Modeling Interpersonal Interaction: Insights from developmental psychology, social signal processing and social robotics

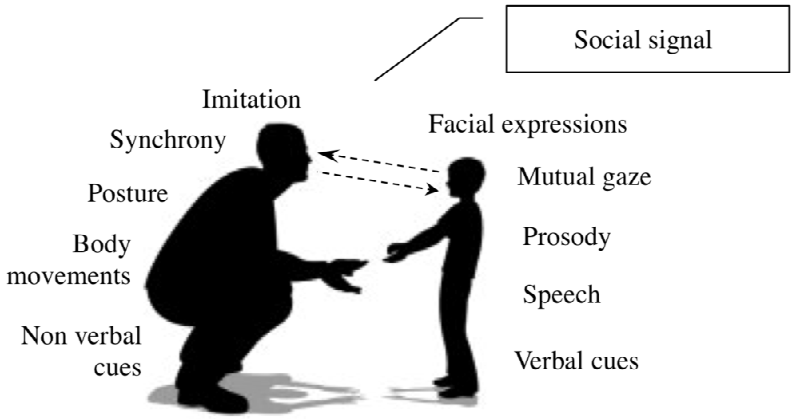
Mohamed CHETOUANI
Professor
Institut Systèmes Intelligents et Robotique (ISIR)
Université Pierre et Marie Curie - Sorbonne Universités

Mohamed.Chetouani@upmc.fr

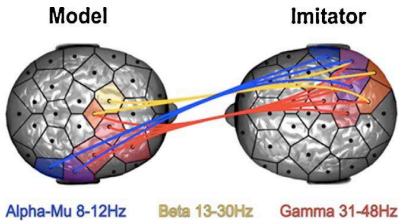
Social signal processing

- Human communication dynamics (Delaherche et al. 2012a):
  - Computational models with explicit notion of social interaction
  - From signal processing to interpretation of behaviours
  - Inter-personal interaction: mutual and dynamic influence of partners
  - Key concepts in psycho-pathology and robotics

Still face experiments

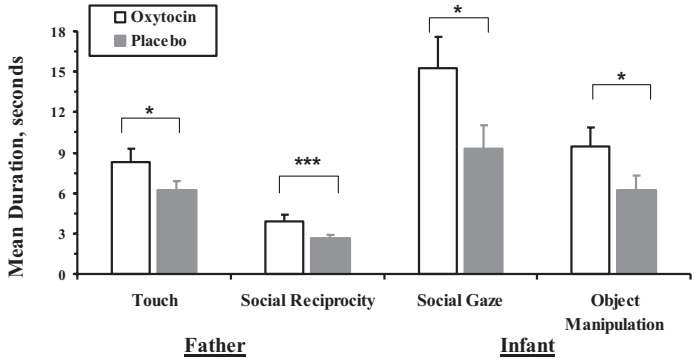


Cerebral basis



Dumas et al., 2011

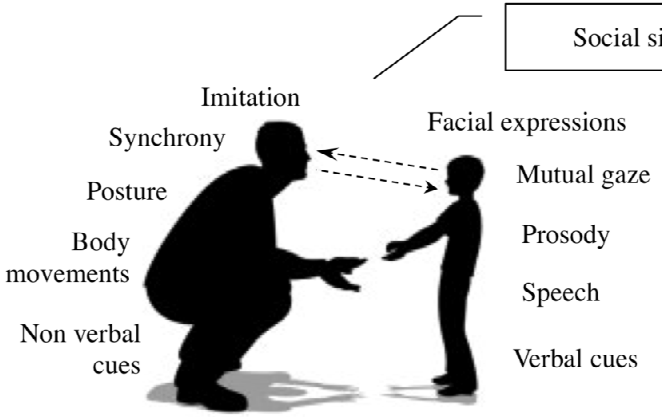
Physiology



Weisman et al., 2012

From Impersonal to Interpersonal Interaction

- Human-Machine Interaction has traditionally been inspired by Interpersonal Interaction
- Interpersonal interaction involves the exchange of verbal and non-verbal messages
- As for Human-Human Interactions, Interpersonal Human-Machine Interactions could be ranged along a continuum: from impersonal at one end to highly personal at the other.

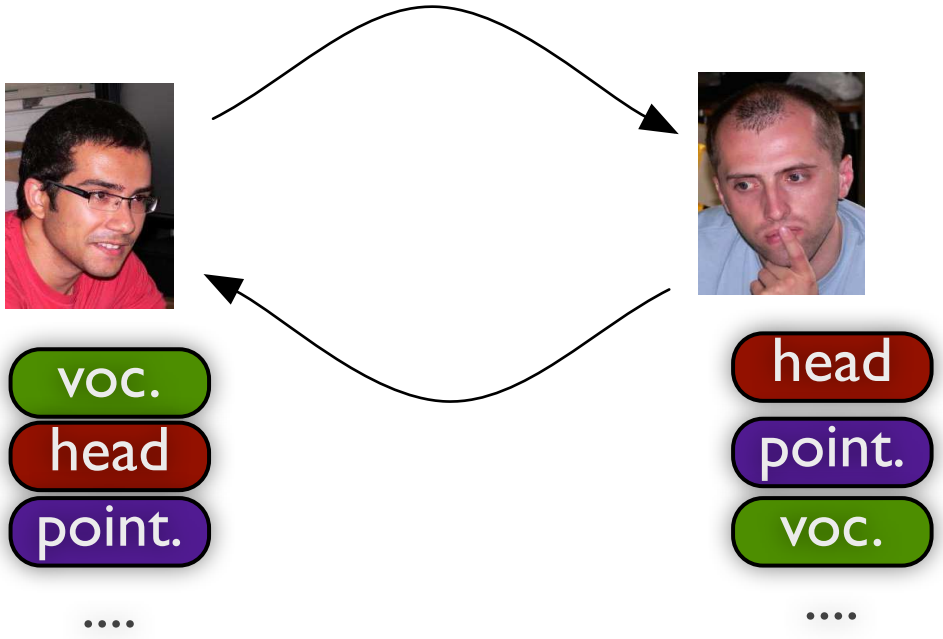


Impersonal

Interpersonal

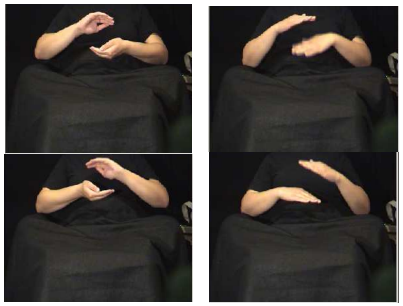
Interpersonal interaction is a highly dynamic process

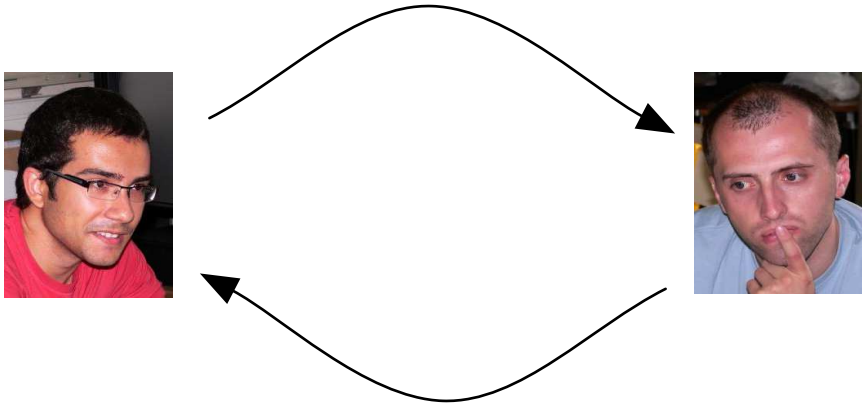
- Behavioral dynamics: non-verbal signals (e.g. gesture)
- Individual dynamics: multimodal signals (e.g. gesture + speech)
- Interpersonal dynamics: social signals (e.g. gazing in response to pointing of the partner)
- The «Telegraphist model» of communication (Shannon) is usually considered in Human-Computer Interaction
  - Emit / Receive / Respond (Answer)

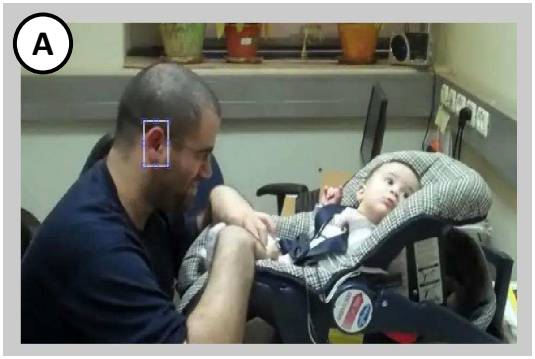


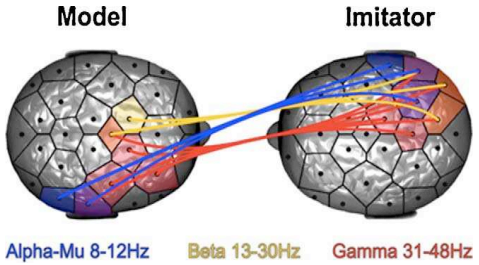
- **While Interpersonal Interaction in Humans involves «connected individuals»:**
  - **Interdependent individuals**
  - **Inherently relational (e.g. role)**
  - **Transactional (a person serves simultaneously as speaker and listener)**

But these processes involve more than behaviors...

