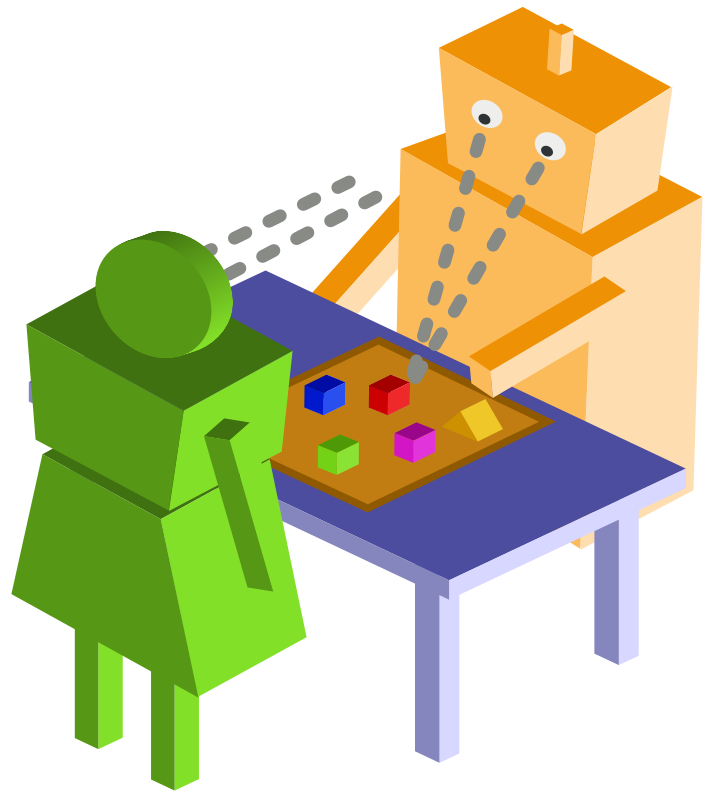
cognition & HRI

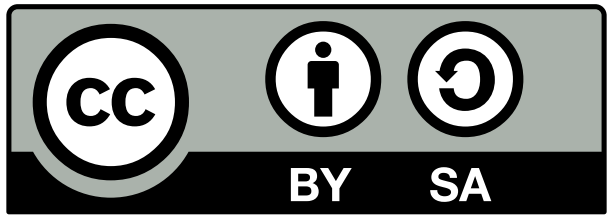
how to *do* together?

UKRAS19 – 24th Jan. 2019



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

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

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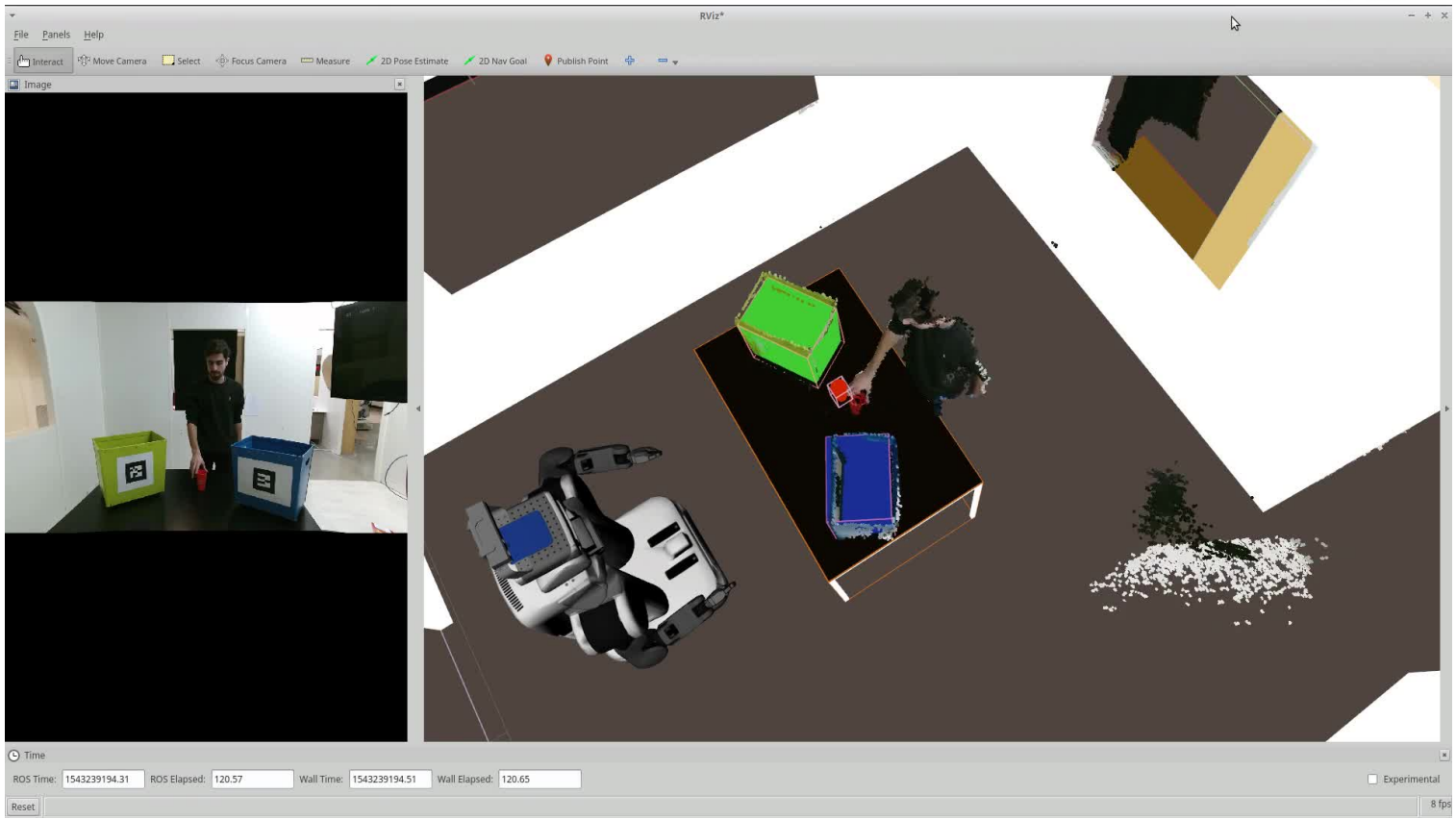

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HOW DO HUMANS PERFORM TASKS TOGETHER?

Collaborating is a costly socio-cognitive activity.

