



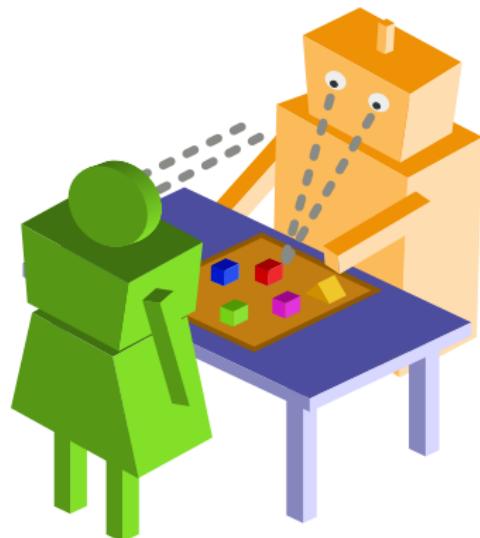
child-robot interaction for learning

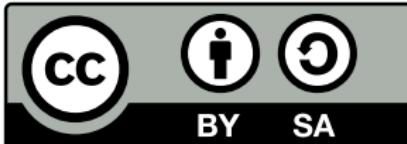
are we ready yet to push the classroom's door?

Robot4SEN – 05 Jul. 2019

Séverin Lemaignan

Bristol Robotics Lab University of the West of England

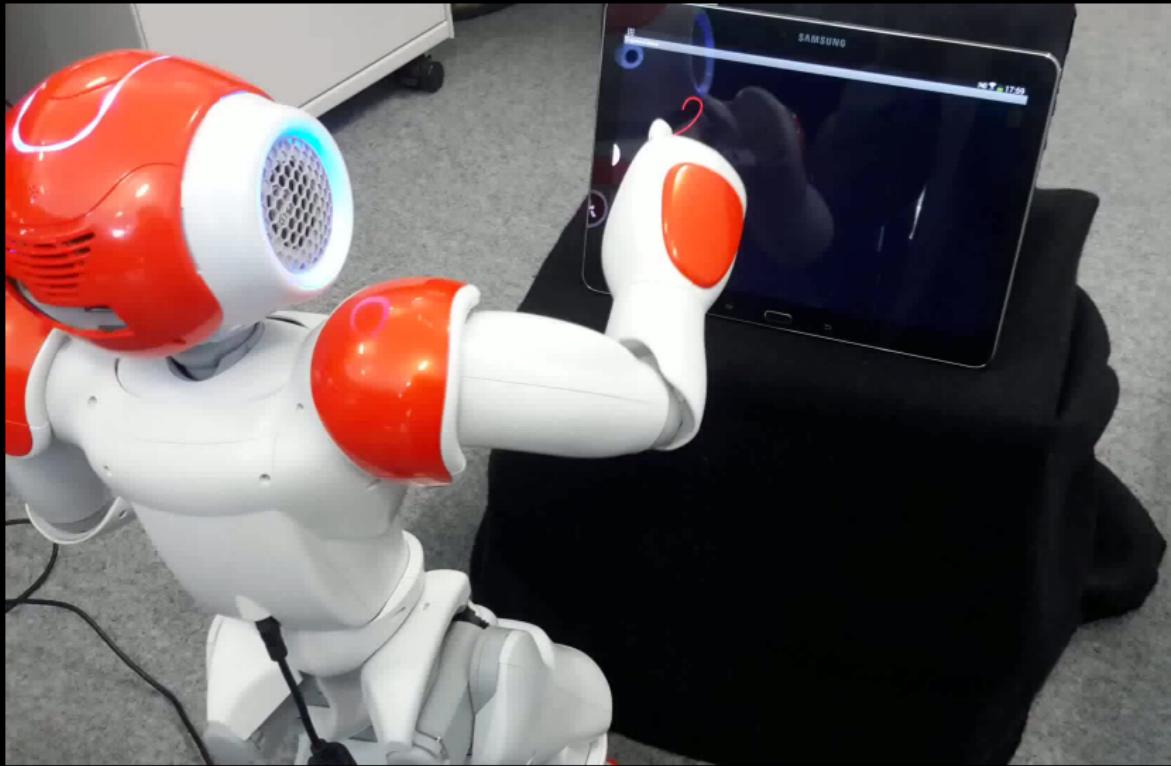




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You can download the sources of this presentation here:
github.com/severin-lemaignan/child-robot-interaction-for-learning



Quick poll:

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

Quick poll:

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

Lack of appropriate teaching material?

Quick poll:

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

Lack of appropriate teaching material?

Getting robots accepted & used in schools, without
engineers/researchers being around...?



Experimental set-up





What about some maths now?

Yeah, yeah...

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?

Yeah, yeah...

Let's frame it bit

What about some maths now?

Yeah, yeah...

What about some maths now?

Yeah, yeah...

What about some maths now?

Yeah, yeah...

What about some maths now?

Teacher

Robot

Classroom

Yeah, yeah...

