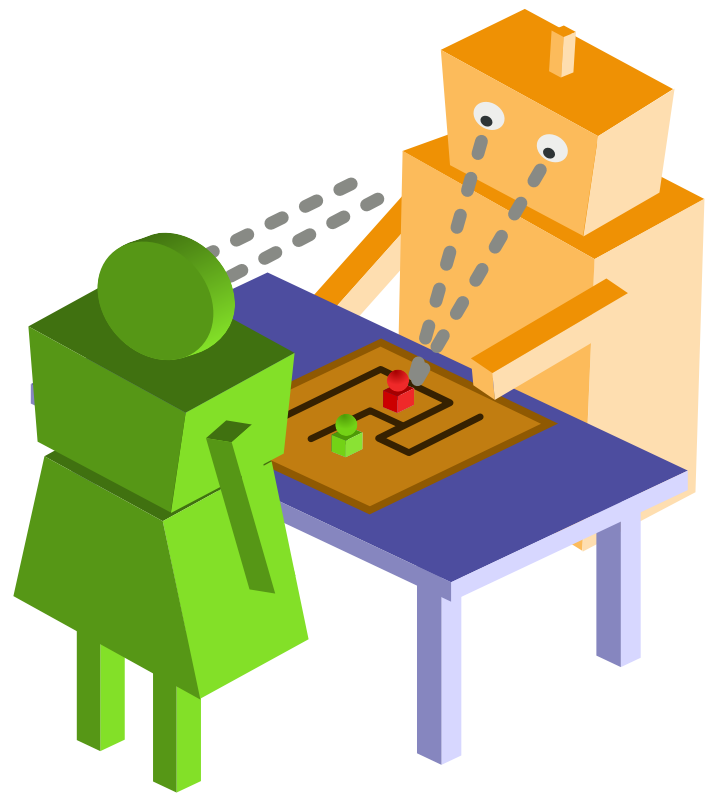
WITH PLYMOUTH UNIVERSITY

MARIE CURIE ACTIONS

From Children Free Play to Robot AI

on the way to artificial social cognition in HRI

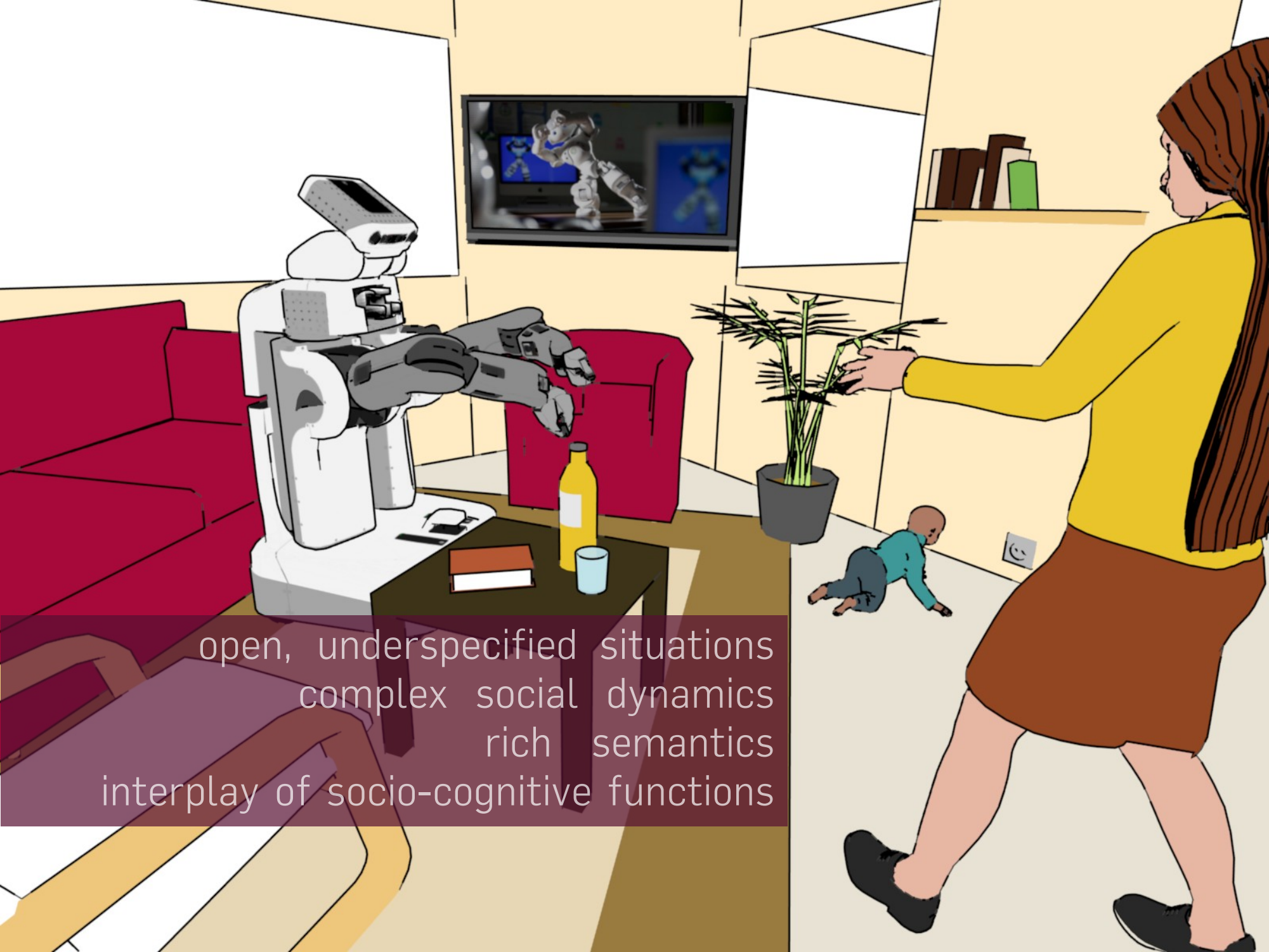
@Plymouth School of Psychology – 29 nov. 2017



Séverin Lemaignan

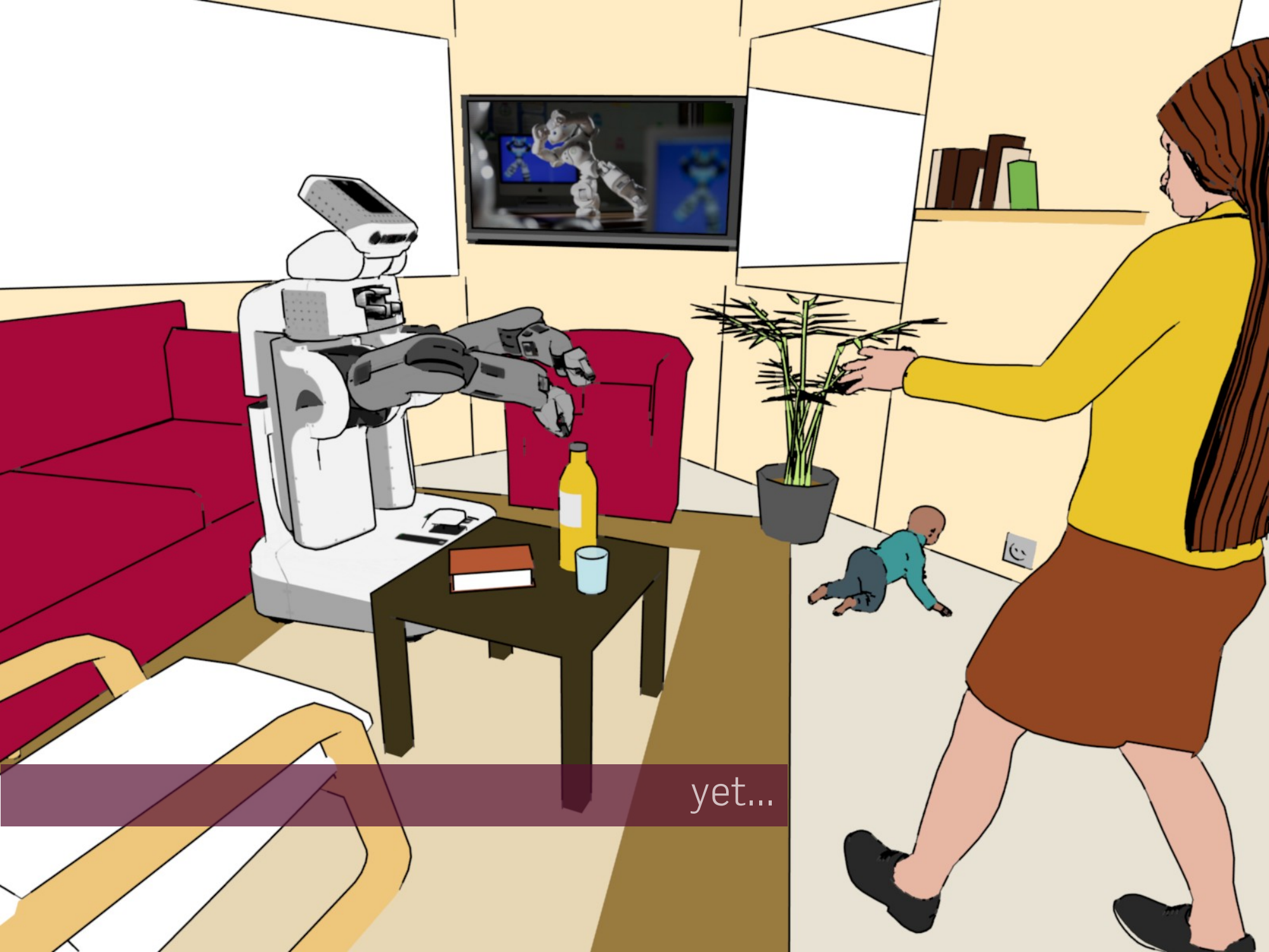
Centre for Robotics and Neural Systems
Plymouth University

How to push back the boundaries of social robotics?