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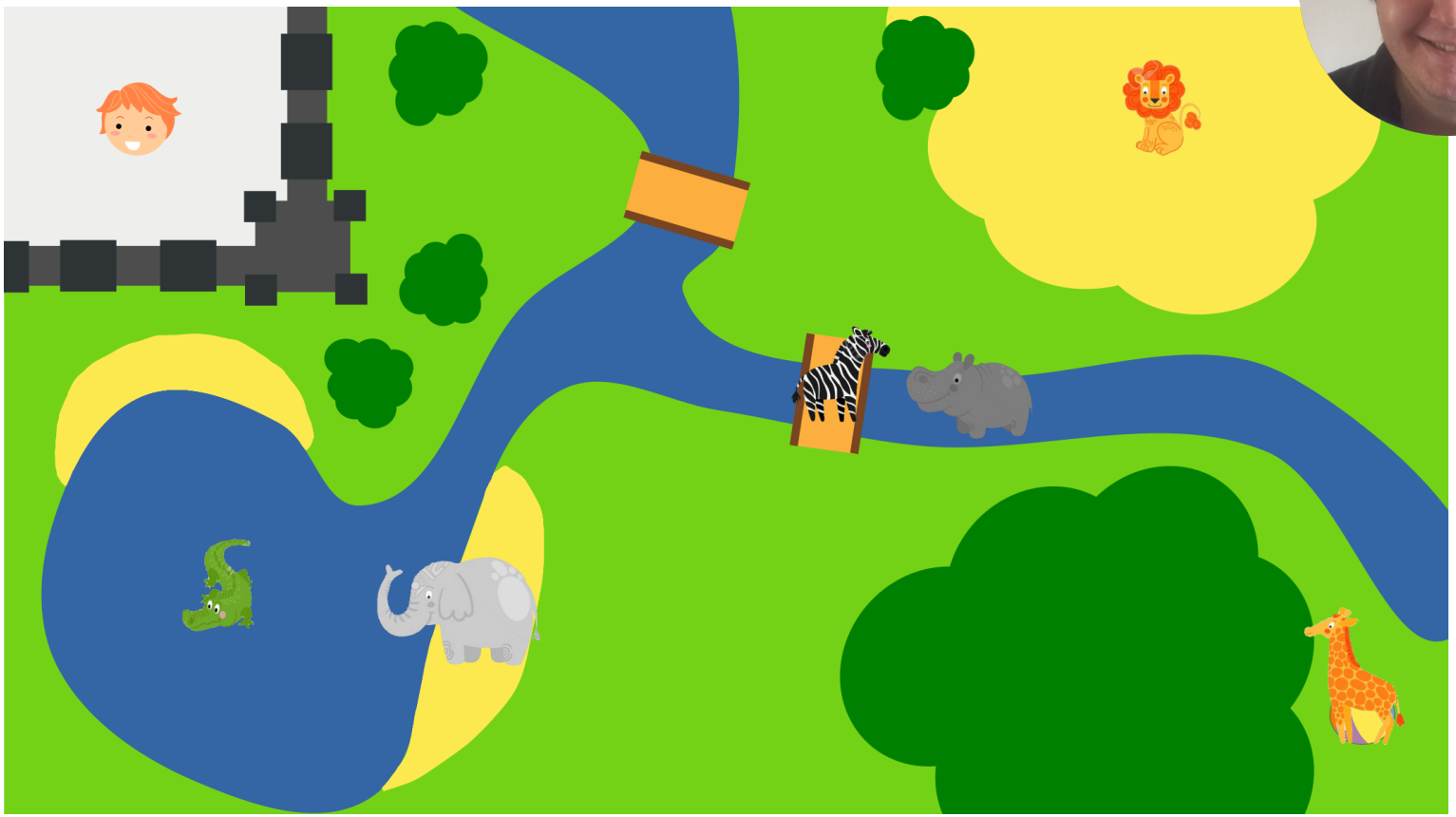
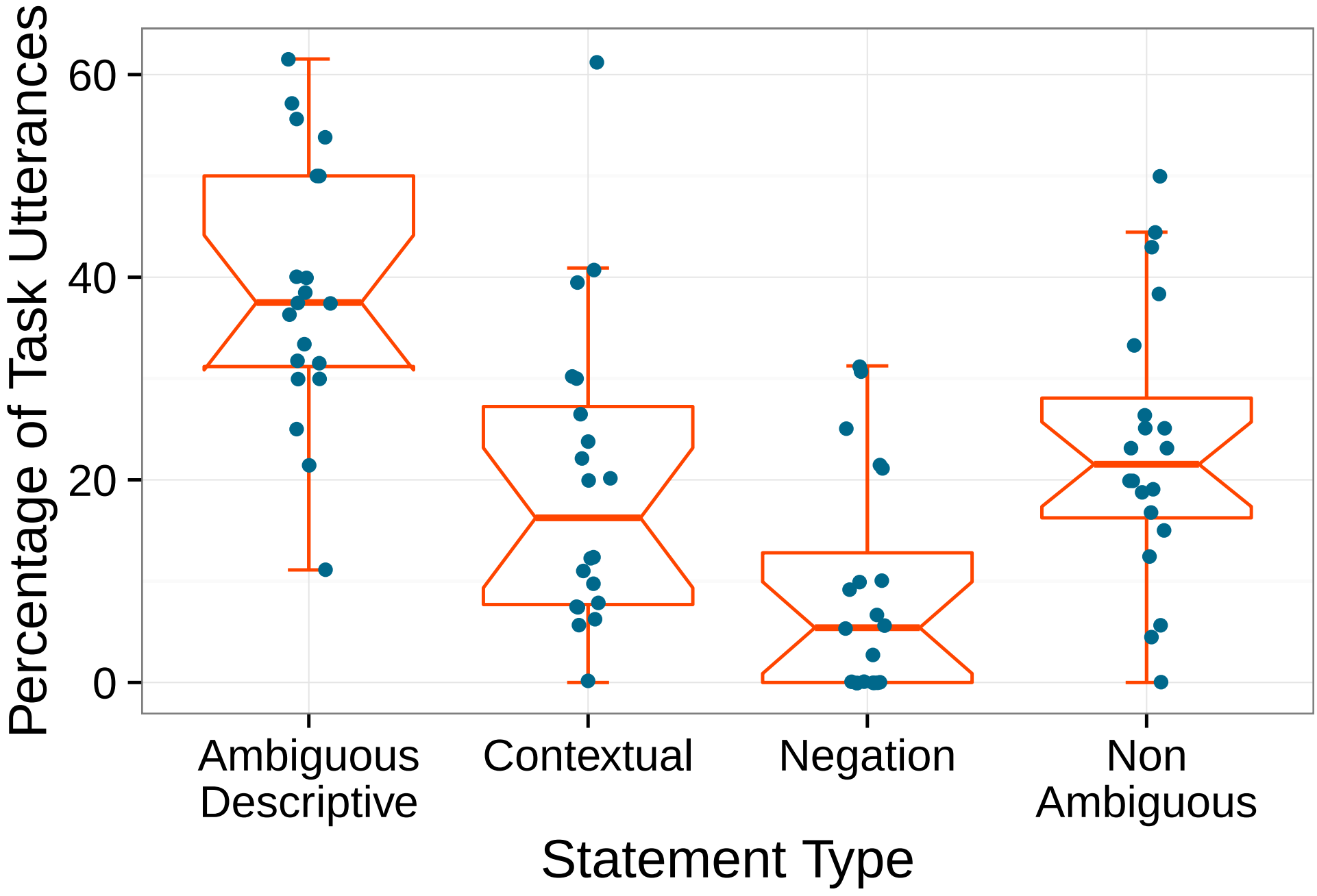
What does "be lazy" mean for robots?

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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- 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
- $\Rightarrow$ 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,
- implicit turn-taking,
- joint attention
- ...and others

IN SOCIAL HUMAN-ROBOT INTERACTION

- 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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- rich semantics
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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**

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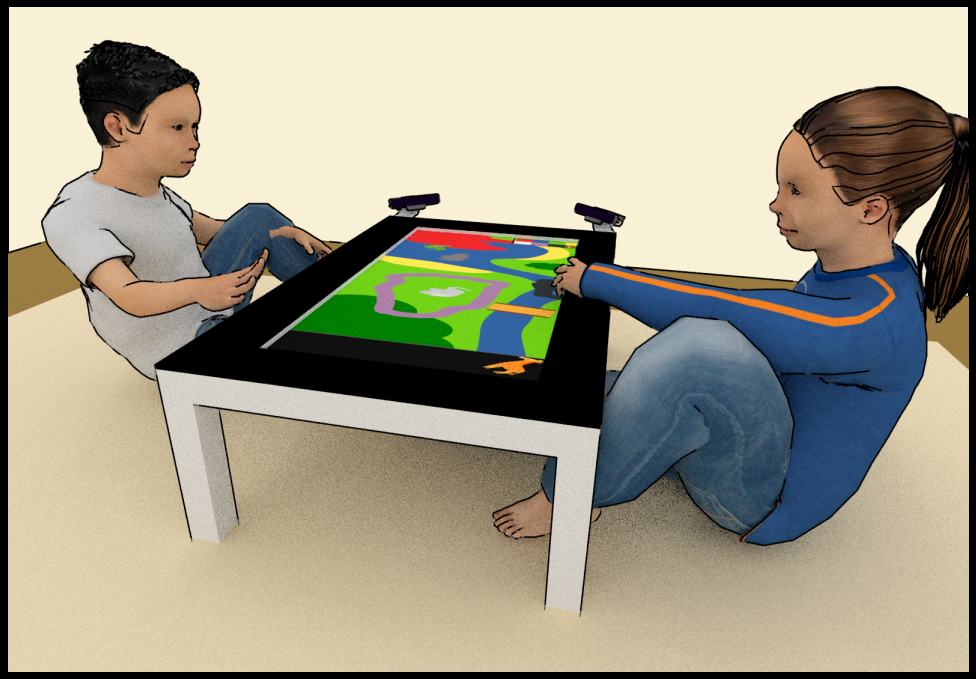
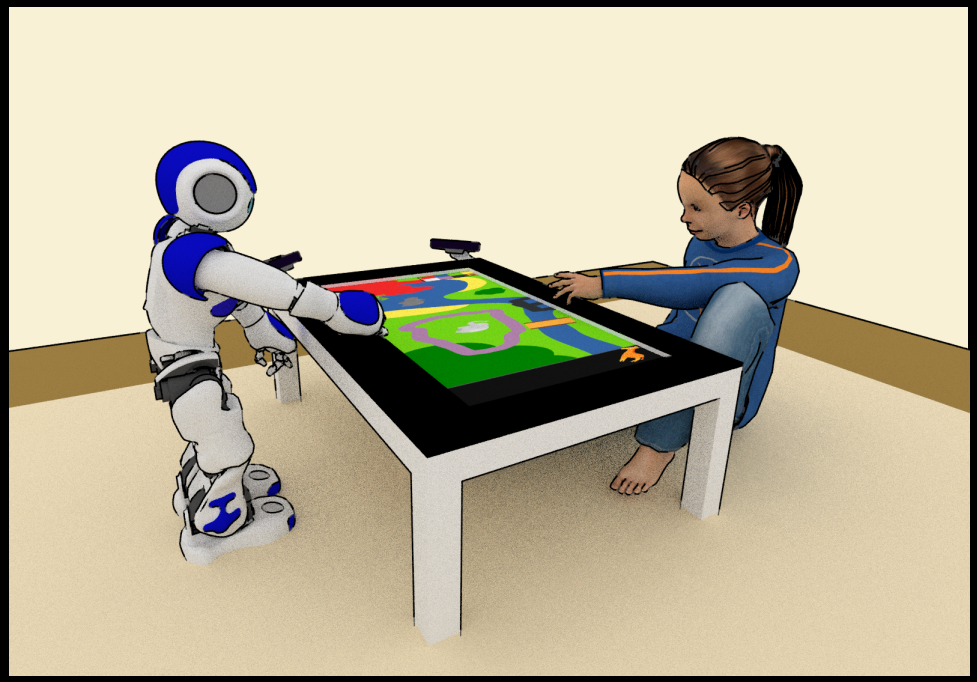
- focus on children
- with a little bit of scaffolding & framing





