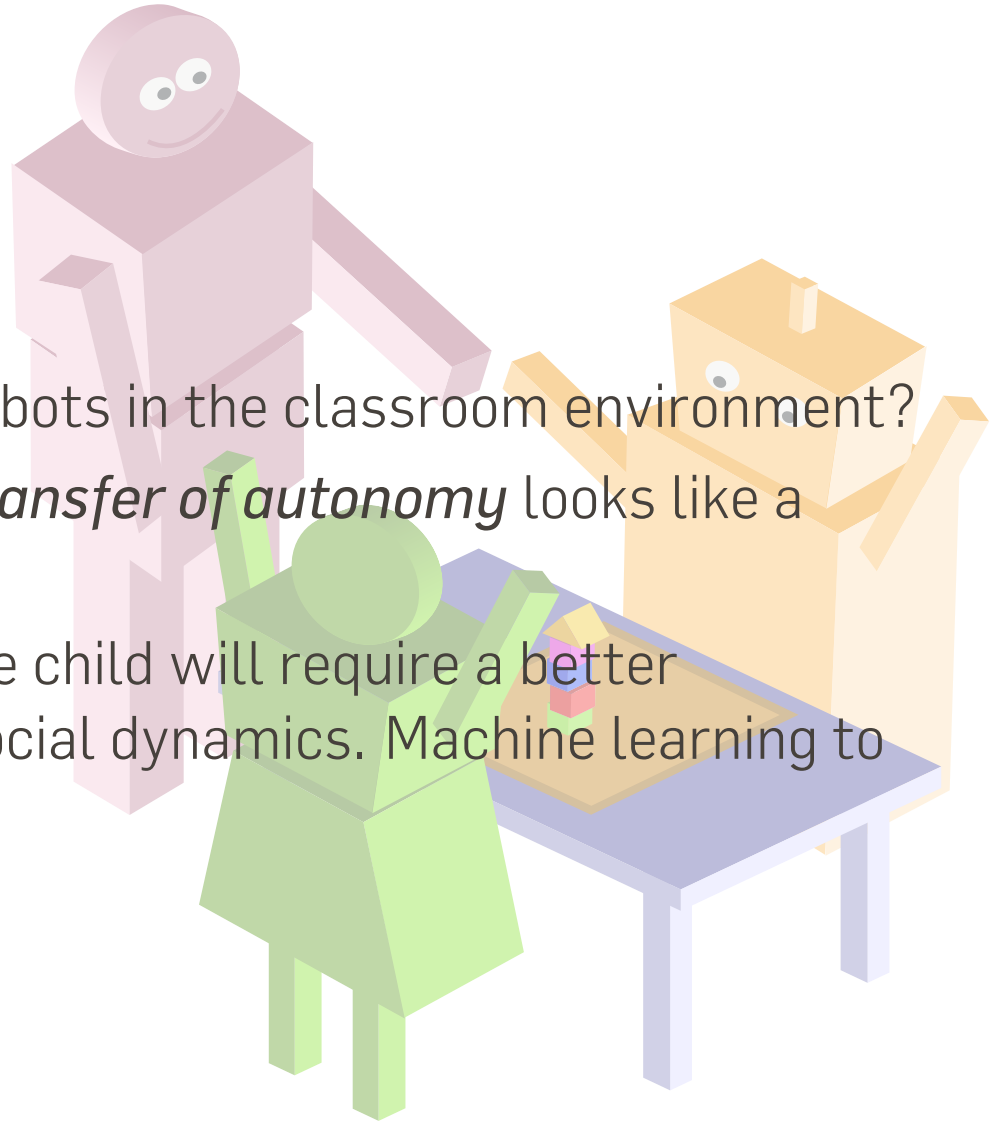

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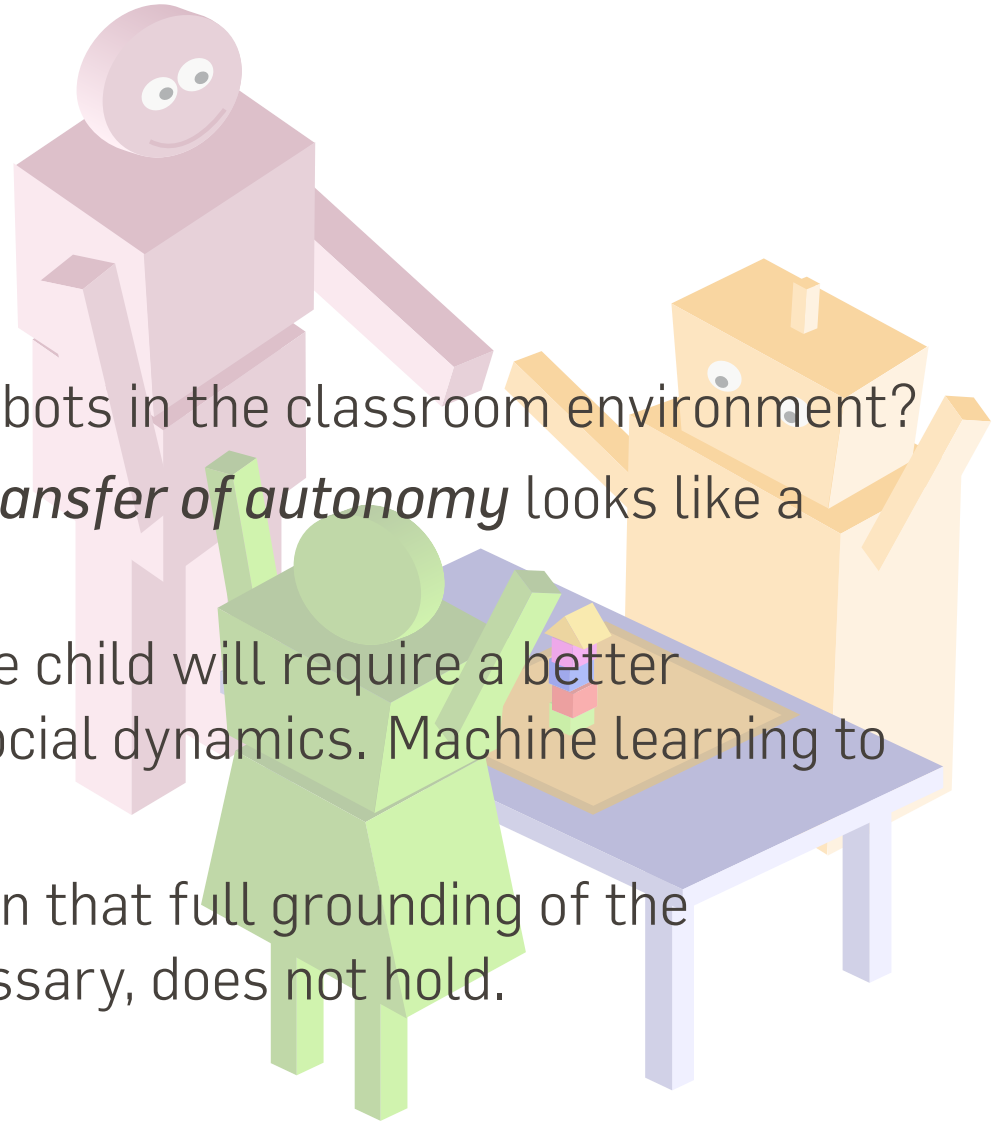