Child

Child

Teacher



Classroom

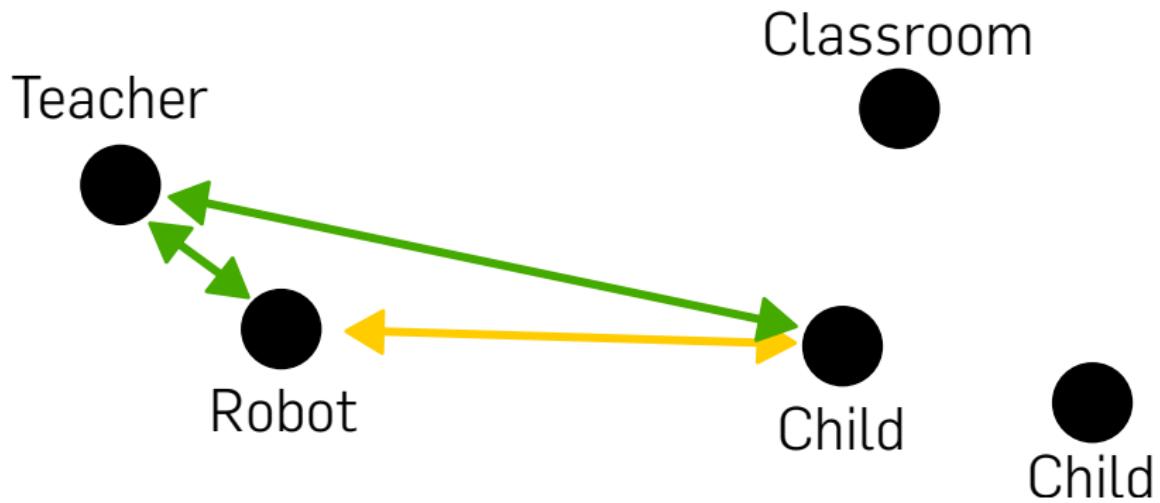


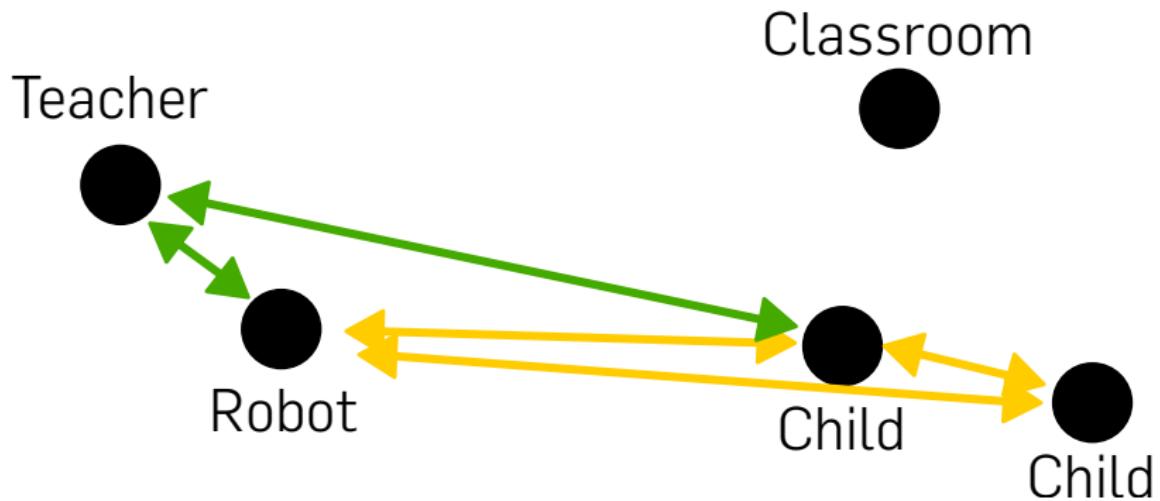
Robot

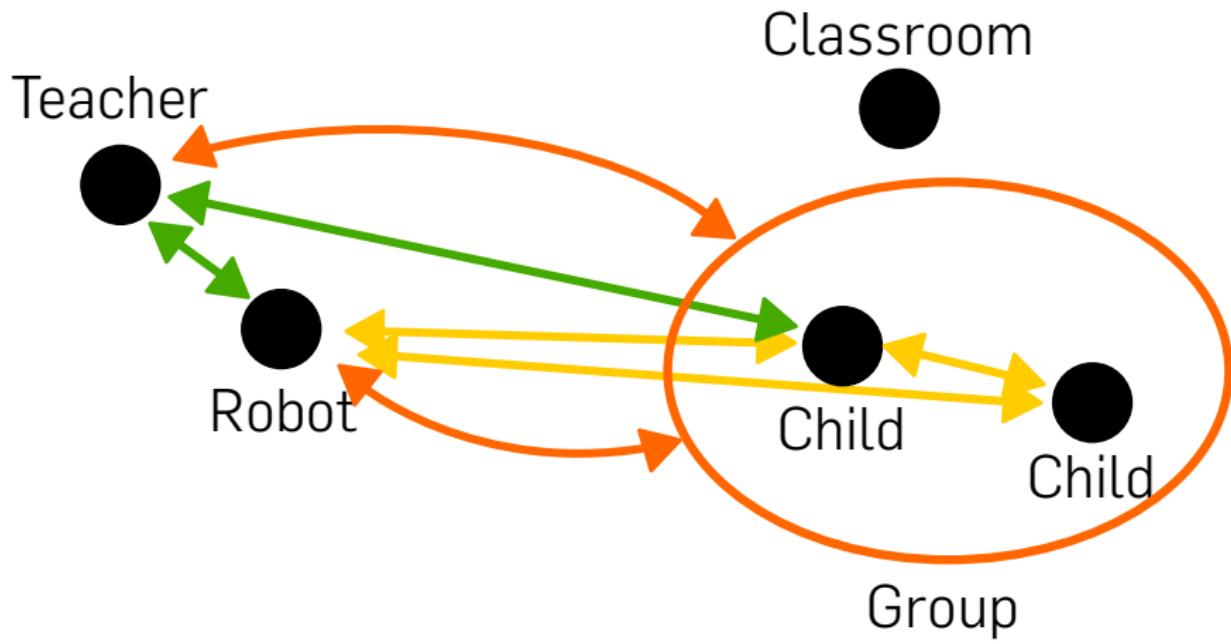


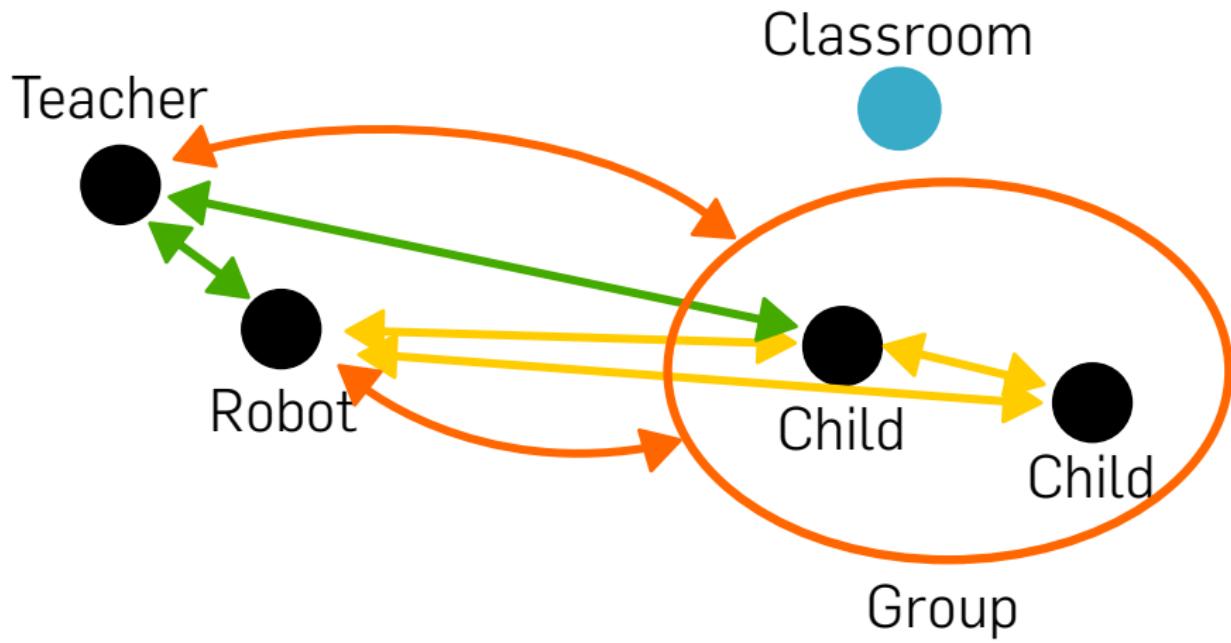
Child

Child









THE CLASSROOM

What is the most effective learning tool in a classroom?



The classroom

○○○●○○○○○○○○○○○○○○

The teacher

○○○○○○○○○○

The children

○○○○○○○○○○

Assessing the interaction

A horizontal row of 15 small, uniform circles, likely representing data points or markers.

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)
- **versatile:** applicable to a broad range of learning scenarios; good tools are not overly specialised (appearance and interaction modalities do not imply or force a specific/unique use case)

WHY THAT?

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- **versatile:** applicable to a broad range of learning scenarios; good tools are not overly specialised (appearance and interaction modalities do not imply or force a specific/unique use case)
- **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...

...what about robots?



屋內發生火警，但門被鎖上時，
消防員需要什麼工具才能破門救人呢？



What does it take 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)

DESIGN PRINCIPLES FOR THE CLASSROOM

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DESIGN PRINCIPLES FOR THE CLASSROOM

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- **versatile**: applicable to a broad range of learning scenarios; the robots' hardware, appearance and interaction modalities must not imply or be constrained to specific use cases
- **effective**: to gain field acceptance in the classrooms, educative robots must critically represent a net educative gain and must not incur higher workload for the teachers (**easy orchestration**)



WORDMANIA





WORDMANIA



The classroom

oooooooooooo●oooooooo

The teacher

oooooooooooo

The children

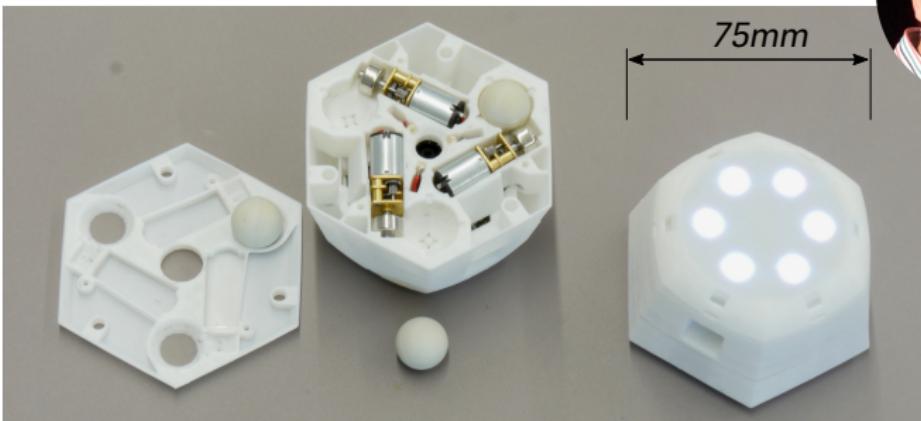
oooooooooooo

Assessing the interaction

oooooooooooooooooooooooooooo

CELLULO: HARDWARE

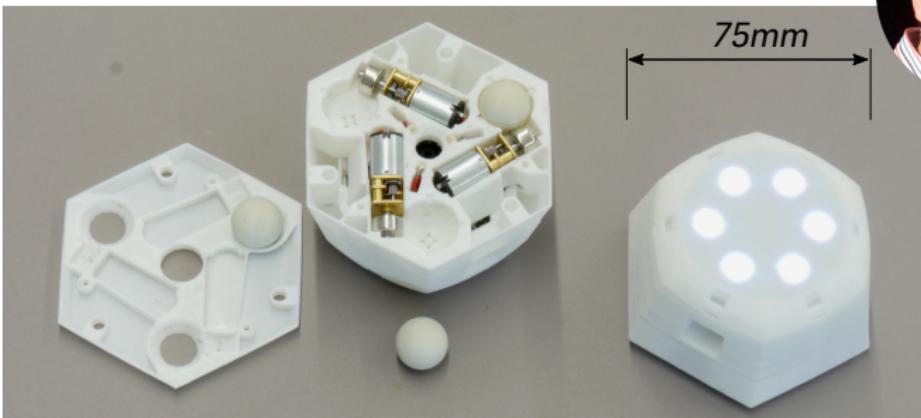
EPFL



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

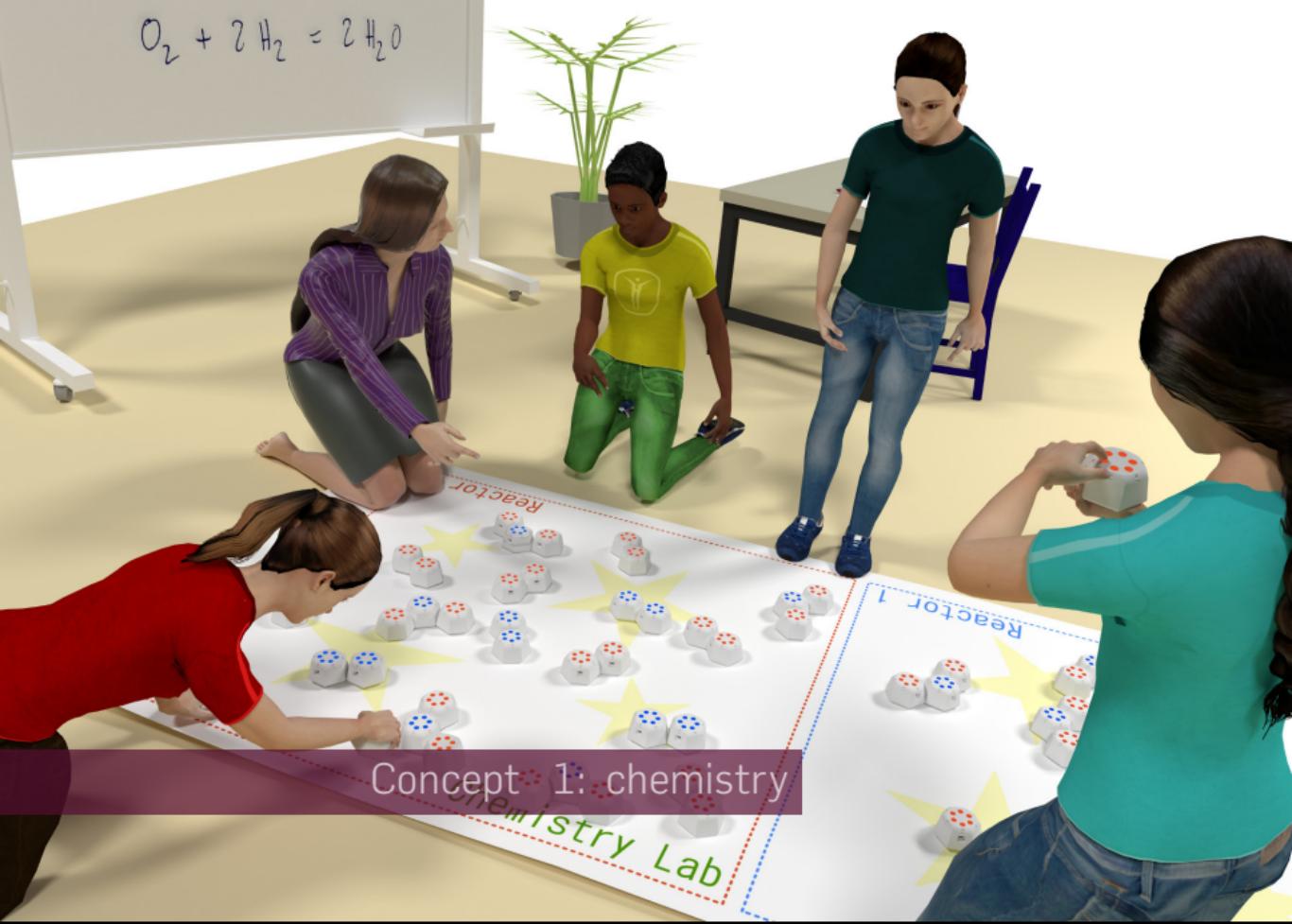
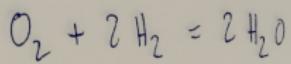
CELLULO: HARDWARE