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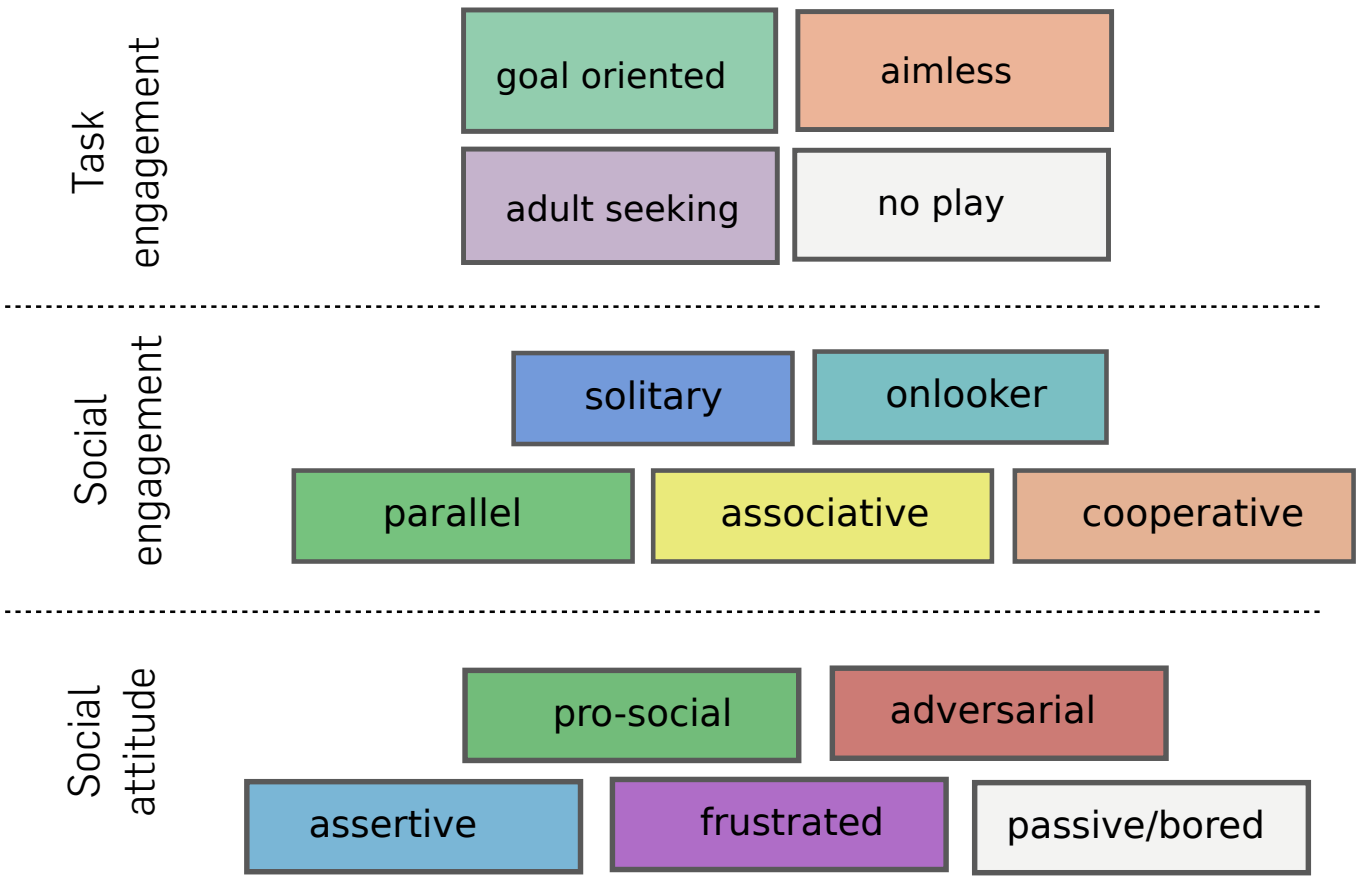
→ **paradigm for socio-cognitive investigation**

THE PINSORO DATASET

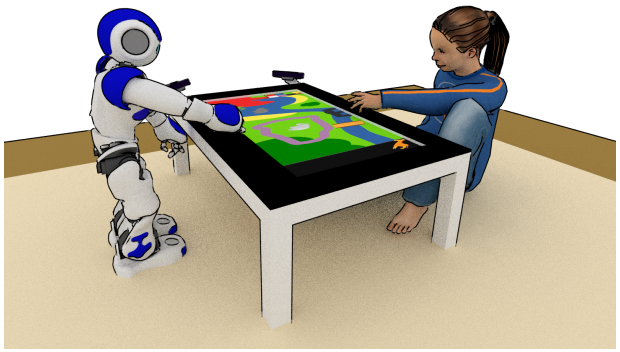
- 120 children, 4 to 8 years old
- 75 interactions
  - 90 children playing with another child,
  - 30 playing with a robot
- About 45h+ of recordings; 2M+ frames; ≈ 2TB
- average duration of freeplay interactions: 24min in child-child condition; 19min in child-robot condition

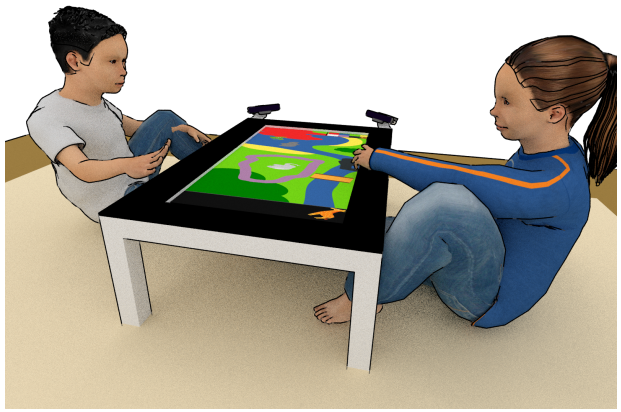
[Lemaignan et al. **The PInSoRo dataset: Supporting the data-driven study of [...]** PLOS One 2018]