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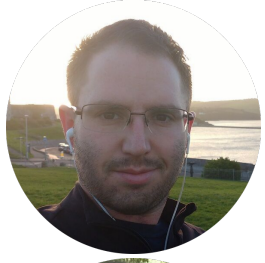
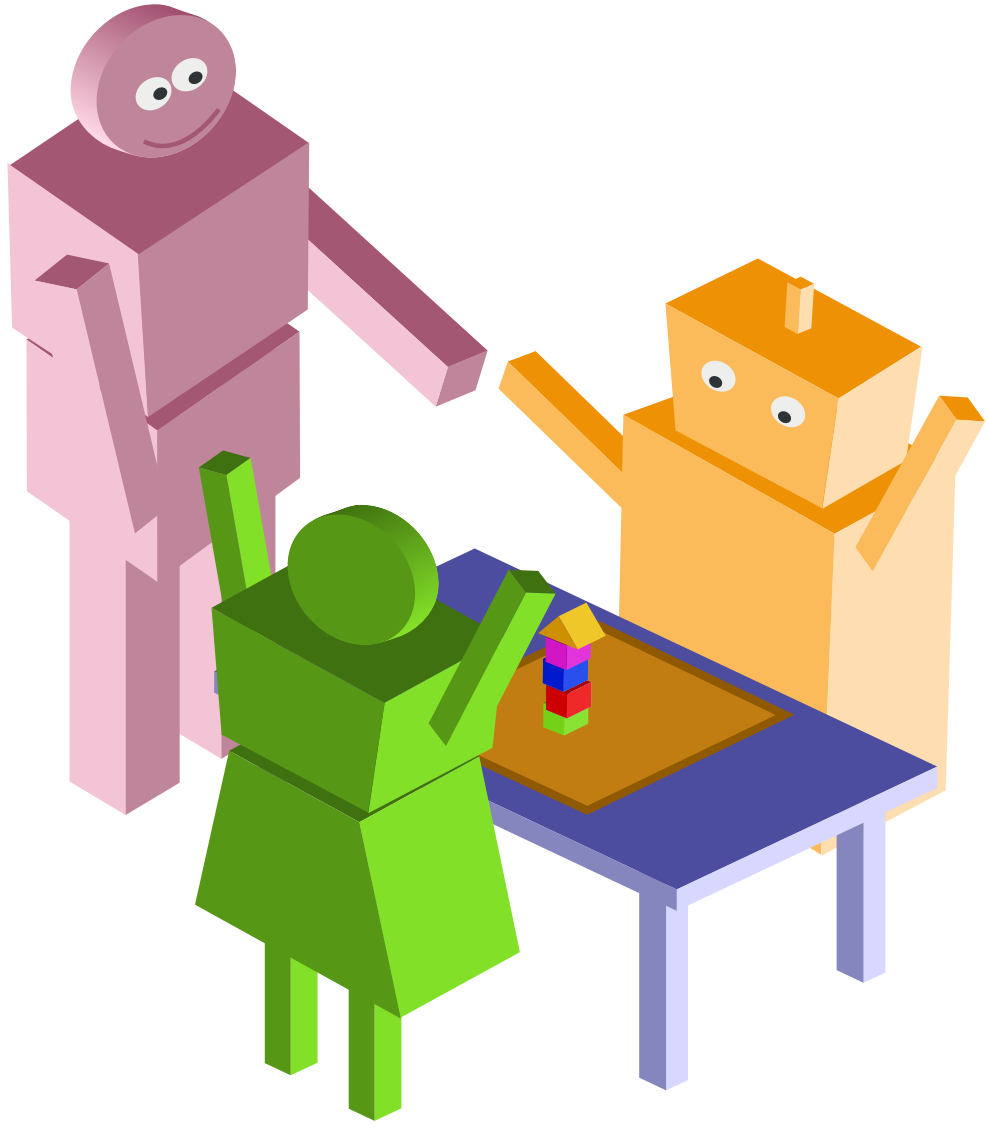
- Role of the teacher? ***Transfer of autonomy*** looks like a promising lead.
- ***Doing together*** with the child will require a better understanding of the social dynamics. Machine learning to the rescue?
- ...but the old assumption that full grounding of the communication is necessary, does not hold.





Thank you!

SOME MORE STUFF

SOME BUILDING BLOCKS EXISTS

- **Multi-modal fusion**

  e.g. Noda et al. **Multimodal integration learning of robot behavior using DNN**, Robotics and Autonomous Systems 2014

- **Behavioural sequences recognition**

  How et al. **Behavior recognition for humanoid robots using long short-term memory**, IJARS 2016 → *LSTM to recognise Nao behaviours*

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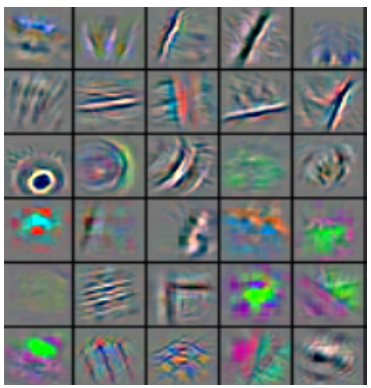
DBSoC: Deep Behavioural Social Cloning – LfD + CNNs + LSTM

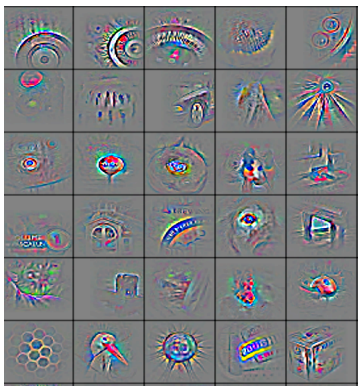
Two tasks for a telepresence robot:

1. position itself in a (dynamic) group of persons
2. follow 2 persons

DEEP NETWORKS ≡ BLACK BOXES?