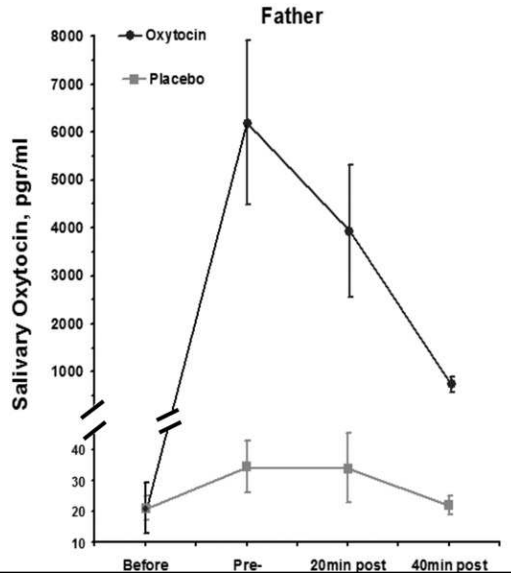


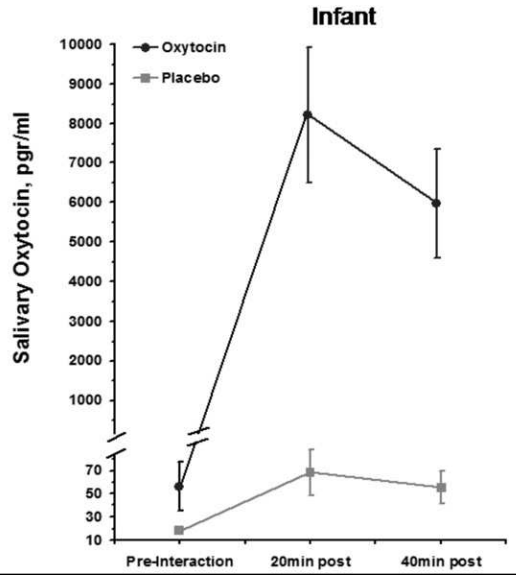






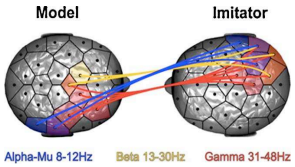
- **While Interpersonal Interaction in Humans involves «connected individuals»:**
  - **« Two body neuroscience »**
  - **« Biological synchrony »**

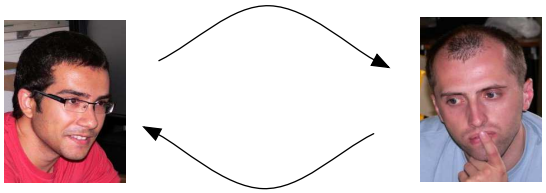


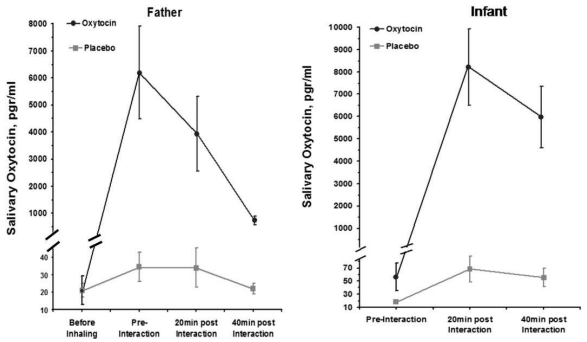


Timing issues

Still face experiments





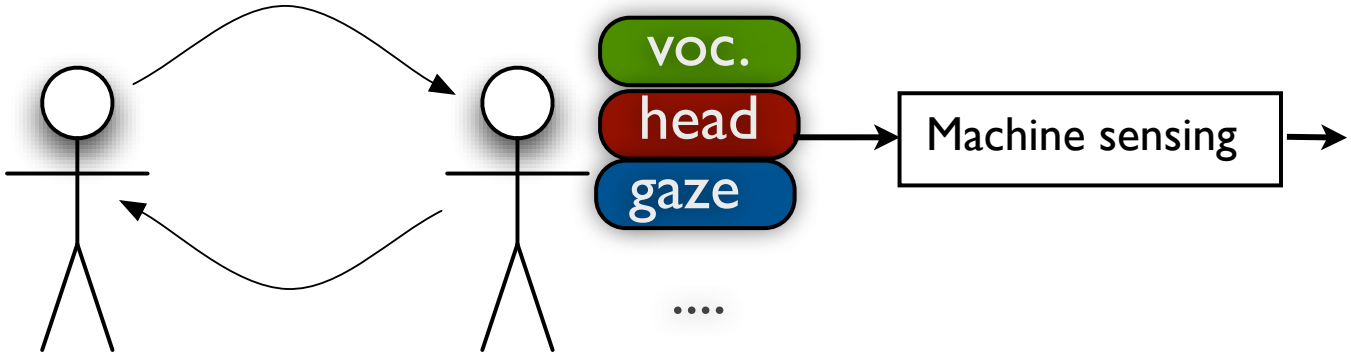


Neural level | Behavioral level | Hormonal level

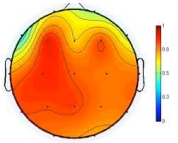
miliseconds | seconds | minutes

Time-scales

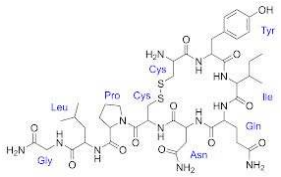
Computational modeling of interpersonal interactions



Pathology, Imitation recognition



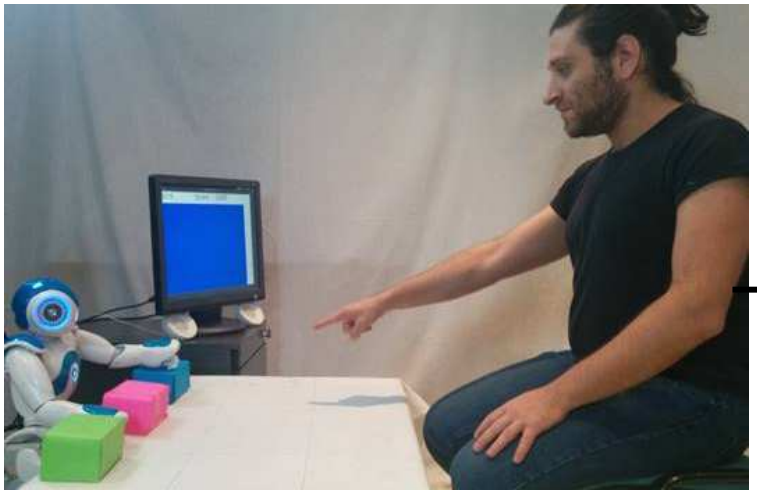
Neural correlates



Hormonal correlates

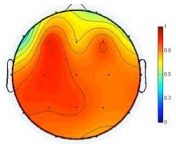
Capture multimodal traces of interpersonal dynamics from observable behaviors

Computational modeling of interpersonal interactions



Machine sensing

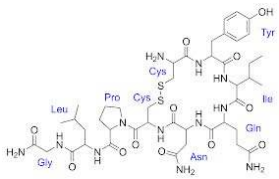
Pathology, Imitation recognition



Neural correlates

Detectable traces of interdependence of partners by Machines that Perceive and Act!

- **Cross-coupling reveals a social signature (pathology)**



Hormonal correlates

Interpersonal synchrony

Definitions:

- « The degree to which the behaviors in an interaction are non-random, patterned, or synchronized in both timing and form» (Bernieri et al., 1988)
- Social resonance, mirroring, mimicking, matching, congruence, imitation, convergence, the chameleon effect... or interactional synchrony

E. Delaherche et al. : Evaluation of inter-personal synchrony: multidisciplinary approaches. *IEEE Trans. on Affective Computing (2012)*

Human communication dynamics

Definition?

- Interpersonal synchrony in social interaction between interactive partners is the dynamic and reciprocal adaptation of their verbal and nonverbal behaviors (Delaherche et al. 2012)
- What are the scales? annotation schemes?