13000+ ANNOTATIONS



TWO BASELINES





child - non-social robot

child - child

richness of social interactions

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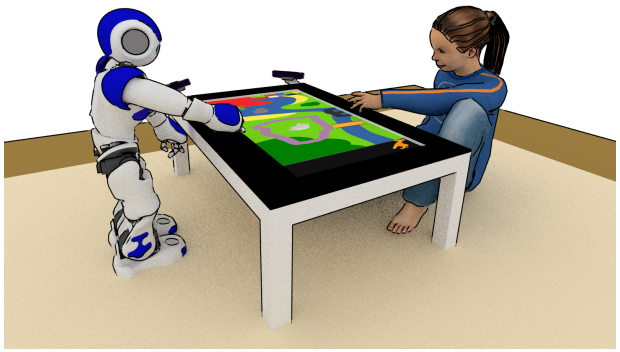
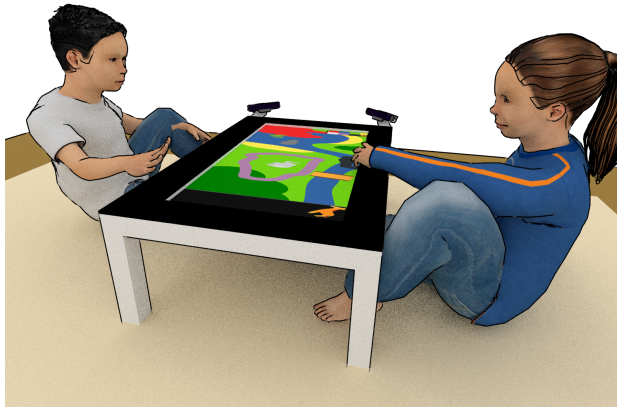


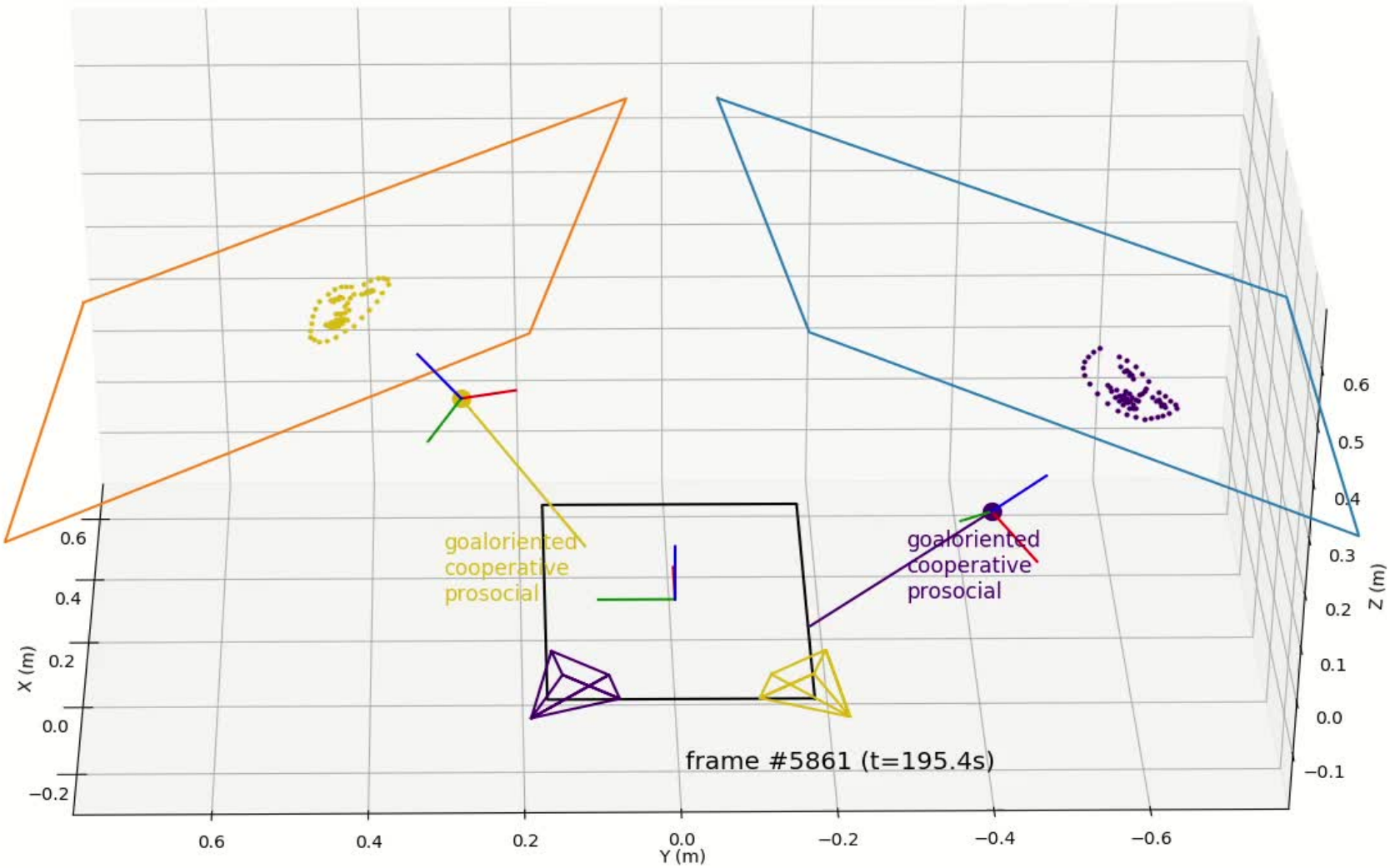


child - non-social robot

your next socio-cognitive model

child - child

richness of social interactions


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

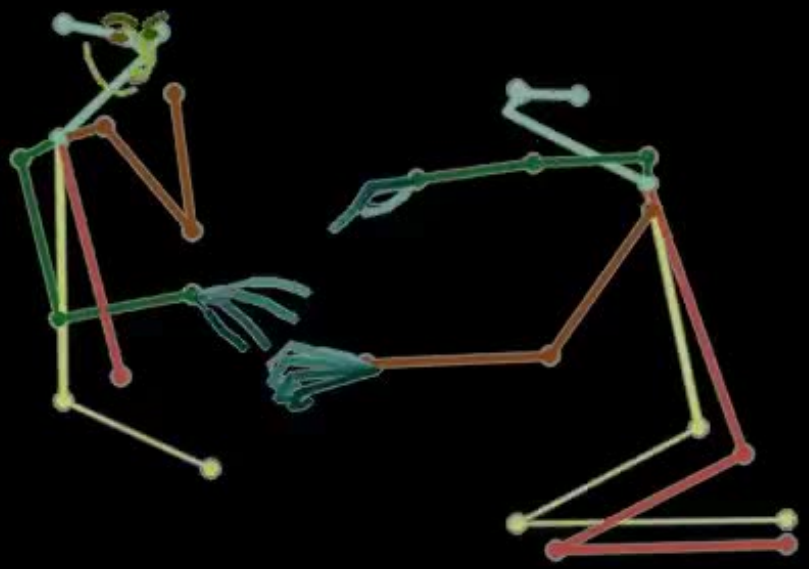
LARGEST OPEN DATASET OF NATURAL SOCIAL INTERACTIONS

Anonymised version (7.2GB) available on-line.
Grab it now!