→ Low-Level features → Mid-Level features → High-Level features → Trainable classifier





[taken from a NIPS2015 tutorial by Geoff Hinton, Yoshua Bengio & Yann LeCun]

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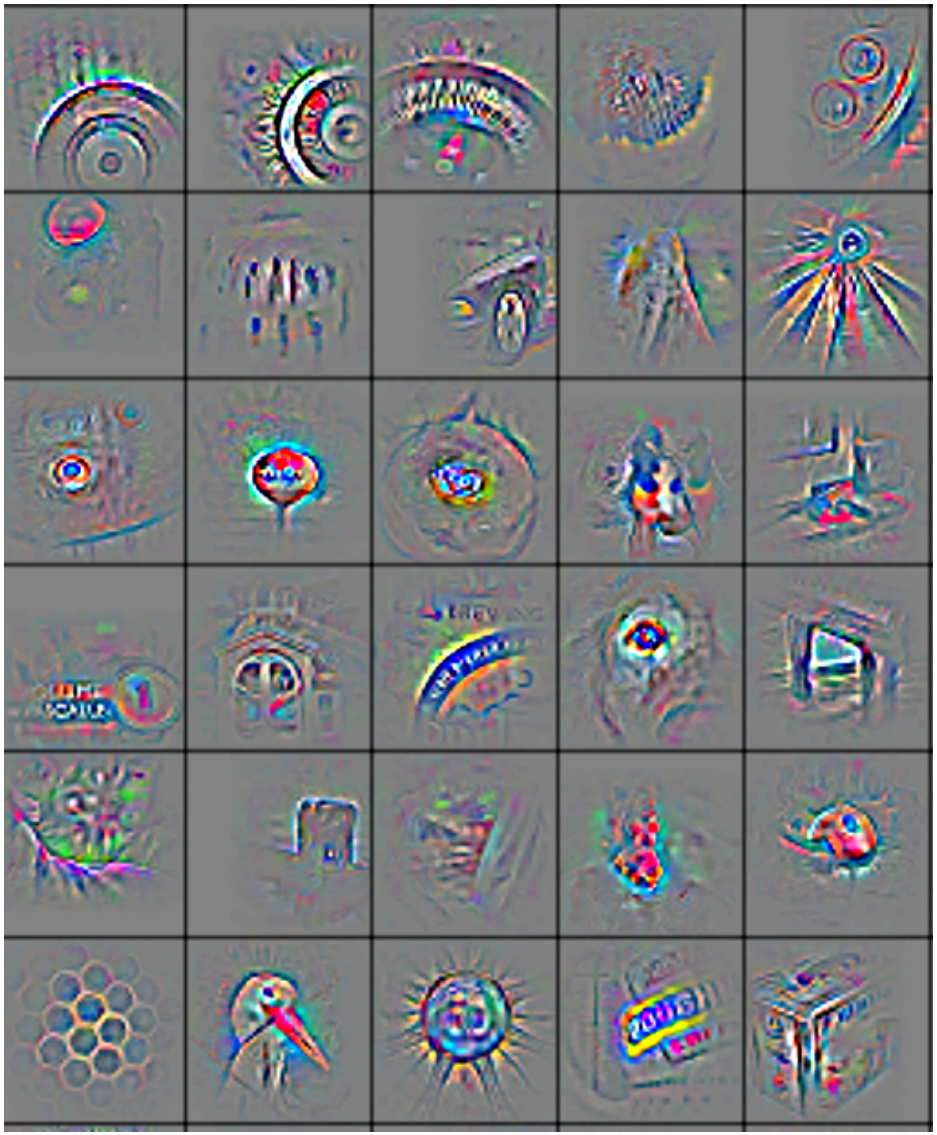

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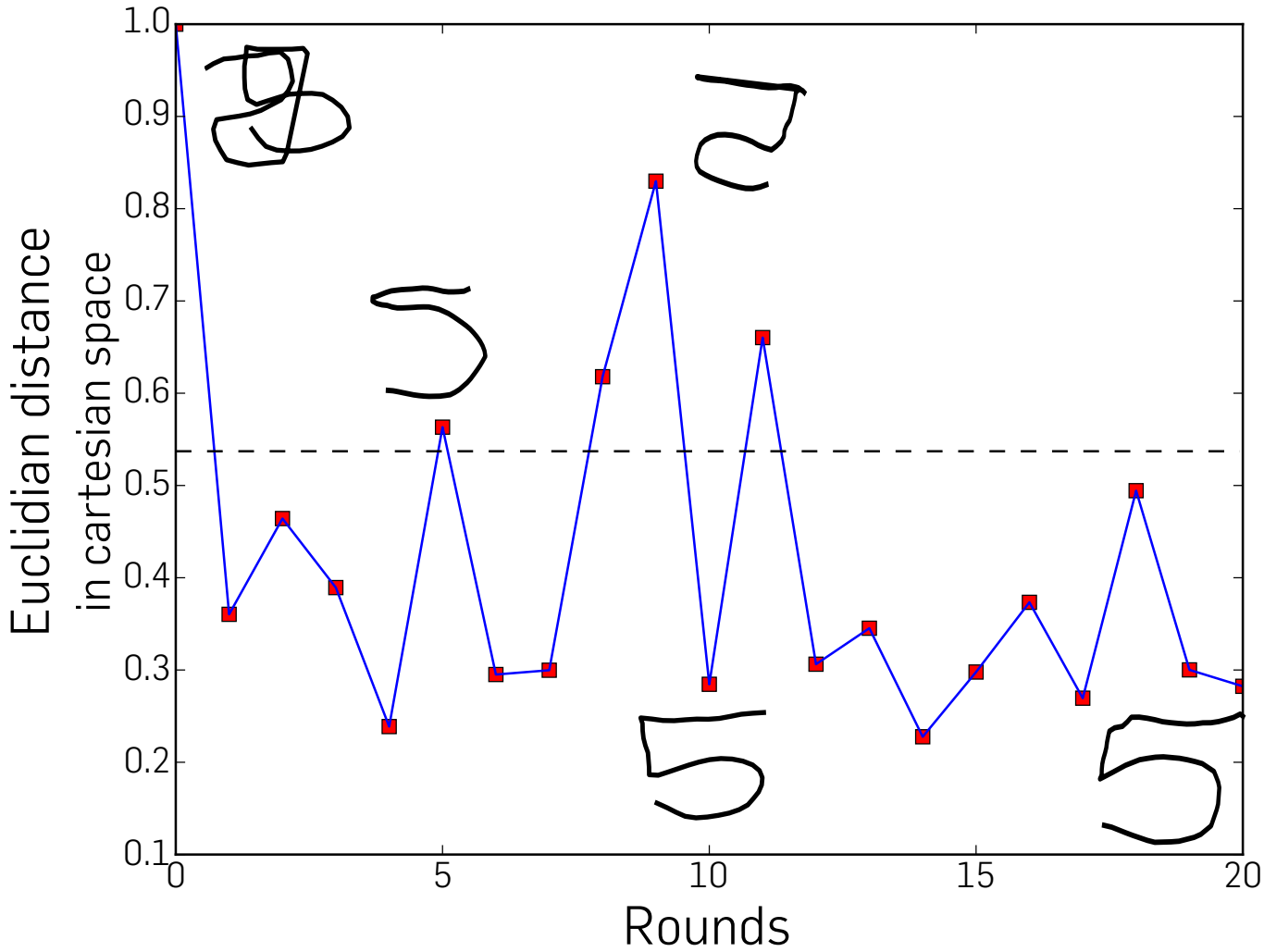
LEARNING TO DRAW A 5