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

SURFACE FUNCTIONS FOR SOCIAL COGNITION

[Baxter, Lemaignan, Trafton **Workshop on Cognitive Architectures for Social HRI** – HRI 2016]


yet...

WHAT METHODOLOGY FOR SOCIAL HRI?

- typical socio-cognitive tasks **too simple and constrainted**
- yet, research *in the wild* is **difficult to conduct rigorously and to replicate**

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Finding the right task is difficult

- natural interactions $\Leftarrow$ meaningful task
- realistic with today's technologies
- practical, reproducible and measurable
- focus on social cognition

THE FREE PLAY PARADIGM

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**

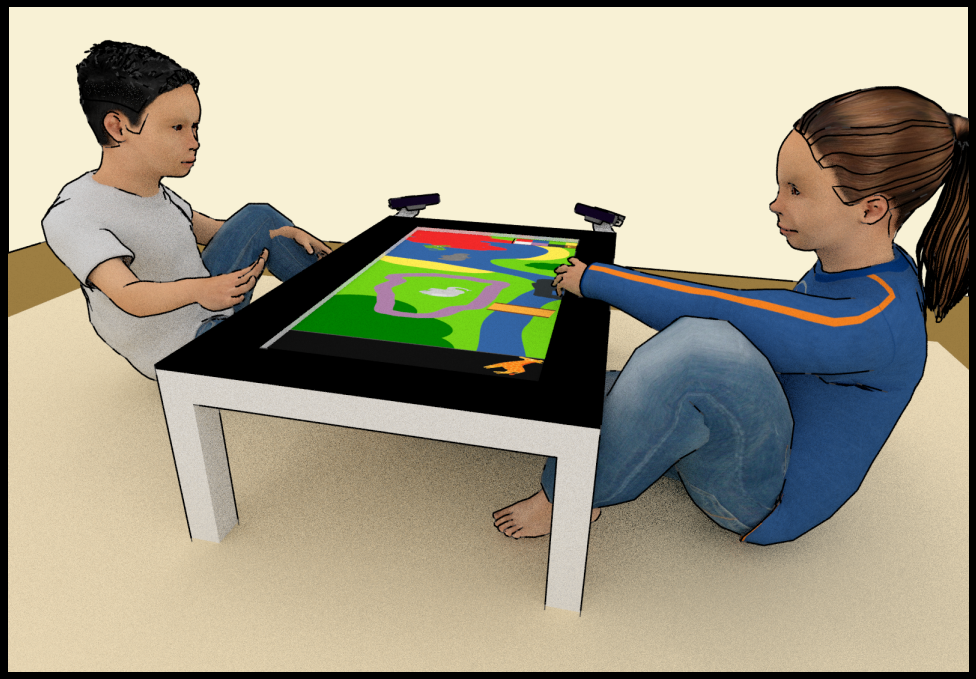
STAGES OF PLAY

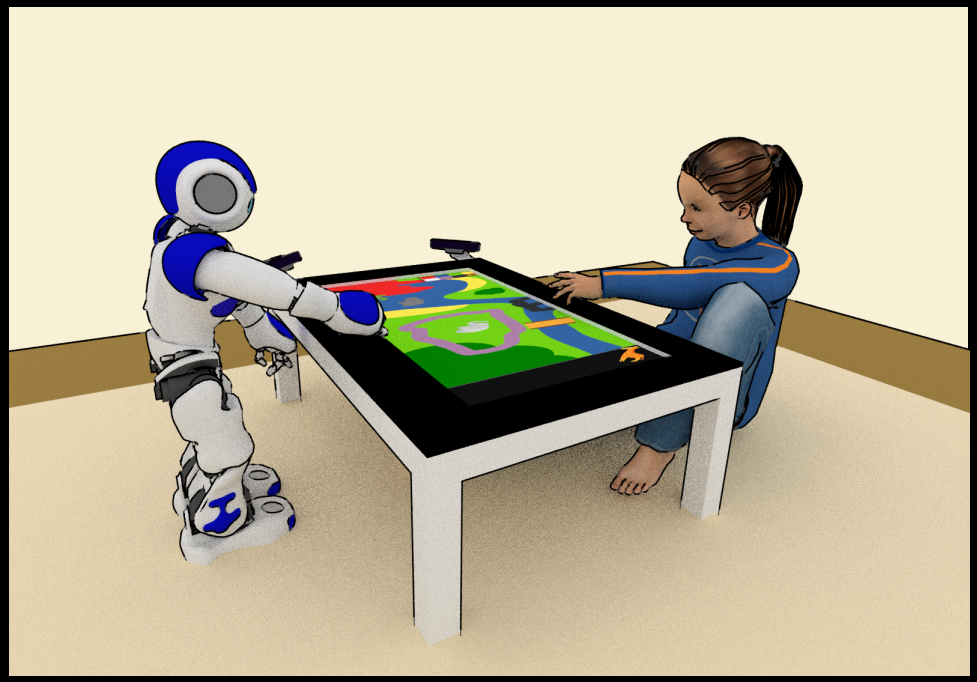
In developmental psychology, Parten's **stages of play**:

1.  **Solitary (independent) play**
2.  **Onlooker play**
3.  **Parallel play**
4.  **Associative play**
5.  **Cooperative play**

[Parten, **Social participation among preschool children** Journal of Abnormal and Social Psychology 1932]

Can we make it work for HRI?

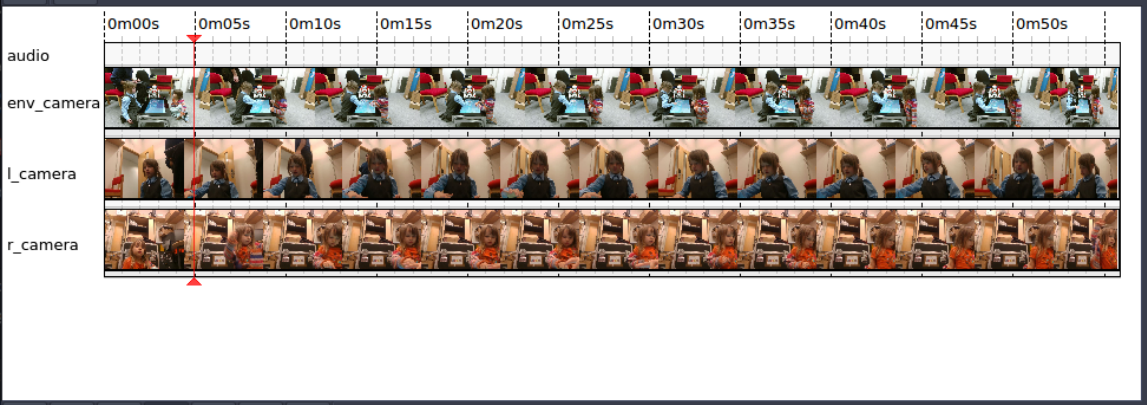




freeplay_sandbox_analysis__Free-play sandbox analysis tool - rqt

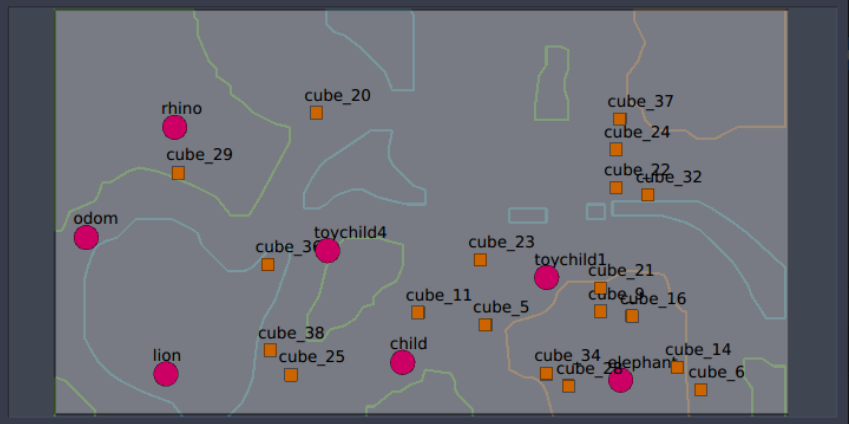
File Help

Bag



1489767416.116s | Mar 17 2017 16:16:56.115 | 4.956s | > | 365.16 MB

Sandtray



env_camera

l_camera

r_camera

'SANDBOXED FREE PLAY' EXPERIMENTAL PARADIGM

- **Structured methodology** (sandtray) yet **loosely structured task** (free play)

