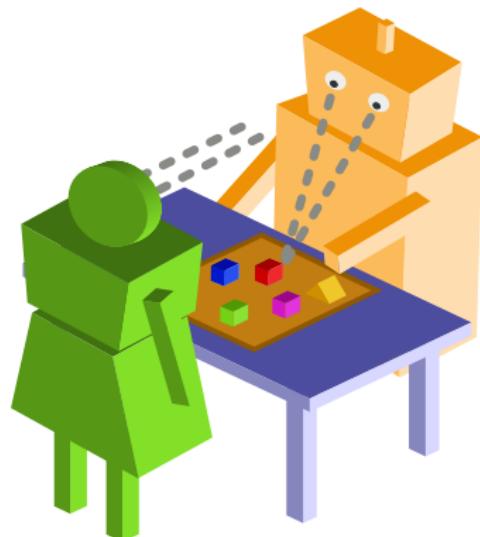




child-robot interaction for learning

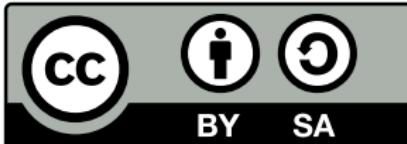
are we ready yet to push the classroom's door?

Robot4SEN – 05 Jul. 2019



Séverin Lemaignan @skadge

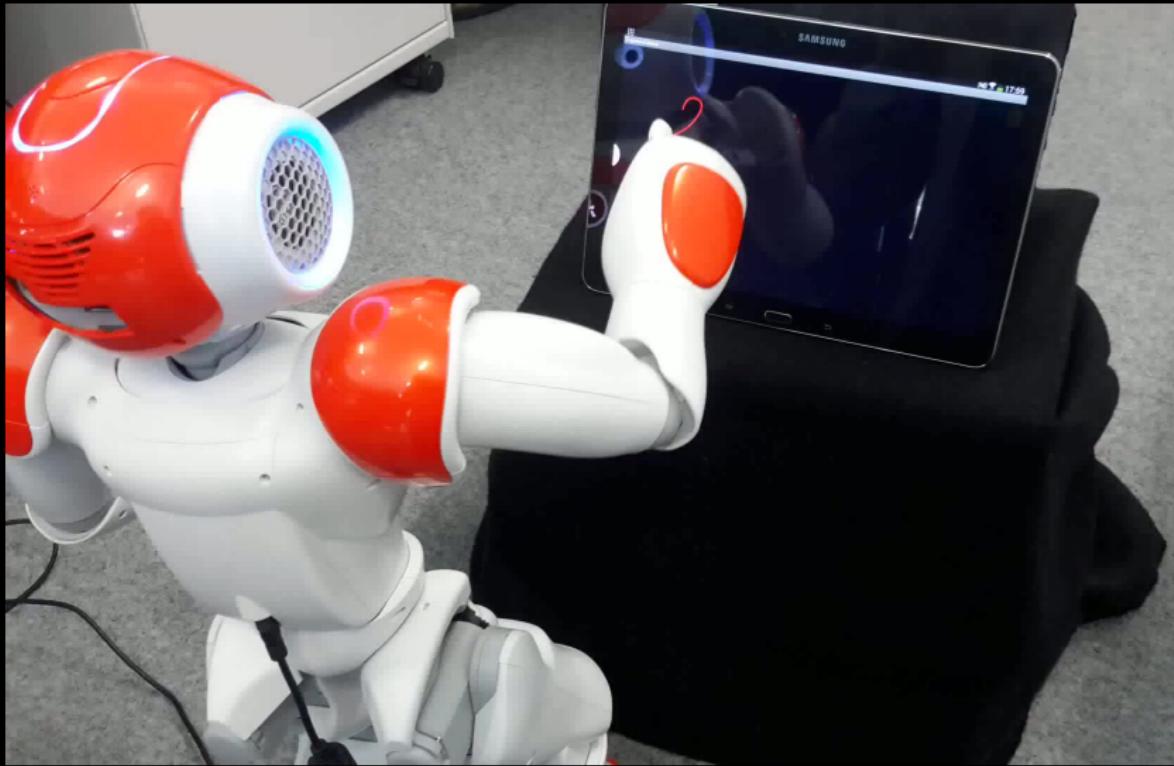
Bristol Robotics Lab University of the West of England



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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

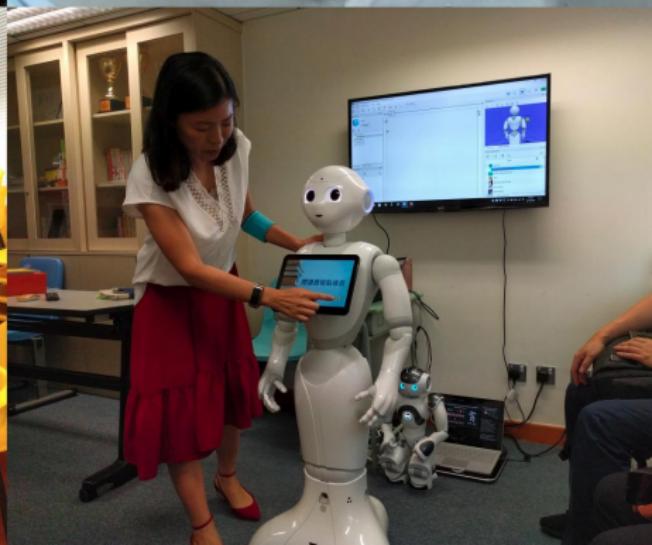




What about some maths now?