[Lemaignan et al. **Learning by Teaching a Robot: The Case of Handwriting** – Robotics and Automation Magazine 2016]

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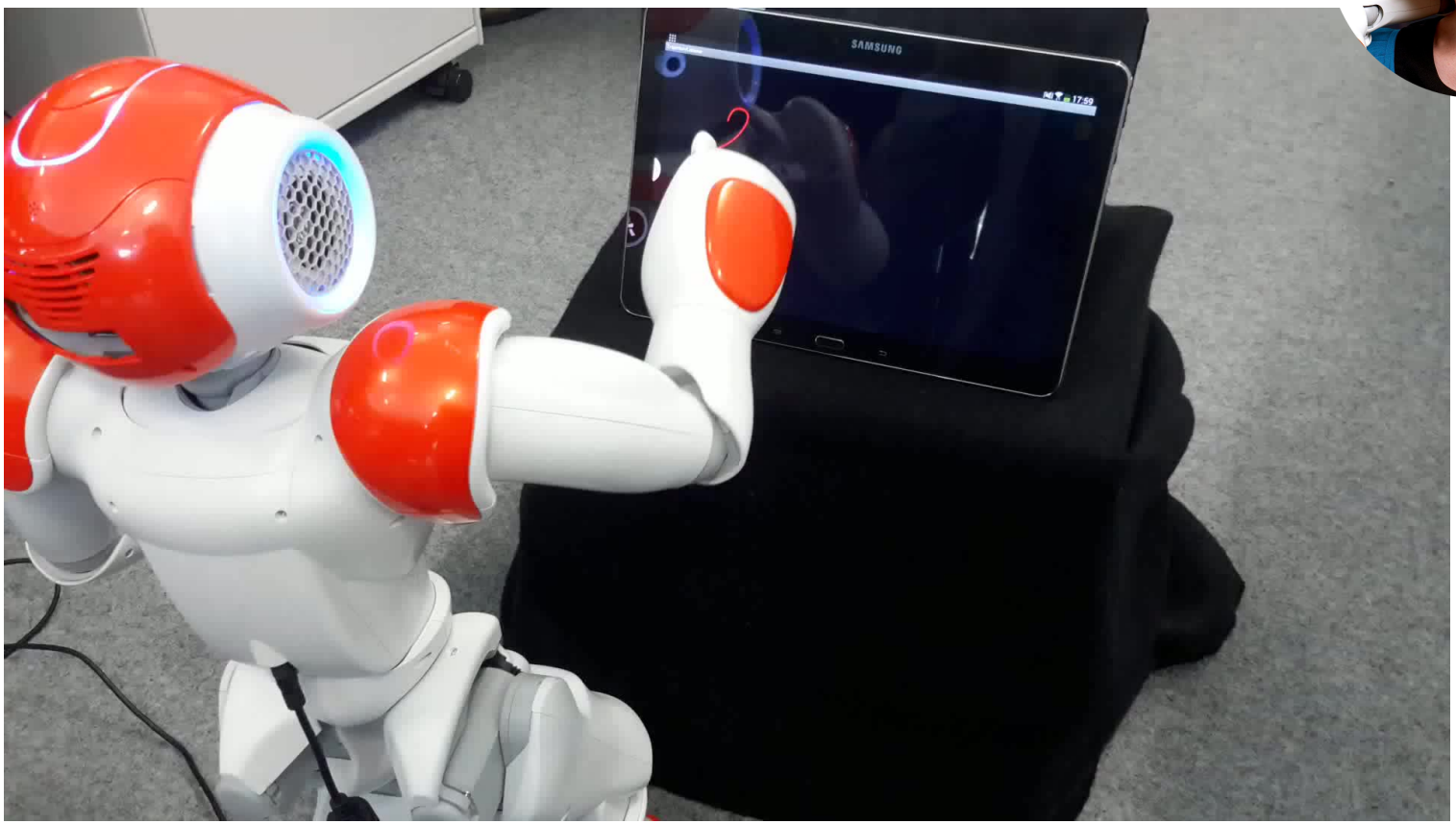