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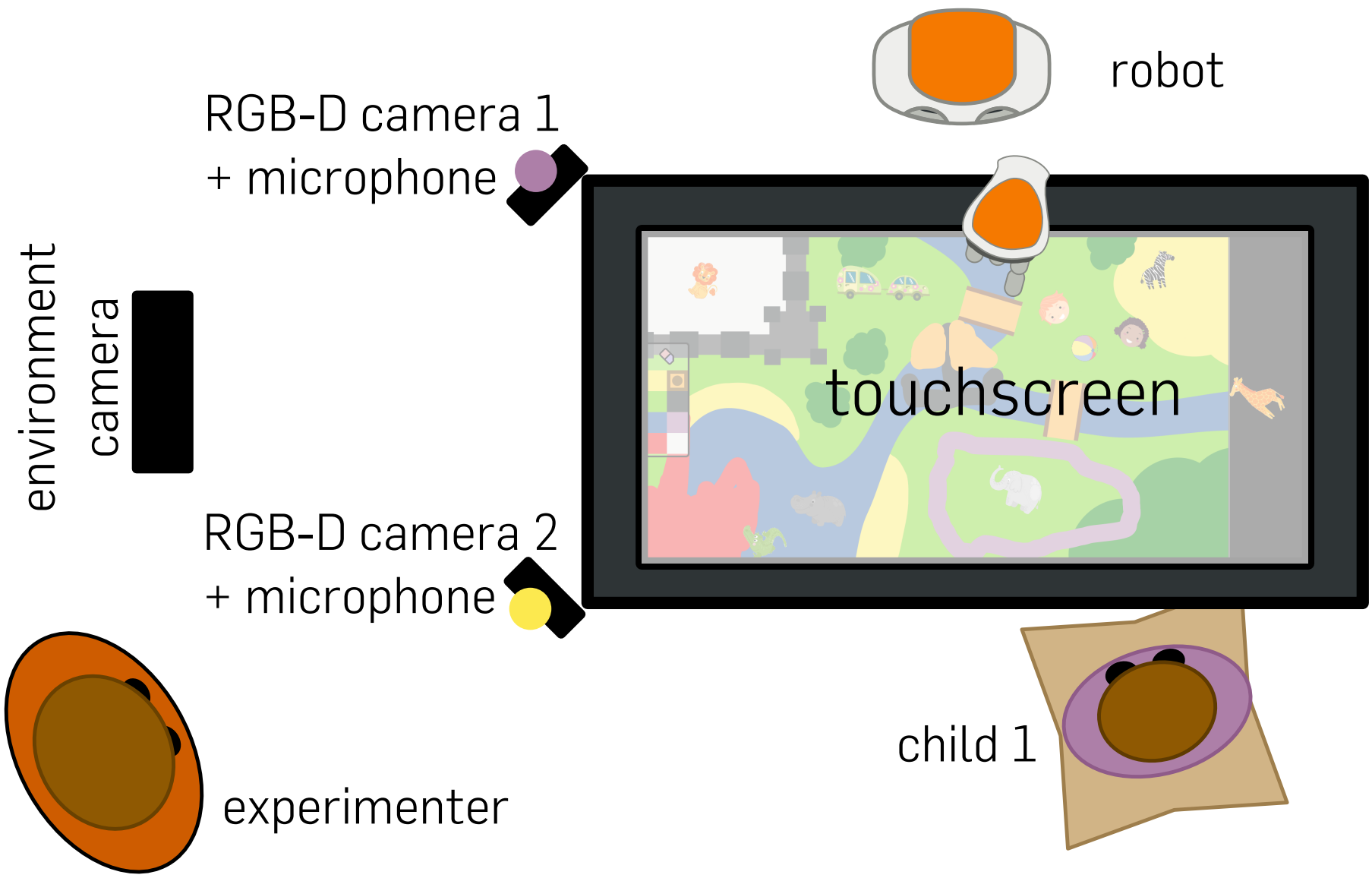
'SANDBOXED FREE PLAY' EXPERIMENTAL PARADIGM

- **Structured methodology** (sandtray) yet **loosely structured task** (free play)
- physical playground → **replaced by large touchscreen**: escape perception and manipulation in dense & cluttered scene (but *only* that)
- importantly, **perception and interaction with the partner is unimpaired**


robot
RGB-D camera 1
+ microphone
environment
camera
touchscreen
RGB-D camera 2
+ microphone
child 1
experimenter

CHECK OUR 'SHOPPING LIST'

We were looking for a task that exhibits...

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

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- interplay of many socio-cognitive functions

And as well:

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

WHAT DO WE WANT TO OBSERVE?

- ~~the **semantic of the interaction**~~

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  are the participants 'on task' or not?

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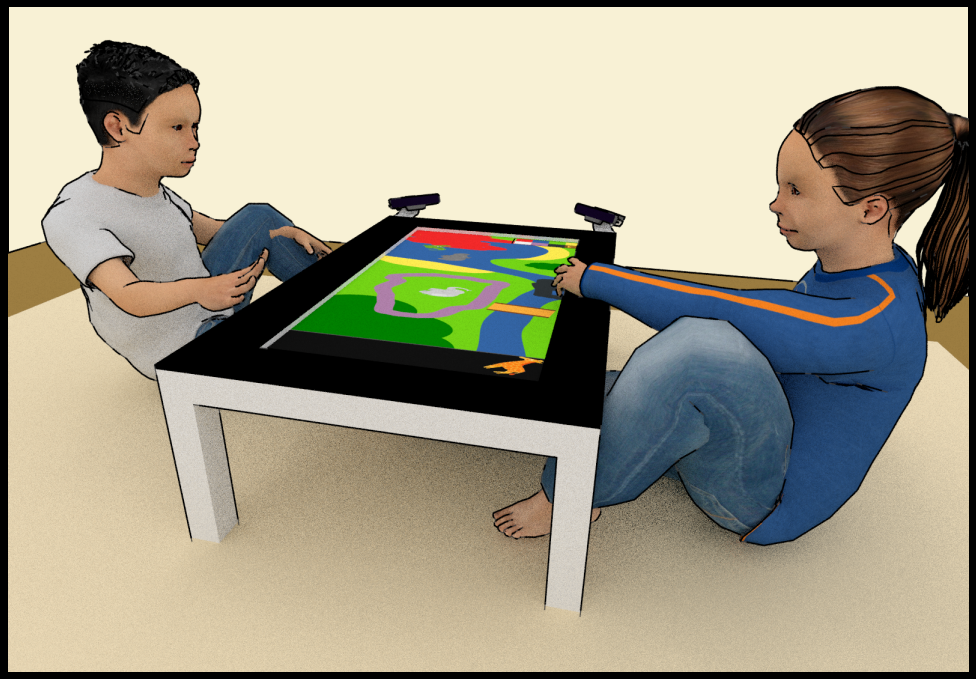
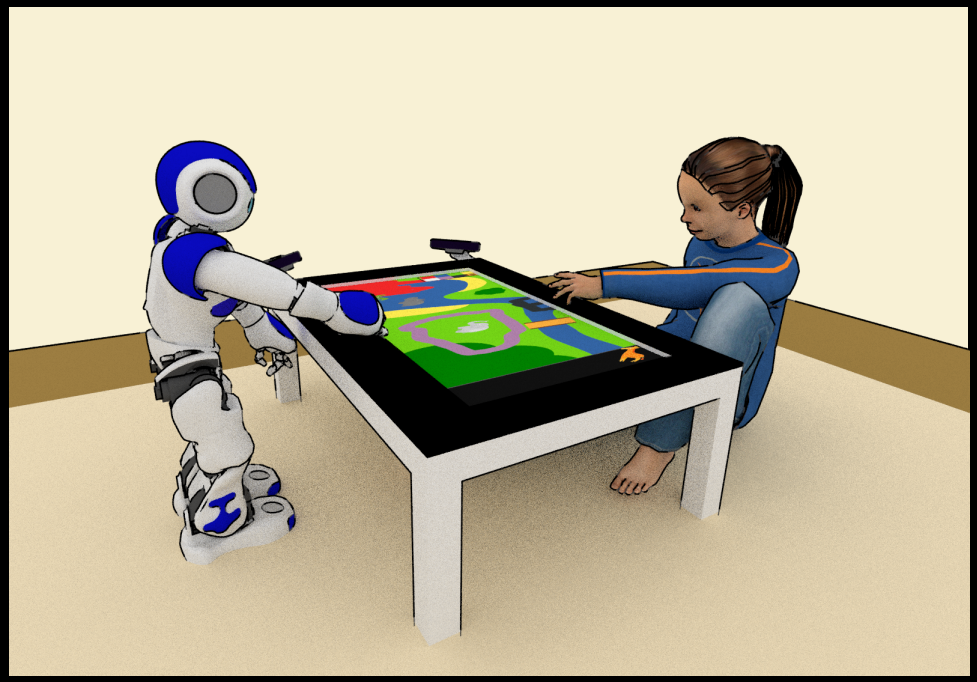
→ **paradigm for socio-cognitive investigation**