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

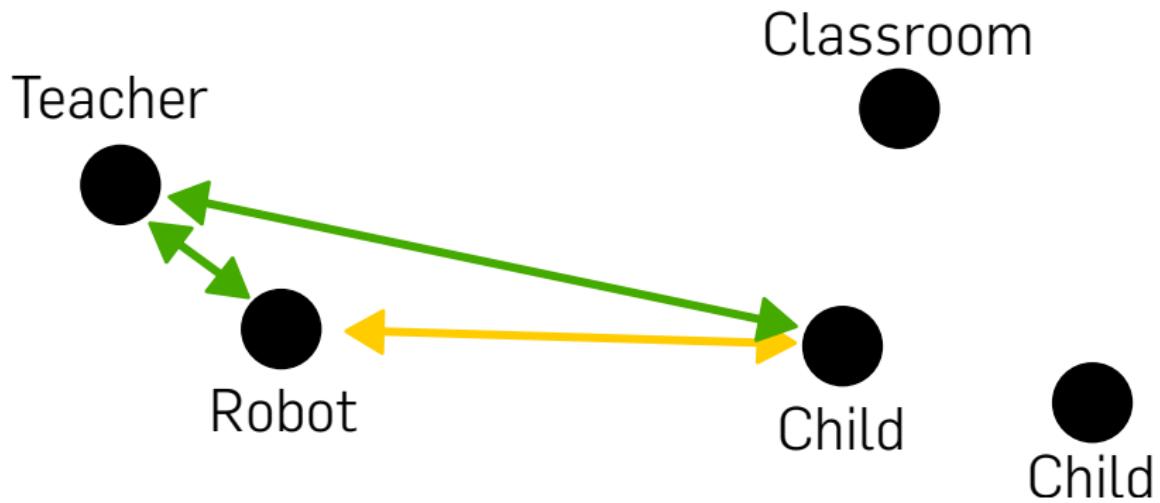


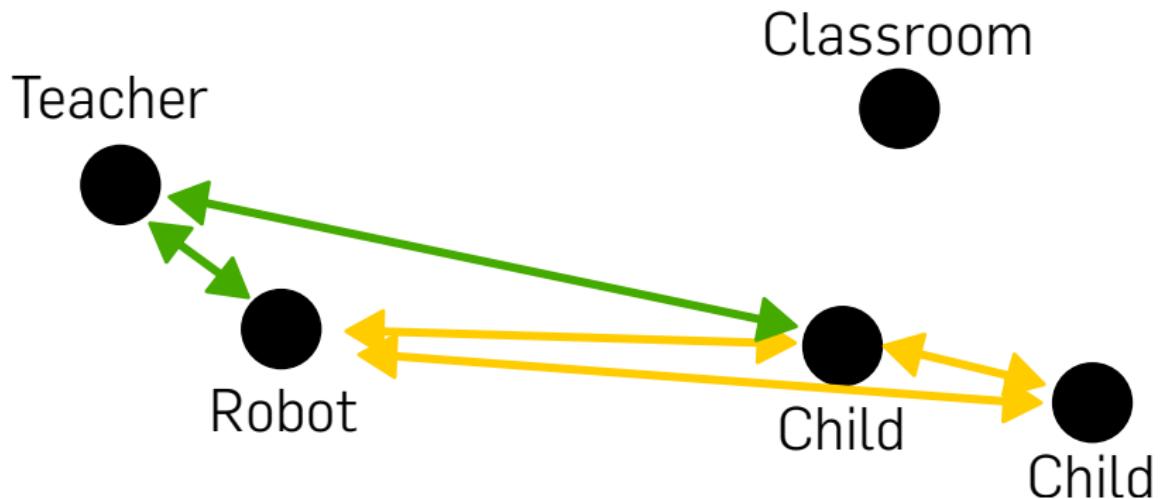
Robot

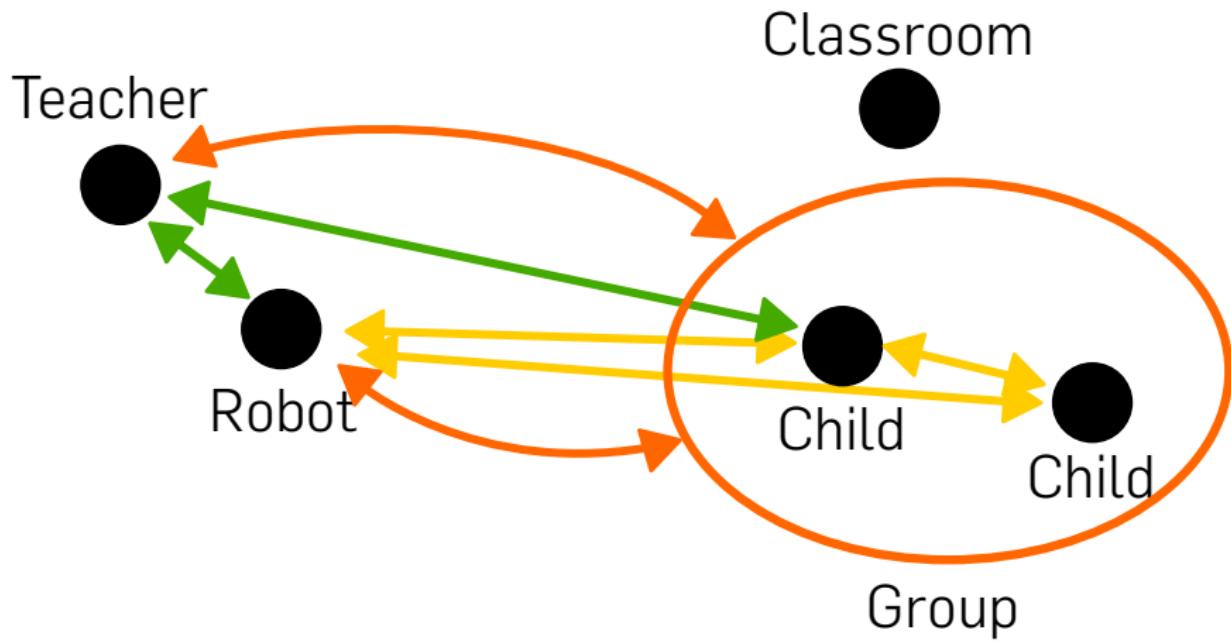


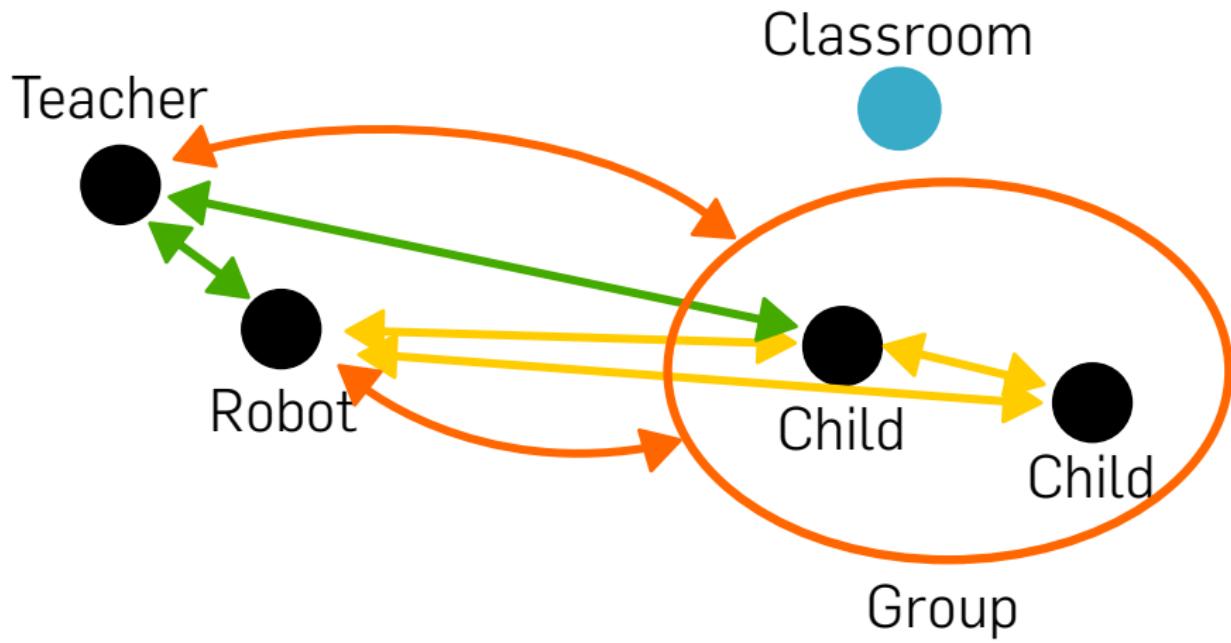
Child

Child









THE CLASSROOM

What is the most effective learning tool in a classroom?



The classroom



The teacher



The children



Assessing the interaction



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)

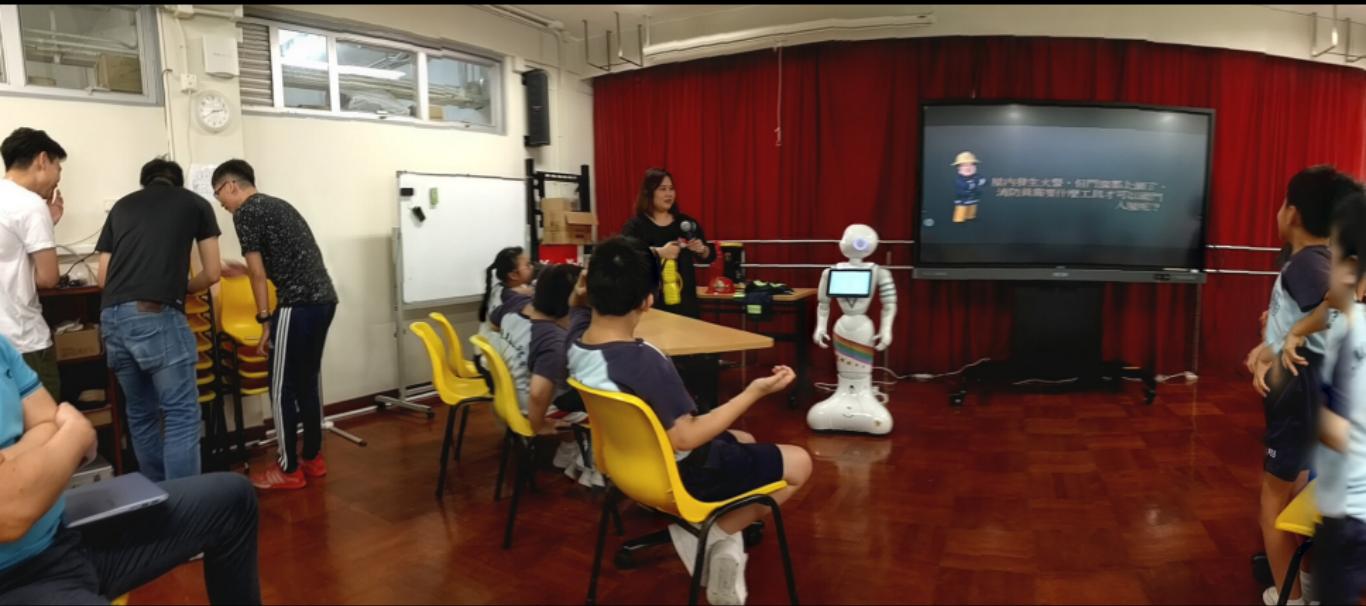
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- **versatile:** applicable to a broad range of learning scenarios; good tools are not overly specialised (appearance and interaction modalities do not imply or force a specific/unique use case)
- **effective:** to gain broad acceptance in a classroom,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



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)

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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

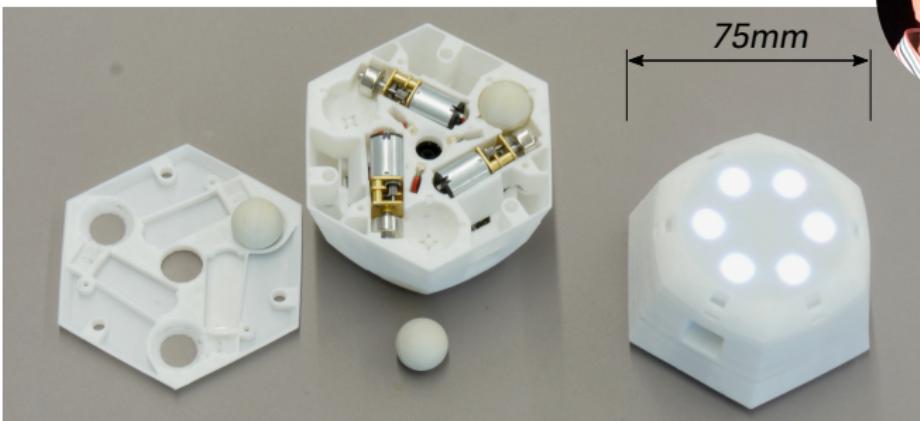
oooooooooooo

Assessing the interaction

oooooooooooooooooooooooooooo

CELLULO: HARDWARE

EPFL



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

The classroom

oooooooooooo●oooooooo

The teacher

oooooooooooo

The children

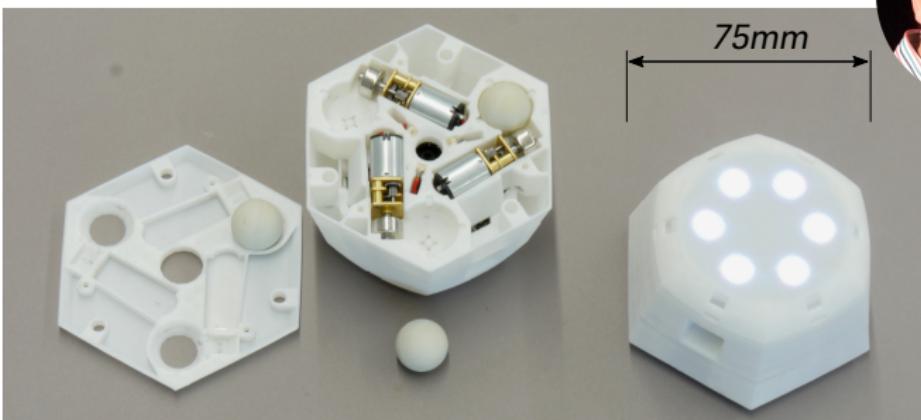
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Assessing the interaction

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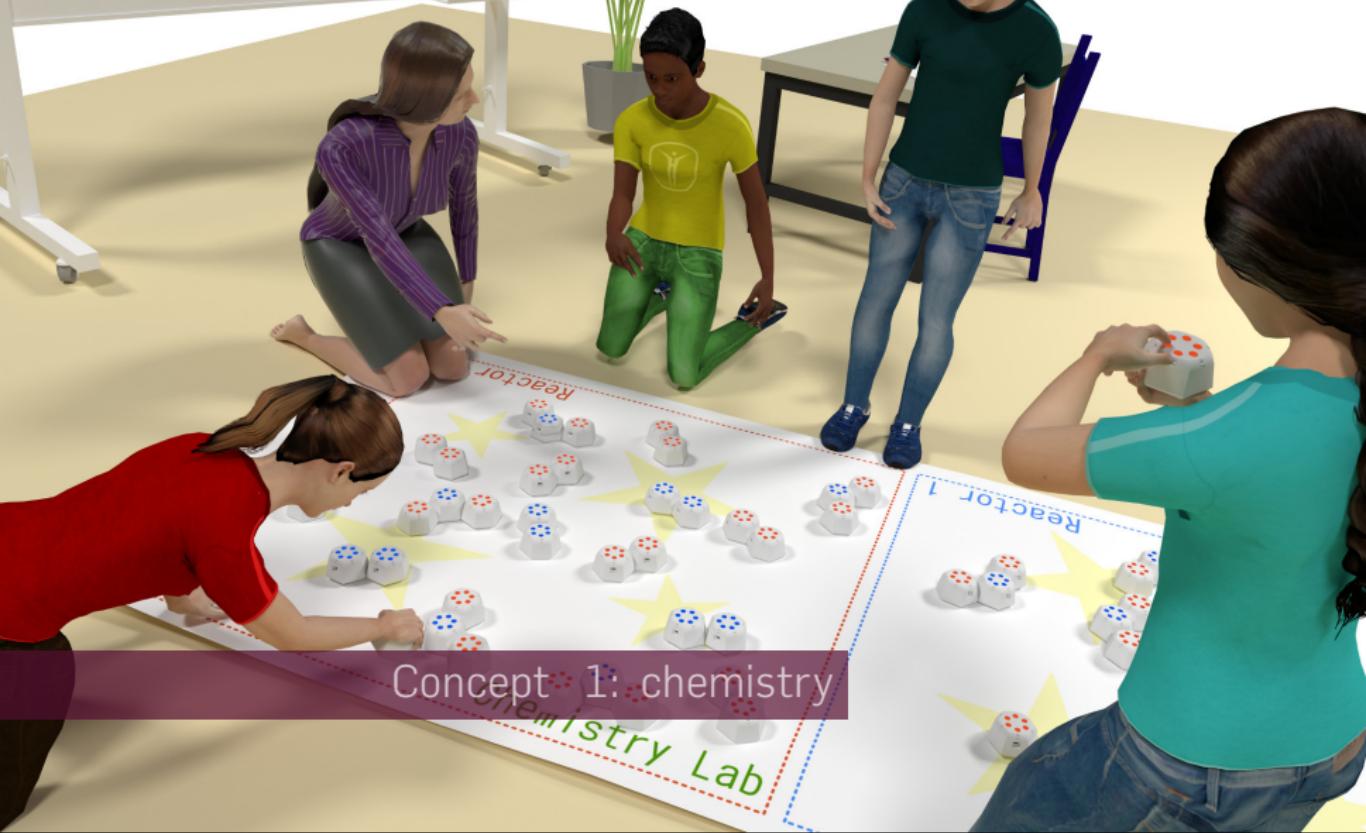
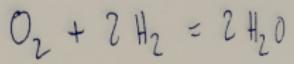
CELLULO: HARDWARE