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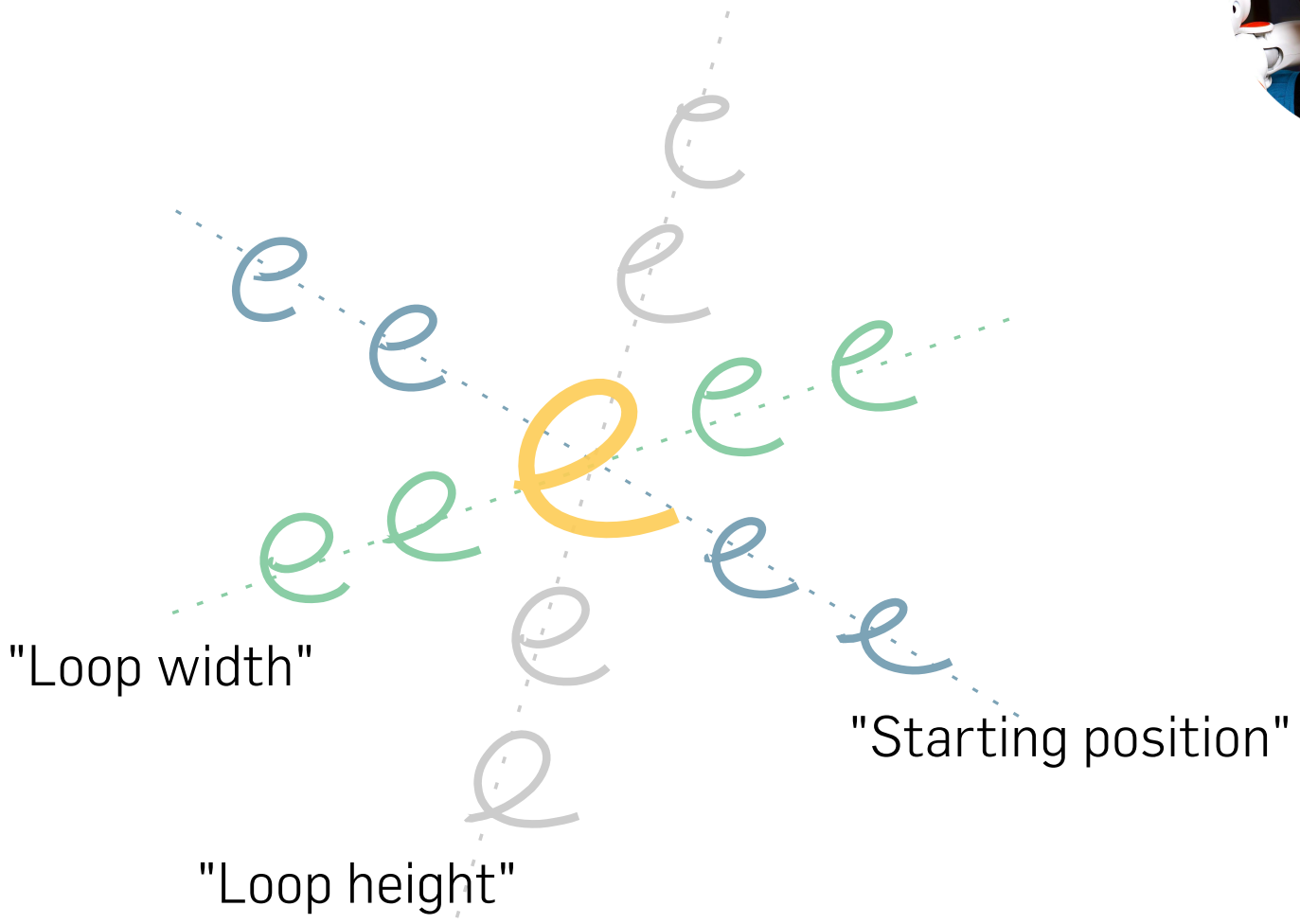

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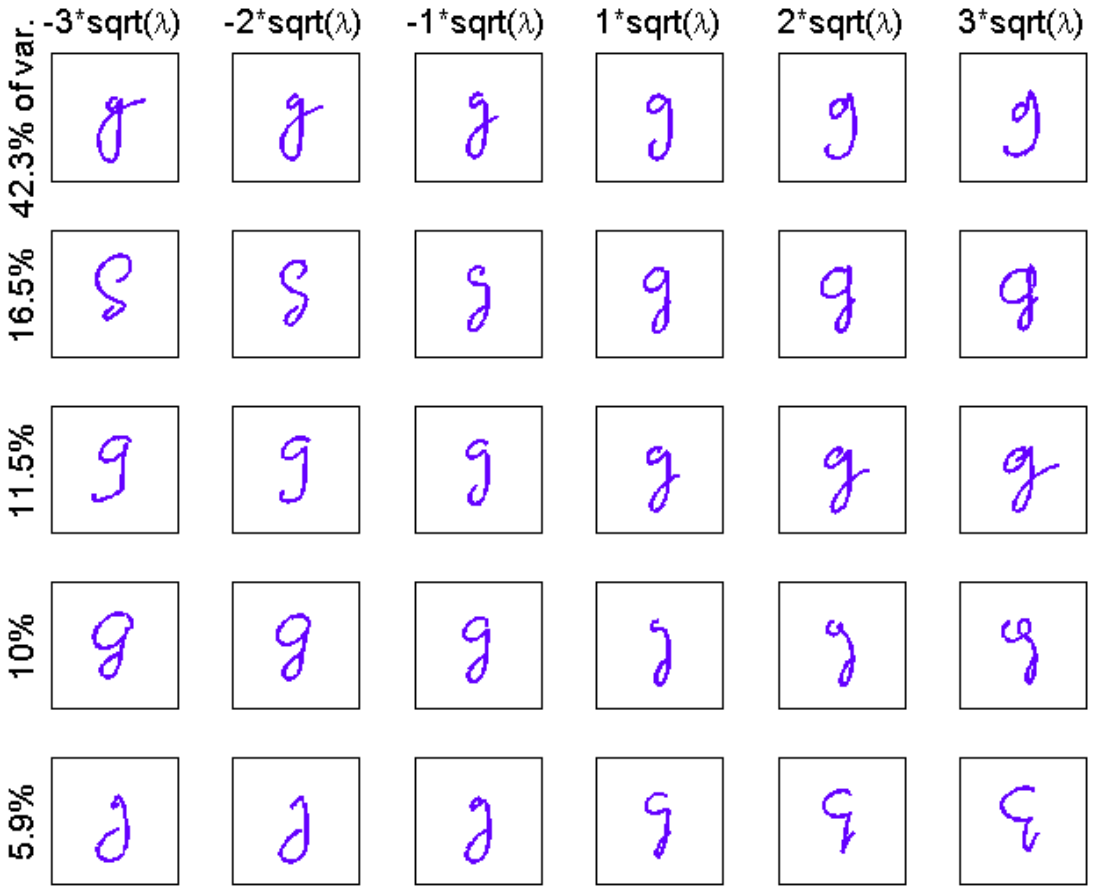