EPFL

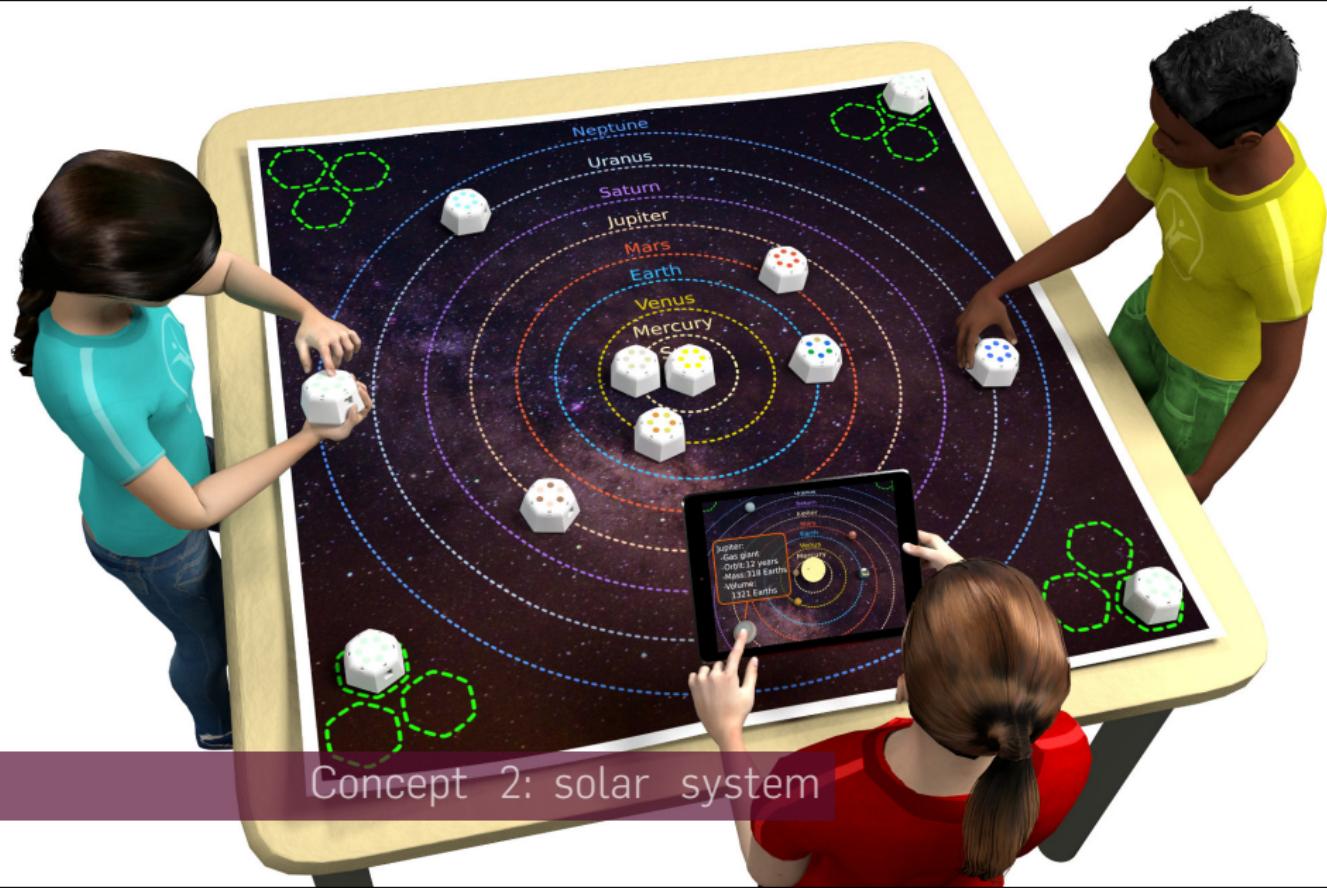


- Holonomic motion
- Sub-mm absolute localisation (no external hardware)
- Haptic feedback + tactile RGB LED buttons
- Bluetooth
- Affordable (prototype: €125)



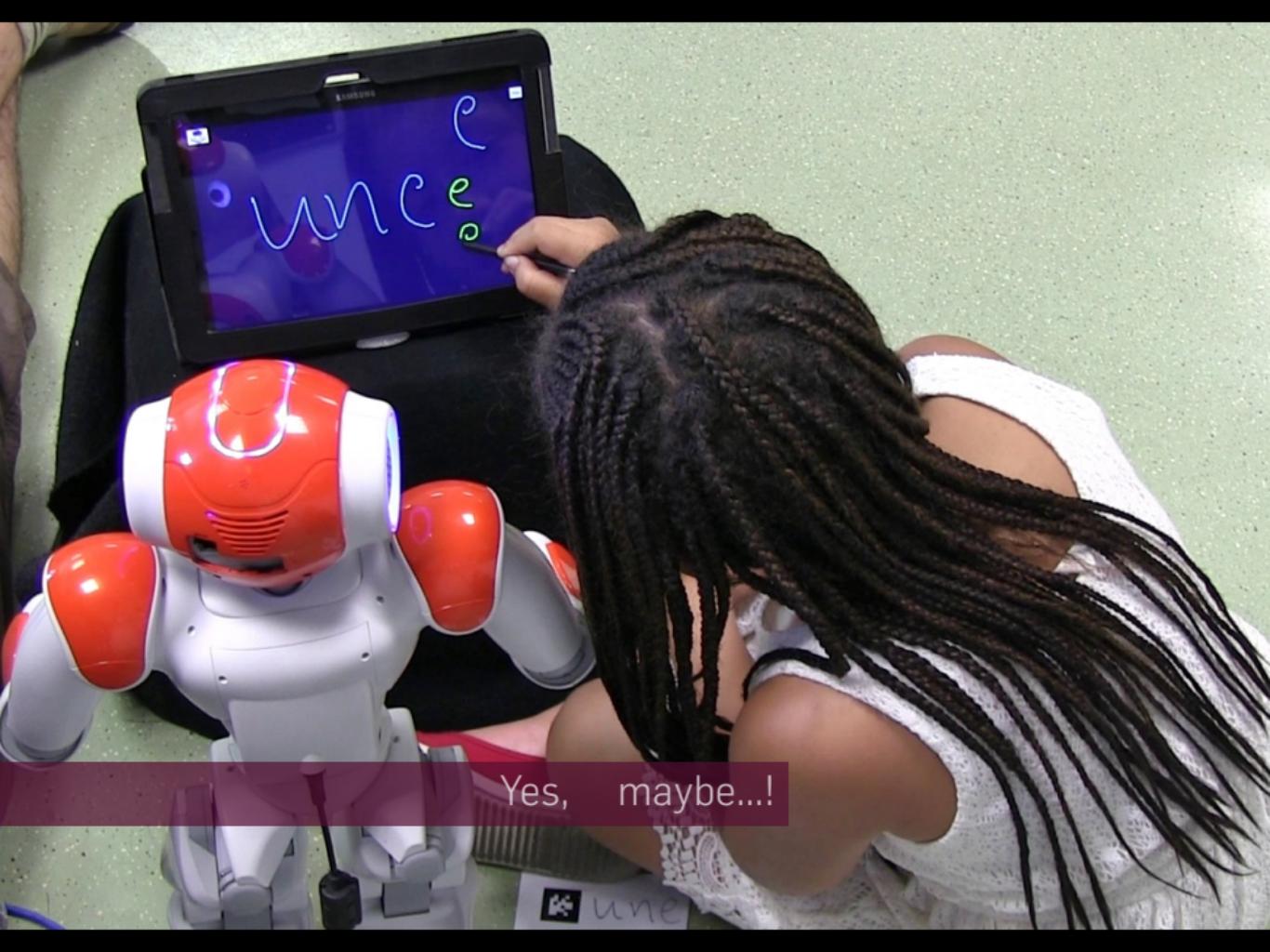


Concept 2: solar system



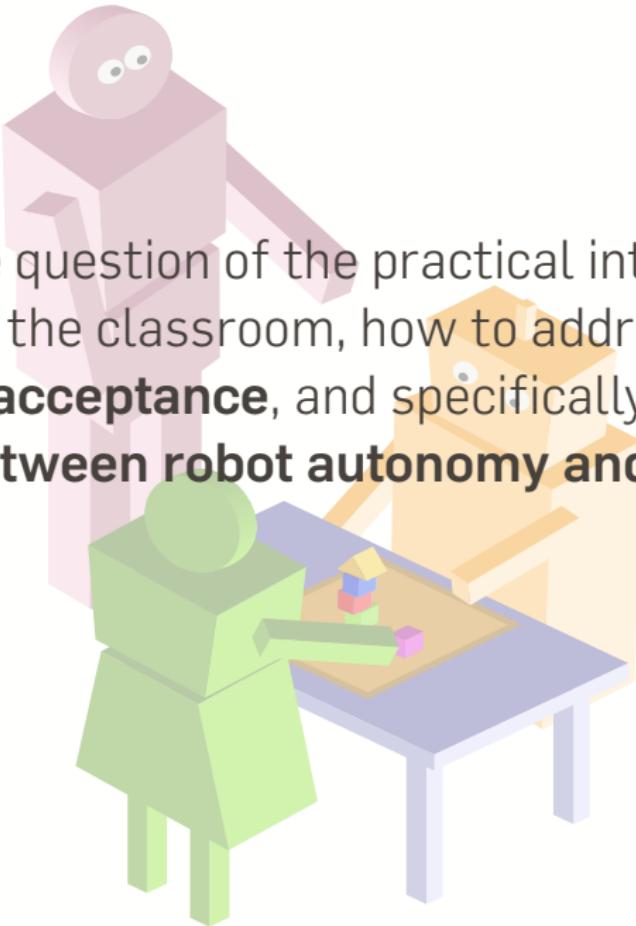


If a “pen-like” robot is actually doable,
...are social robots relevant at all...?



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?**

The classroom

oooooooooooooooooooo

The teacher

oo●oooooooo

The children

oooooooooooo

Assessing the interaction

oooooooooooooooooooo

AUTONOMOUS ROBOT, YET TEACHER IN THE LOOP?



One experiment with:

- a real robot

The classroom

oooooooooooooooooooo

The teacher

oo●oooooooo

The children

oooooooooooo

Assessing the interaction

oooooooooooooooooooo

AUTONOMOUS ROBOT, YET TEACHER IN THE LOOP?



One experiment with:

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

AUTONOMOUS ROBOT, YET TEACHER IN THE LOOP?



One experiment with:

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

AUTONOMOUS ROBOT, YET TEACHER IN THE LOOP?



One experiment with:

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

AUTONOMOUS ROBOT, YET TEACHER IN THE LOOP?