Leclère C et al. (2014) Why Synchrony Matters during Mother-Child Interactions: A Systematic Review. PLoS ONE 9(12): e113571. doi: 10.1371/journal.pone.0113571
E. Delaherche et al. : Evaluation of inter-personal synchrony: multidisciplinary approaches. *IEEE Trans. on Affective Computing (2012)*

Interpersonal synchrony

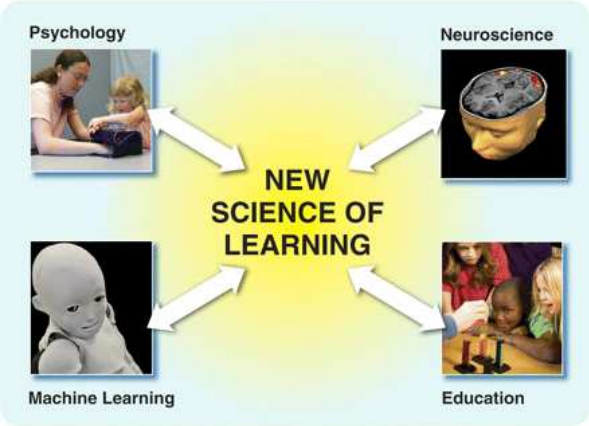
Definitions:

- Interpersonal synchrony in social interaction between interactive partners is the dynamic and reciprocal adaptation of their verbal and nonverbal behaviors (Delaherche et al. 2012)
- Three main types of assessment methods for studying synchrony emerged:
  - (1) global interaction scales with dyadic items;
  - (2) specific synchrony scales;
  - (3) micro- coded time-series analyses.
- It appears that synchrony should be regarded as a social signal per se as it has been shown to be valid in both normal and pathological populations.

Leclère C et al. (2014) Why Synchrony Matters during Mother-Child Interactions: A Systematic Review. PLoS ONE 9(12): e113571. doi: 10.1371/journal.pone.0113571
E. Delaherche et al. : Evaluation of inter-personal synchrony: multidisciplinary approaches. *IEEE Trans. on Affective Computing (2012)*

Imitation characterization through social signal processing

- Social learning
  - Infant's development
  - Learning in robotics



Social learning
(Meltzoff et al., 2009)

- Problem :
  - Modeling imitation during interaction

- Computational modeling of synchrony (Delaherche et al 2012b):
  - Time (rhythm of partners, delay between responses)
  - Pattern (similar gesture)

Imitation characterization through social signal processing

- Unsupervised action recognition (Delaherche et al. 2012b)

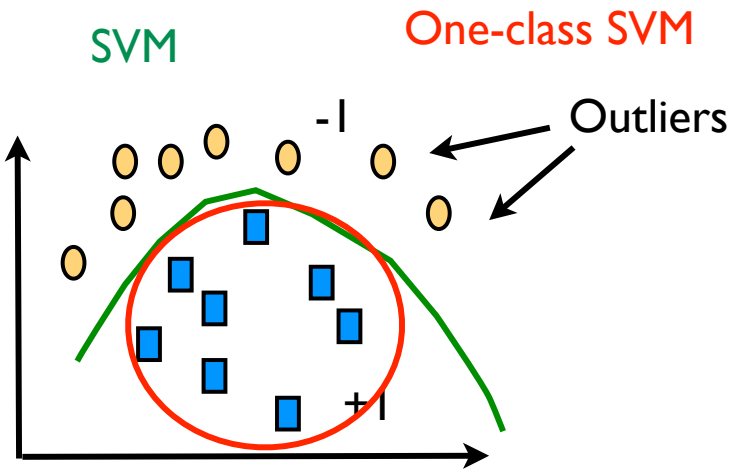
Unsupervised learning of a model A

Unsupervised learning of a model B

Evaluation of model B on data of A

Evaluation of model A on data of B

Metrics in the model space



Feature space

Interpretation:

Novelty detection

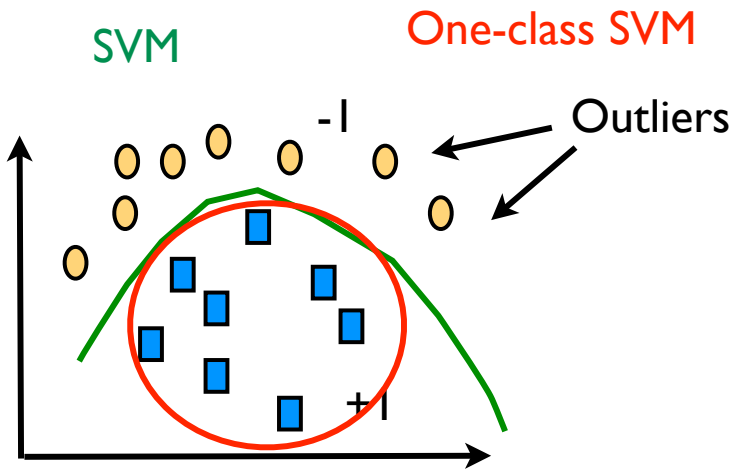
$$\begin{cases} H_0 : P_A = P_B \text{ (the gestures are identical)} \\ H_1 : P_A \neq P_B \text{ (the gestures are different)} \end{cases}$$

Imitation characterization through social signal processing

- Unsupervised action recognition (Delaherche et al. 2012b)

Unsupervised learning of a model A

Unsupervised learning of a model B



The aim of 1-SVM is to learn from the training set a function f such that most of the data in the training set belong to the set:

$$R_h = \{h \in X \setminus f(h) \geq 0\}$$

Decision function:

$$f(h) = \sum_{i=1}^{n} \alpha_i k(h, h_i) - \rho$$

- h represents an histogram of codewords
- Intersection kernel:

$$k(h_i, h_j) = \sum_{i=1}^{d} min(h_i, h_j)$$

Imitation characterization through social signal processing

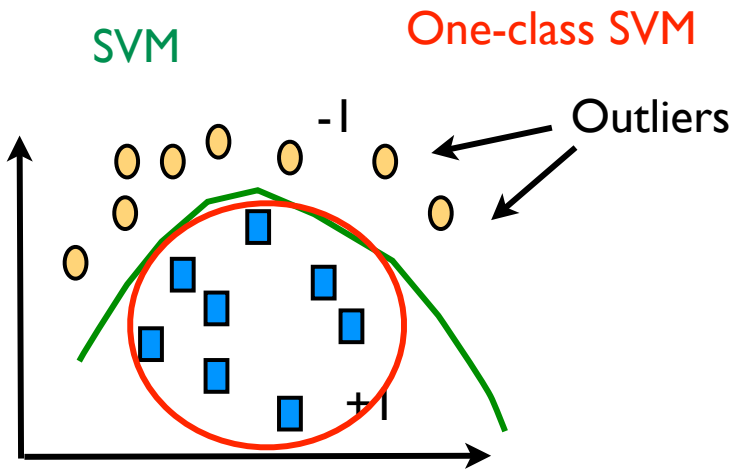
- Unsupervised action recognition (Delaherche et al. 2012b)

Unsupervised learning of a model A

Unsupervised learning of a model B

Evaluation of model B on data of A

Evaluation of model A on data of B



Distance:

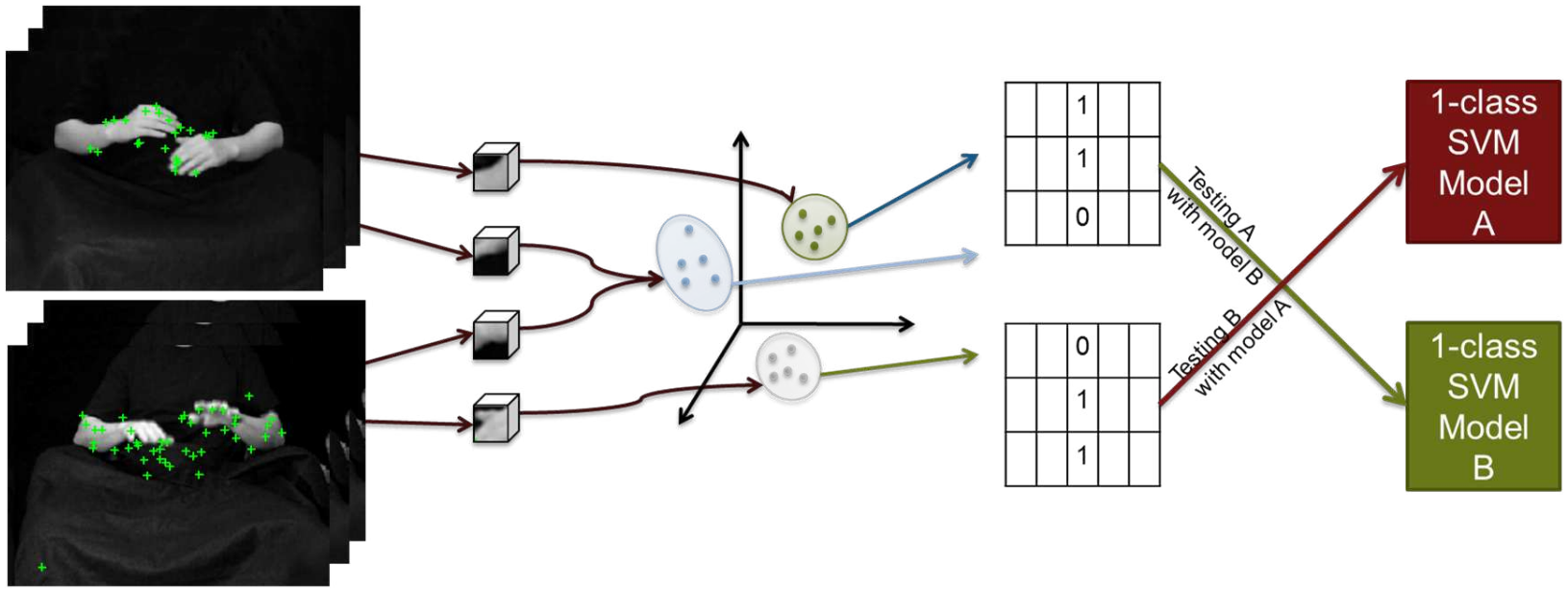
Two gestures are similar if the likelihood ratio between $H0$ and $H1$ is inferior to a given threshold.