EPFL

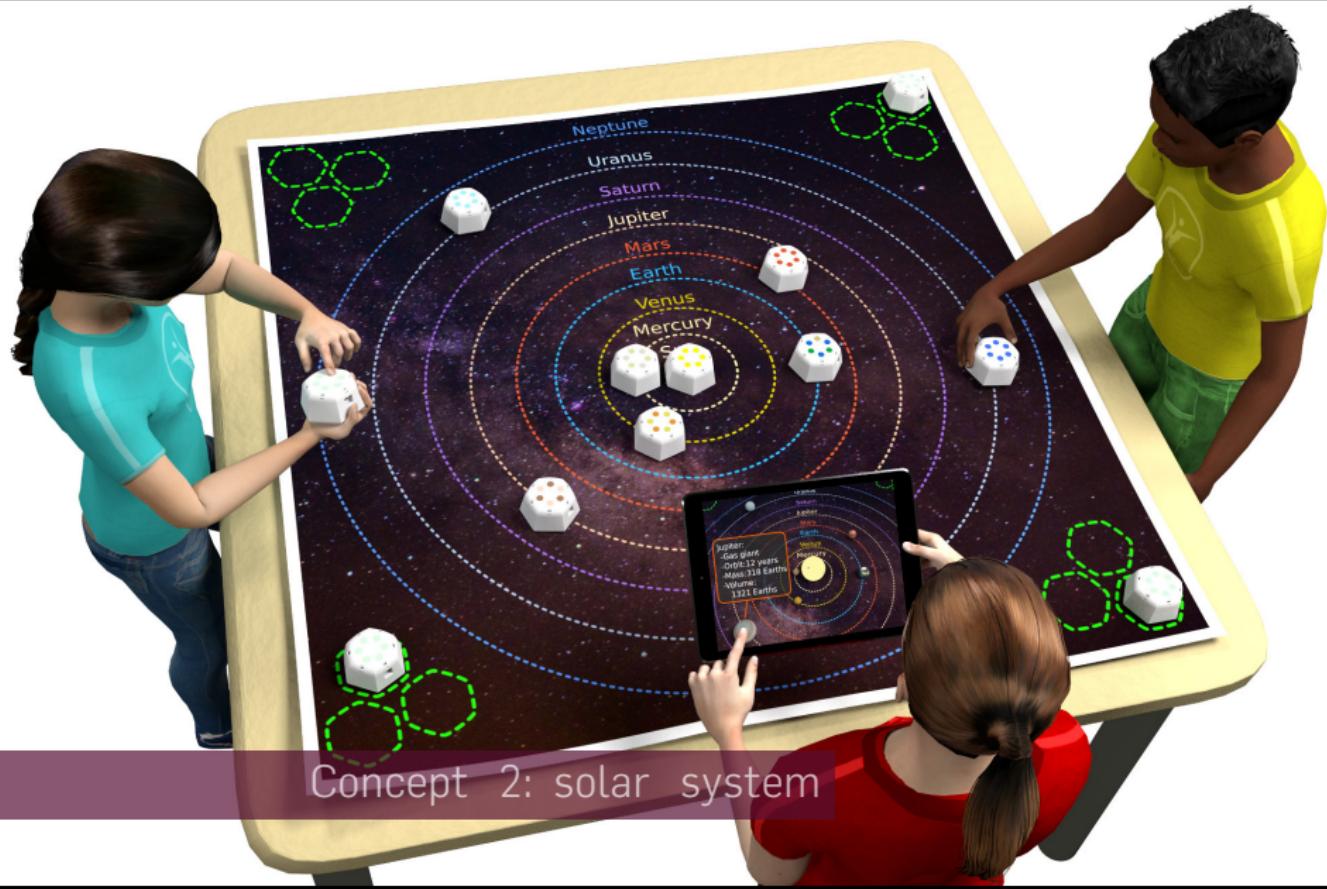


- Holonomic motion
- Sub-mm absolute localisation (no external hardware)
- Haptic feedback + tactile RGB LED buttons
- Bluetooth
- Affordable (prototype: €125)



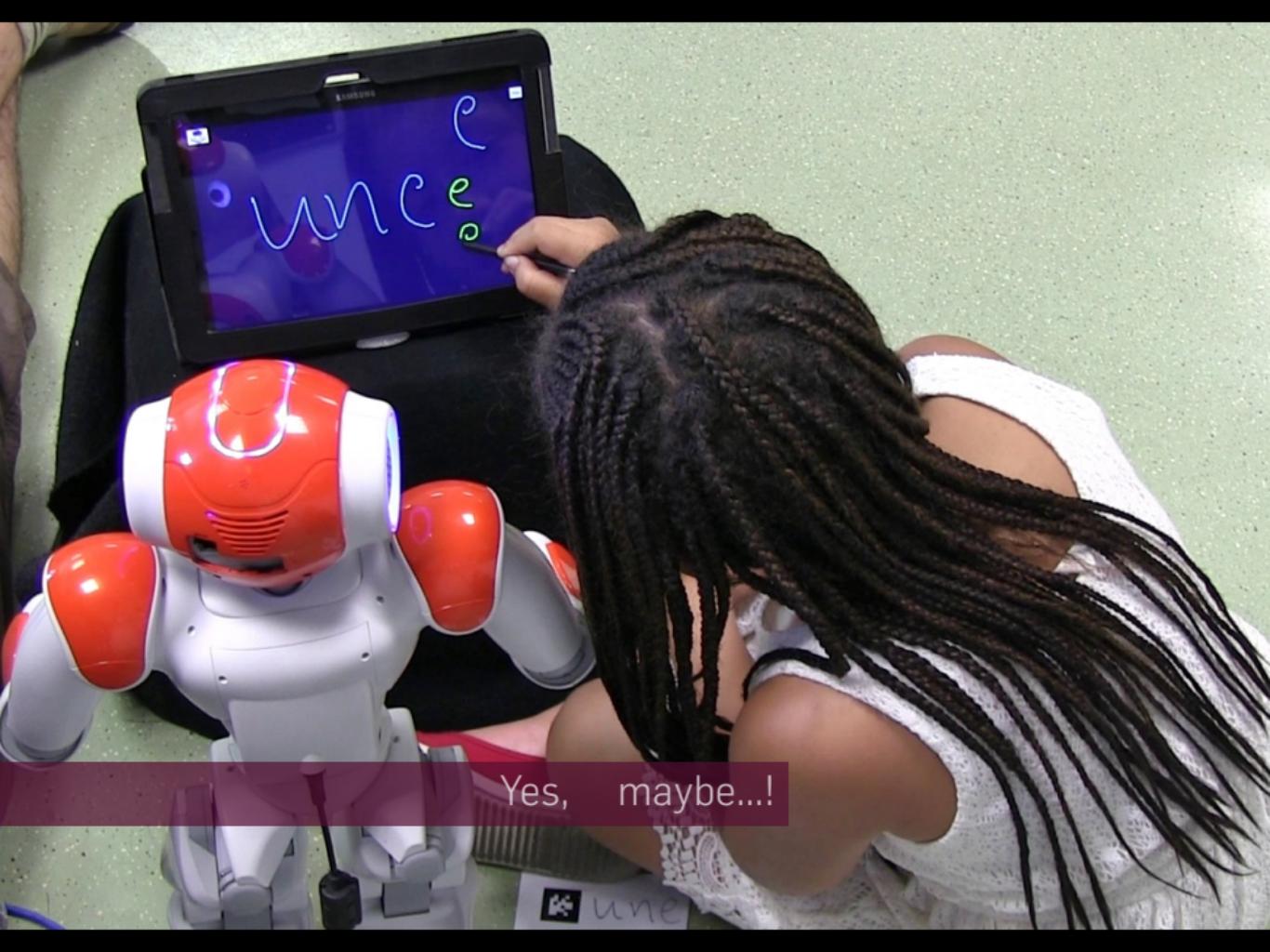


Concept 2: solar system



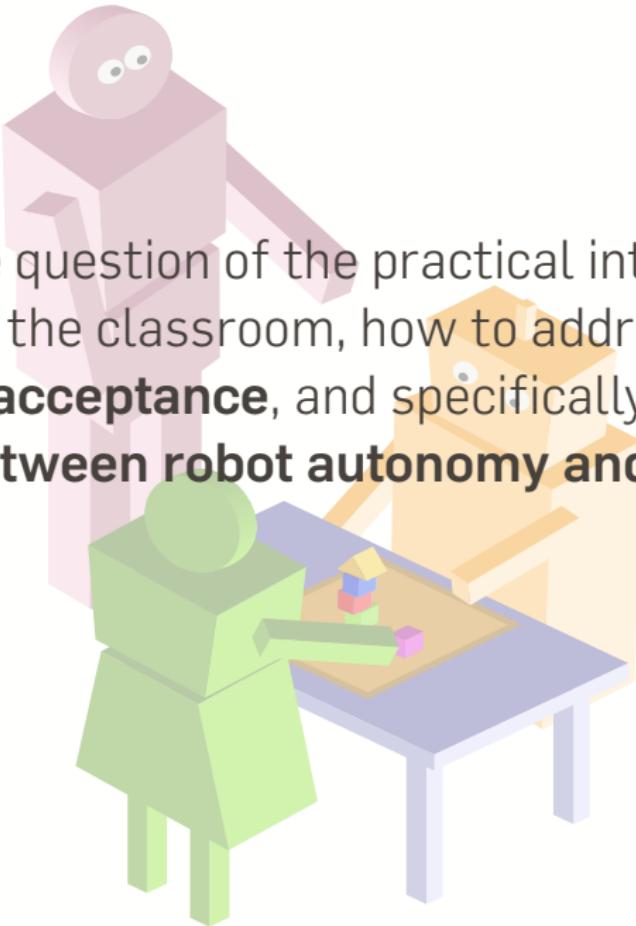


If a “pen-like” robot is actually doable,
...are social robots relevant at all...?



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



The teacher



The children



Assessing the interaction



AUTONOMOUS ROBOT, YET TEACHER IN THE LOOP?



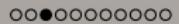
One experiment with:

- a real robot

The classroom



The teacher



The children



Assessing the interaction



AUTONOMOUS ROBOT, YET TEACHER IN THE LOOP?



One experiment with:

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

The classroom

oooooooooooooooooooo

The teacher

oo●oooooooooo

The children

oooooooooooo

Assessing the interaction

oooooooooooooooooooooooooooo

AUTONOMOUS ROBOT, YET TEACHER IN THE LOOP?



One experiment with:

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

The classroom

oooooooooooooooooooo

The teacher

oo●oooooooooo

The children

oooooooooooo

Assessing the interaction

oooooooooooooooooooooooooooo

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?