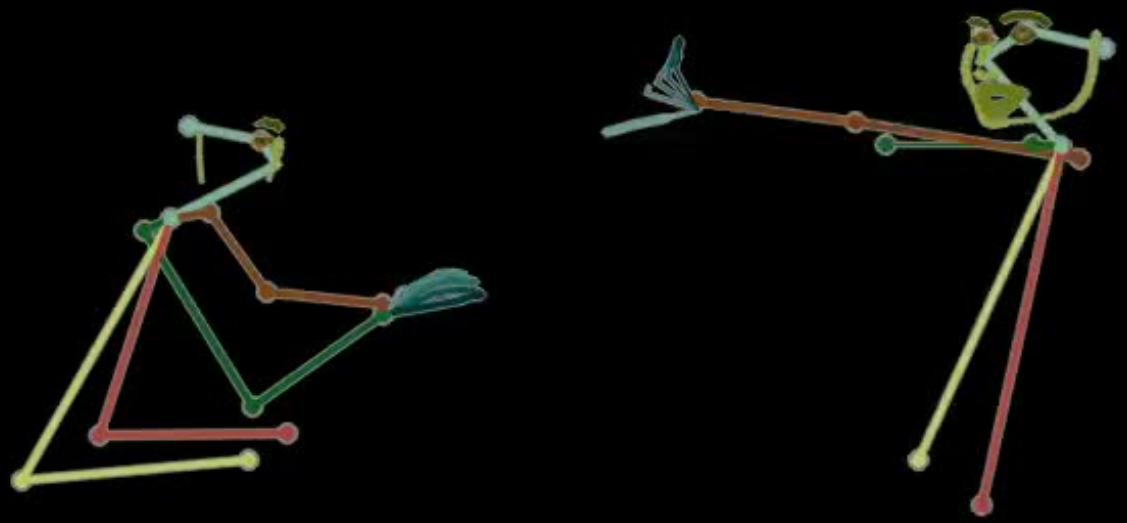
freeplay-sandbox.github.io

Open data! Hosted on EU's zenodo

MINING THE DATA




Focused!
ILLUMINATED POLITICAL
& PHYSICAL




open me

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, 4 clips each, on MTurk

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

	pptID	condition	age	gender	diffSad	sumSad	diffHappy	sumHappy	diffAngry	sumAngry	...	diffDistracted	sumDistracted	diffBored	sumBored	d
0	186	2	30	Female	0	-2	0	4	1	-1	...	0	0	1	-1	
1	186	2	30	Female	1	3	0	0	0	2	...	1	3	0	2	
2	186	2	30	Female	1	3	0	0	0	0	...	1	3	0	2	
3	186	2	30	Female	0	2	1	1	1	1	...	1	3	0	2	
4	94	1	23	Male	0	-2	0	2	0	-2	...	0	-2	1	-1	
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12	156	2	29	Female	0	-4	0	2	0	-4	...	0	-4	0	-4	
13	156	2	29	Female	2	0	0	-2	2	0	...	0	-4	0	-4	
14	156	2	29	Female	0	-4	0	4	0	-4	...	3	-1	0	-4	
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17	157	2	31	Male	0	-4	1	3	1	-4	...	1	-3	0	-2	
18	157	2	31	Male	1	-3	1	1	0	-4	...	1	-3	1	-3	
19	157	2	31	Male	0	-2	1	1	0	-2	...	2	0	1	-3	

For each construct, calculate Δ and Σ

EFA: EXPLORATORY FACTOR ANALYSIS

	Factor 1 *full-scene*	Factor 2 *full-scene*	Factor 3 *full-scene*
Δ Sad	0.41		
Σ Sad		0.72	
Δ Happy	0.49		
Σ Happy			-0.55
Δ Angry	0.40		
Σ Angry		0.81	
Δ Excited	0.53		
Σ Excited			-0.71
Δ Calm	0.45		
Σ Calm			
Δ Friendly	0.69		
Σ Friendly			-0.43
Δ Aggressive	0.78		
Σ Aggressive		0.80	-0.36
Δ Engaged			0.65
Σ Engaged			-0.64
Δ Distracted			0.65
Σ Distracted		0.63	
Δ Bored			0.61
Σ Bored		0.58	0.48
Δ Frustrated	0.53		
Σ Frustrated		0.70	
Δ Dominant	0.75		
Σ Dominant		0.53	
Δ Submissive	0.68		
Σ Submissive		0.54	

[Bartlett et al. **What Can You See? Identifying Cues on Internal States from the Kinematics [...]** Frontiers 2019 *(under review)*] 31

EFA: EXPLORATORY FACTOR ANALYSIS

	Factor 1: imbalance *full-scene*	**Factor 2: (negative) valence** *full-scene*	**Factor 3: engagement** *full-scene*
Δ Sad	0.41		
Σ Sad		0.72	
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Δ Angry	0.40		
Σ Angry		0.81	
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	Factor 1: imbalance		Factor 2: (negative) valence		Factor 3: engagement	
	full-scene	*mov.-alone*	*full-scene*	*mov.-alone*	*full-scene*	*mov.-alone*
Δ Sad	0.41	0.52				
Σ Sad			0.72	0.53		0.49
Δ Happy	0.49	0.53				
Σ Happy				-0.51	-0.55	
Δ Angry	0.40	0.62				
Σ Angry			0.81	0.85		
Δ Excited	0.53	0.63				
Σ Excited					-0.71	
Δ Calm	0.45	0.63				
Σ Calm				-0.45		
Δ Friendly	0.69	0.56				
Σ Friendly				-0.60	-0.43	
Δ Aggressive	0.78	0.79				
Σ Aggressive			0.80	0.72	-0.36	
Δ Engaged		0.39			0.65	0.52
Σ Engaged					-0.64	-0.64
Δ Distracted					0.65	0.63
Σ Distracted			0.63			0.82
Δ Bored		0.44			0.61	0.54
Σ Bored			0.58		0.48	0.83
Δ Frustrated	0.53	0.61				
Σ Frustrated			0.70	0.69		
Δ Dominant	0.75	0.81				
Σ Dominant			0.53	0.52		
Δ Submissive	0.68	0.72				
Σ Submissive			0.54			

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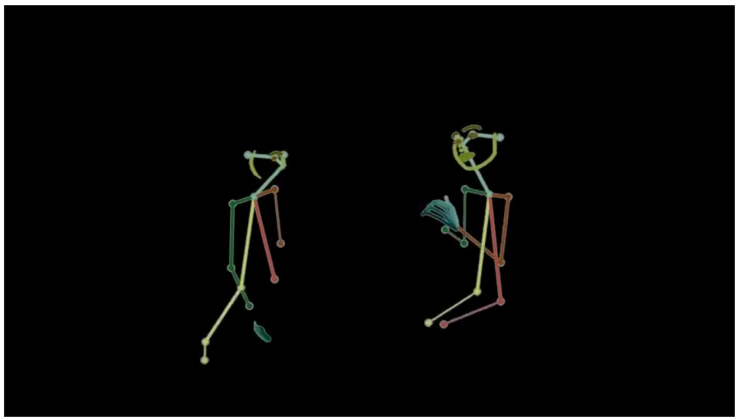
THREE CONSTRUCTS TO RULE THEM ALL



Interaction imbalance

Interaction valence

Engagement

DEEP LEARNING OF SOCIAL INTERACTIONS?


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

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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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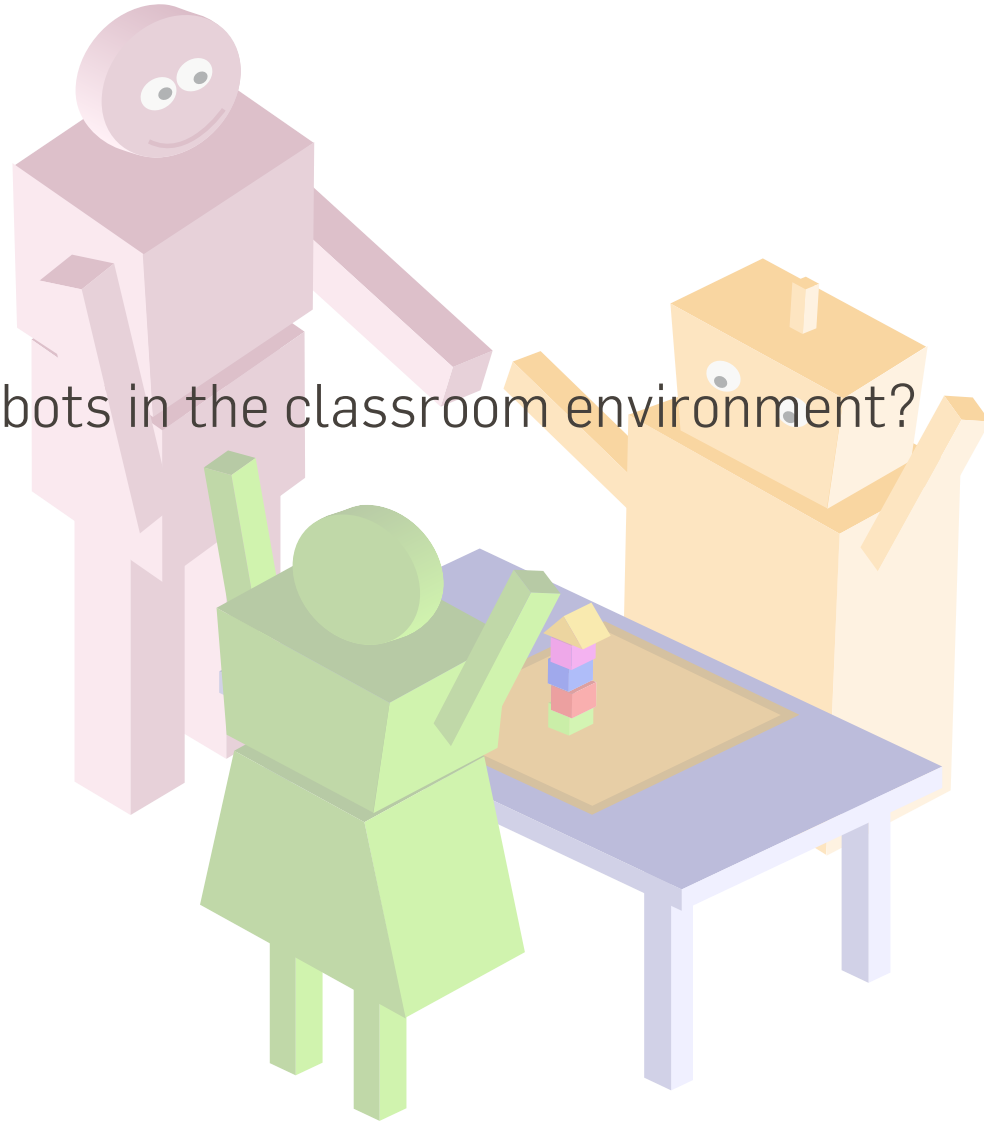
- We have some raw material. Time to process it together!