The likelihood ratio can be interpreted as the similarity $s_{A_iB_j}$ between h_{A_i} and h_{B_i}

$$s_{A_iB_j} = \sum_{j=1}^{n}\left(\sum_{i=1}^{n}\alpha_i^A k(h_{B_j}, h_{A_i})\right) + \sum_{j=1}^{n}\left(\sum_{i=1}^{n}\alpha_i^B k(h_{A_j}, h_{B_i})\right)$$

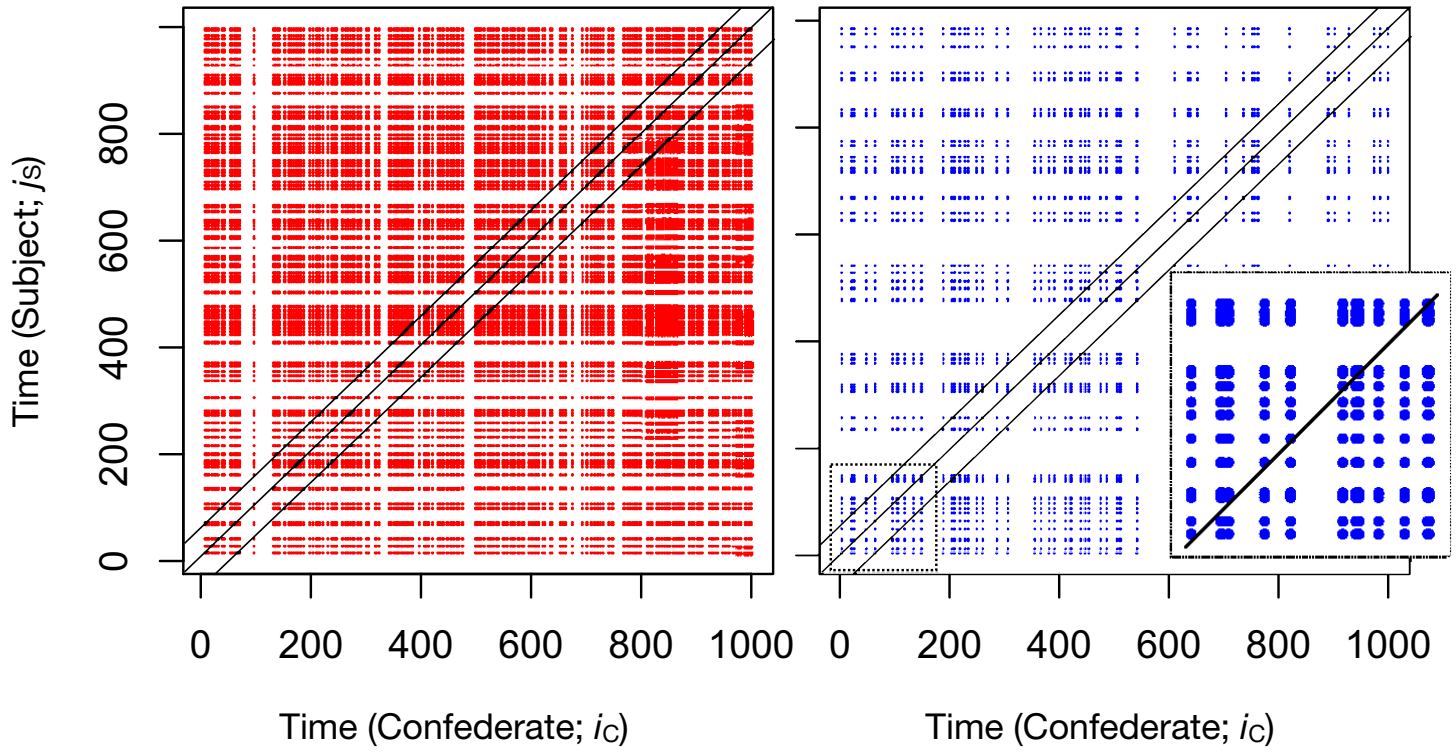
Imitation characterization through social signal processing

- How to analyze the dynamics?
  - Delay between to gestures
  - Response time
  - ...



Imitation characterization through social signal processing

- Recurrence analysis assesses the points in time that two systems visit similar states, called "recurrence points".
- They represent the points in time that the two systems show similar patterns of change or movement.



*Coco MI and Dale R (2014) Cross-recurrence quantification analysis of categorical and continuous time series: an R package. Front. Psychol. **5**:510.*

Imitation characterization through social signal processing

- Back to our imitation detection problem:
  - 1-Class SVMs provide a metric
  - To assess these two forms of imitation, the proposed metric is computed :

a) between simultaneaous gestures,

b) between slightly delayed gestures.

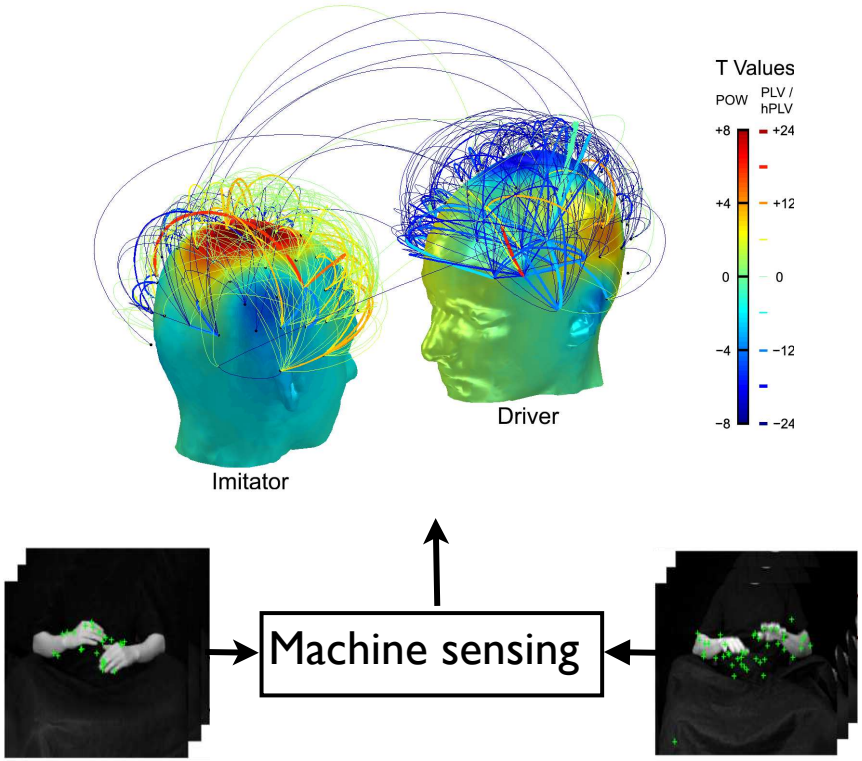
Thus, we obtain a recurrence matrix Ri, j where point (i, j) corresponds to the similarity between the gesture produced at time i by participant A and the gesture produced at time j by participant B.