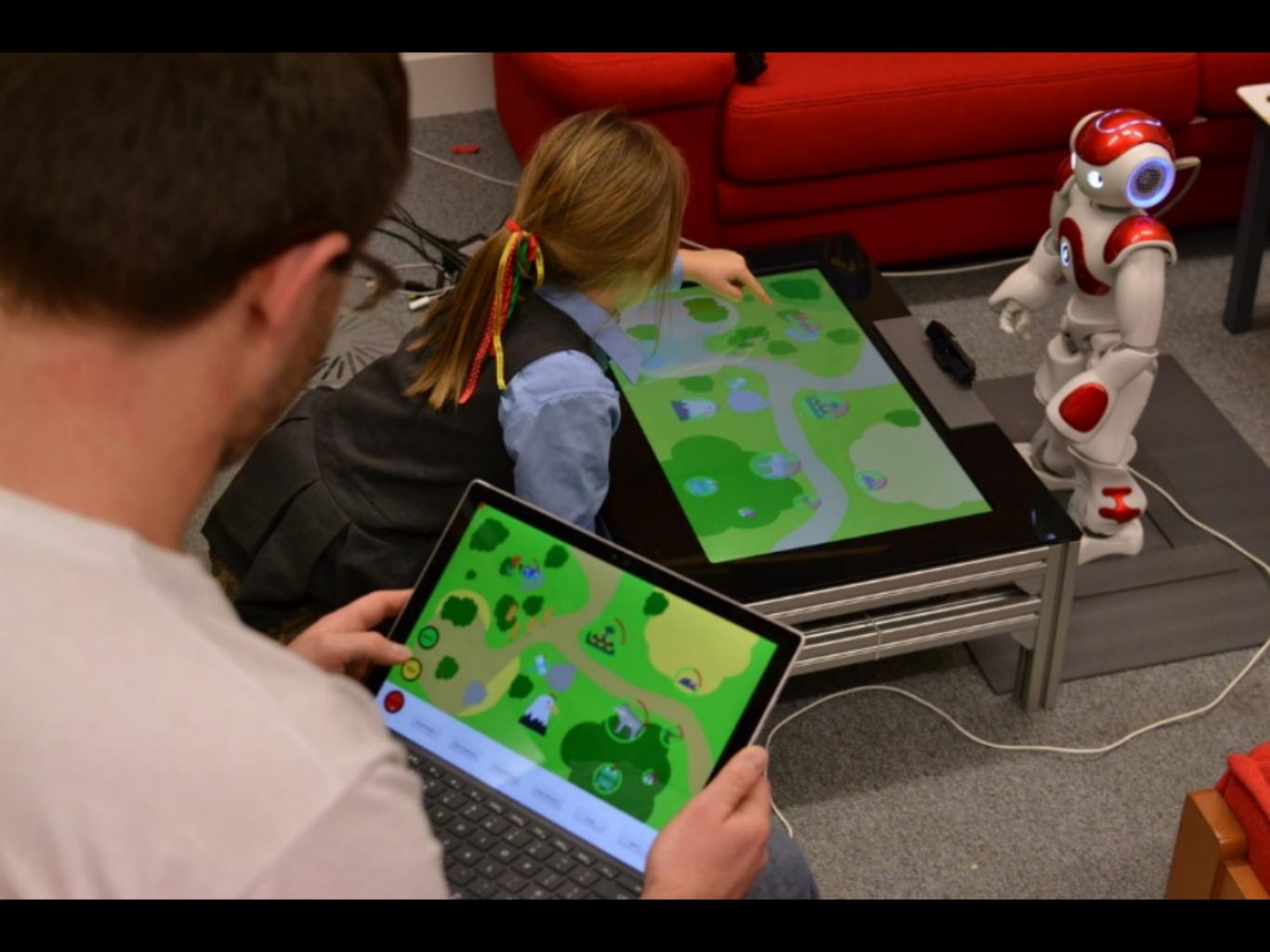
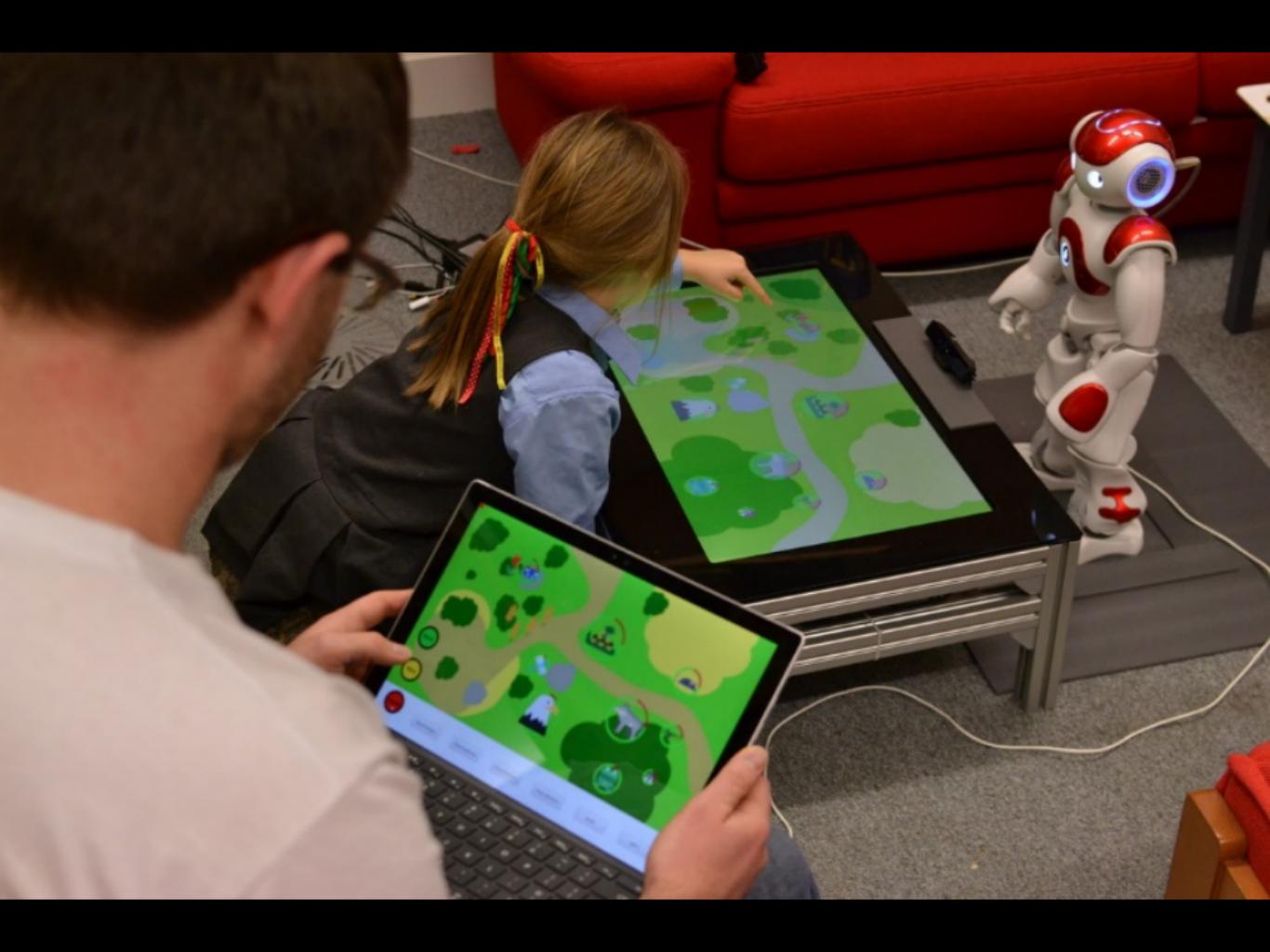


One experiment with:

- 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

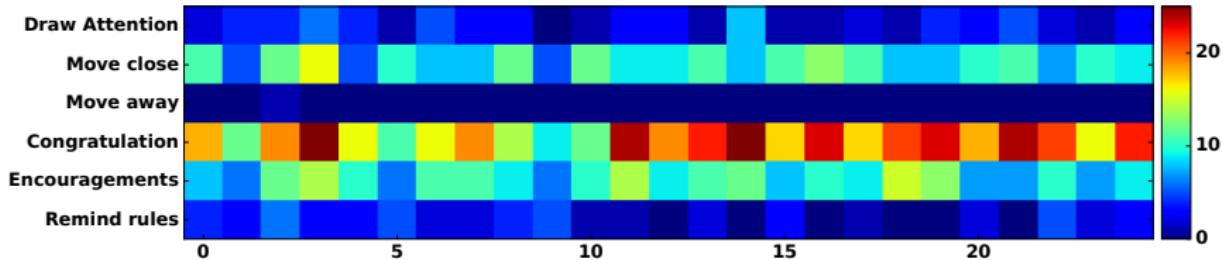


$|state| = 210$ $|action_space| = 655$

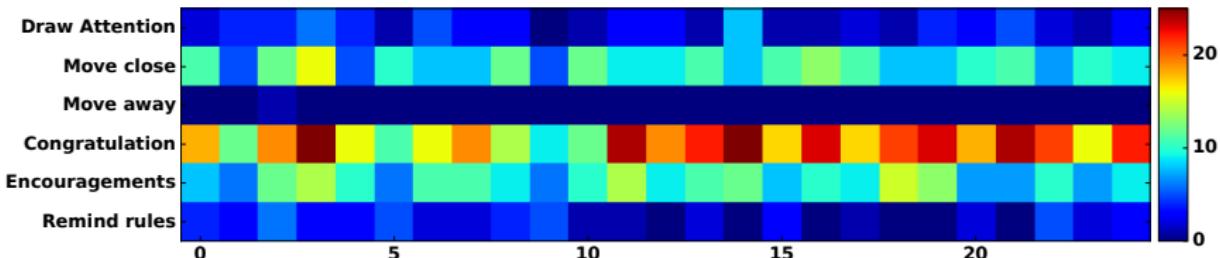




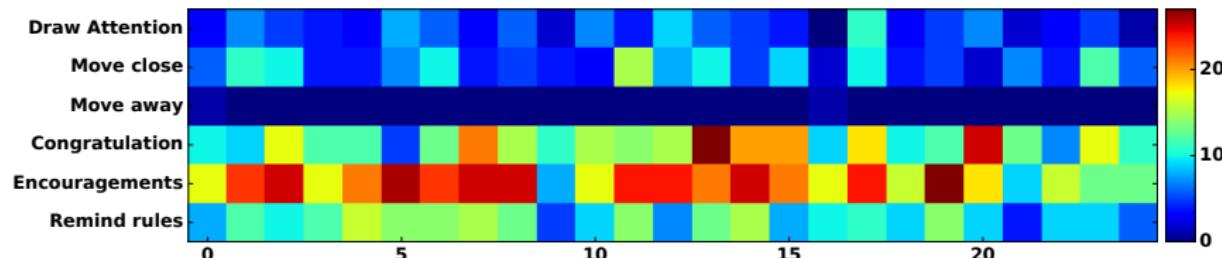
Supervised



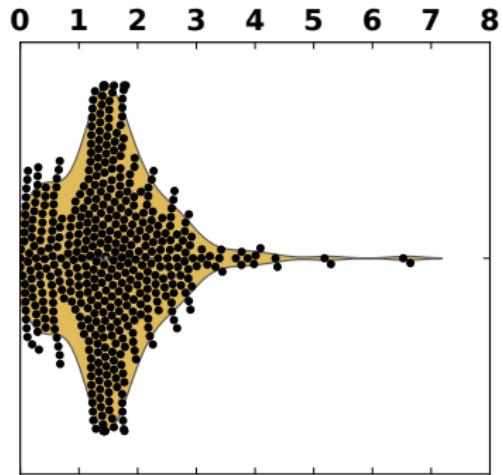
Supervised



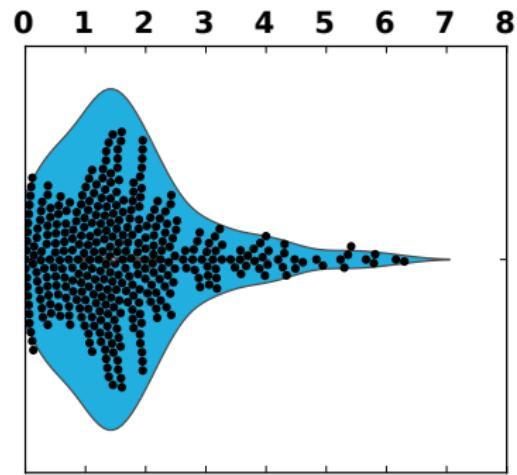
Autonomous



Time since eating event for each congratulation action (s)



supervised



autonomous

The classroom

oooooooooooooooooooo

The teacher

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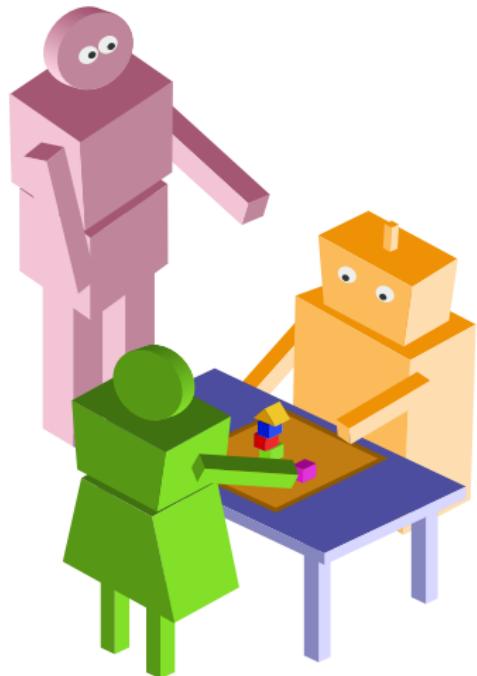
The children

oooooooooo

Assessing the interaction

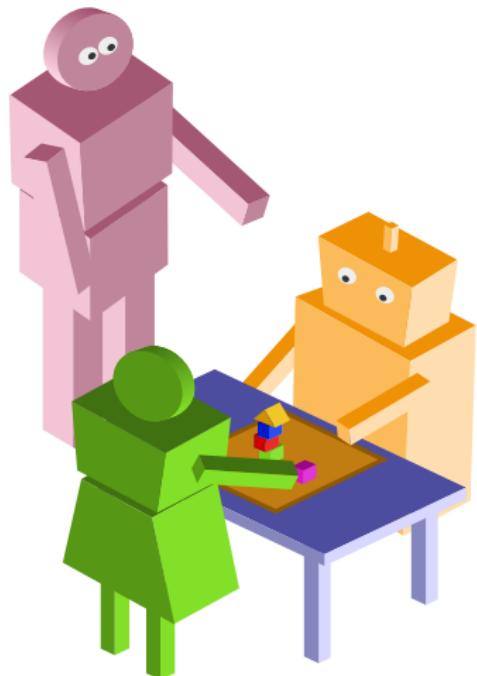
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WHAT DOES THAT MEANS FOR THE TEACHER?