THE PINSORO DATASET

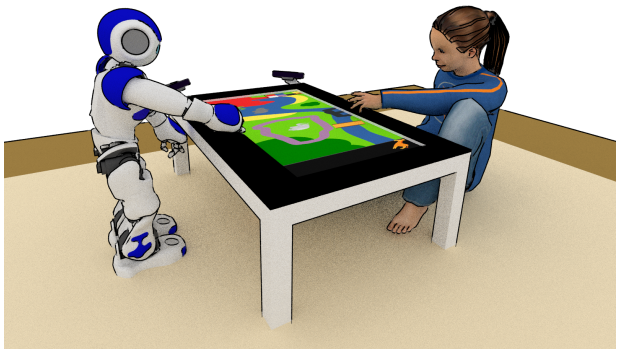


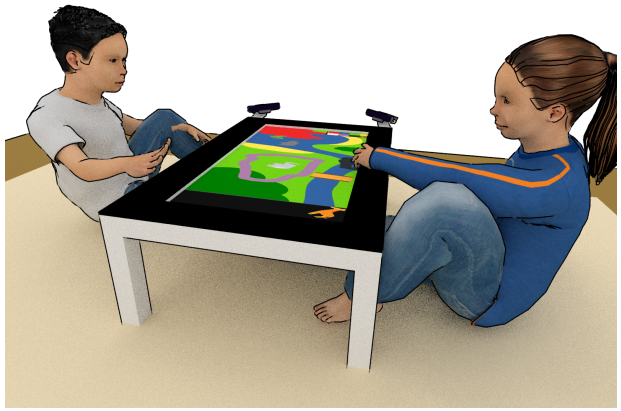


THE PINSORO DATASET

- 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

TWO BASELINES



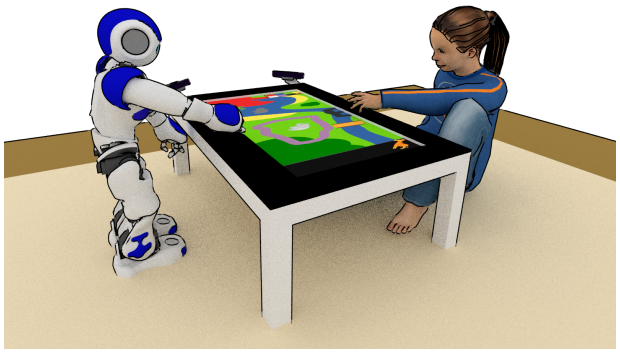


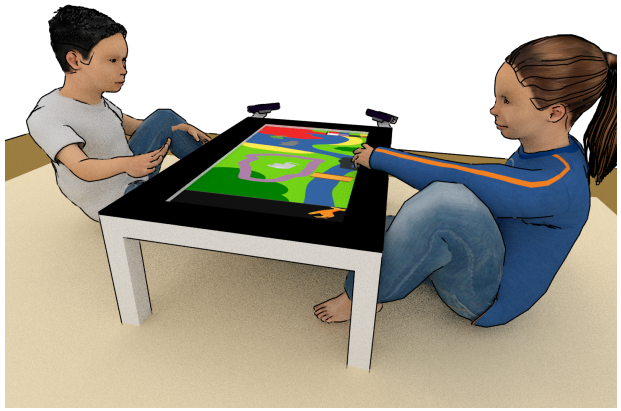
child - non-social robot

child - child

richness of social interactions

TWO BASELINES



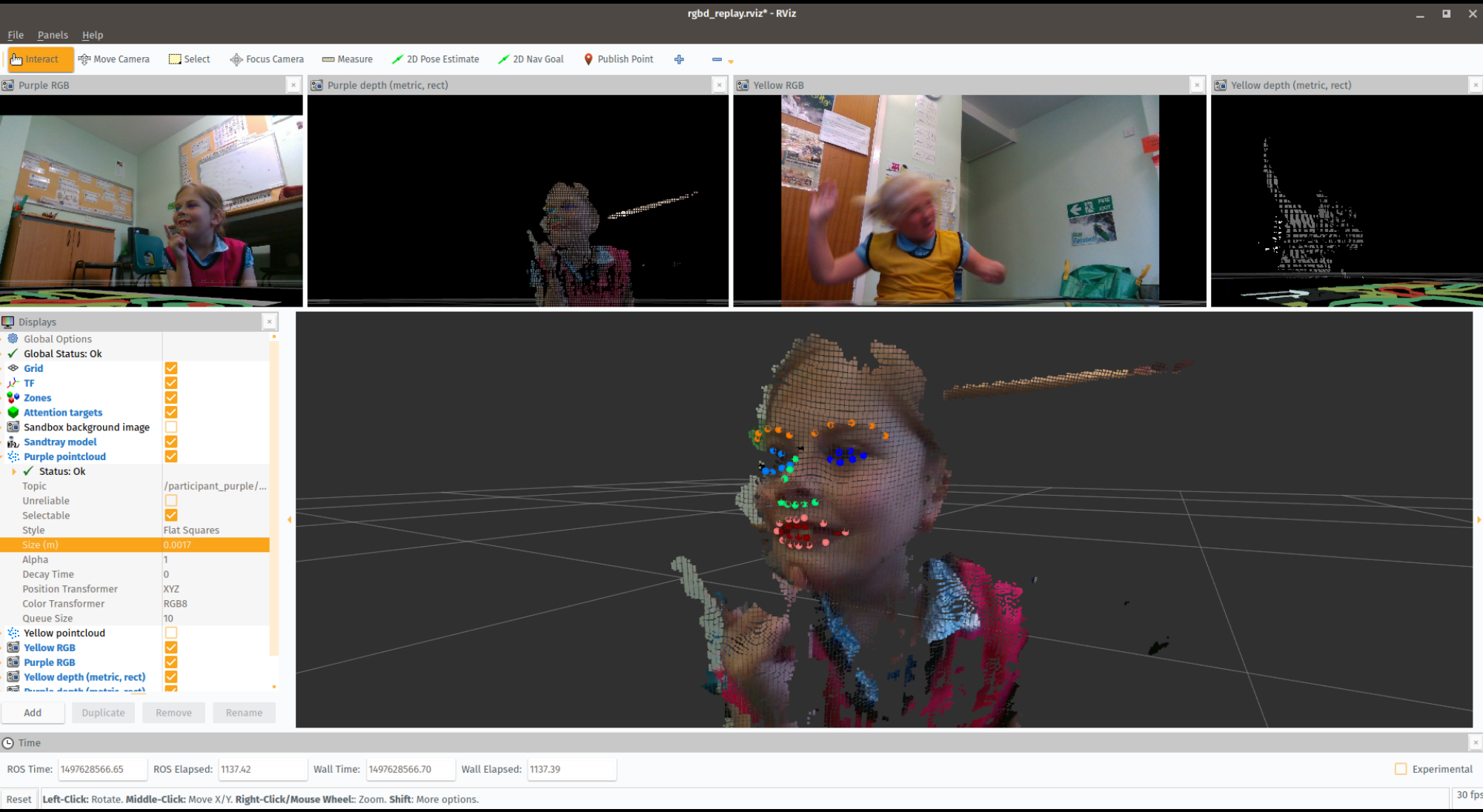


child - non-social robot

your next socio-cognitive model

child - child

richness of social interactions

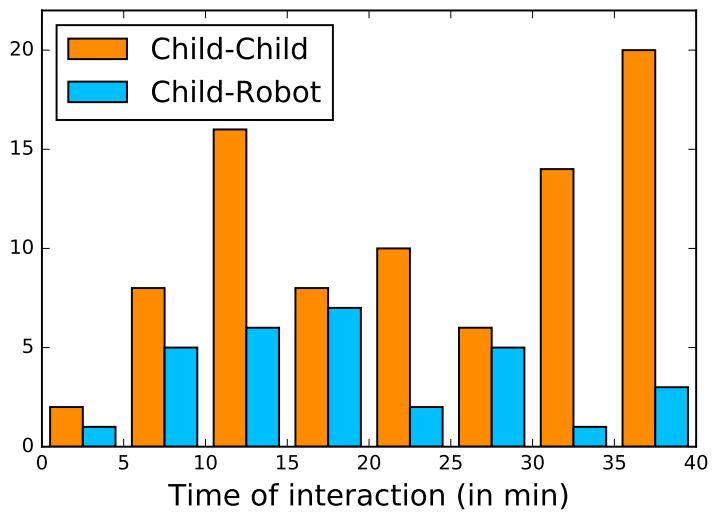

rgbd_replay.rviz* - RViz
File
Panels
Help
Interact
Move Camera
Select
Focus Camera
Measure
2D Pose Estimate
2D Nav Goal
Publish Point
Purple RGB
Purple depth (metric, rect)
Yellow RGB
Yellow depth (metric, rect)
Displays
Global Options
Global Status: Ok
Grid
TF
Zones
Attention targets
Sandbox background image
Sandtray model
Purple pointcloud
Status: Ok
Topic
/participant_purple/...
Unreliable
Selectable
Style
Flat Squares
Size (m)
0.0017
Alpha
1
Decay Time
0
Position Transformer
XYZ
Color Transformer
RGB8
Queue Size
10
Yellow pointcloud
Yellow RGB
Purple RGB
Yellow depth (metric, rect)
Add
Duplicate
Remove
Rename
Time
ROS Time:
1497628566.65
ROS Elapsed:
1137.42
Wall Time:
1497628566.70
Wall Elapsed:
1137.39
Experimental
Reset
Left-Click: Rotate. Middle-Click: Move X/Y. Right-Click/Mouse Wheel:: Zoom. Shift: More options.
30 fps

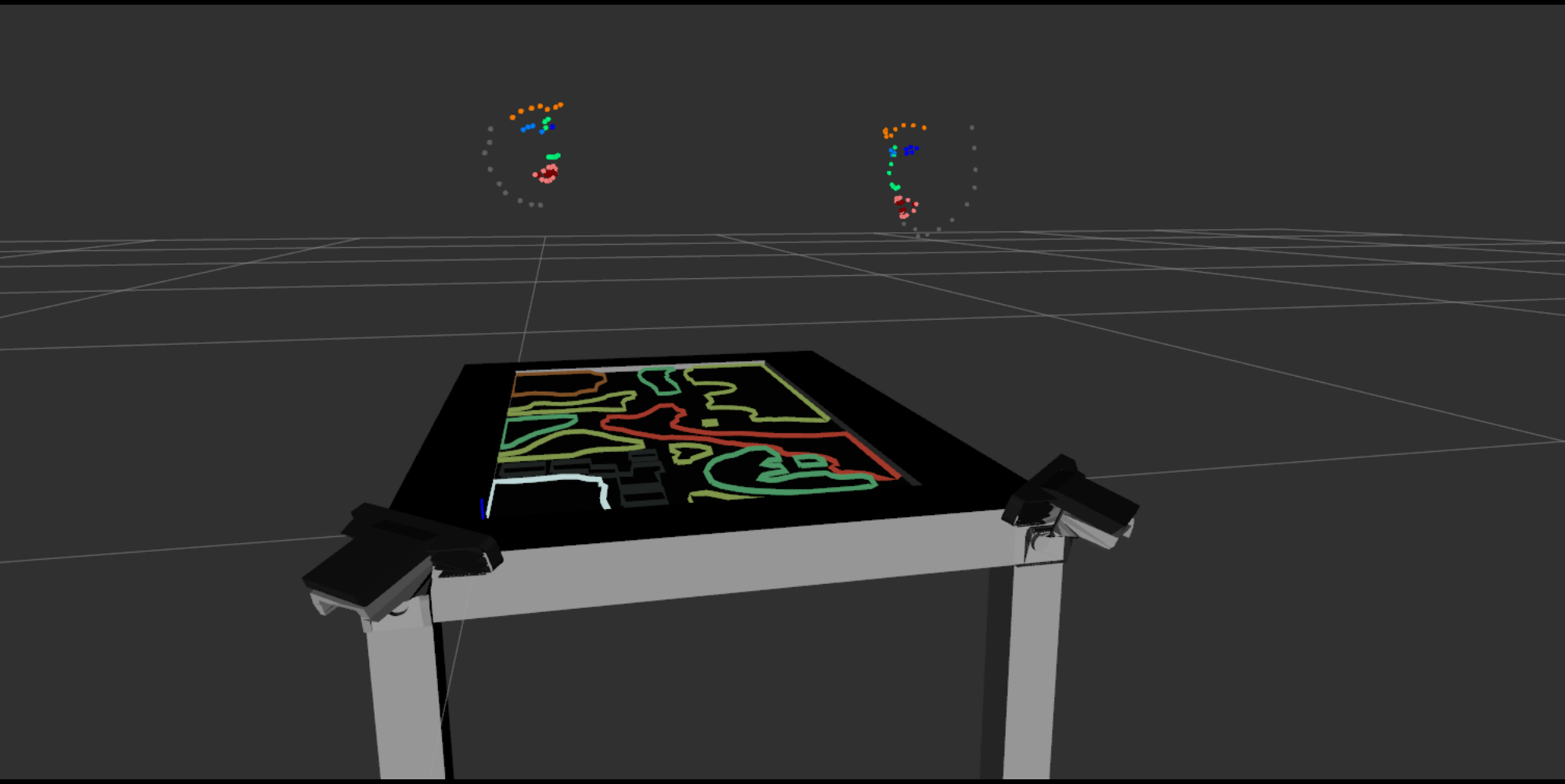
WHAT DID WE RECORD?