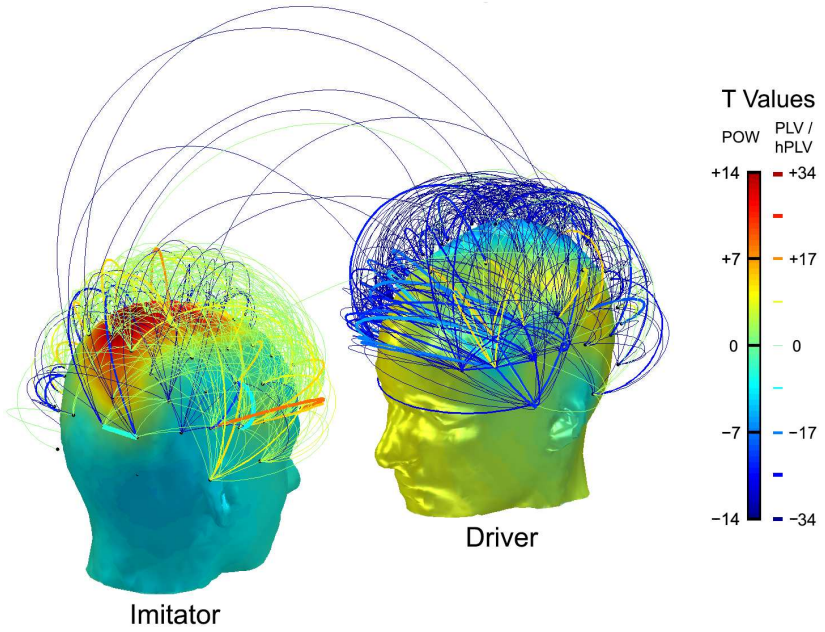
- The recurrence matrix represents the points in time when the dyadic partners are in similar states.

Delaherche et al. : Automatic measure of imitation: during social interaction: a behavioral and hyperscanning-EEG benchmark. *Pattern Recognition Letters (2015)*

Imitation characterization through social signal processing

- Using behaviors to analyze brain synchonization (Delaherche et al., 2015)





(a) Manual indexing

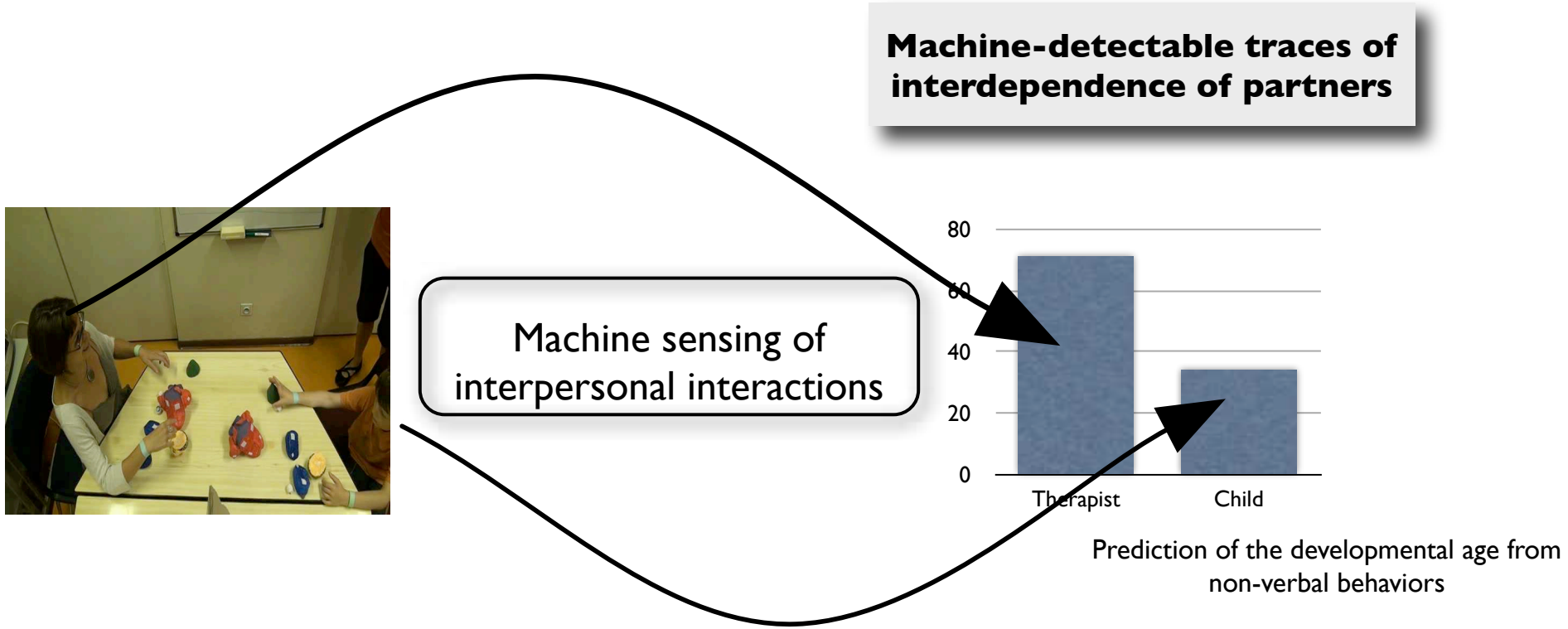
Machine-detectable traces of interdependence of partners:

- **From behaviors to brain**

Delaherche et al. : Automatic measure of imitation: during social interaction: a behavioral and hyperscanning-EEG benchmark. *Pattern Recognition Letters (2015)*

Extraction of social signatures during Human-Robot Joint Action

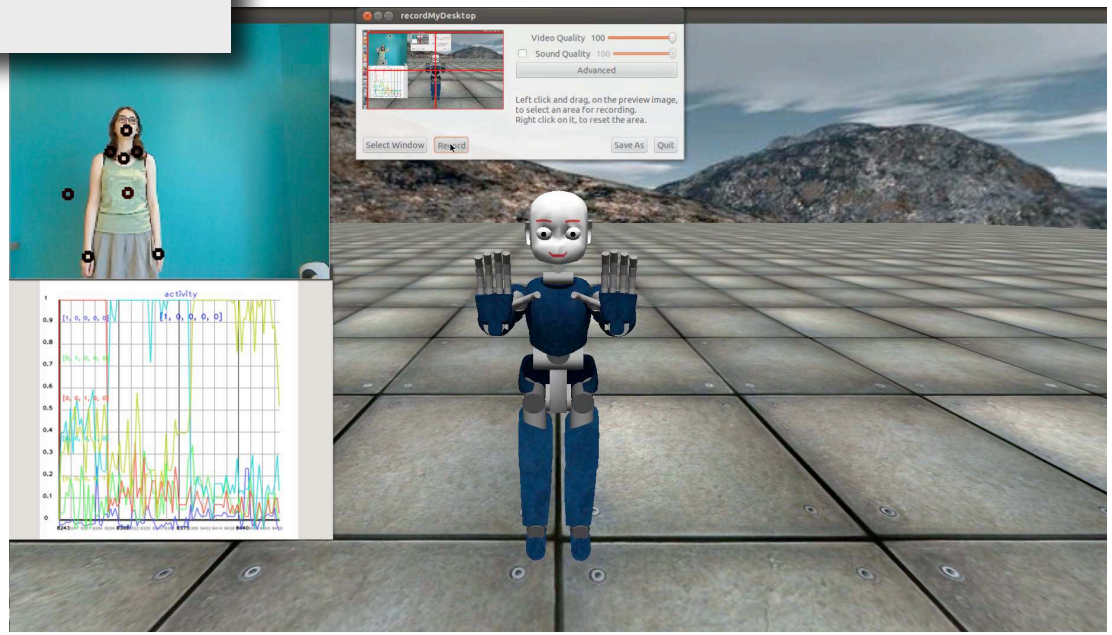
- Case of Human-Human Interaction
  - Mutual influence of partners
  - Paradigm-shift Looking at partner A to analyze partner B!