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

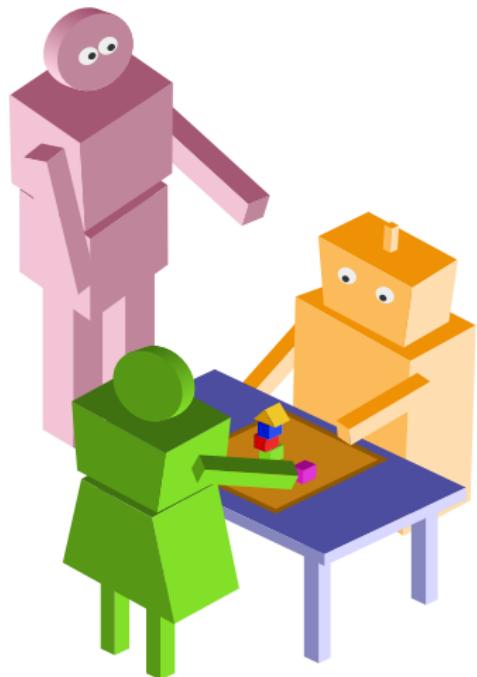
WHAT DOES THAT MEANS FOR THE TEACHER?



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



Social support beyond learning

THE CHILDREN: THE CHALLENGE OF “DOING TOGETHER”

The classroom



The teacher



The children



Assessing the interaction



SOCIAL OR NOT SOCIAL?

Non-social



Social

The classroom



The teacher



The children



Assessing the interaction



SOCIAL OR NOT SOCIAL?

Tool?

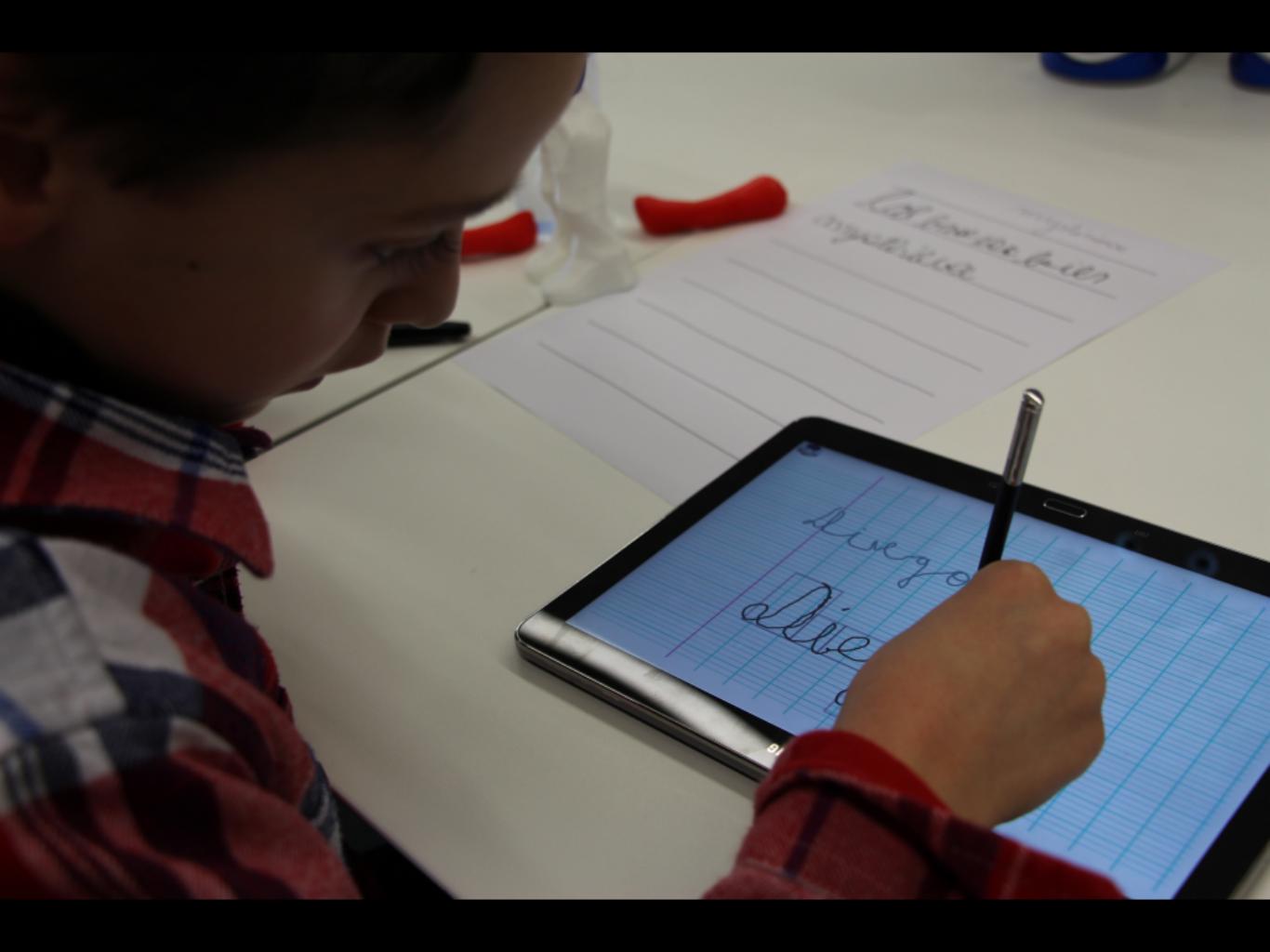


Peer/tutor?

Lithuanian
mythica

Diego

Allie



The classroom

oooooooooooooooooooo

The teacher

oooooooooooo

The children

ooo●oooooo

Assessing the interaction

oooooooooooooooooooooooo

THE COWRITER PROJECT



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

The classroom

oooooooooooooooooooo

The teacher

oooooooooooo

The children

ooo●oooooo

Assessing the interaction

oooooooooooooooooooooooo

THE COWRITER PROJECT



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

- Robots do not know how to write!

The classroom

oooooooooooooooooooo

The teacher

oooooooooooo

The children

ooo●oooooo

Assessing the interaction

oooooooooooooooooooooooo

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)



The classroom

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The teacher

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The children

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Assessing the interaction

oooooooooooooooooooooooooooo

LEARNING FROM DEMONSTRATION

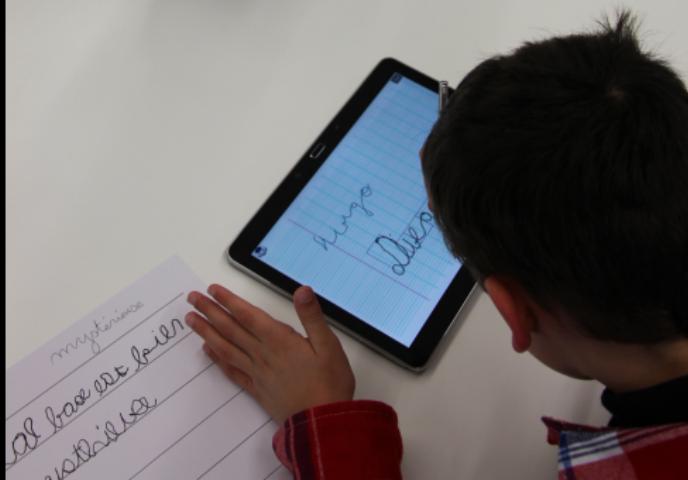


J S S J A A

{ S A A A A



Algunas personas
que viven en la
ciudad tienen que
comer en restaurantes
y no tienen tiempo
para cocinar.



mystérieuse
Al bâton est bâton
mystérieuse

The classroom



The teacher



The children



Assessing the interaction



BEFORE – AFTER



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

The classroom

oooooooooooooooooo

The teacher

oooooooooooo

The children

oooooooo●○○

Assessing the interaction

oooooooooooooooooooooooooooo

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

oooooooooooooooooooo

The teacher

oooooooooooo

The children

oooooooo●oo

Assessing the interaction

oooooooooooooooooooooooooooo

BEFORE – AFTER

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

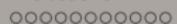
salut mimi
nous pensons
que c'est un
corps
est ce que tu peux
envoyer des
photos de
la base



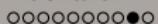
The classroom



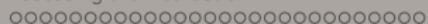
The teacher



The children



Assessing the interaction



WHAT ROLE DOES THE ROBOT PLAY HERE?

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

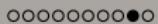
The classroom



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)
- (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?

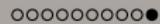
The classroom



The teacher



The children



Assessing the interaction



A NEW SPACE IN THE MIDDLE OF THE SOCIAL SPECTRUM?



The classroom



The teacher



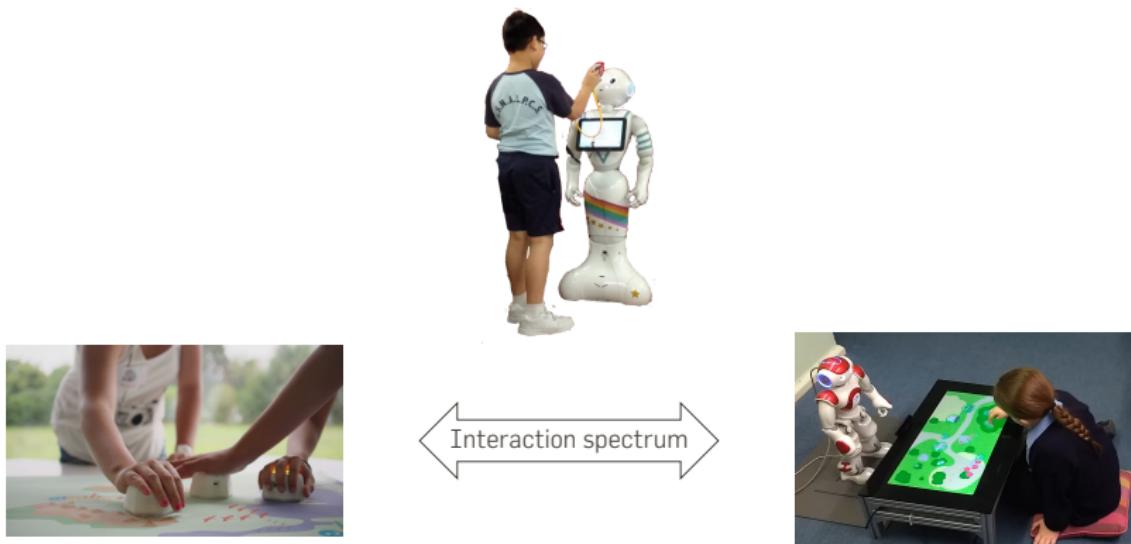
The children



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?