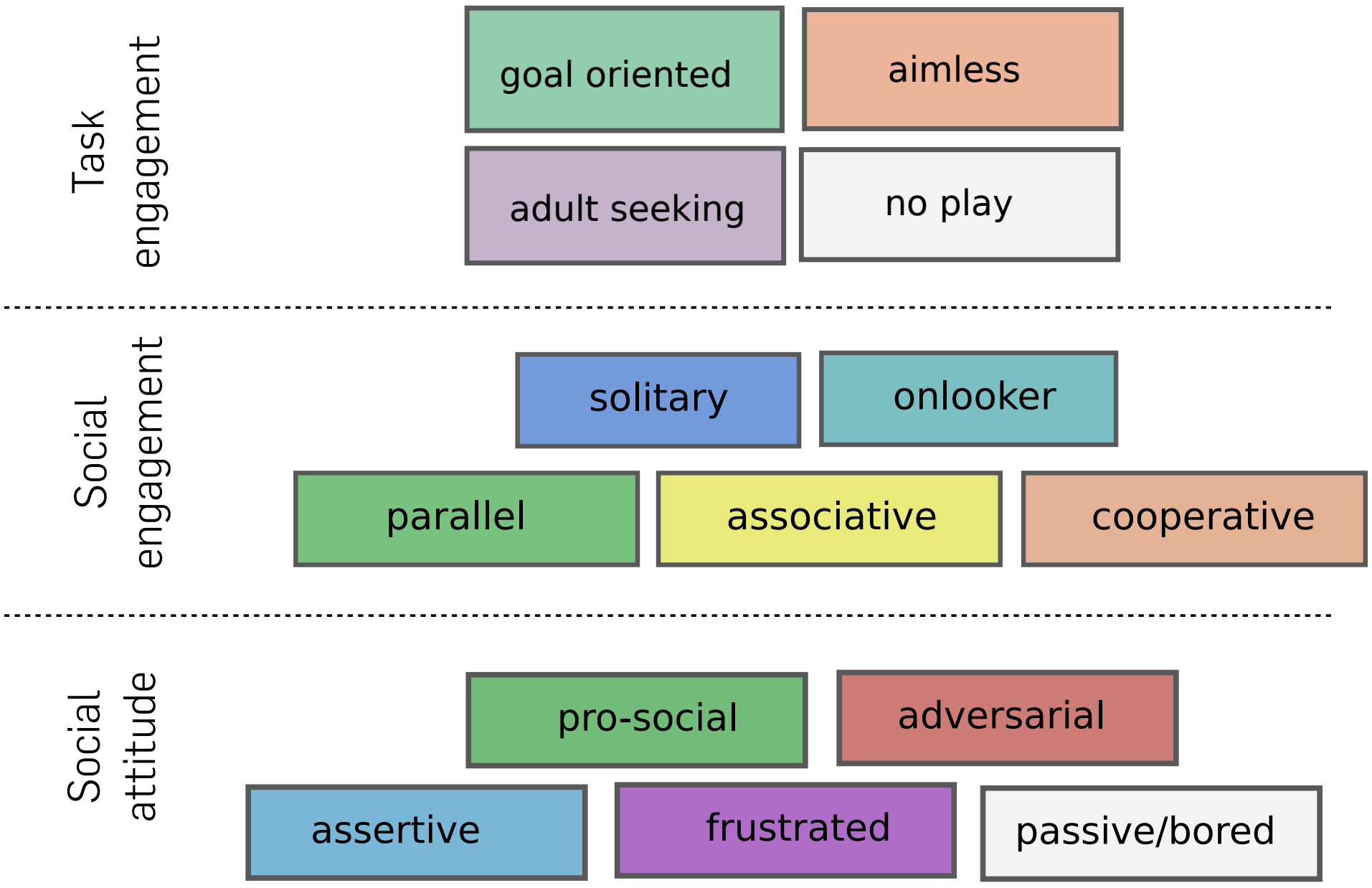
Domain	Type	Details
child × 2	audio	16kHz, mono, semi-directional
	face (RGB)	qHD (960x540), 30Hz
	face (depth)	VGA (640x480), 30Hz
	facial features	70 2D points, 30Hz
	skeleton	15 2D points, 30Hz
	hands	20 x 2 2D points, 30Hz
environment	RGB	qHD (960x540), 29.7Hz
touchscreen	background drawing (RGB)	4Hz
	touches	6 points multi-touch, 10Hz
	items position and orientation	(x,y,theta), 10Hz
annotations	timestamped annotations of social behaviours	
other	static transforms between touchscreen and facial cameras cameras calibration informations	

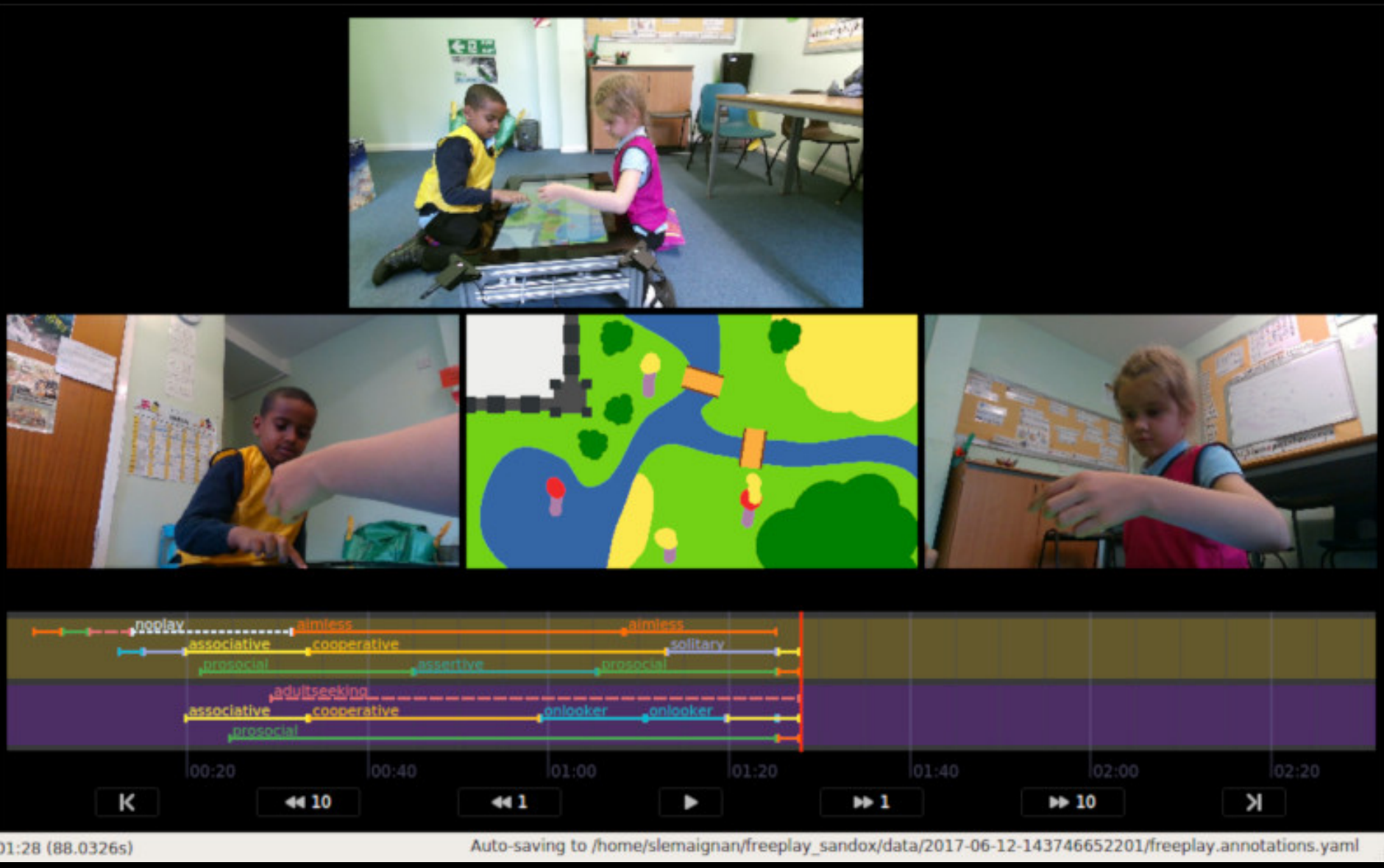
DATASET

- 120 children, 4 to 8 years old; 45h+ of recordings;
- average duration of freeplay interactions: 24min in child-child condition; 19min in child-robot condition
- facial features extracted in 98% of frames