In summary:

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



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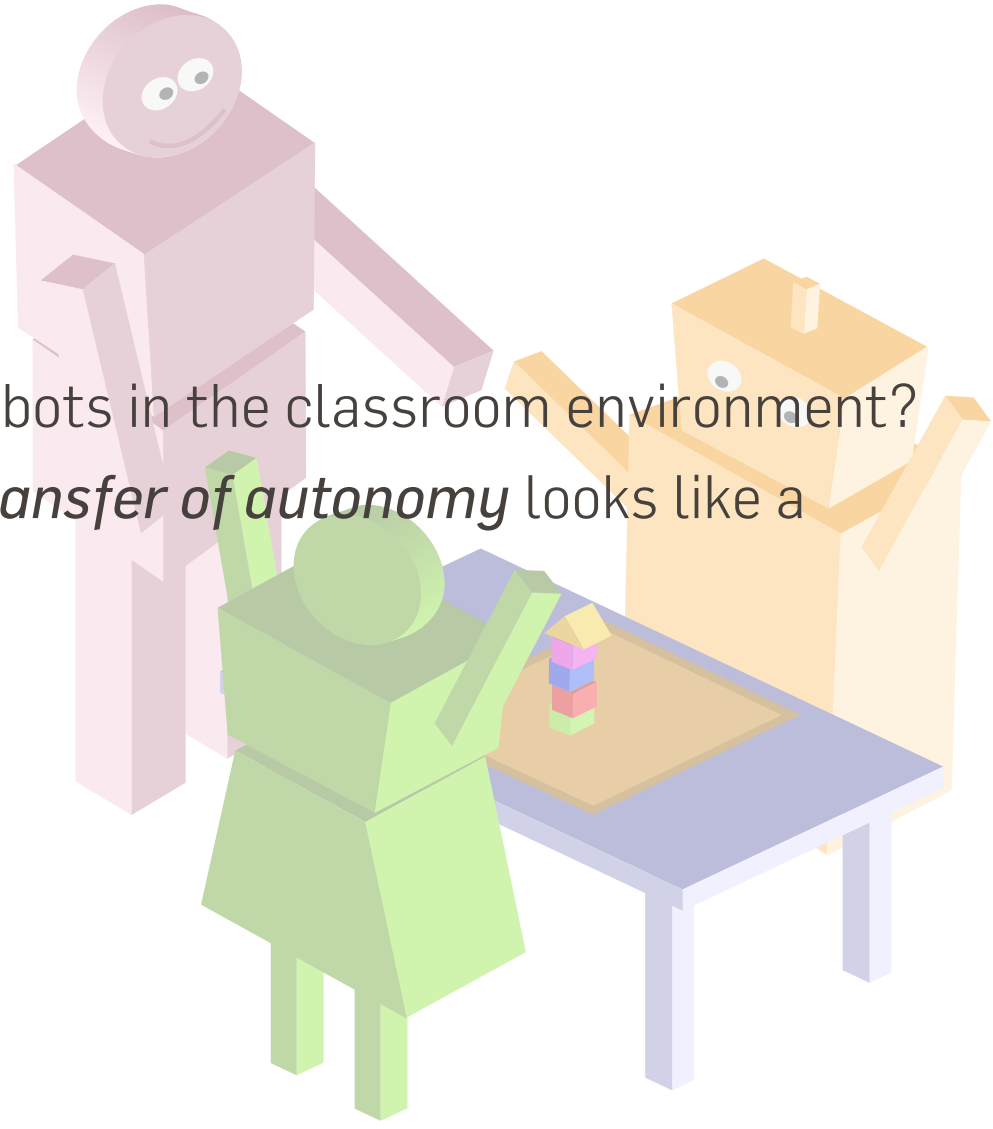

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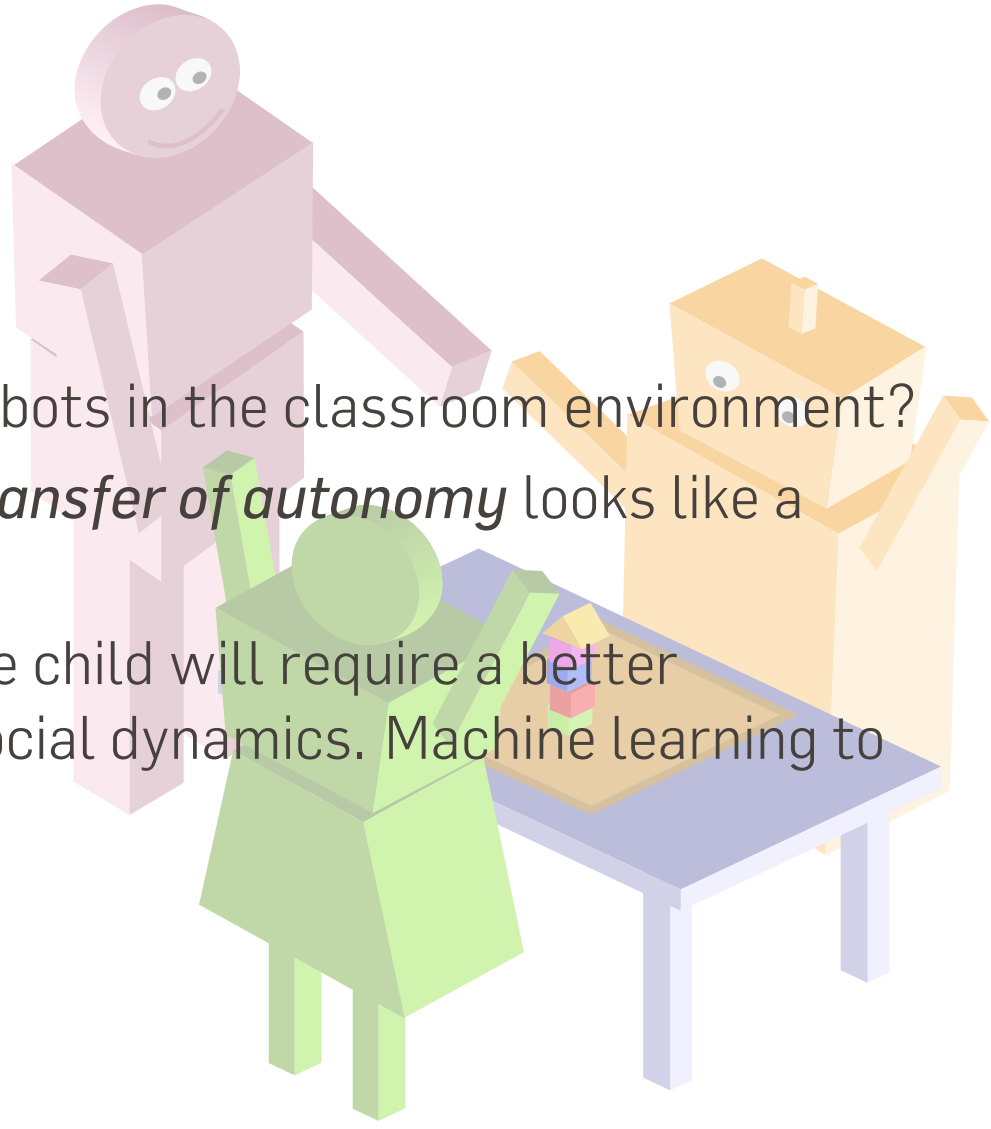