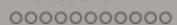
- purely a tool from the perspective of the teacher
- a (somewhat) social agent from the perspective of the child
→ engagement, learning of social behaviours, etc

ASSESSING THE INTERACTION

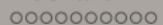
The classroom



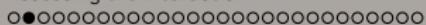
The teacher



The children



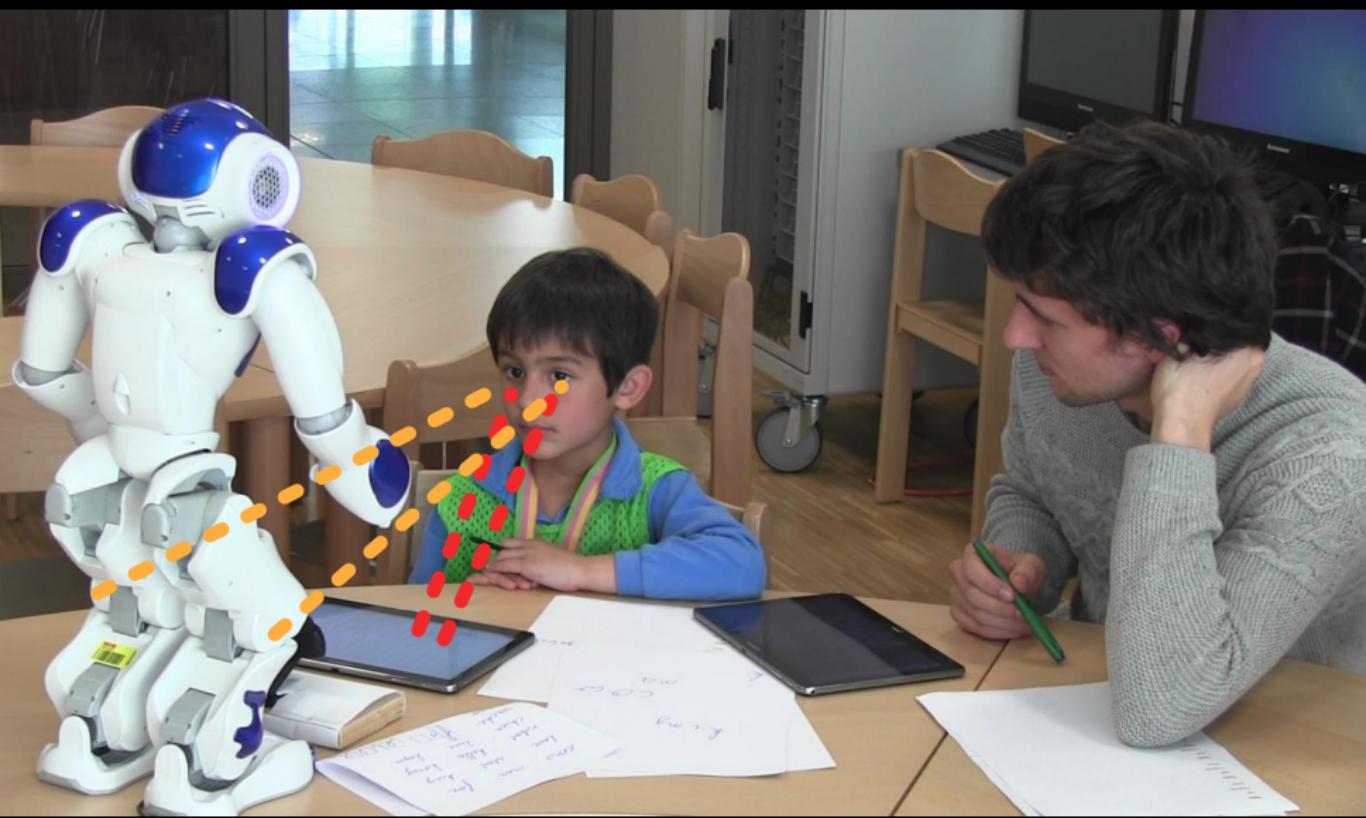
Assessing the interaction



IS THE CHILD ENGAGING WITH THE ACTIVITY?

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





The classroom

oooooooooooooooooooo

The teacher

oooooooooooo

The children

oooooooooooo

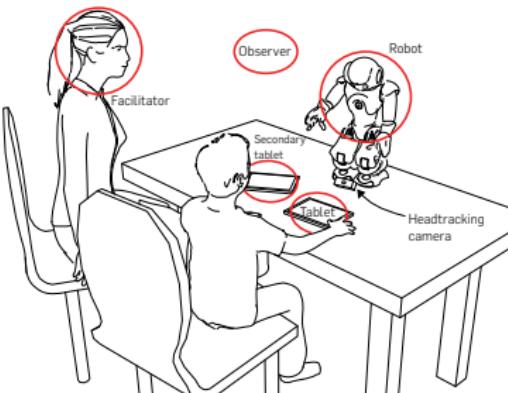
Assessing the interaction

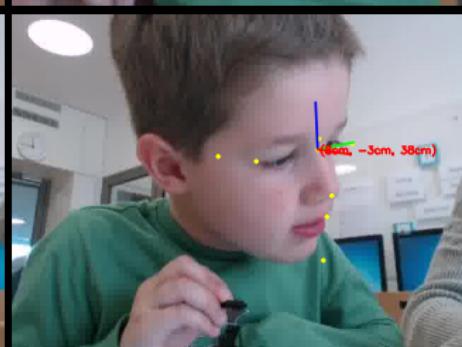
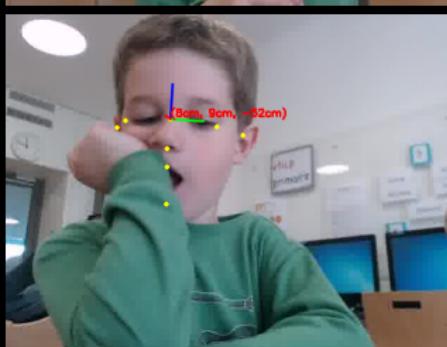
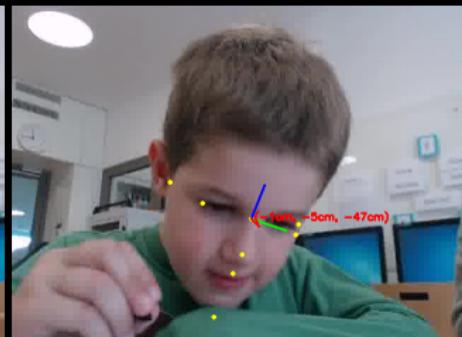
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EXPECTED FOCUS

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

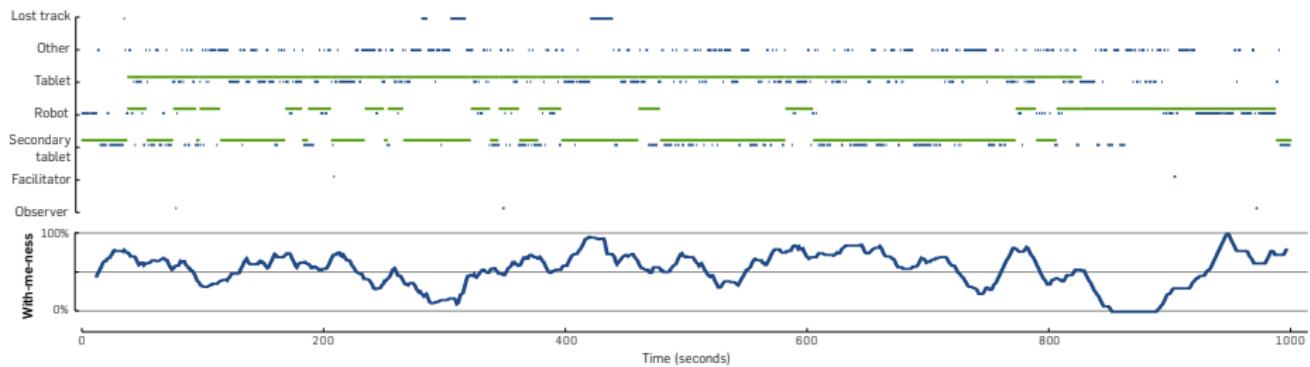
The children

oooooooooooo

Assessing the interaction

oooooooo●oooooooooooooooooooo

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 abilities build on sub-conscious social behaviours:

- 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 abilities build on sub-conscious social behaviours:

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

Let's observe them!



STAGES OF PLAY

In developmental psychology, Parten's **stages of play**:



1. Solitary (independent) play



2. Onlooker play



3. Parallel play



4. Associative play



5. Cooperative play



**Can we turn it into a rigorous research
methodology?**

APPROPRIATE SOCIAL SITUATION?

...a situation/activity that exhibits:

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

APPROPRIATE SOCIAL SITUATION?

...a situation/activity that exhibits:

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

while being...

- reproducible/replicable experimental procedure
- clear quantitative & qualitative metrics
- practical!

FREE PLAY

“Just play! Enjoy yourselves!”

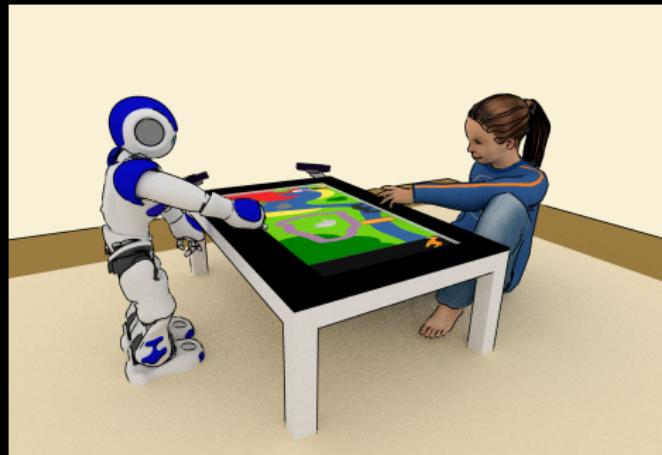
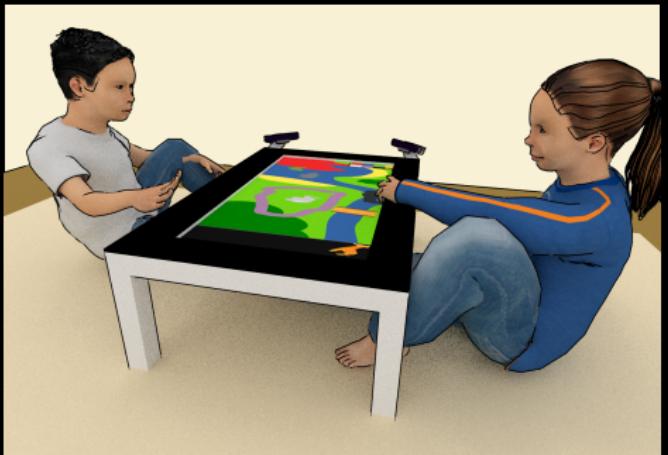
- **rich set of cognitive and social dynamics;** importance of motivation/drive; **uncertain and unexpected situations**
- what is the right action policy? Focus instead on the **social policy**

FREE PLAY

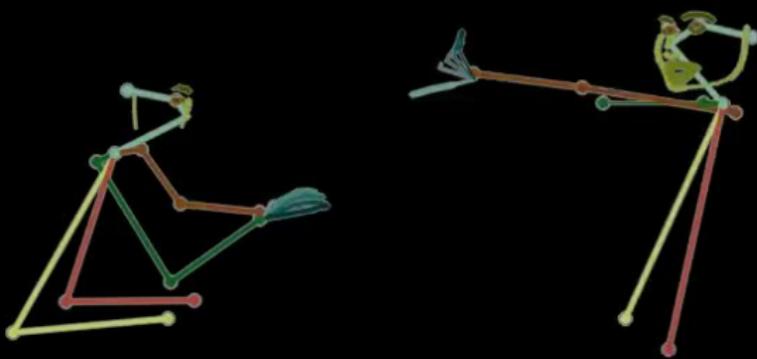
“Just play! Enjoy yourselves!”