Task engagement
goal oriented
aimless
adult seeking
no play
Social engagement
solitary
onlooker
parallel
associative
cooperative
Social attitude
pro-social
adversarial
assertive
frustrated
passive/bored


noplay
aimless
aimless
associative
cooperative
solitary
prosocial
assertive
prosocial
adultseeking
associative
cooperative
onlooker
onlooker
prosocial
00:20
00:40
01:00
01:20
01:40
02:00
02:20
10
1
1
10
01:28 (88.0326s)
Auto-saving to /home/slemaignan/freeplay_sandox/data/2017-06-12-143746652201/freeplay.annotations.yaml

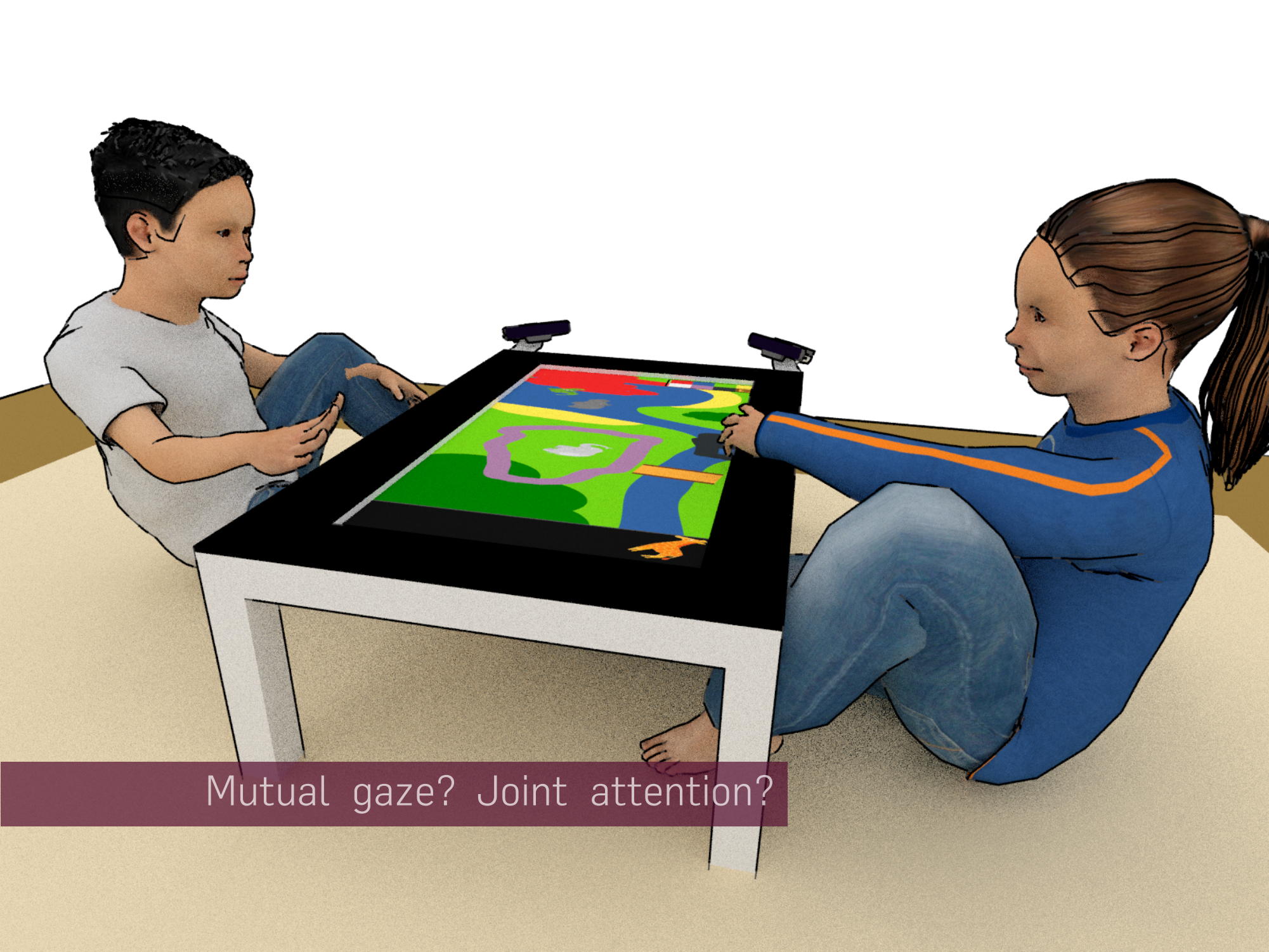

Attitude: passive
Social engag.: onlooker
Task engag.: no play
Attitude: passive
Social engag.: solitary
Task engag.: goal oriented

Anonymised version (only 5.7GB...) available on-line. Grab it now! (or ask me! ;-)

freeplay-sandbox.github.io

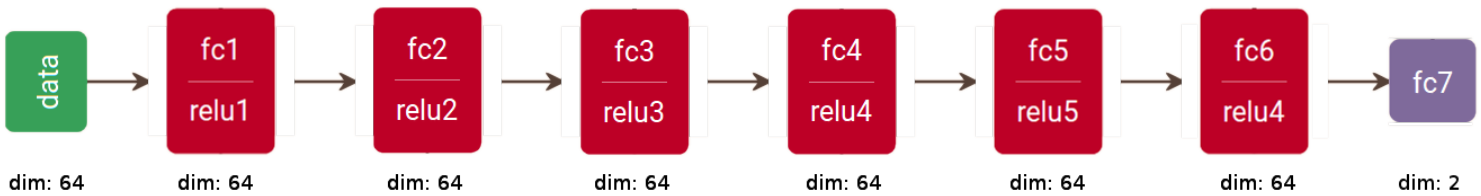
Open data! Hosted on EU's zenodo

WHAT DOES THIS DATASET MEAN TO HRI?

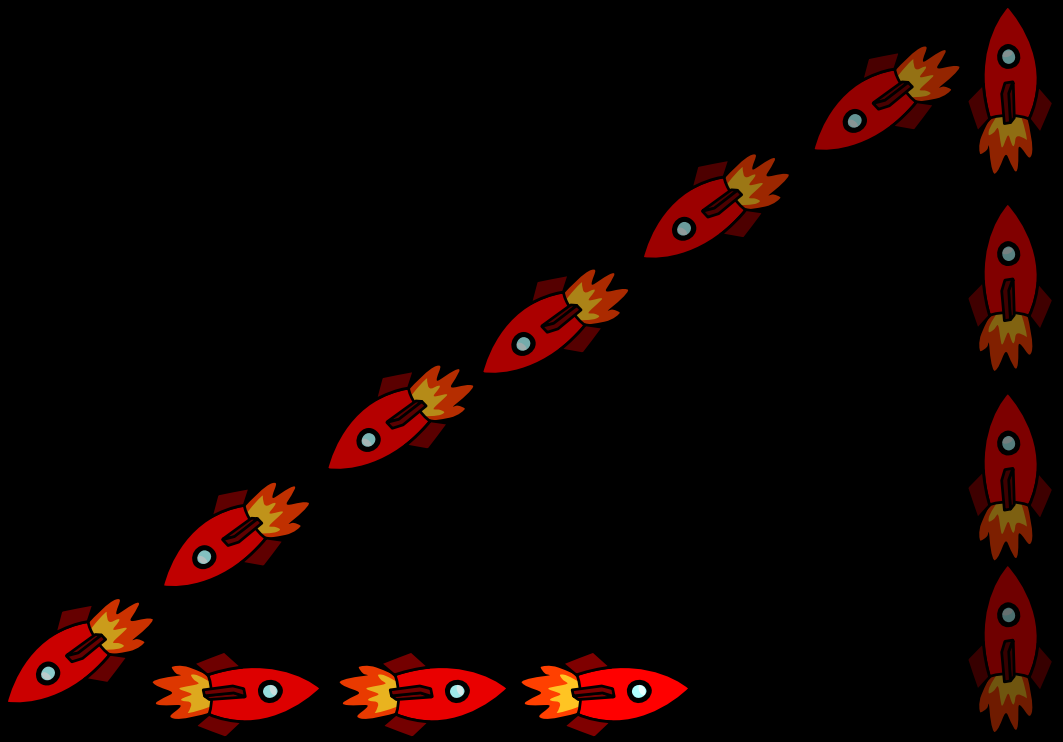

Mutual gaze? Joint attention?