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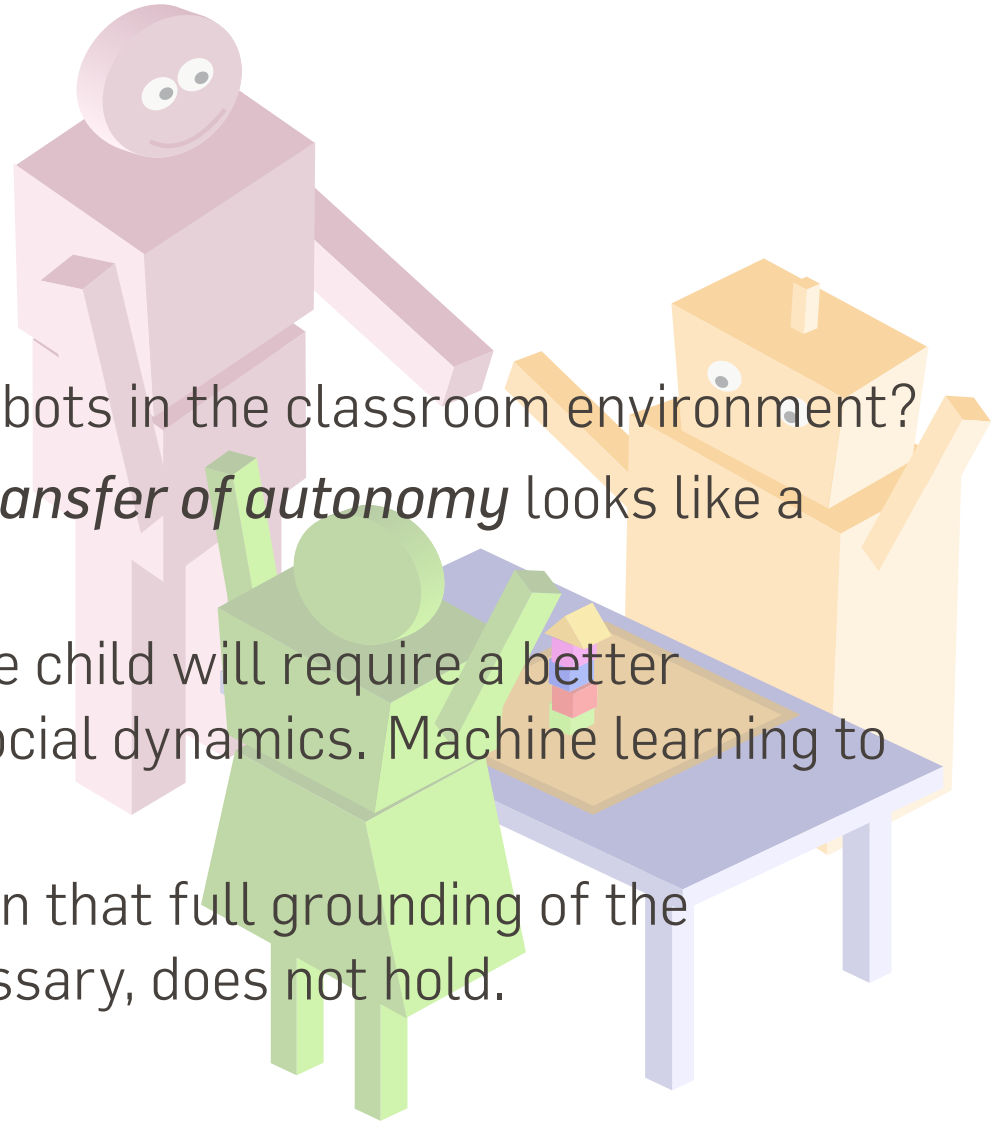

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- ***Doing together*** with the child will require a better understanding of the social dynamics. Machine learning to the rescue?
- ...but the old assumption that full grounding of the communication is necessary, does not hold.

Two open questions for the aspiring PhDs:

- What about group dynamics?

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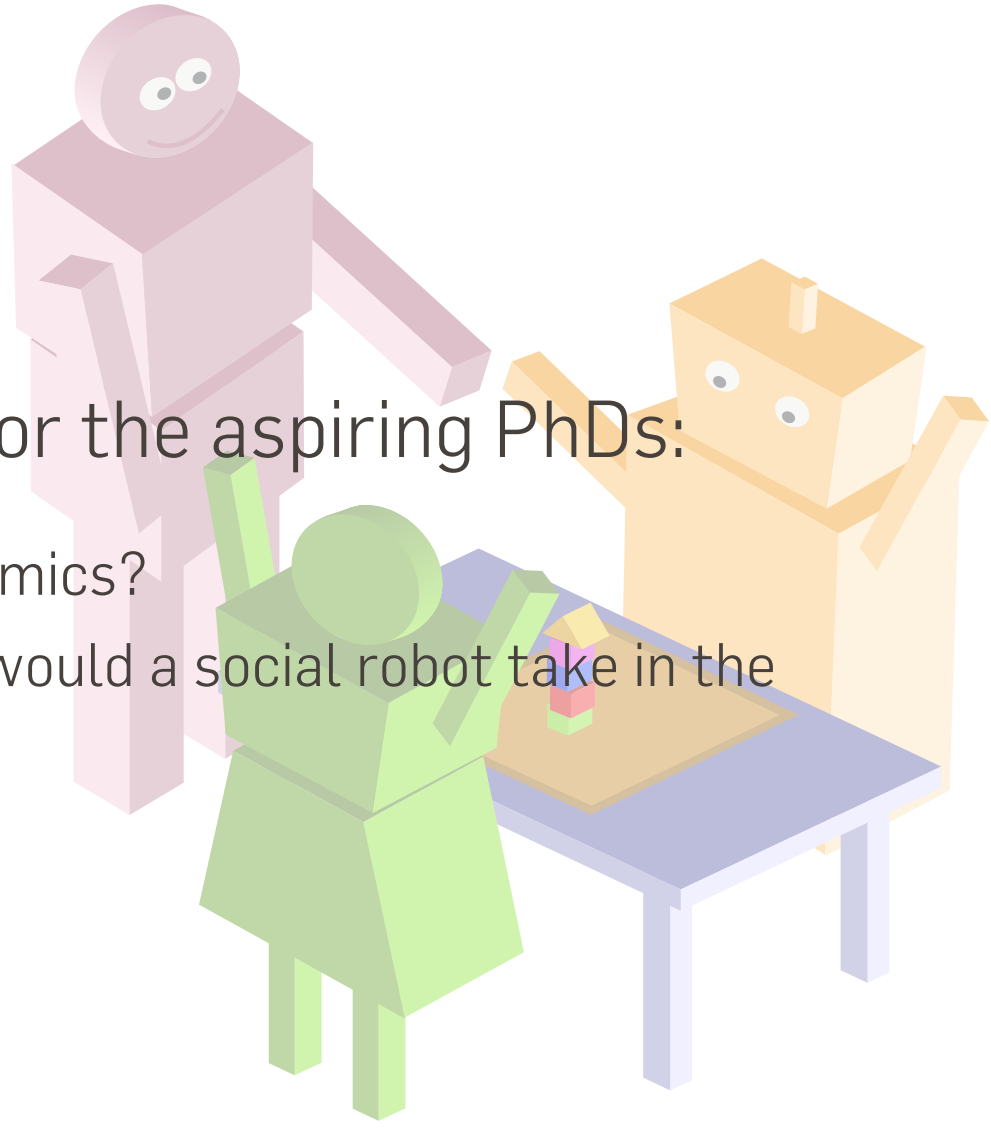
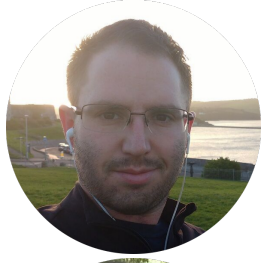
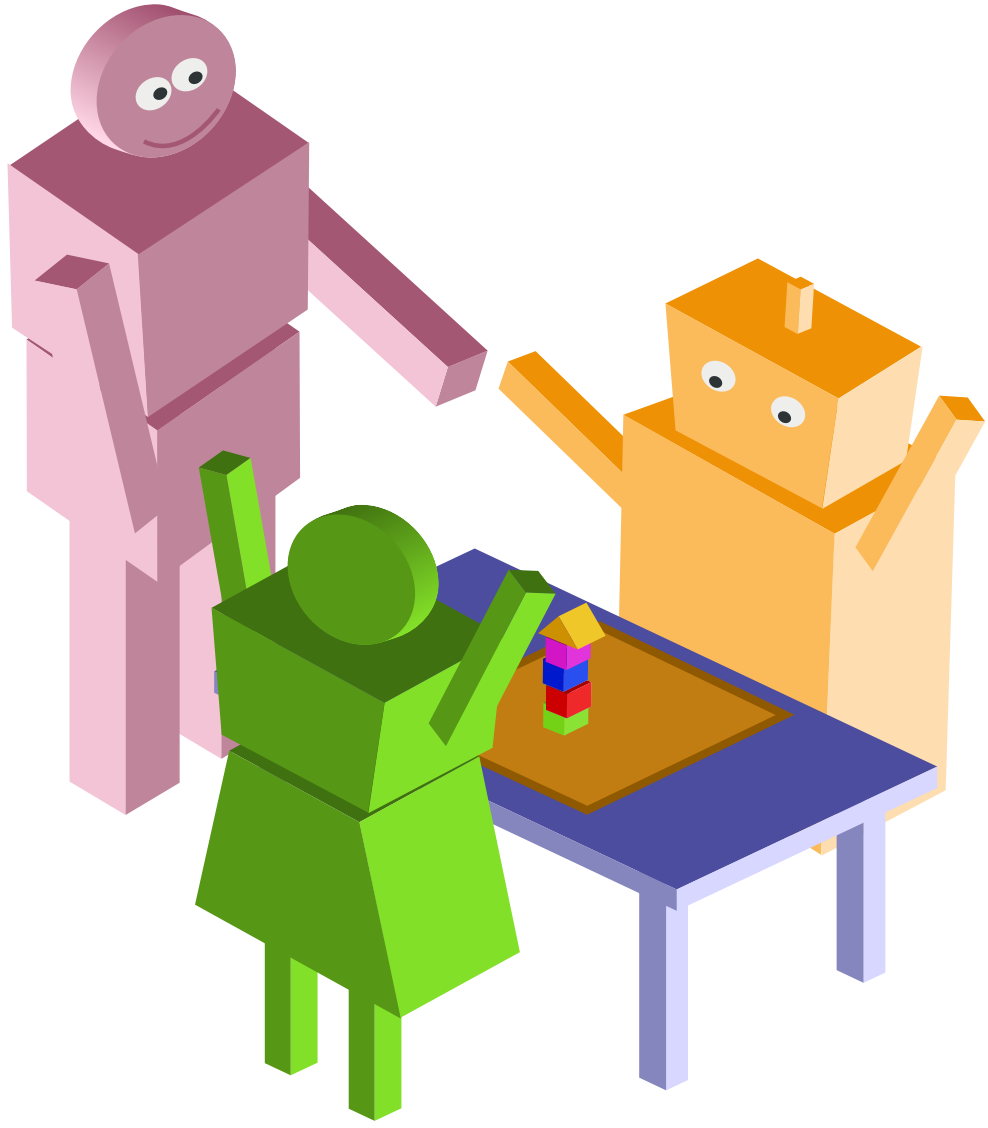
- What about group dynamics?
- Over time, what place would a social robot take in the classroom?