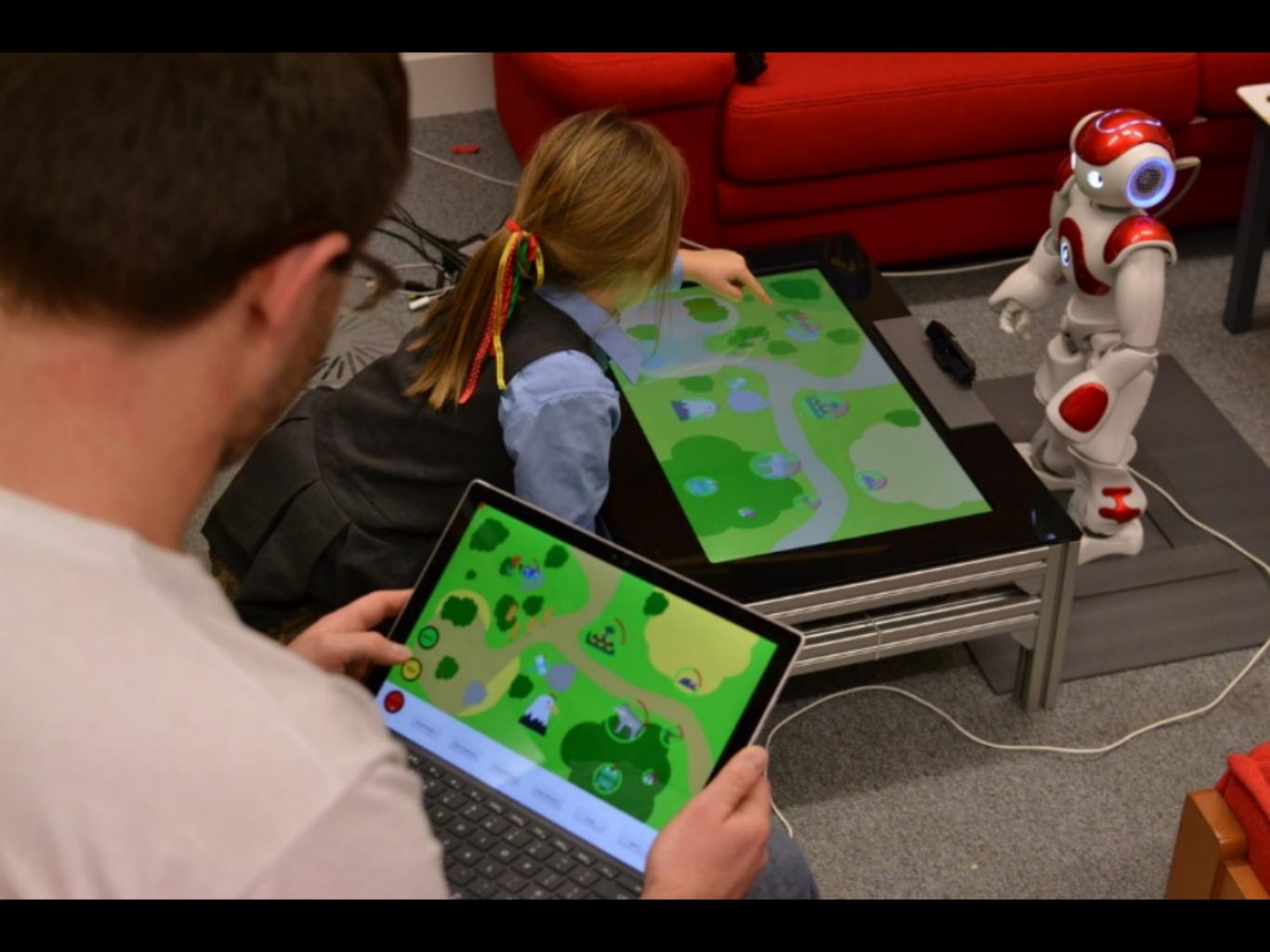
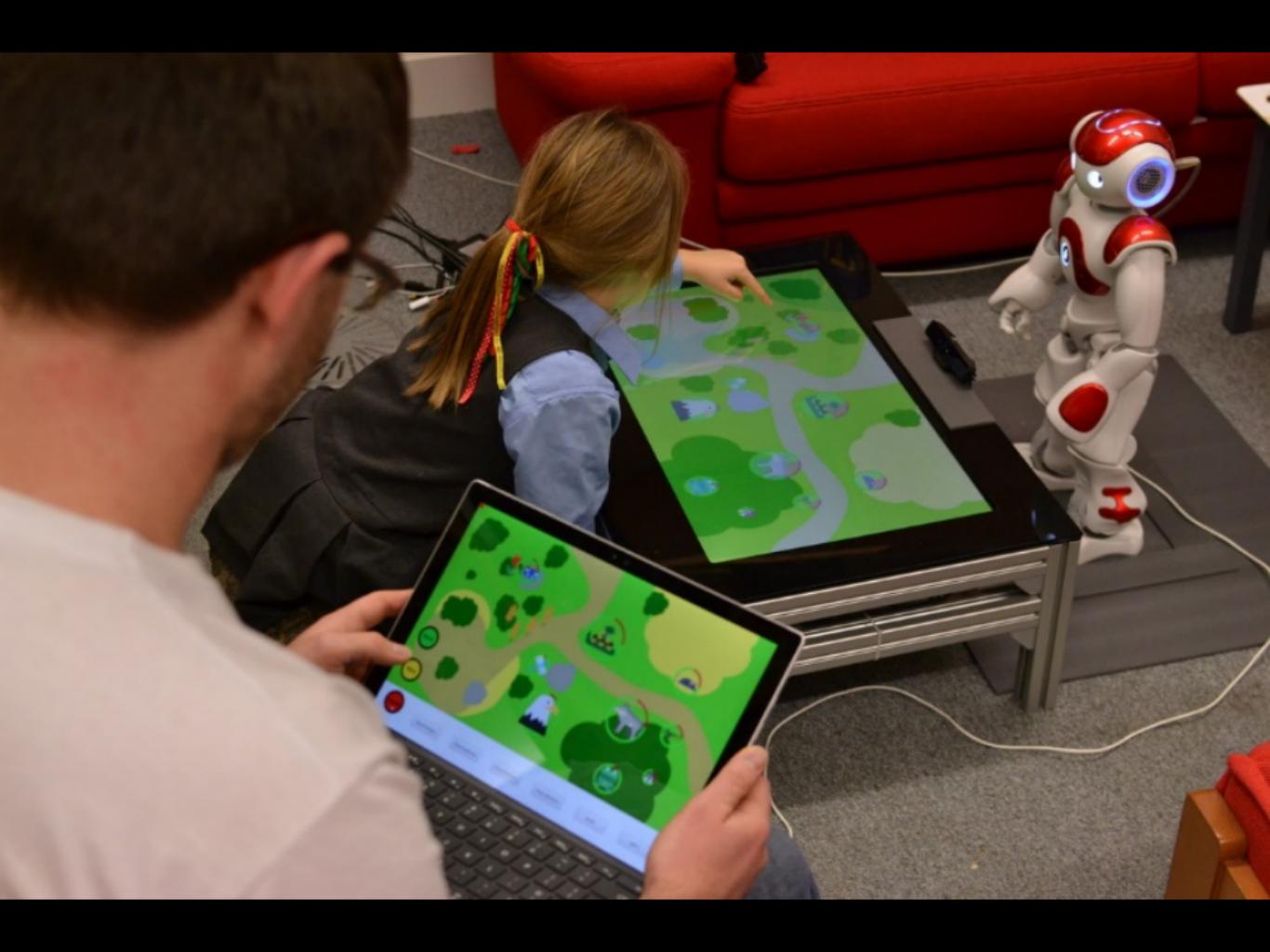


One experiment with:

- 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

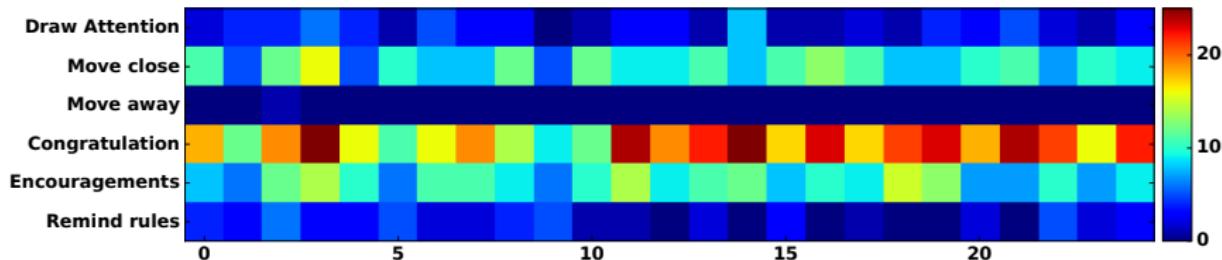


$|state| = 210$ $|action_space| = 655$

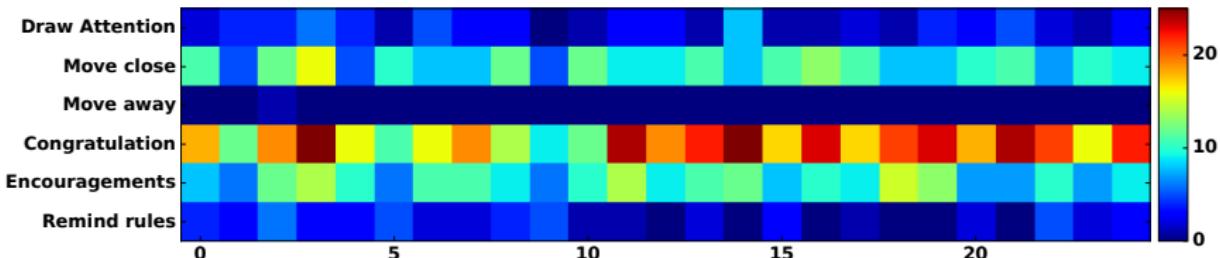




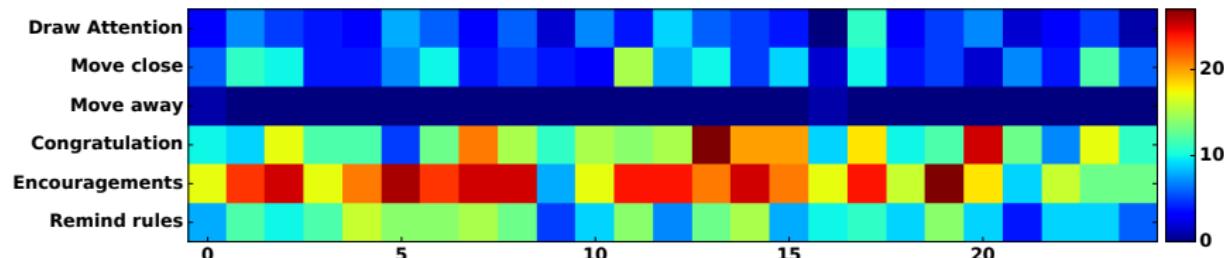
Supervised



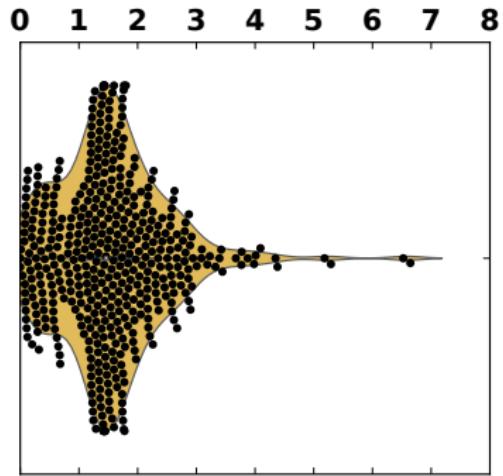
Supervised



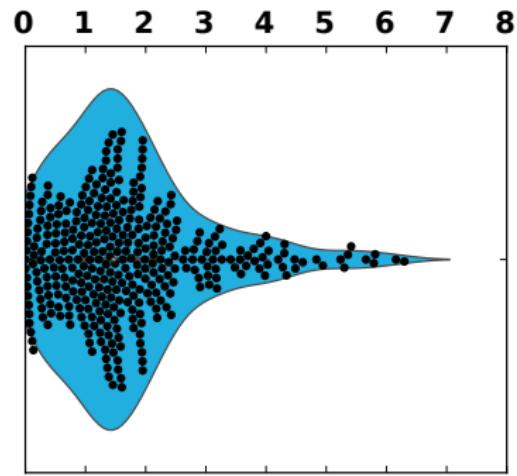
Autonomous



Time since eating event for each congratulation action (s)

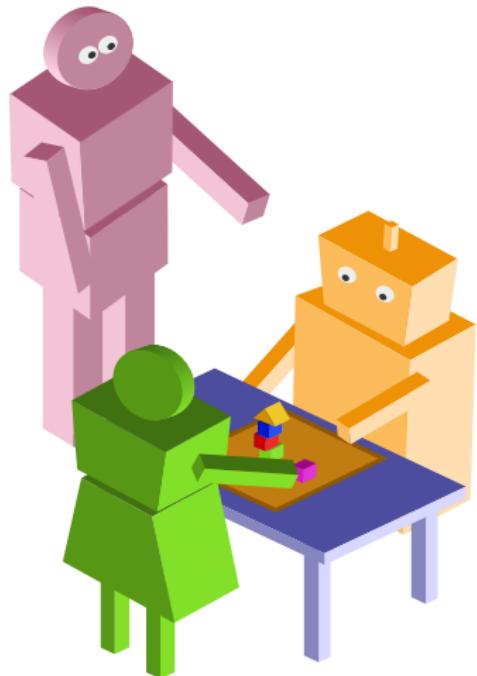


supervised



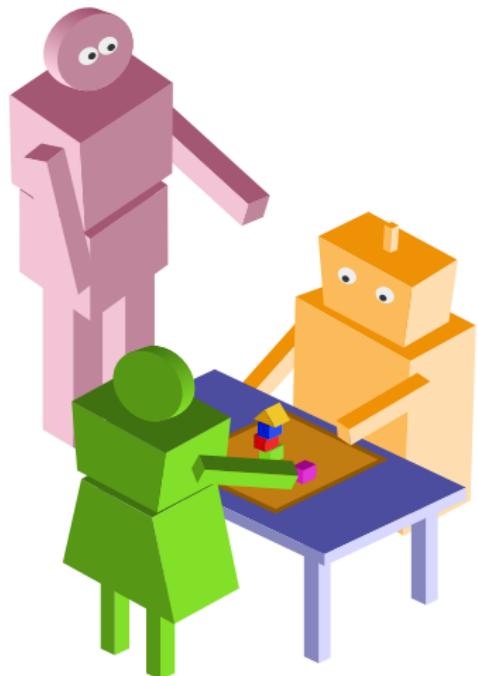
autonomous

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**)

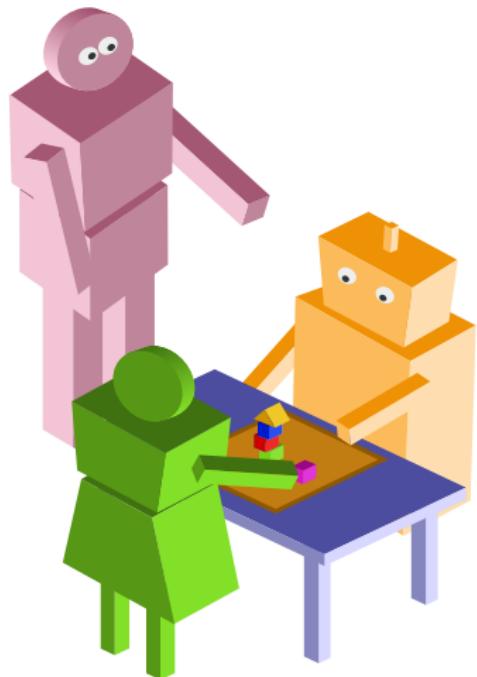
WHAT DOES THAT MEANS FOR THE TEACHER?