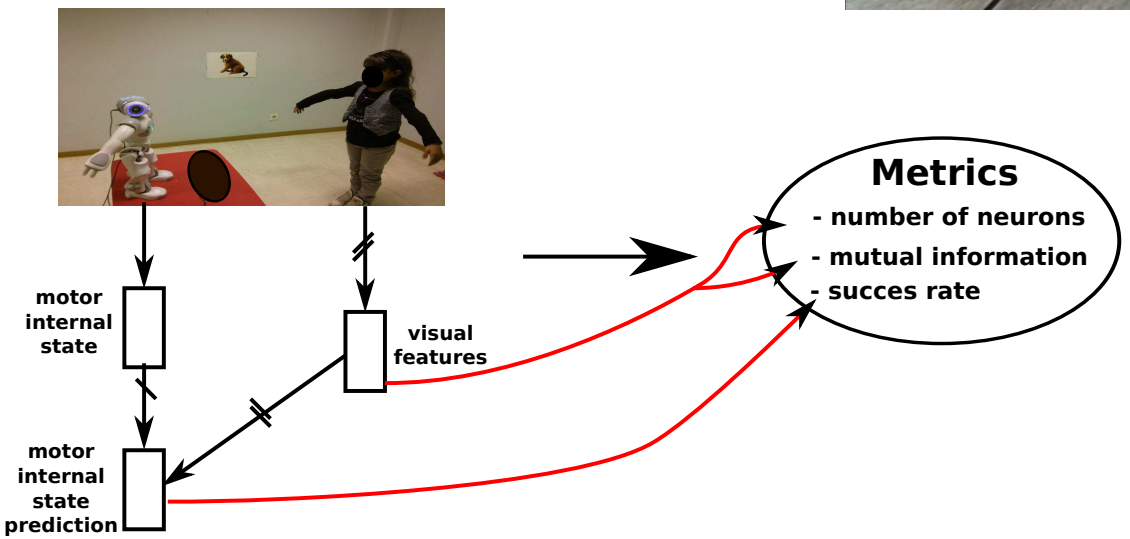


Delaherche et al. : Assessment of Communicative and Coordination Skills of Children with Autism Spectrum Disorders and Typically Developing Children using Social Signal.
Research in Autism Spectrum Disorders (2013)

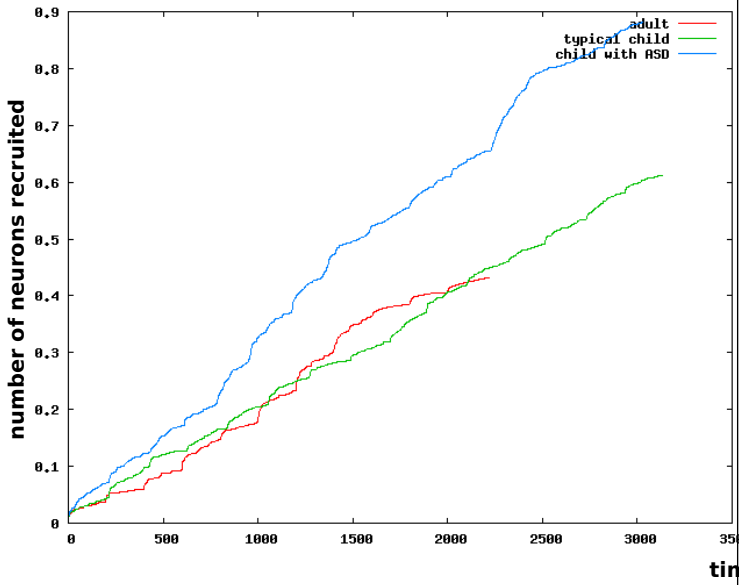
Detectable traces of interdependence of partners by Machines that Perceive and Act!

- **Cross-coupling reveals a social signature (pathology)**





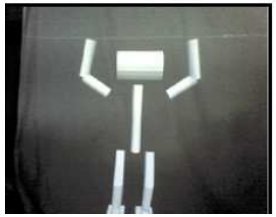
Learning: Sensory Motor architecture



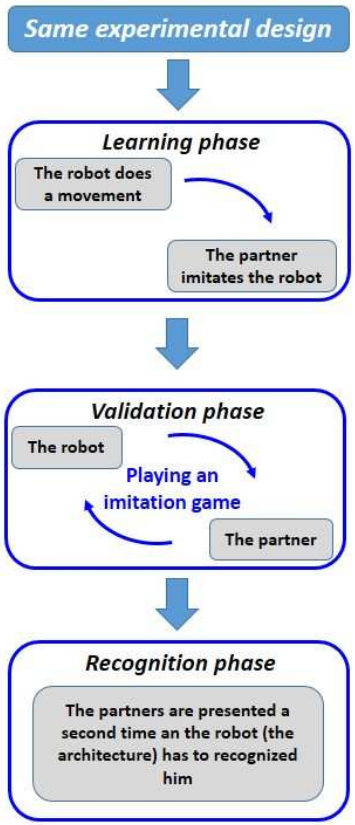
Boucenna et al. : Learning of social signatures through imitation game between a robot and a human partner. *IEEE Transaction on Autonomous Mental Development (2014)*

Extraction of social signatures during Human-Robot Joint Action

- Generalize to other tasks and conditions:
  - « Early imitation serves a social identity function » (Meltzoff, 1992 1994)
  - Learning dynamics of imitation to recognize identity



SAME LEARNING ARCHITECTURE



Experiment 1
Nao learns through a motor imitation task (5 arms positions) with:
- 11 adults
- 15 typical developing children
- 15 children with ASD

Basic experiment

Experiment 2
Robot head learns through a motor facial imitation task (5 facial expressions) with 25 adults

To control for other robot and other task

Experiment 3
Nao learns through a motor imitation task (5 arms positions) with 12 different avatars

To control for visual features independent of motor task

S. Boucenna, D. Cohen, A. Meltzoff, P. Gaussier and M. Chetouani. *Scientific Reports 2016*

Extraction of social signatures during Human-Robot Joint Action

- Extracting social traits and a priori on robotics (Rahbar et al. 2015)
  - Predicting extraversion from non-verbal features during a face-to-face human-robot interaction
  - Interpersonal (Human-Human) Interactions are not necessarily

Participants

39 healthy adults

11 male

28 female

aged 37.8y±15.2y

People's attitude towards robots

- Attitude towards situation of interaction with robots
- Attitude towards social influence of robots
- Attitude towards emotions in interaction with robots

Rahbar et al. Predicting extraversion from non-verbal features during a face-to-face human-robot interaction, *International Conference on Social Robotics (2015)*

Extraction of social signatures during Human-Robot Joint Action

- Extracting social traits and a priori on robotics (Rahbar et al. 2015)
  - Predicting extraversion from non-verbal features during a face-to-face human-robot interaction
  - Interpersonal (Human-Human) Interactions are not necessarily

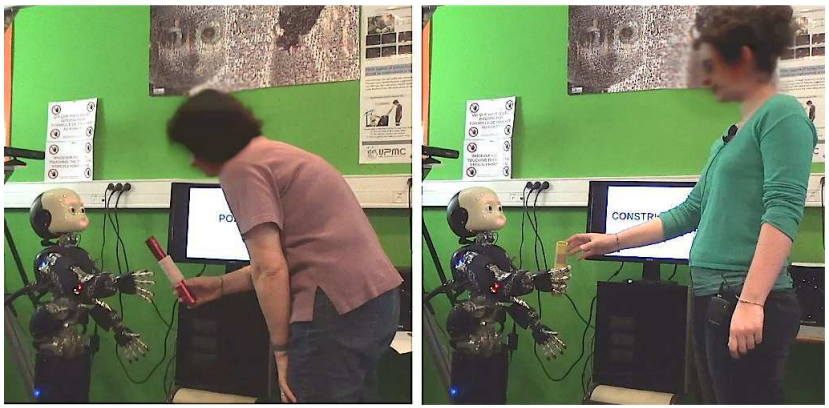


Fig. 2. iCub interacting with two participants.

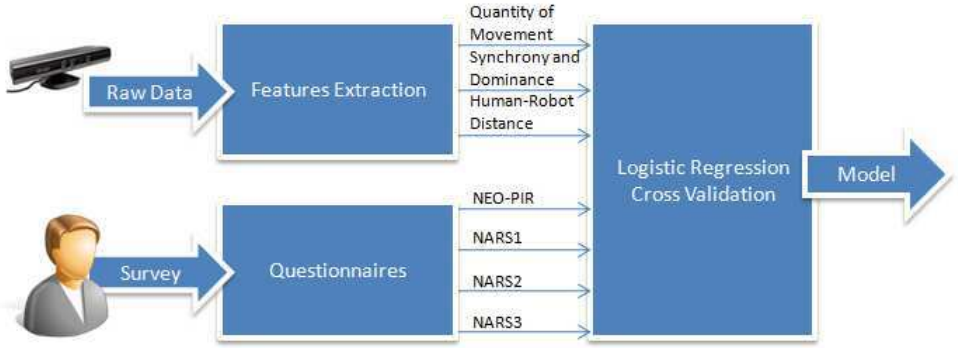


Fig. 1. Overview of the proposed system.