- **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

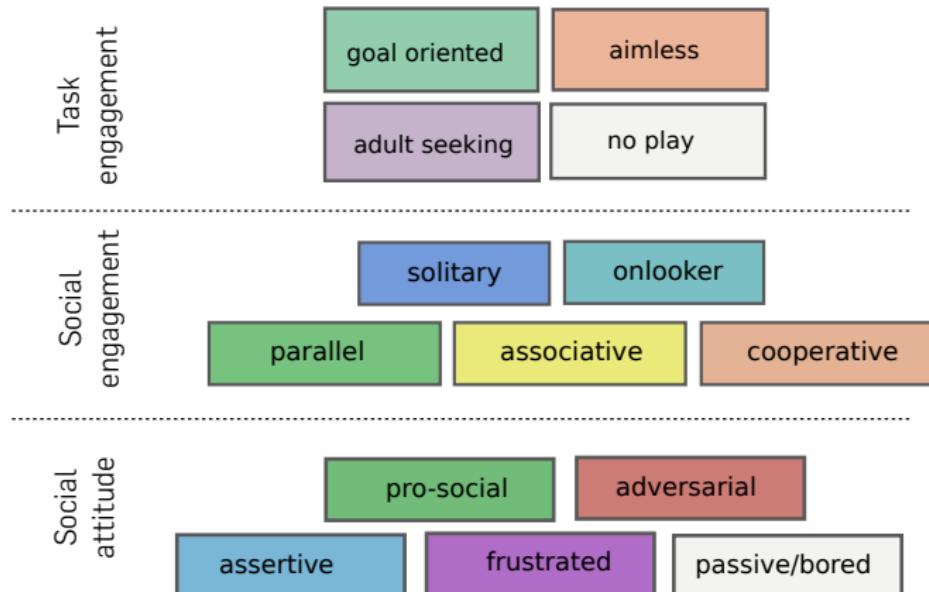
The children

oooooooooooo

Assessing the interaction

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13000+ ANNOTATIONS



Attitude: passive

Social engag.: onlooker

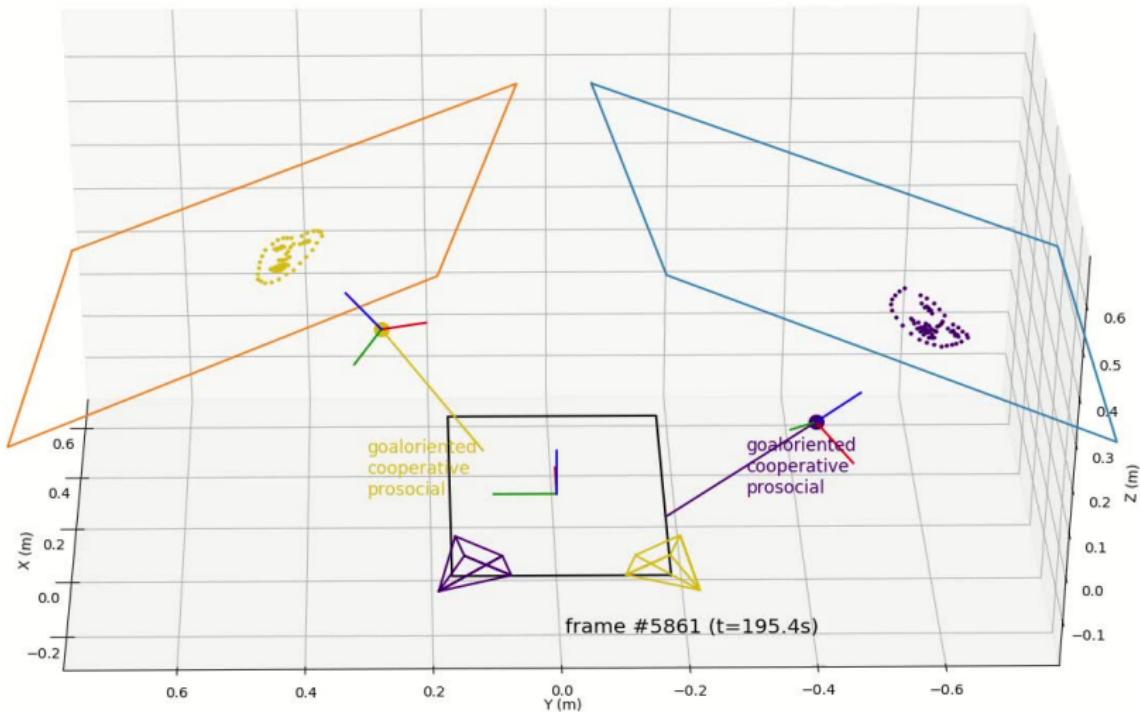
Task engag.: no play

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



The teacher



The children



Assessing the interaction



THREE CONSTRUCTS TO RULE THEM ALL



Interaction imbalance

Interaction valence

Engagement

The classroom

oooooooooooooooooooo

The teacher

oooooooooooo

The children

ooooooooooo

Assessing the interaction

oooooooooooooooooooo●ooo

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

ooooooooooo

Assessing the interaction

oooooooooooooooooooo●ooo

OUR GOAL

Real-time identification by the robot of...

- the **task engagement**
is my partner 'on task' or not?
- the **interaction flow & situation awareness**
what is happening right now? should I do something?

The classroom

oooooooooooooooooooo

The teacher

oooooooooooo

The children

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Assessing the interaction

oooooooooooooooooooo●ooo

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Pro-social, hostile, assertive ('bossy'), passive...

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entrainment (coupling), mimicry, turn-taking, joint attention

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

oooooooooooooooooooo

The teacher

oooooooooooo

The children

ooooooooooo

Assessing the interaction

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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?*

The classroom

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The teacher

oooooooooooo

The children

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Assessing the interaction

oooooooooooooooooooo●oo

IN CONCLUSION



- Not only 'child-robot interaction for learning', but also 'classroom-robot interaction' (importance of *orchestration*)
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IN CONCLUSION



- Not only 'child-robot interaction for learning', but also 'classroom-robot interaction' (importance of *orchestration*)
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- *Doing together* with the child will require a better understanding of the social dynamics. Machine learning to the rescue?

IN CONCLUSION

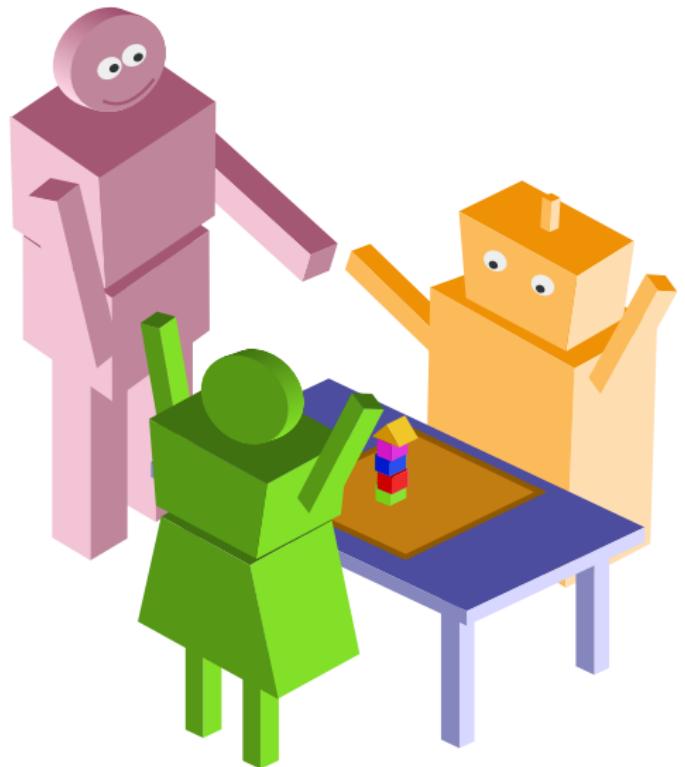


- Not only 'child-robot interaction for learning', but also 'classroom-robot interaction' (importance of *orchestration*)
- Right balance *tool-social robot?*
- Role of the teacher? *Supervised autonomy* looks like a possible direction.
- *Doing together* with the child will require a better understanding of the social dynamics. Machine learning to the rescue?
- However: *you reminded us not to forget to just try!* Thank you!



And don't loose the focus:

robots to support rich & fun human-human interactions!



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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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

oooooooooooooooooooo

The teacher

oooooooooooo

The children

oooooooooooo

Assessing the interaction

oooooooooooooooooooooooooooo

DEEP NETWORKS ≡ BLACK BOXES?

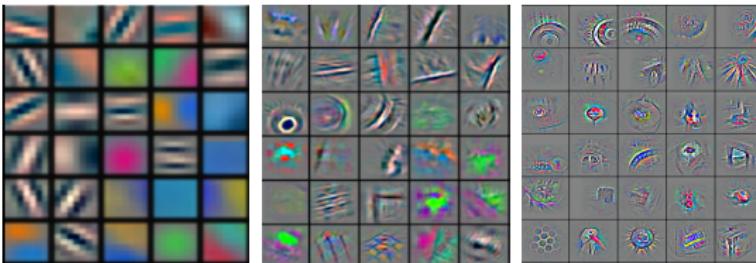


→
Low-Level
features

→
Mid-Level
features

→
High-Level
features

→
Trainable
classifier



The classroom

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The teacher

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The children

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Assessing the interaction

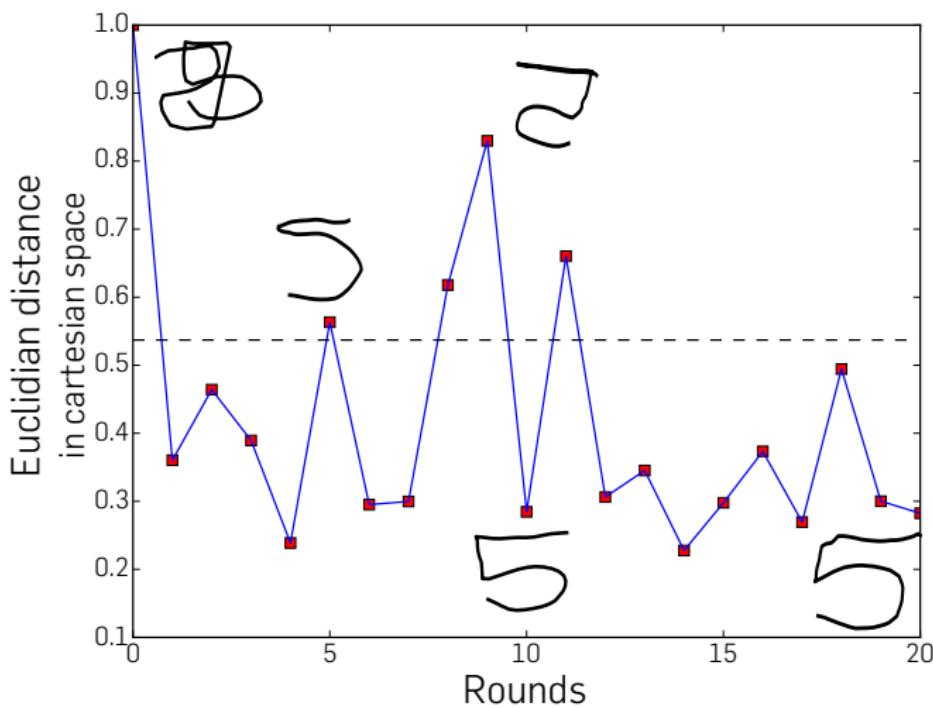
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DEEP NETWORKS \equiv BLACK BOXES?