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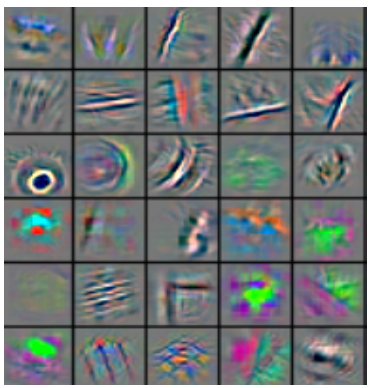
DBSoC: Deep Behavioural Social Cloning – LfD + CNNs + LSTM

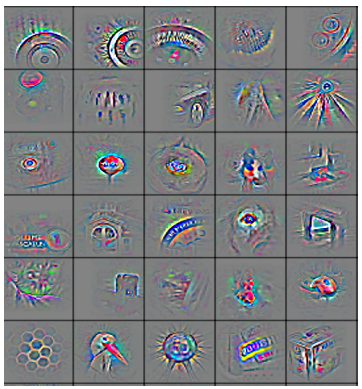
Two tasks for a telepresence robot:

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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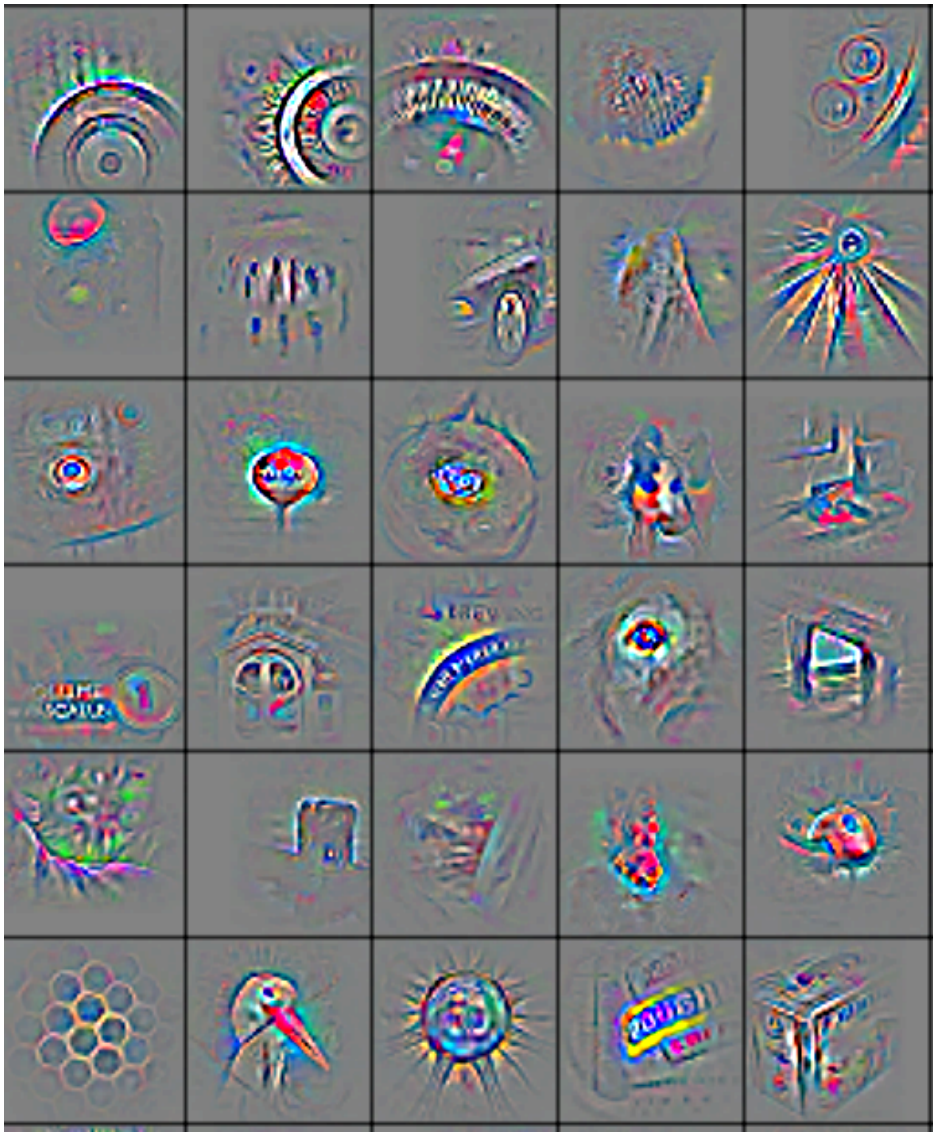

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WHAT DID WE RECORD?

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...	