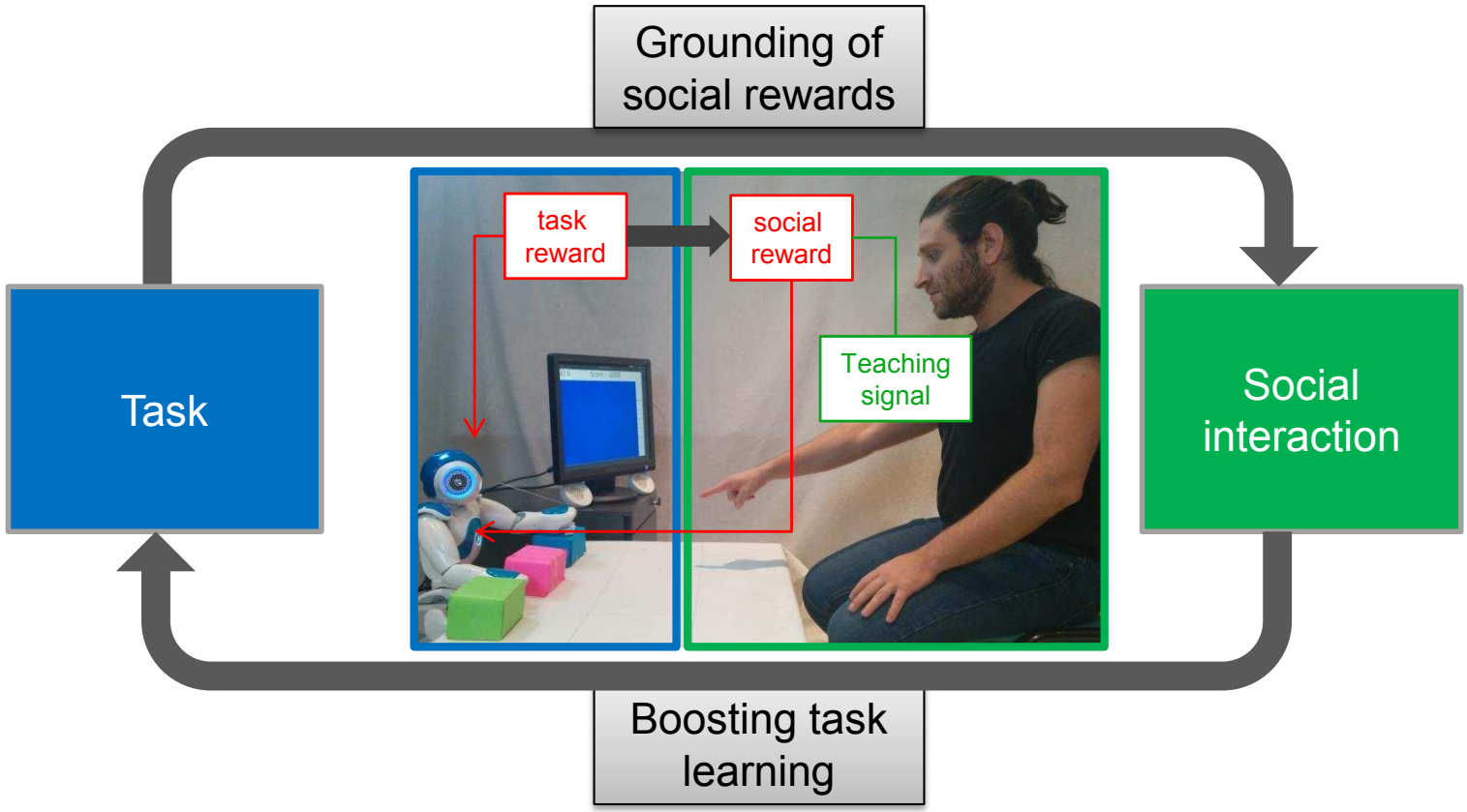
Table 1. Performances of the classifier when the 70% of features is used.

	Accuracy	F1-score	Prec.	Recall
NEO-PI-R	62%	59%	69%	52%
NARS	53%	62%	62%	63%
NEO-NARS	70%	62%	77%	52%

Rahbar et al. Predicting extraversion from non-verbal features during a face-to-face human-robot interaction, *International Conference on Social Robotics (2015)*

Interpersonal interaction for robot learning

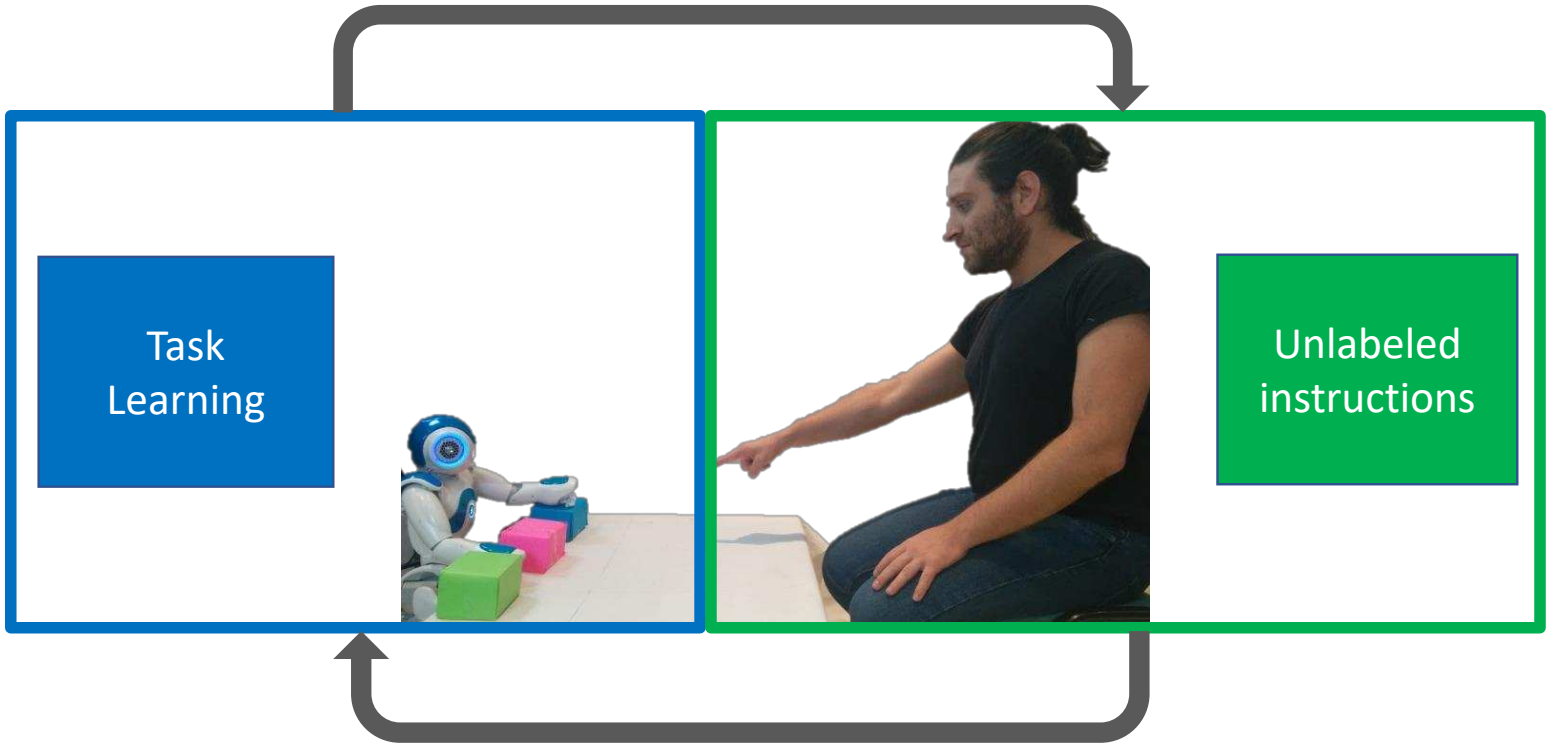
- Learning new skills (Najar et al. 2015)
  - Boosting traditional task-learning by interpersonal interactions