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

LEARNING TO DRAW A 5

EPFL

The classroom

oooooooooooooooooooo

The teacher

oooooooooooo

The children

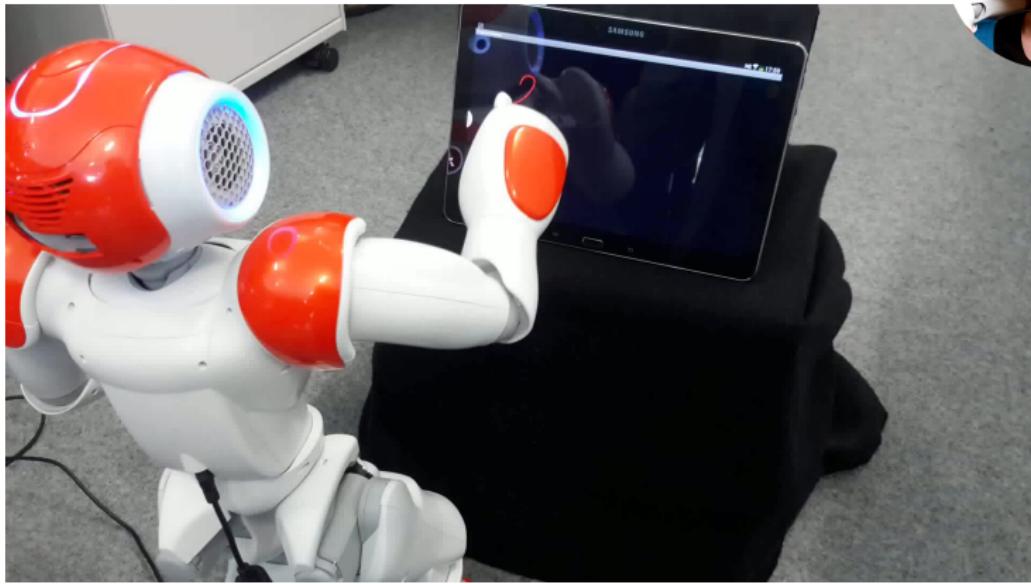
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Assessing the interaction

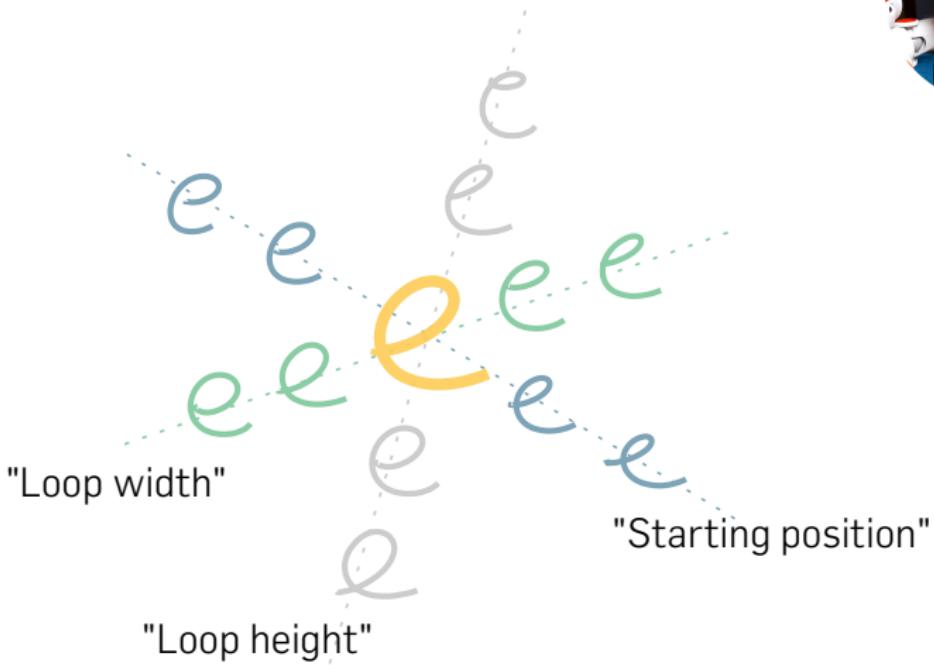
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COWRITER IMPLEMENTATION

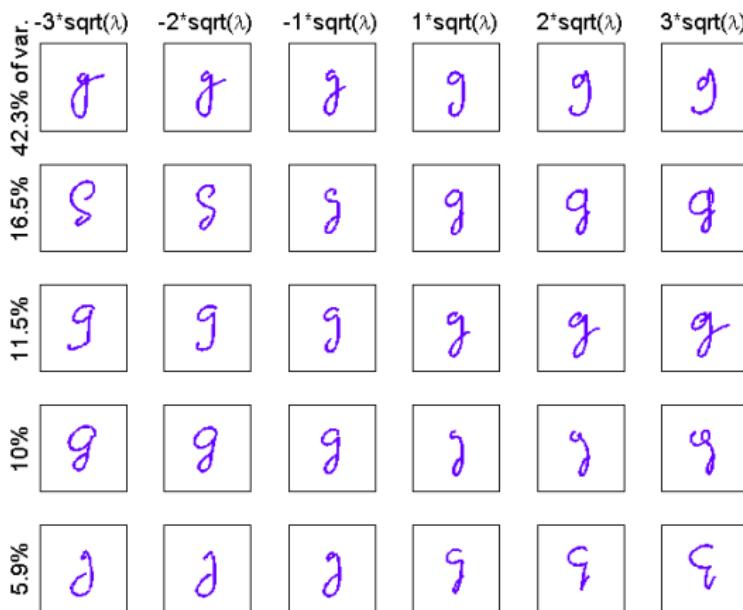
EPFL



COWRITER IMPLEMENTATION



COWRITER IMPLEMENTATION

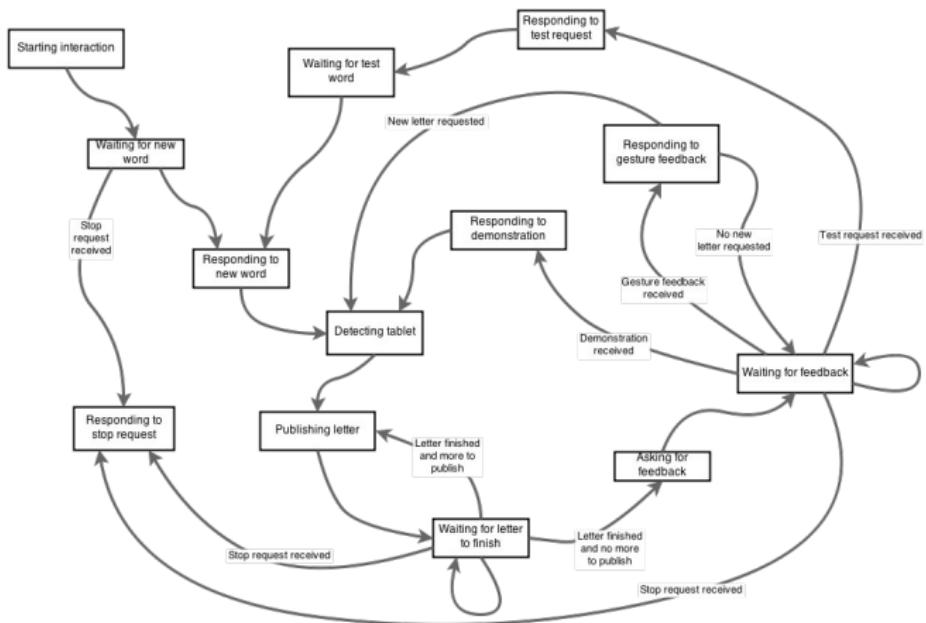


COWRITER IMPLEMENTATION



J S S J J J

S S A A A A



The classroom

oooooooooooooooooooo

The teacher

oooooooooooo

The children

oooooooooooo

Assessing the interaction

oooooooooooooooooooooooo

INTERACTION WITH THE PAPER



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

The classroom

oooooooooooooooooooo

The teacher

oooooooooooo

The children

oooooooooooo

Assessing the interaction

oooooooooooooooooooooooo

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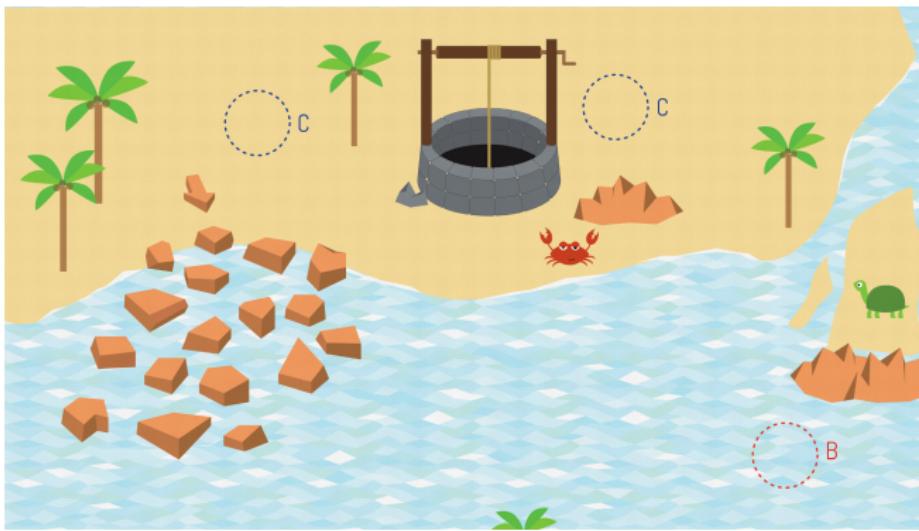
Achieved through a **paper-based absolute localisation system**

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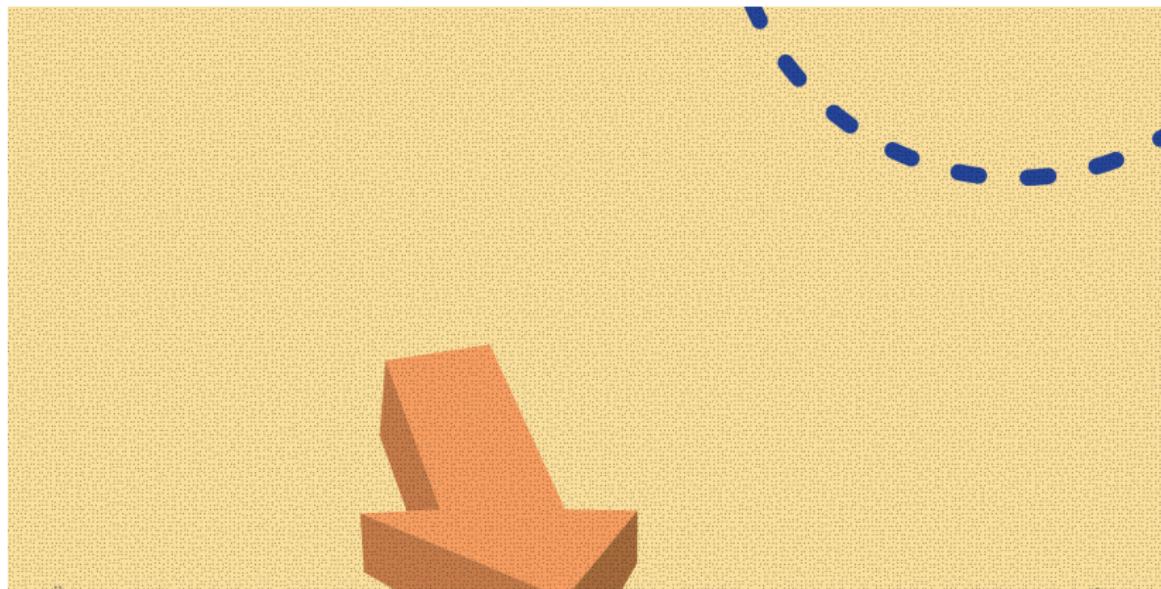


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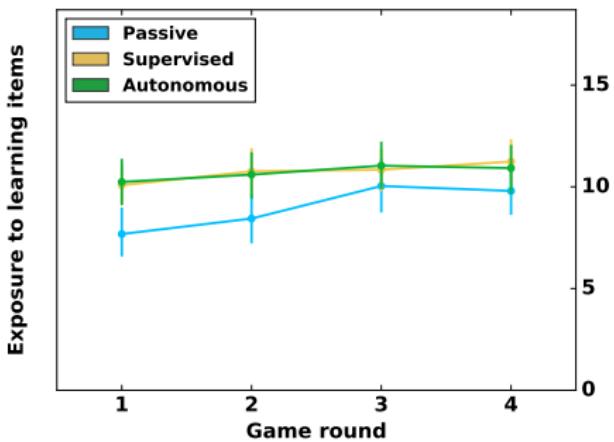
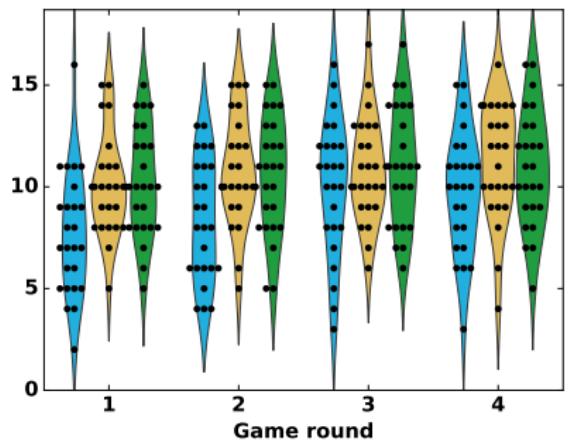
INTERACTION WITH THE PAPER



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

- 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

oooooooooooo

The children

ooooooooooo

Assessing the interaction

oooooooooooooooooooo

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...	