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”

The classroom

oooooooooooooooooooo

The teacher

oooooooooooo

The children

○●oooooooooo

Assessing the interaction

oooooooooooooooooooo

SOCIAL OR NOT SOCIAL?

Non-social



Social

The classroom

oooooooooooooooooooo

The teacher

oooooooooooo

The children

○●oooooooooo

Assessing the interaction

oooooooooooooooooooo

SOCIAL OR NOT SOCIAL?

Tool?



Peer/tutor?

Lithuanian
mythica

Diego

Allie



The classroom

oooooooooooooooooooo

The teacher

oooooooooooo

The children

ooo●oooooo

Assessing the interaction

oooooooooooooooooooo

THE COWRITER PROJECT



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

THE COWRITER PROJECT



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

- Robots do not know how to write!

THE COWRITER PROJECT



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

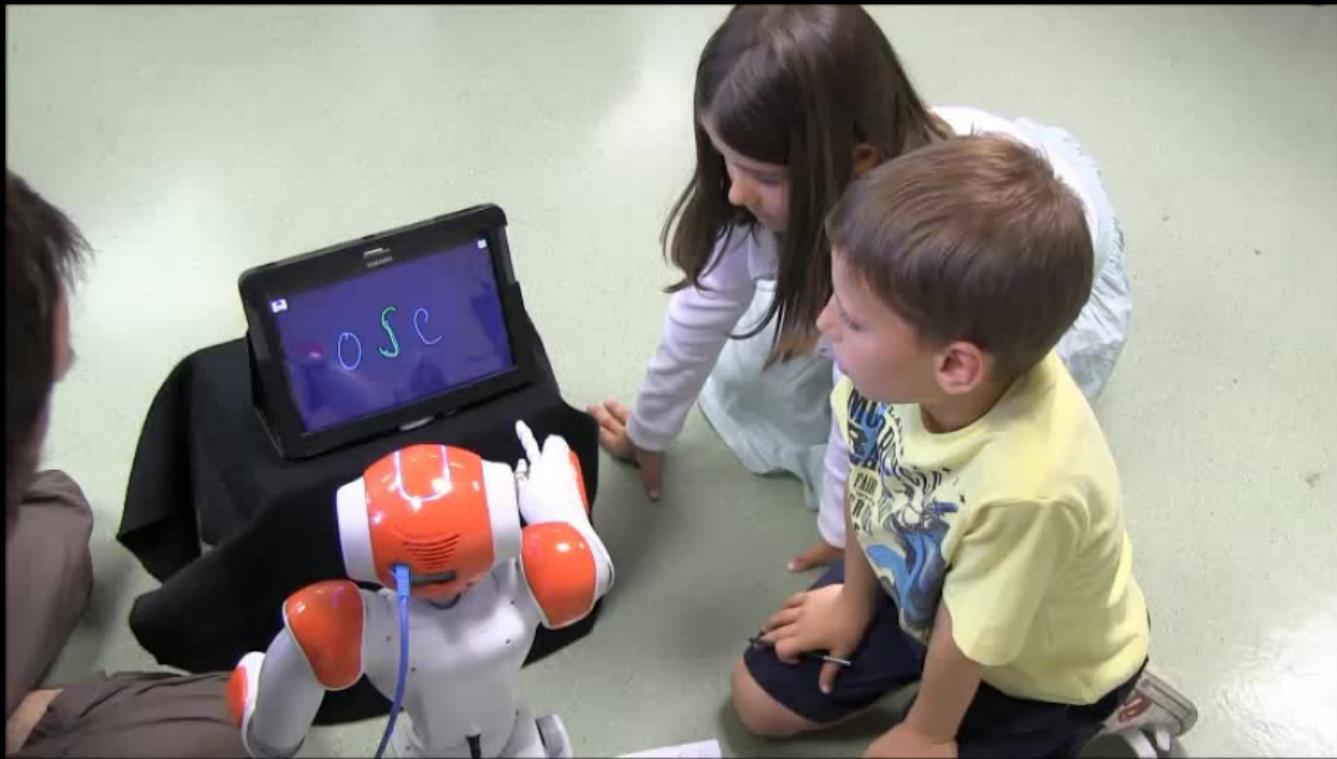
- Robots do not know how to write!
- Learning by Teaching

THE COWRITER PROJECT



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)



LEARNING FROM DEMONSTRATION



J S S J A A

{ S A A A A



Algunas personas
se sienten mejor
cuando se quedan
en casa y no salen
a la calle. Algunas
personas
se quedan en casa
y no salen a la calle.



mystérieuse
Al bâton est bâton
mystérieuse

The classroom

oooooooooooooooooooo

The teacher

oooooooooooo

The children

oooooooo●○○

Assessing the interaction

oooooooooooooooooooo

BEFORE – AFTER



salut mimi
now persons
que c est un
corps
est ce que tu penses
croire des
photos de
la lune

The classroom

oooooooooooooooooooo

The teacher

oooooooooooo

The children

oooooooo●oo

Assessing the interaction

oooooooooooooooooooo

BEFORE – AFTER

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

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



The classroom

oooooooooooooooooo

The teacher

oooooooooooo

The children

oooooooo●○○

Assessing the interaction

oooooooooooooooooooo

BEFORE – AFTER

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

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



The classroom



The teacher



The children



Assessing the interaction



WHAT ROLE DOES THE ROBOT PLAY HERE?

- The robot as 'cognitive agent' is key here (Protégé effect, metacognition)

The classroom

oooooooooooooooooooo

The teacher

oooooooooooo

The children

oooooooo●○

Assessing the interaction

oooooooooooooooooooo

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!)

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?

The classroom



The teacher



The children



Assessing the interaction



A NEW SPACE IN THE MIDDLE OF THE SOCIAL SPECTRUM?



The classroom



The teacher



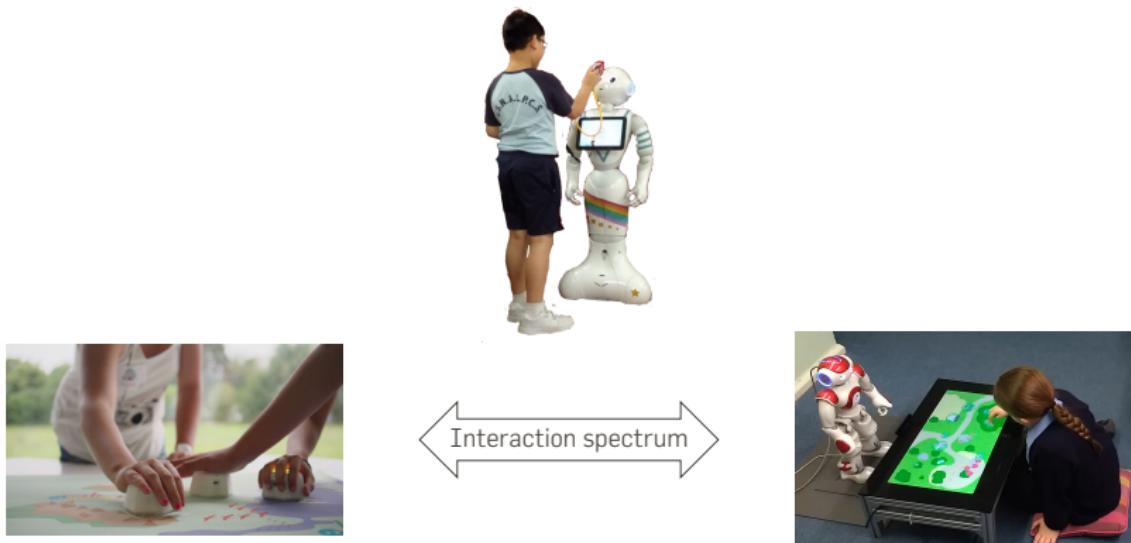
The children



Assessing the interaction



A NEW SPACE IN THE MIDDLE OF THE SOCIAL SPECTRUM?



A NEW SPACE IN THE MIDDLE OF THE SOCIAL SPECTRUM?

Can we take the best of both world?

- purely a tool from the perspective of the teacher
- a (somewhat?) social agent from the perspective of the child
→ engagement, learning of social behaviours, etc

ASSESSING THE INTERACTION

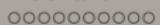
The classroom



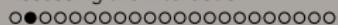
The teacher



The children



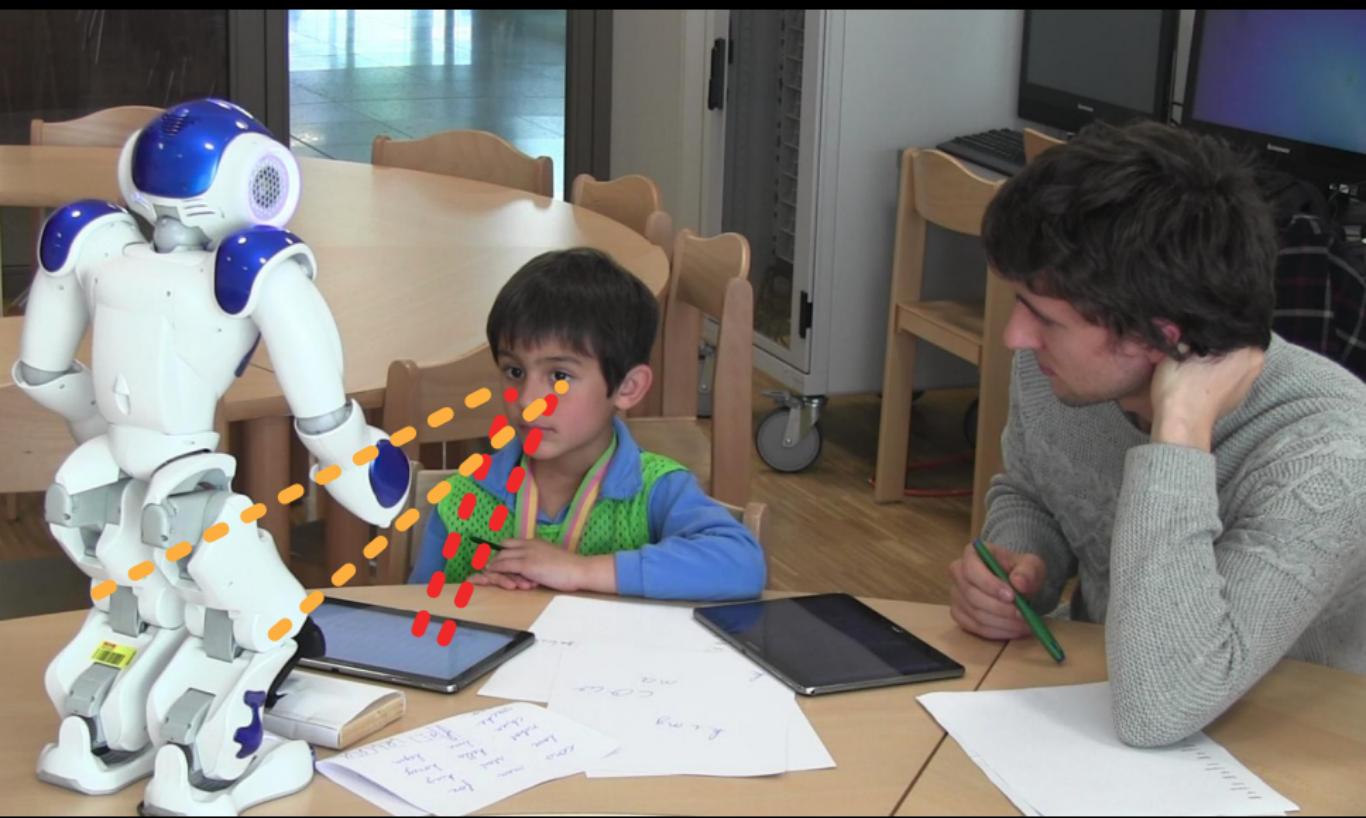
Assessing the interaction



IS THE CHILD ENGAGING WITH THE ACTIVITY?