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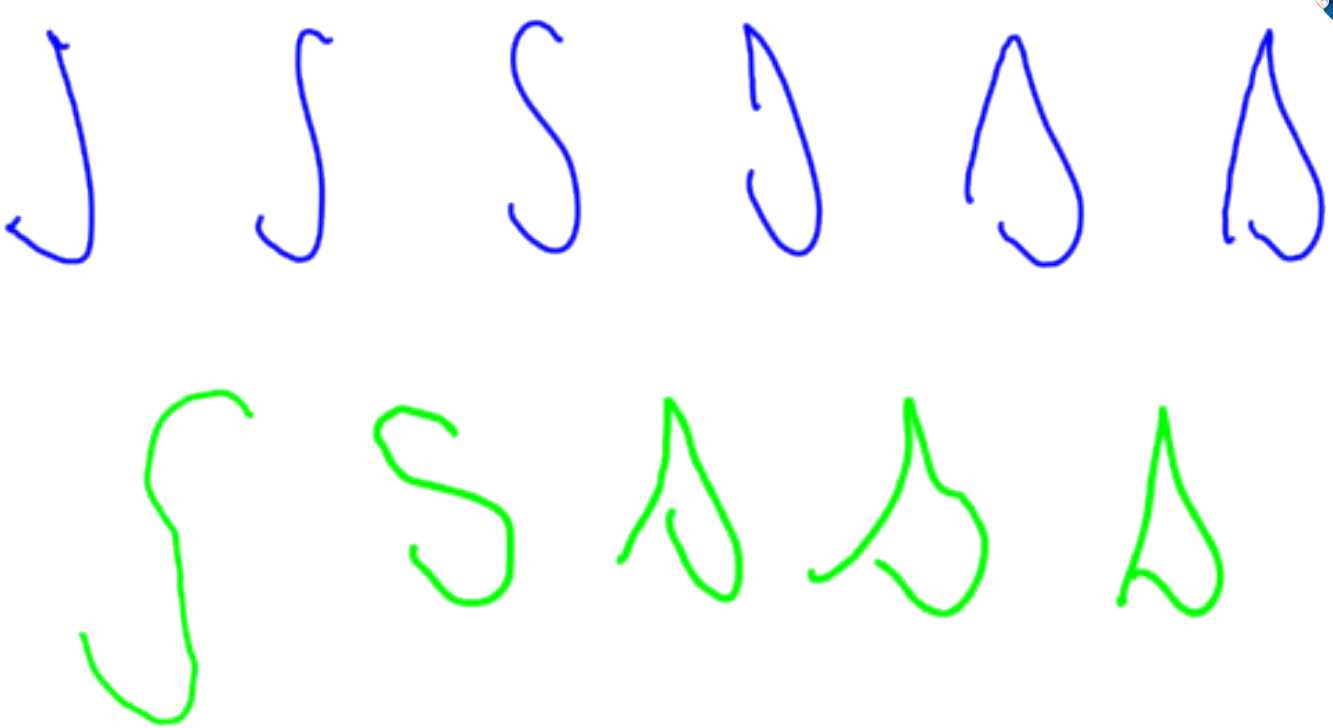

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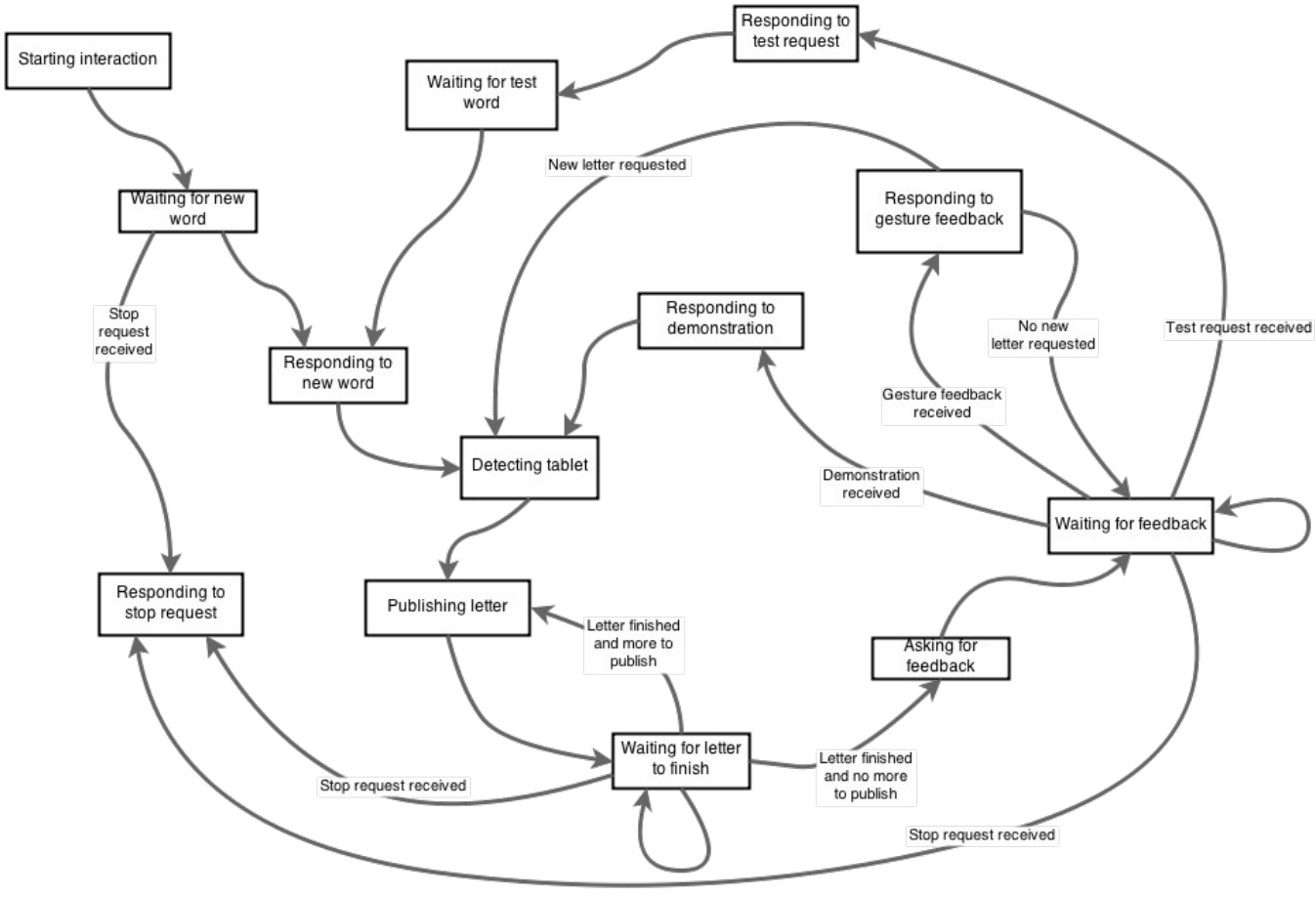
Starting interaction
Responding to test request
Waiting for test word
Waiting for new word
New letter requested
Responding to gesture feedback
Stop request received
Responding to demonstration
No new letter requested
Test request received
Responding to new word
Gesture feedback received
Detecting tablet
Demonstration received
Waiting for feedback
Responding to stop request
Publishing letter
Letter finished and more to publish
Asking for feedback
Waiting for letter to finish
Letter finished and no more to publish
Stop request received
Stop request received

INTERACTION WITH THE PAPER

Critically, Cellulo is meant as an **interaction between (classroom-friendly) paper and the robots**.