A. Najar, O. Sigaud, M. Chetouani. Social-Task Learning for HRI. *International Conference on Social Robotics (2015)*

Interpersonal interaction for robot learning

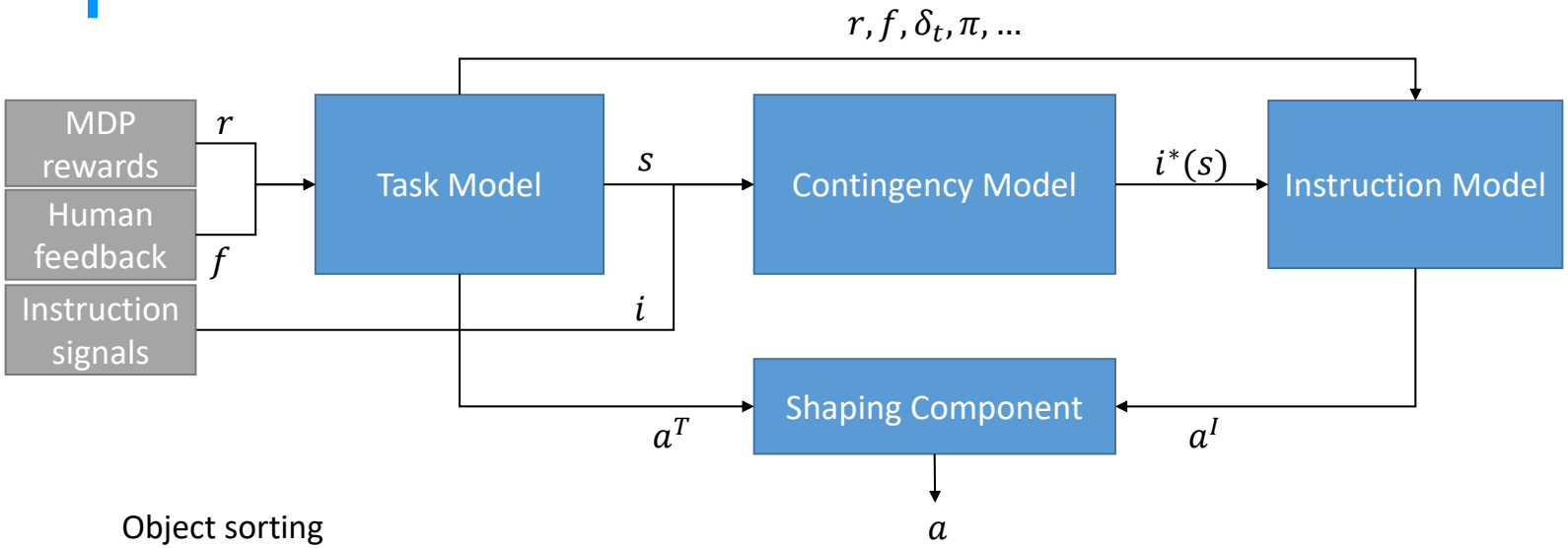
Interpretation
Grounding the meaning of instructions
in the task learning process



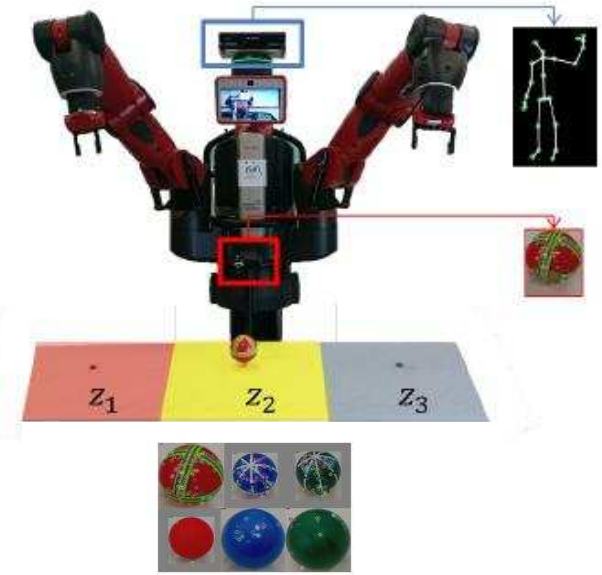
Shaping
Using the interpreted instructions
For guiding the learning process

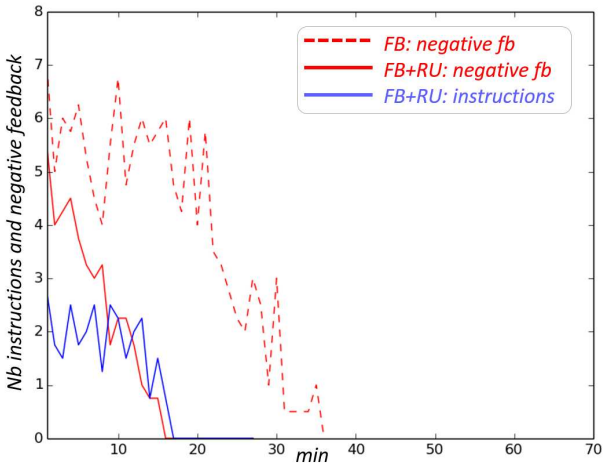
A. Najar, O. Sigaud, M. Chetouani. Training a robot with evaluative feedback and unlabeled guidance signals. IEEE RO-MAN 2016.

Interpersonal interaction for robot learning



Object sorting



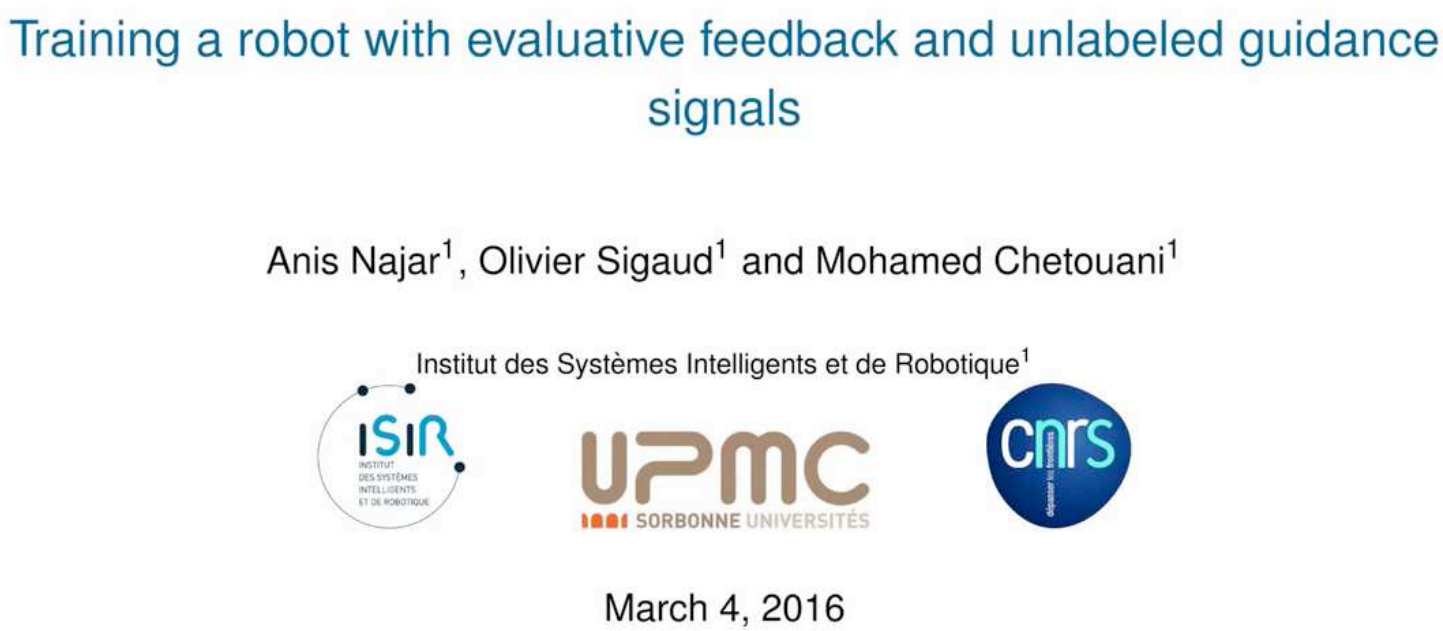


Accelerates the learning process
and
reduces the number of required teaching signals

A. Najar, O. Sigaud, M. Chetouani. Training a robot with evaluative feedback and unlabeled guidance signals. IEEE RO-MAN 2016.

Interpersonal interaction for robot learning

- Exploiting dynamics of social and task learning


Training a robot with evaluative feedback and unlabeled guidance signals

Anis Najar[1], Olivier Sigaud[1] and Mohamed Chetouani[1]

Institut des Systèmes Intelligents et de Robotique[1]

March 4, 2016

A. Najar, O. Sigaud, M. Chetouani. Training a robot with evaluative feedback and unlabeled guidance signals. IEEE RO-MAN 2016.

ANIMATAS

H2020 MSCA – ITN

Advancing intuitive human-machine interaction with human-like social capabilities for education in schools

http://www.ananimatas.isir.upmc.fr

Partners:

- Universite Pierre Et Marie Curie - Paris 6 (UPMC) (Coordinator)
- Uppsala Universitet (UU)
- Institut Mines-Telecom (IMT)
- Kungliga Tekniska Hoegskolan (KTH)
- Ecole Polytechnique Federale De Lausanne (EPFL)
- Instituto De Engenhariade Sistemas E Computadores, Investigacao E Desenvolvimento Em Lisboa (INESC ID)
- Jacobs University Bremen (JACOBSUNI)
- Softbank Robotics Europe (SBR)

Hiring 15 PhD students in HRI, Virtual Agent, Interactive Robot Learning, Educational Sciences, Social Sciences...

Conclusions

- Modeling and exploiting interpersonal interaction dynamics for individual characterization
- What are the good representation(s) of social signals?
- Nature of signals: discrete, events, dynamics, multimodal...
- Learning Interpersonal Human-Robot Interaction during focused tasks
- Scenarios and applications: lack of synchrony, pathology, Human-agent interaction
- SyncPy: Python Library for Synchrony characterisation

Thank you for your attention

Questions?