“With-me-ness”: real-time estimation of surface engagement

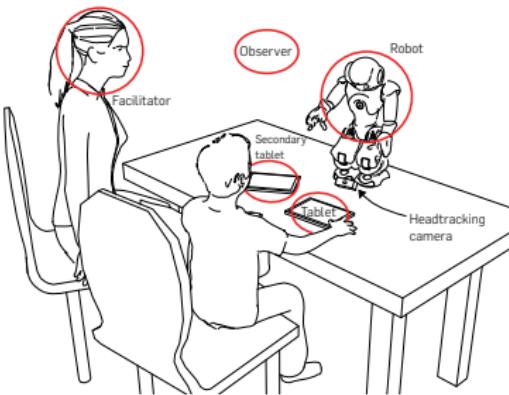


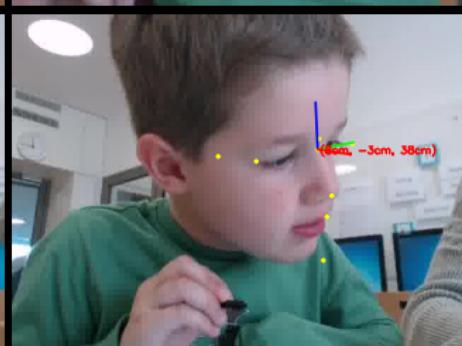
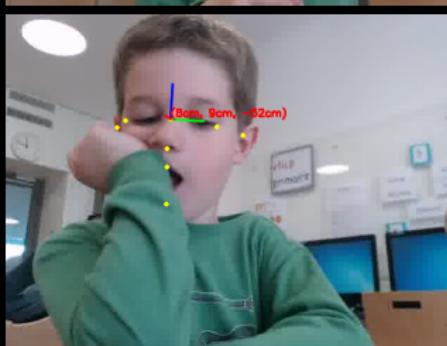
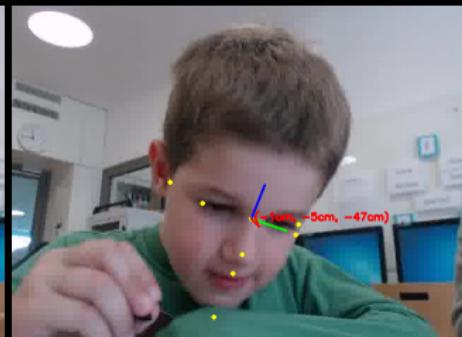


EXPECTED FOCUS

Example for the CoWriter task:

Interaction Phase	Expected targets
Presentation	robot
Waiting for word	secondary tablet
Writing word	tablet robot
Waiting for feedback	tablet secondary tablet
Story telling	robot
Bye	robot





The classroom

oooooooooooooooooooo

The teacher

oooooooooooo

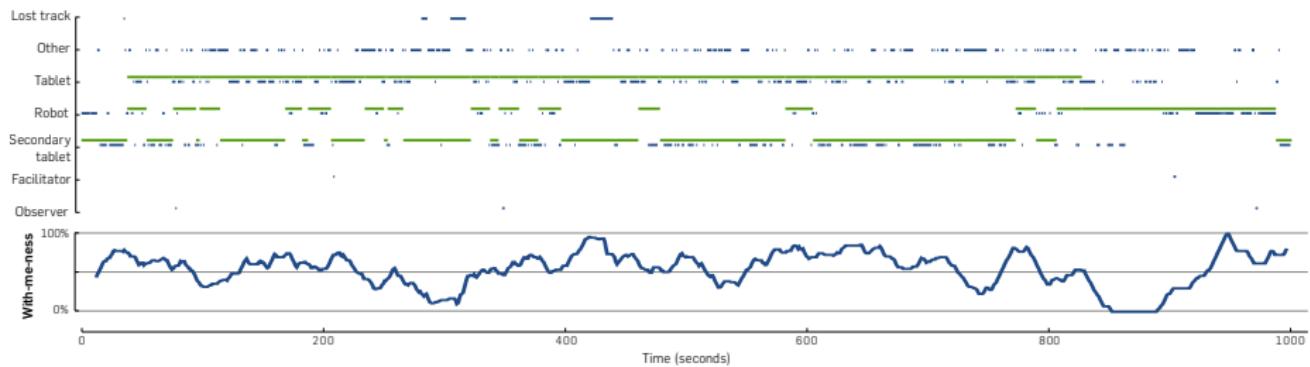
The children

oooooooooooo

Assessing the interaction

oooooooo●oooooooooooo

WITH-ME-NESS



Can we make one step further to understand what's going on when we interact?

Can we make one step further to understand what's going on when we interact?

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

- entrainment (coupling),
- mimicry,
- implicit turn-taking,
- joint attention
- ...and others

Can we make one step further to understand what's going on when we interact?

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

- entrainment (coupling),
- mimicry,
- implicit turn-taking,
- joint attention
- ...and others

Let's observe them!

The classroom

oooooooooooooooooooo

The teacher

oooooooooooo

The children

oooooooooooo

Assessing the interaction

oooooooo●oooooooooooo

FREE PLAY

“Just play! Enjoy yourselves!”

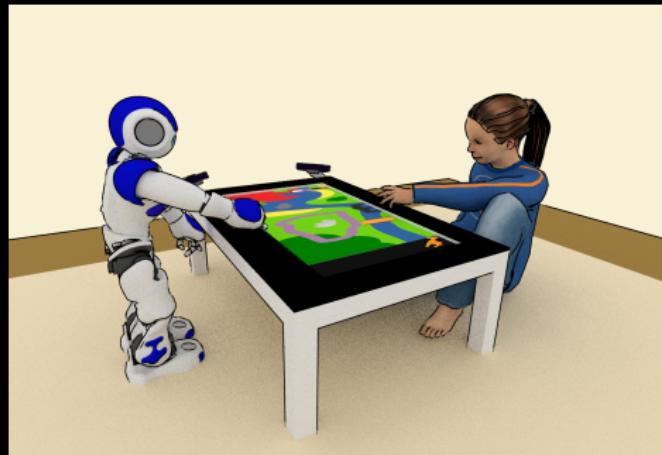
- **rich set of cognitive and social dynamics;** importance of motivation/drive; **uncertain and unexpected situations**
- what is the right action policy? Focus instead on the **social policy**

FREE PLAY

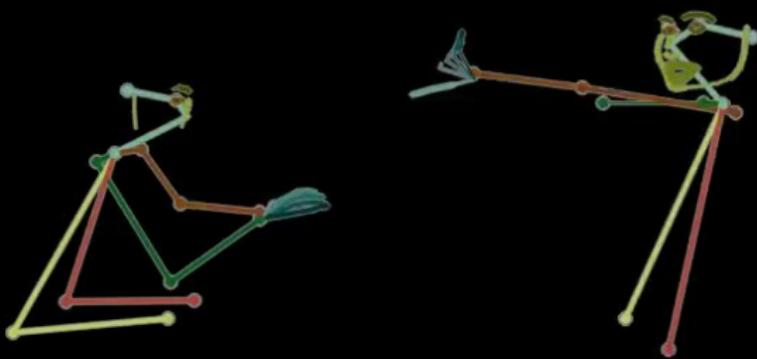
“Just play! Enjoy yourselves!”

- **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**

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









The classroom

oooooooooooooooooooo

The teacher

oooooooooooo

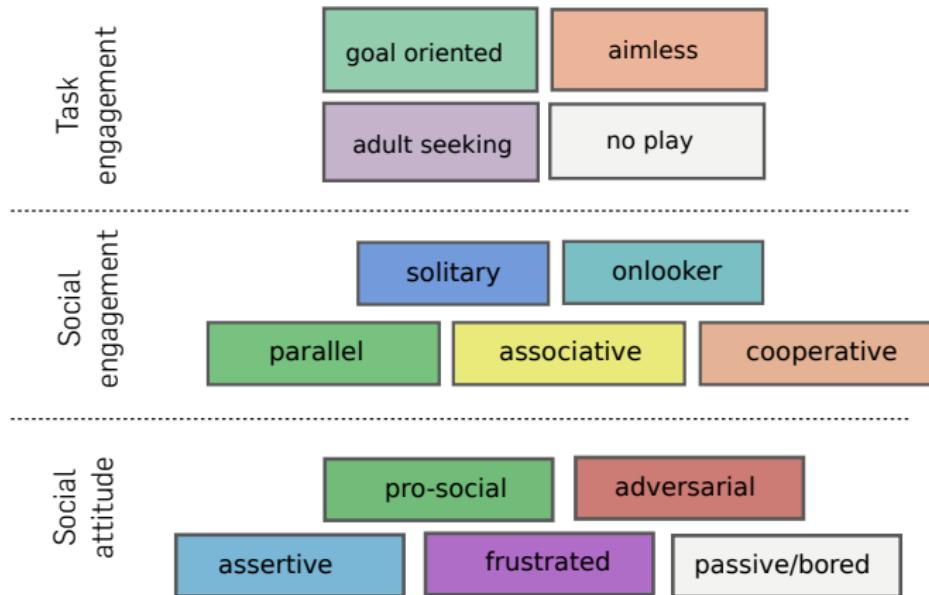
The children

oooooooooooo

Assessing the interaction

oooooooooooooooooooo●oooooooooooo

13000+ ANNOTATIONS



Attitude: passive

Social engag.: onlooker

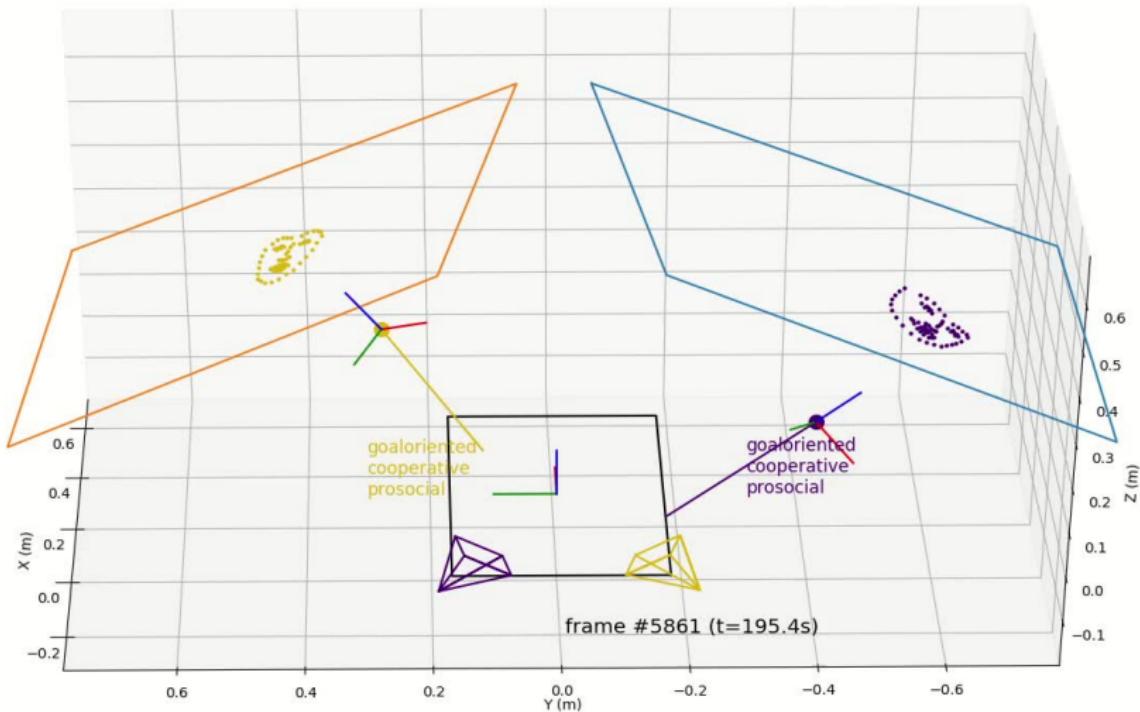
Task engag.: no play

Attitude: passive

Social engag.: solitary

Task engag.: goal oriented







Page 1 of 4.