[Hostettler, Özgür, Lemaignan et al. **Real-Time High-Accuracy 2D Localization with Structured Patterns** – ICRA 2016]

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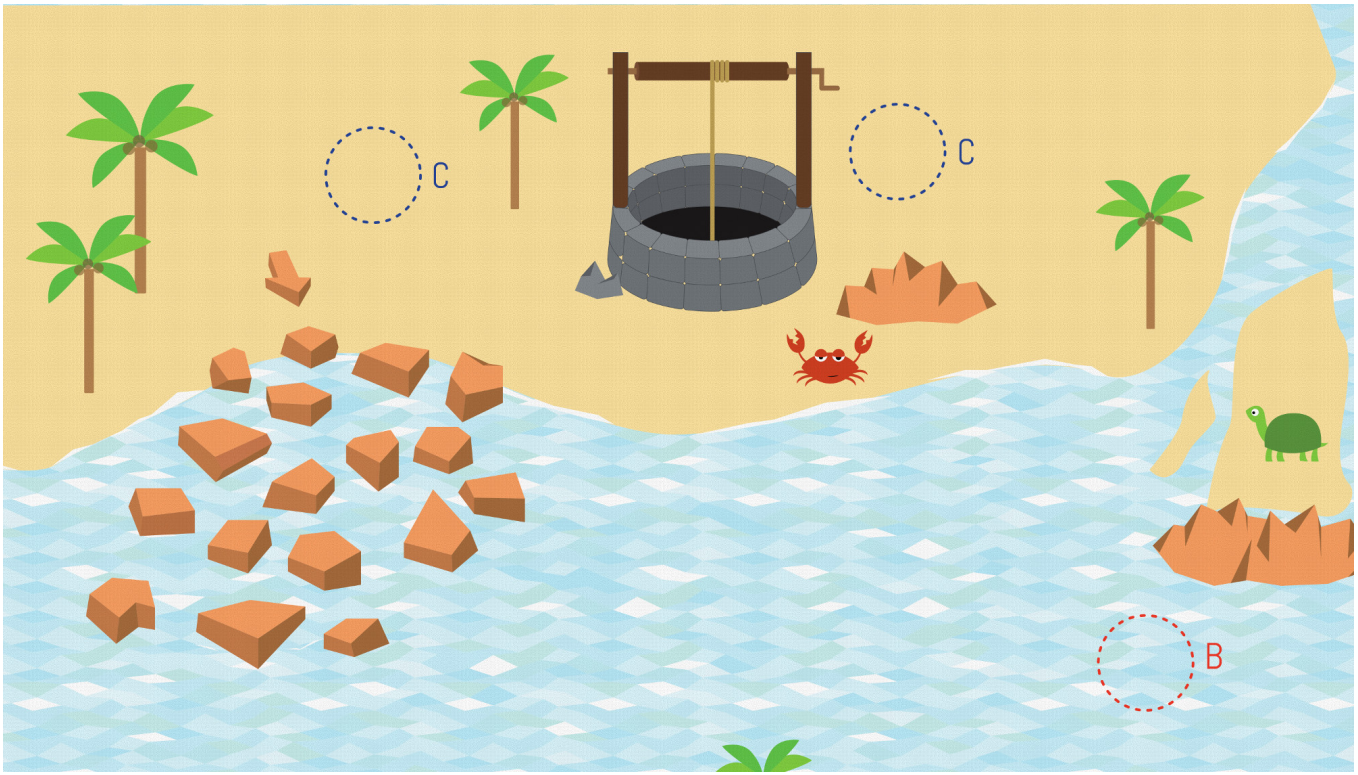

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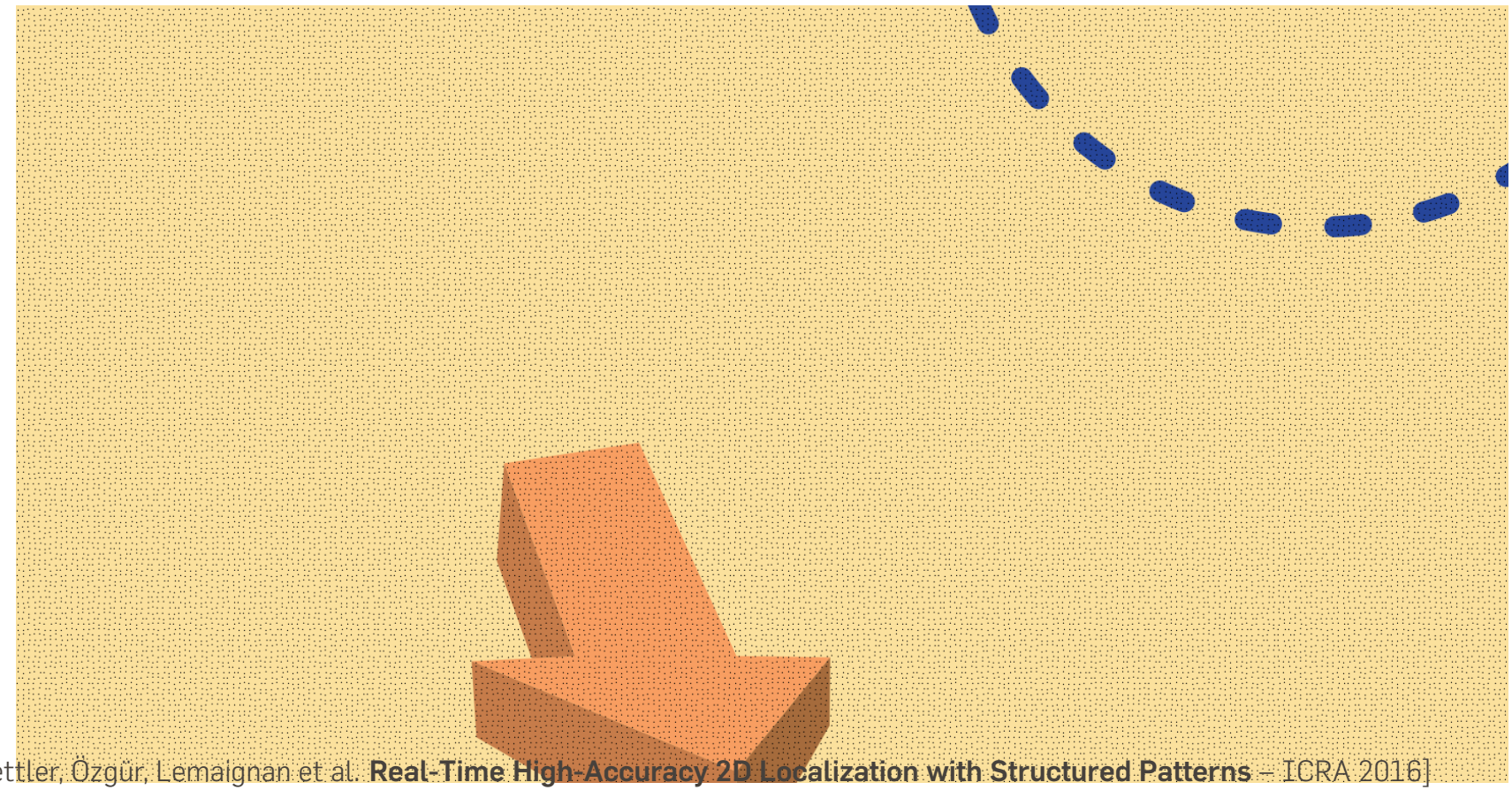