TRAINING FOR GAZE ESTIMATION

End-to-end training to map 2D facial features to gaze location



- **Input**: 32 2D points (eyes, eyebrows, nose, ears, shoulders)
- **Output**: 2D gaze location on the interactive table



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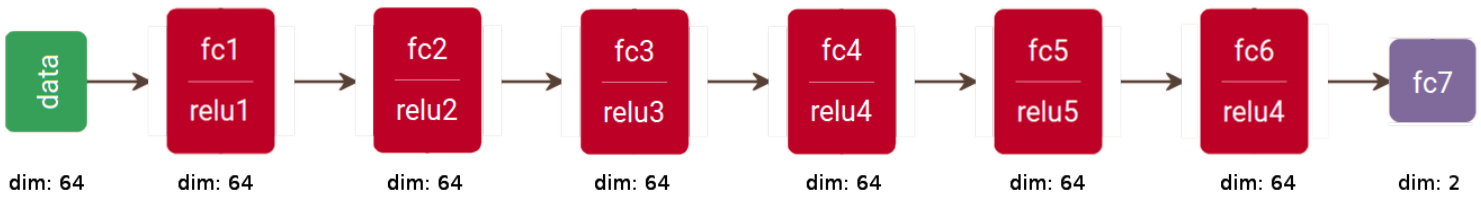
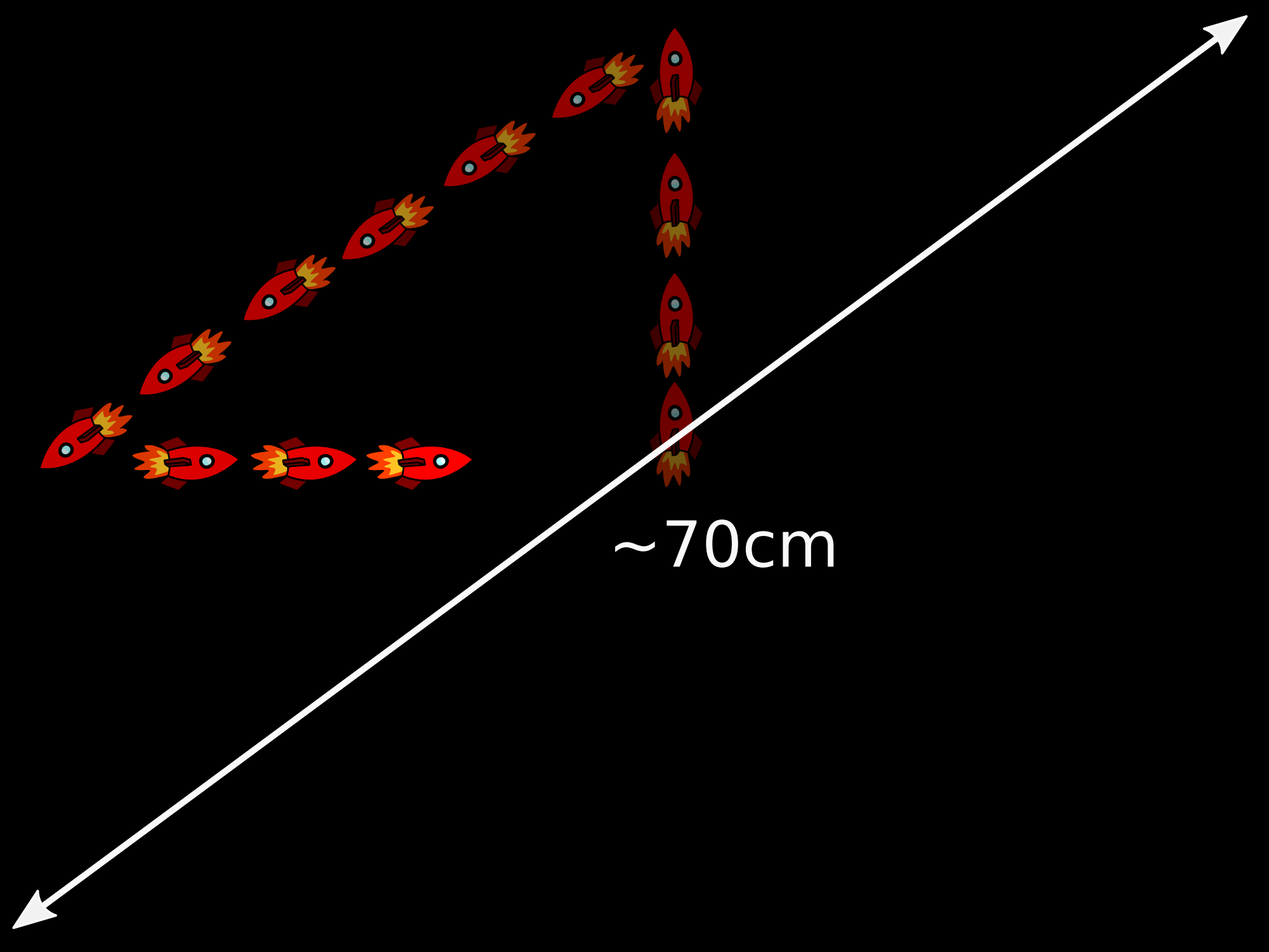
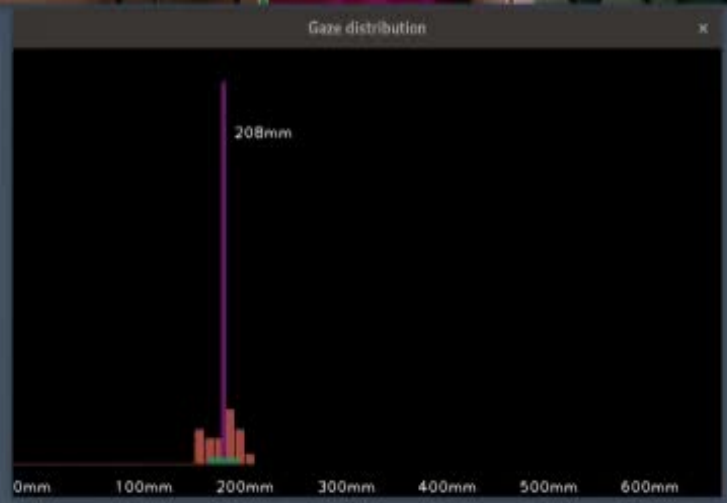


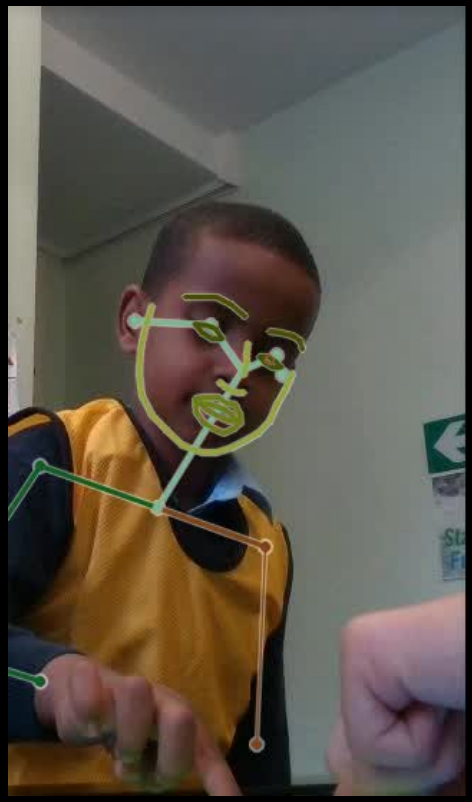
- **Pros**: no calibration; no eye tracking device; 2D images
- **Cons**: require a initial ground truth; accurate?

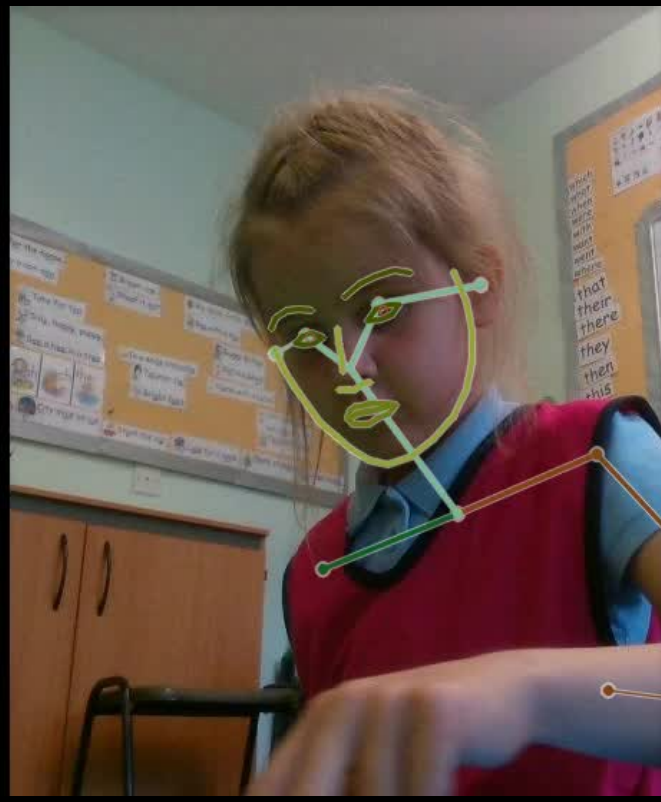

~70cm


FIRE EXIT


Gaze estimate


Gaze distribution
208mm
0mm
100mm
200mm
300mm
400mm
500mm
600mm




that
their
there
they
then
this

What about social HRI?

DEEP LEARNING AND ROBOTICS

LEARNING COMPLEX BEHAVIOURS

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

[Mnih et al. **Human-level control through deep reinforcement learning** – Nature 2015]

LEARNING COMPLEX BEHAVIOURS

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

[Mnih et al. **Human-level control through deep reinforcement learning** – Nature 2015]

LEARNING SEQUENCES

Ogata's demonstration (published this year in IEEE RAL):

- 2 arms, 12 DoF
- Inputs: on-board 112×112px camera, joint state

[Yang et al. **Repeatable Folding Task by Humanoid Robot Worker using Deep Learning** – Robotics and Automation Letters 2017]

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Not only learning poses, but **sequences as well**.

Time-Delay Neural Network (TDNN) to learn to predict the next step (no RNNs!).

[Yang et al. **Repeatable Folding Task by Humanoid Robot Worker using Deep Learning** – Robotics and Automation Letters 2017]

DEEP LEARNING OF SOCIAL INTERACTIONS?