How much do you agree with the following statements?

The children were competing with one another.

Strongly Disagree

Disagree

Not Sure

Agree

Strongly Agree

200 participants

The child on the left was sad.

Strongly Disagree

Disagree

Not Sure

Agree

Strongly Agree

	pptID	condition	age	gender	leftSad	rightSad	leftHappy	rightHappy	leftAngry	rightAngry	...	leftDistracted	rightDistracted	leftBored	rightBored
0	186	2	30	Female	1	1	4	4	2	1	...	2	2	1	2
1	186	2	30	Female	3	4	2	2	3	3	...	3	4	3	3
2	186	2	30	Female	3	4	2	2	2	2	...	3	4	3	3
3	186	2	30	Female	3	3	2	3	2	3	...	3	4	3	3
4	94	1	23	Male	1	1	3	3	1	1	...	1	1	2	1
5	94	1	23	Male	1	1	2	2	1	3	...	1	0	1	1
6	94	1	23	Male	2	1	2	2	1	1	...	4	1	4	1
7	94	1	23	Male	1	1	3	3	1	1	...	1	1	1	1
8	155	2	28	Male	0	2	1	1	4	3	...	0	4	3	2
9	155	2	28	Male	0	3	0	0	3	0	...	3	0	4	1
10	155	2	28	Male	3	0	4	2	2	0	...	0	4	4	1
11	155	2	28	Male	0	3	4	4	3	2	...	2	4	2	0
12	156	2	29	Female	0	0	3	3	0	0	...	0	0	0	0
13	156	2	29	Female	1	3	1	1	1	3	...	0	0	0	0
14	156	2	29	Female	0	0	4	4	0	0	...	3	0	0	0
15	156	2	29	Female	0	2	3	2	0	0	...	3	0	0	0
16	157	2	31	Male	0	0	4	3	0	1	...	0	1	0	1
17	157	2	31	Male	0	0	3	2	0	0	...	0	1	1	1
18	157	2	31	Male	1	0	2	3	0	0	...	0	1	0	1
19	157	2	31	Male	1	1	3	2	1	1	...	1	3	1	0

The classroom

oooooooooooooooooooo

The teacher

oooooooooooo

The children

oooooooooooo

Assessing the interaction

oooooooooooooooooooo●ooo

THREE CONSTRUCTS TO RULE THEM ALL



Interaction imbalance

Interaction valence

Engagement

The classroom

oooooooooooooooooooo

The teacher

oooooooooooo

The children

oooooooooooo

Assessing the interaction

oooooooooooooooooooo●oo

OUR GOAL

Real-time identification by the robot of...

- the **task engagement**
is my partner 'on task' or not?

The classroom

oooooooooooooooooooo

The teacher

oooooooooooo

The children

oooooooooooo

Assessing the interaction

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OUR GOAL

Real-time identification by the robot of...

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is my partner 'on task' or not?
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Social behaviours; Social dynamics: **generation as well!**

The classroom

oooooooooooooooooooo

The teacher

oooooooooooo

The children

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Assessing the interaction

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IN CONCLUSION

- Not only 'child-robot interaction for learning', but also 'classroom-robot interaction': importance of orchestration



The classroom

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The teacher

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The children

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Assessing the interaction

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IN CONCLUSION

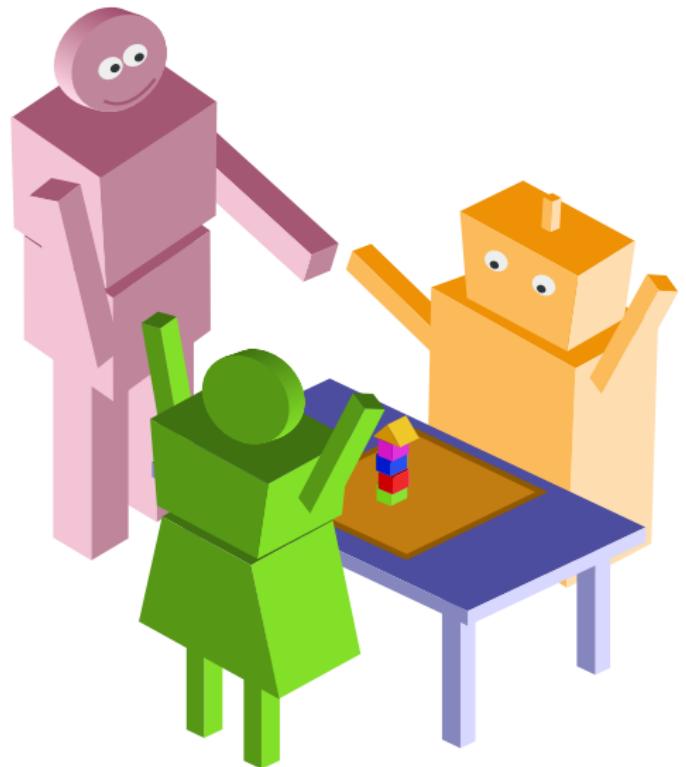


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IN CONCLUSION



- Not only 'child-robot interaction for learning', but also 'classroom-robot interaction': importance of orchestration
- Right balance *tool-social robot?*
- Role of the teacher? *Supervised autonomy* looks like a possible direction.
- *Doing together* with the child will require a better understanding of the social dynamics. Machine learning to the rescue?



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*
Shiarlis et al. **Acquiring Social Interaction Behaviours for Telepresence Robots via Deep Learning from Demonstration**, IROS 2017

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Shiarlis et al. **Acquiring Social Interaction Behaviours for Telepresence Robots via Deep Learning from Demonstration**, IROS 2017

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

The classroom

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The teacher

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The children

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Assessing the interaction

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DEEP NETWORKS \equiv BLACK BOXES?

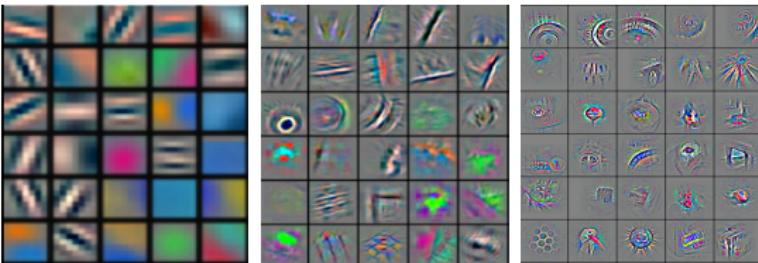


→
Low-Level
features

→
Mid-Level
features

→
High-Level
features

→
Trainable
classifier



The classroom

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The teacher

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The children

oooooooooooo

Assessing the interaction

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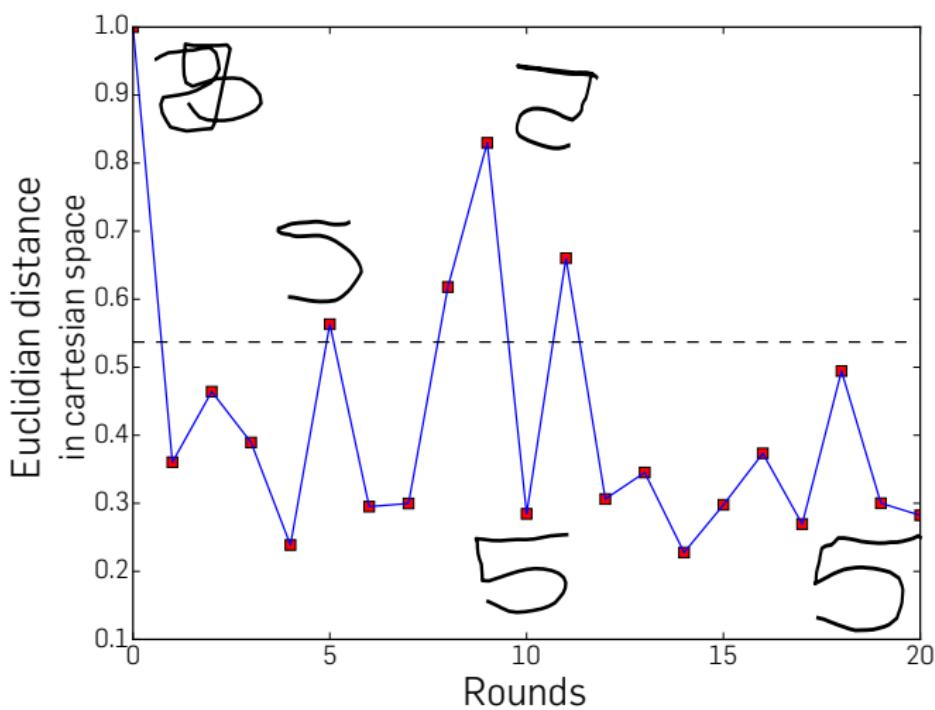
DEEP NETWORKS ≡ BLACK BOXES?