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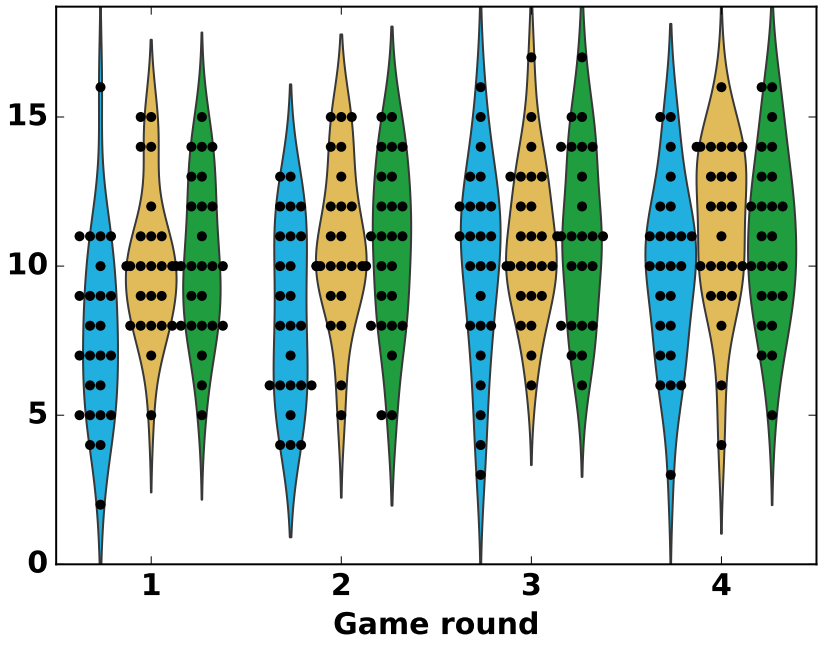
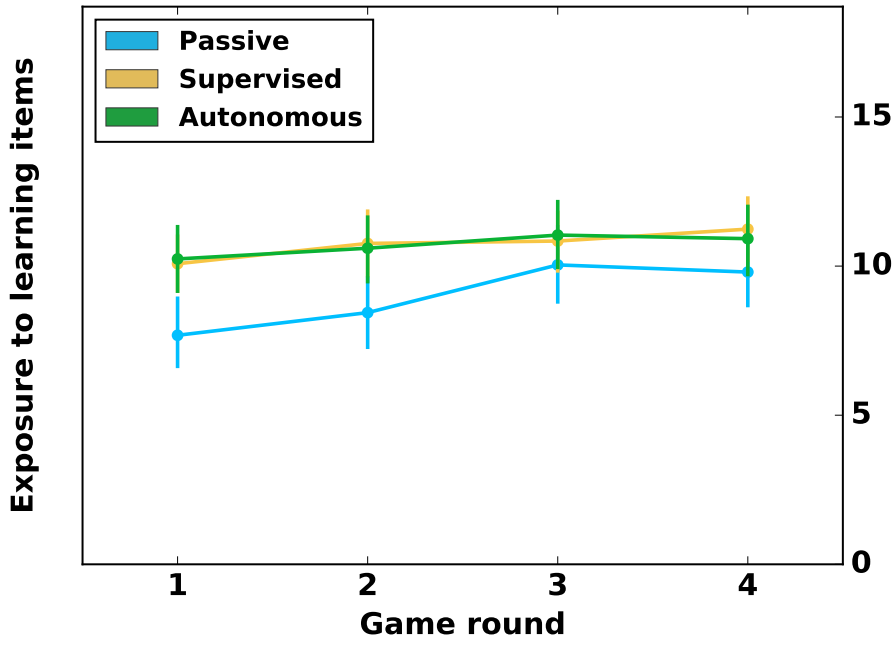
- even more than 'classroom-friendly', paper is 'teacher-friendly'
- easy to manipulate, copy, print, cutout, dispose...
- unique activity IDs: drop the robots onto the sheet, it recognizes the activity

[Hostettler, Özgür, Lemaignan et al. **Real-Time High-Accuracy 2D Localization with Structured Patterns** – ICRA 2016]





Learning-related game actions

WHAT DID WE RECORD?

Domain	Type	Details
child × 2	audio	16kHz, mono, semi-direction
	face (RGB)	qHD (960x540), 30Hz
	face (depth)	VGA (640x480), 30Hz
	facial features	70 2D points, 30Hz
	skeleton	15 2D points, 30Hz
	hands	20 x 2 2D points, 30Hz
environment	RGB	qHD (960x540), 29.7Hz
touchscreen	background drawing (RGB)	4Hz
	touches	6 points multi-touch, 10Hz
	items position and orientation	(x,y,theta), 10Hz
annotations	timestamped annotations of social behaviours	
+ post-process	optical flow, audio features facial action units...	