Attitude: passive
Social engag.: onlooker
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AIM

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!**

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

Attitude: pro—social

Social engag.: parallel play

Task engag.: goal oriented

Attitude: pro—social

Social engag.: parallel play

Task engag.: goal oriented

The problem is framed, data is available, next step: **mining it!**

BACK TO THE BIGGER PICTURE

ONE QUESTION

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Both “emerge” as ***arise from*** and “emerge“ as in ***emergent paradigm of cognition***

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“Social cognition arising in interaction”? → a situated & embodied view on cognition

DEEP LEARNING OF SOCIAL INTERACTIONS

Working hypothesis: **Sociality emerges from interaction**

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$\Rightarrow$ **learning how to interact might lead to an emergent socio-cognitive behaviour**

$\Rightarrow$ **(Deep) learning of socio-cognitive human-robot interactions**

(Supervised (or unsupervised!) recurrent neural networks to model others' minds $\rightarrow$ a connectionist theory of mind!)

DEEP LEARNING OF SOCIAL INTERACTIONS

Working hypothesis: **Sociality emerges from interaction**

$\Rightarrow$ **learning how to interact might lead to an emergent socio-cognitive behaviour**

$\Rightarrow$ **(Deep) learning of socio-cognitive human-robot interactions**

(Supervised (or unsupervised!) recurrent neural networks to model others' minds $\rightarrow$ a connectionist theory of mind!)

...towards a principled model of social cognition?

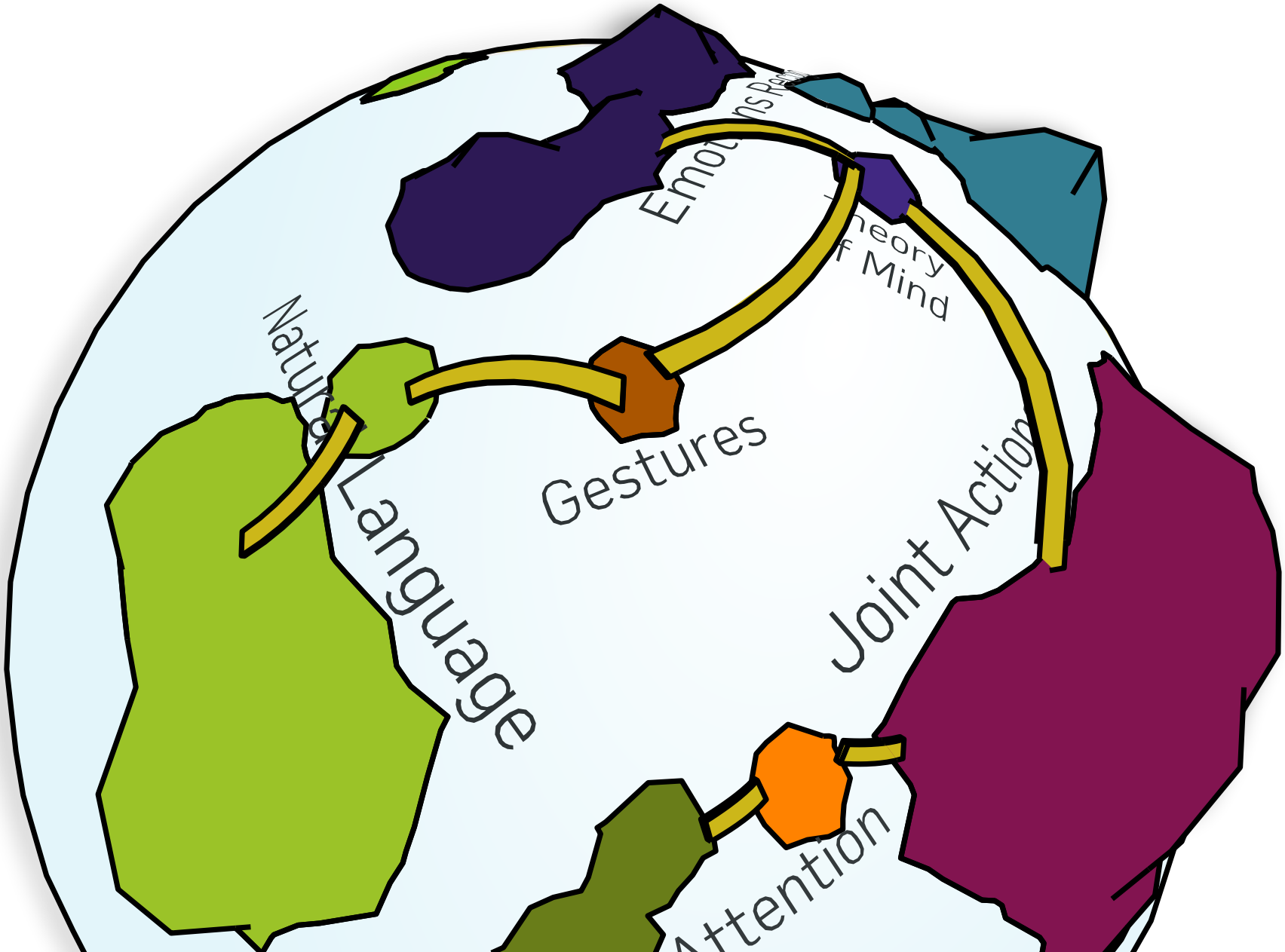
A MODEL?

Models attempt to ***explain***:

> *"identifying the causes for an event or phenomenon of interest"*
>
> *"unifying disparate phenomena"*

[cited in Lewandowsky and Farrell, **Computational Modeling In Cognition**, 2011]


Emotions
Theory of Mind
Natural Language
Gestures
Joint Actions
Attention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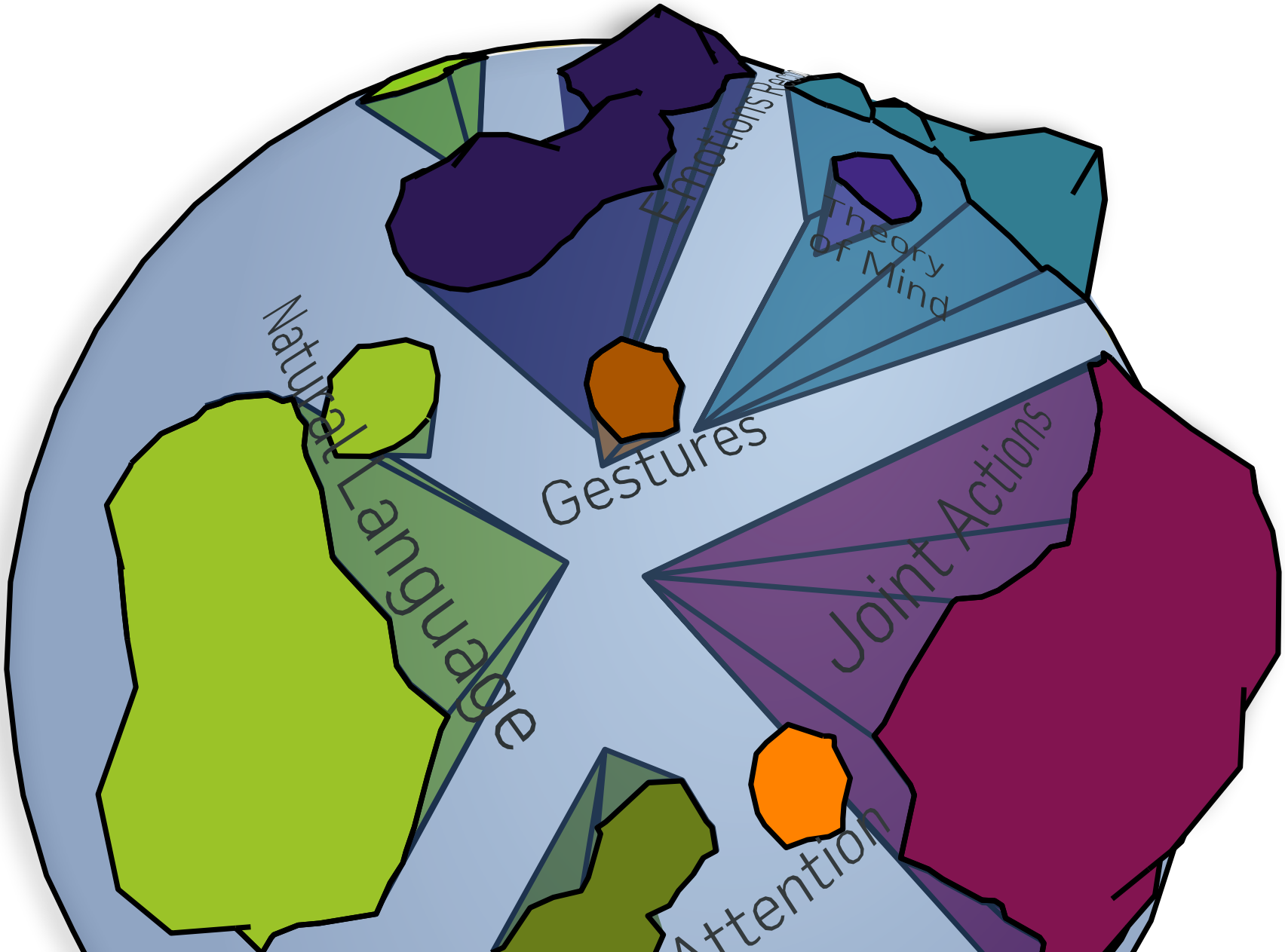
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A MODEL?

Models attempt to ***explain***:

> *"identifying the causes for an event or phenomenon of interest"*
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> *"unifying disparate phenomena"*

A model's value is gained from

> *"predicting facts that, absent the theory, would be antecedently improbable"*

[cited in Lewandowsky and Farrell, **Computational Modeling In Cognition**, 2011]

TOWARDS DEVELOPMENTAL SOCIO-ROBOTICS?

Emergence of Parten's stages of play?

1.  Solitary (independent) play
2.  Onlooker play
3.  Parallel play
4.  Associative play
5.  Cooperative play

Attitude: pro-social

Social engag.: parallel play

Task engag.: goal oriented

Attitude: pro-social

Social engag.: parallel play

Task engag.: goal oriented

Thank you!

freeplay-sandbox.github.io