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

LEARNING TO DRAW A 5

EPFL



The classroom

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The teacher

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The children

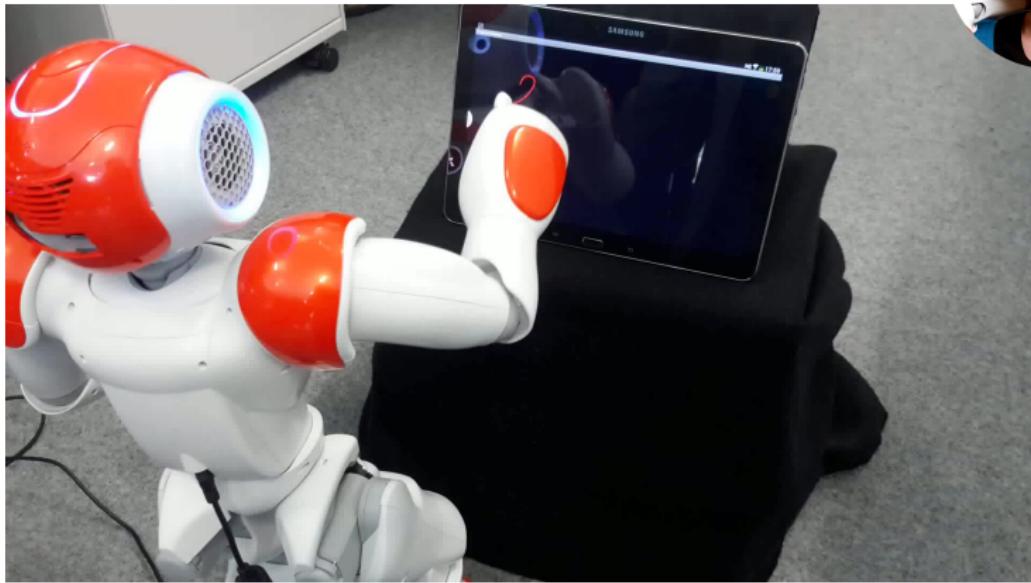
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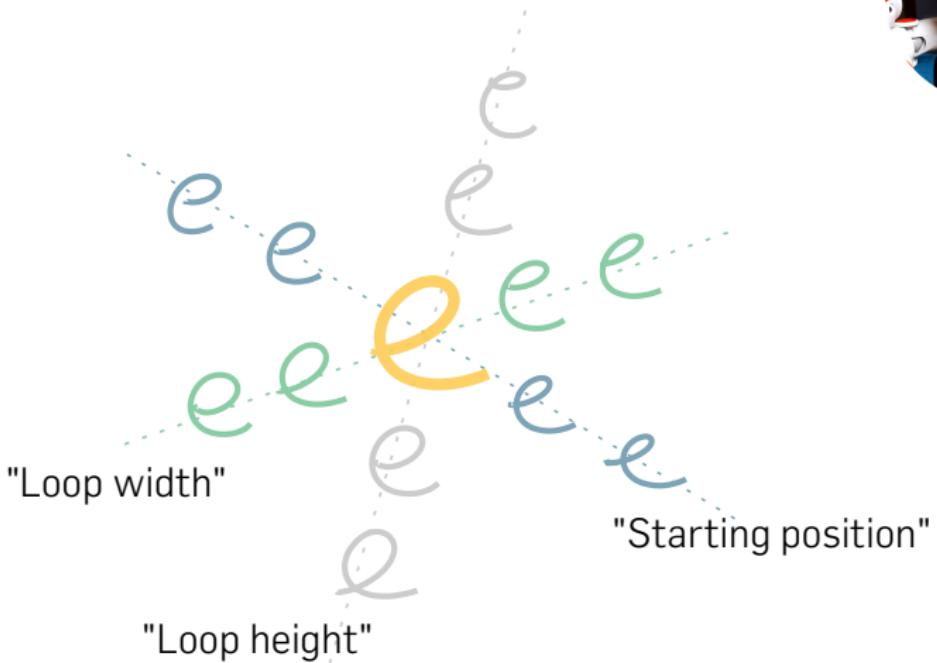
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COWRITER IMPLEMENTATION

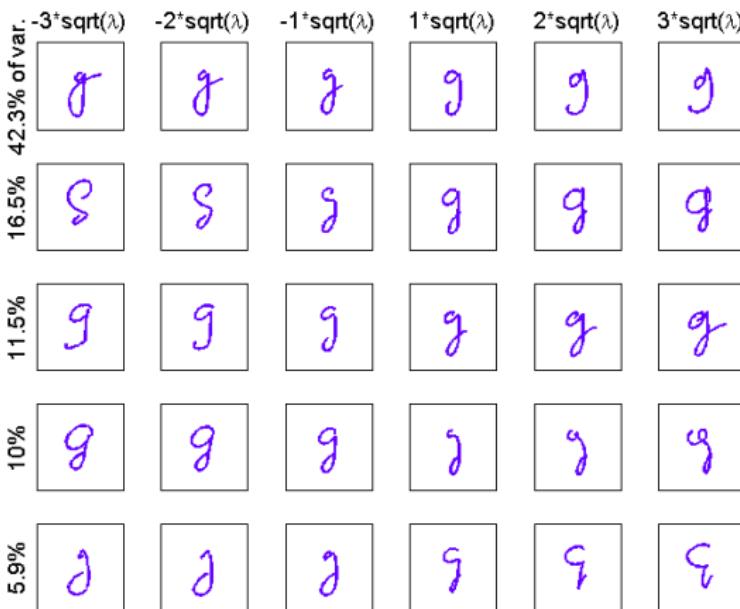
EPFL



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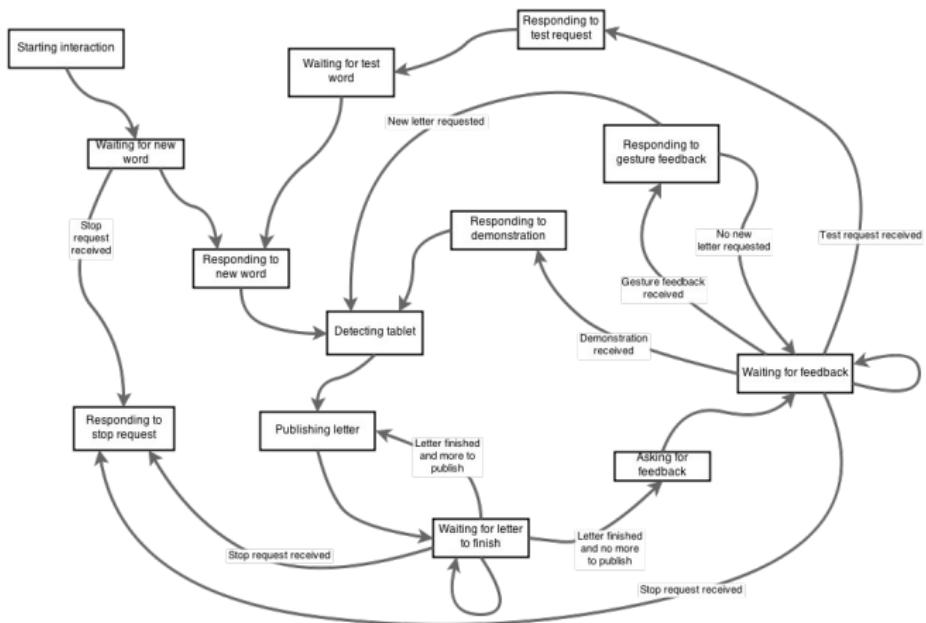


COWRITER IMPLEMENTATION



J S S J A A

S S A A A A



The classroom

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The teacher

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The children

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Assessing the interaction

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INTERACTION WITH THE PAPER



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

The classroom

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The teacher

oooooooooooo

The children

oooooooooooo

Assessing the interaction

oooooooooooooooooooo

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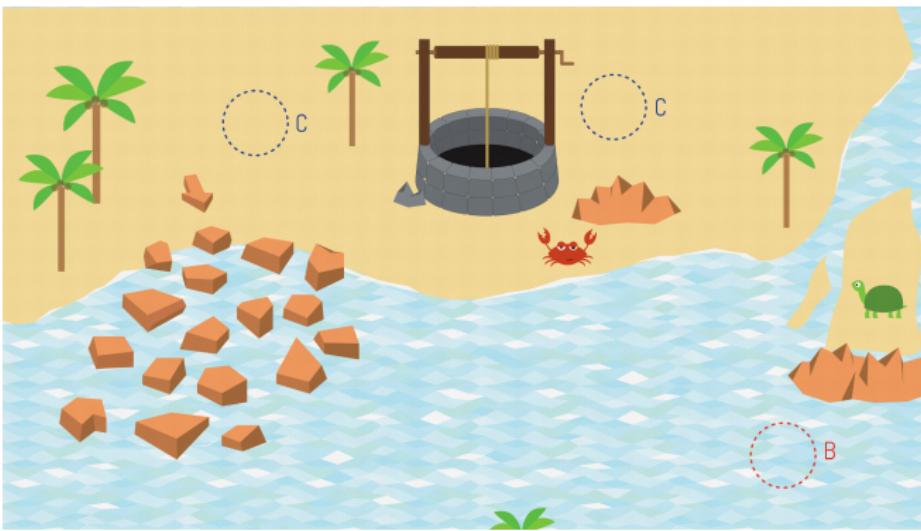
Achieved through a **paper-based absolute localisation system**

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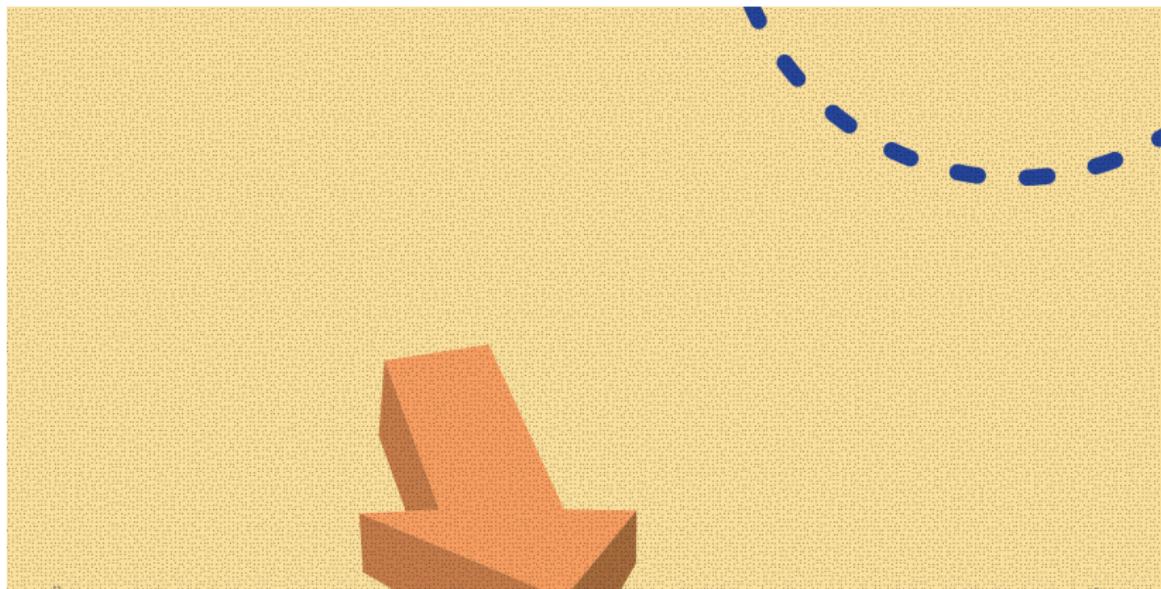


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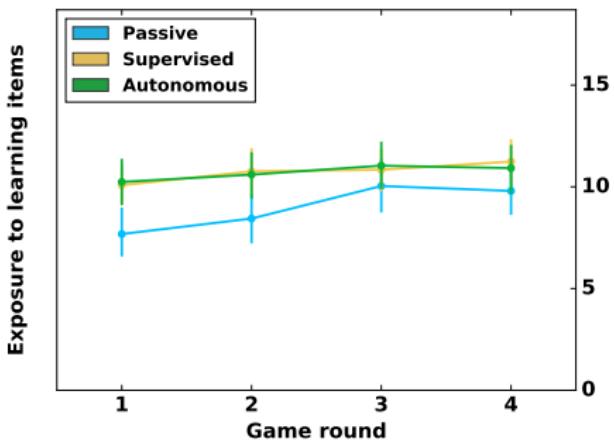
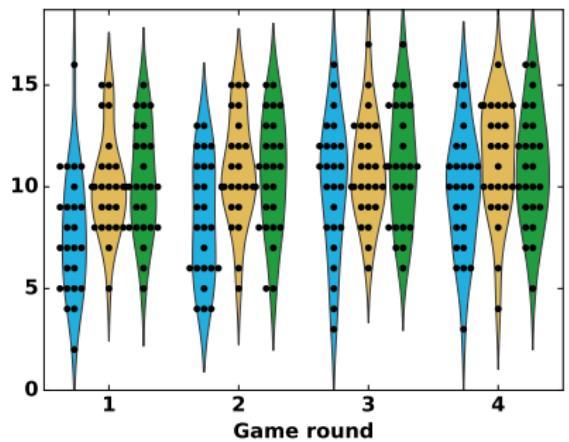
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- even more than 'classroom-friendly', paper is 'teacher-friendly'
- easy to manipulate, copy, print, cutout, dispose...
- unique activity IDs: drop the robots onto the sheet, it recognizes the activity



Learning-related game actions

The classroom

oooooooooooooooooooo

The teacher

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The children

oooooooooooo

Assessing the interaction

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WHAT DID WE RECORD?

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