# Social signal processing and social robotics:
## revealing social signatures

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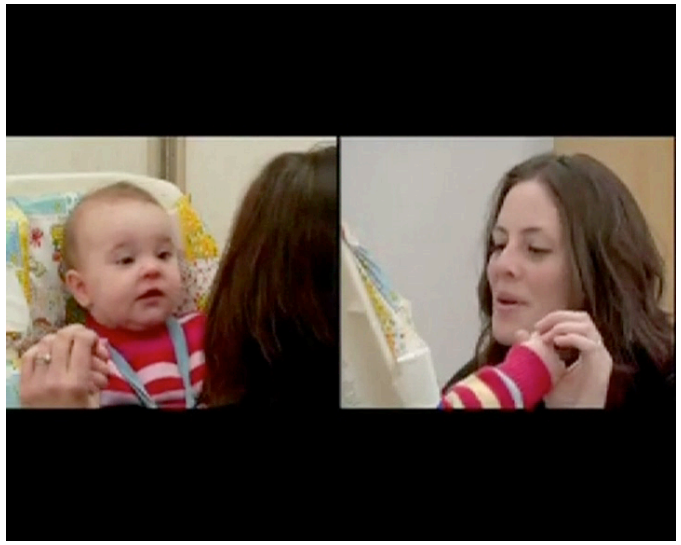
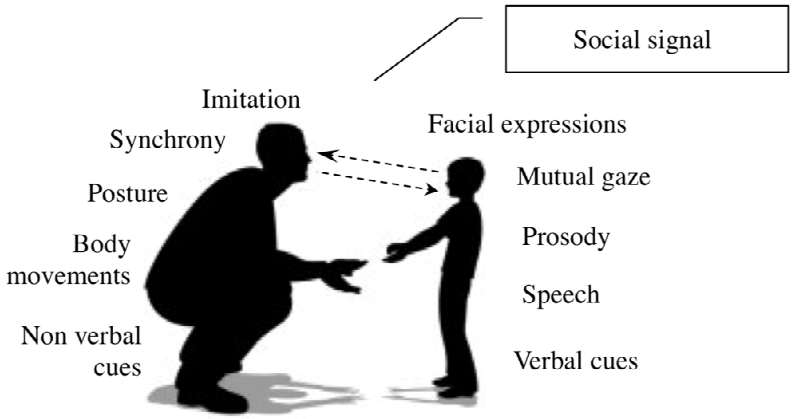
# Social signal processing

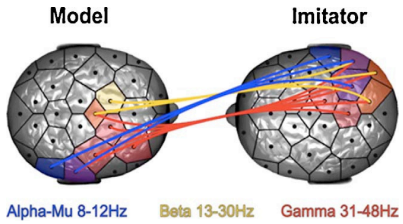
- Human communication dynamics (Delaherche et al. 2012a):
  - Computational models with explicit notion of social interaction
  - From signal processing to interpretation of behaviours
  - Inter-personal interaction: mutual and dynamic influence of partners
  - Key concepts in psycho-pathology and robotics

Still face experiments



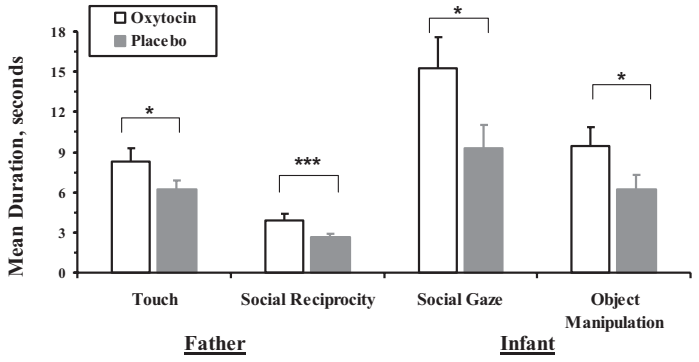



Cerebral basis




Dumas et al., 2011

Physiology



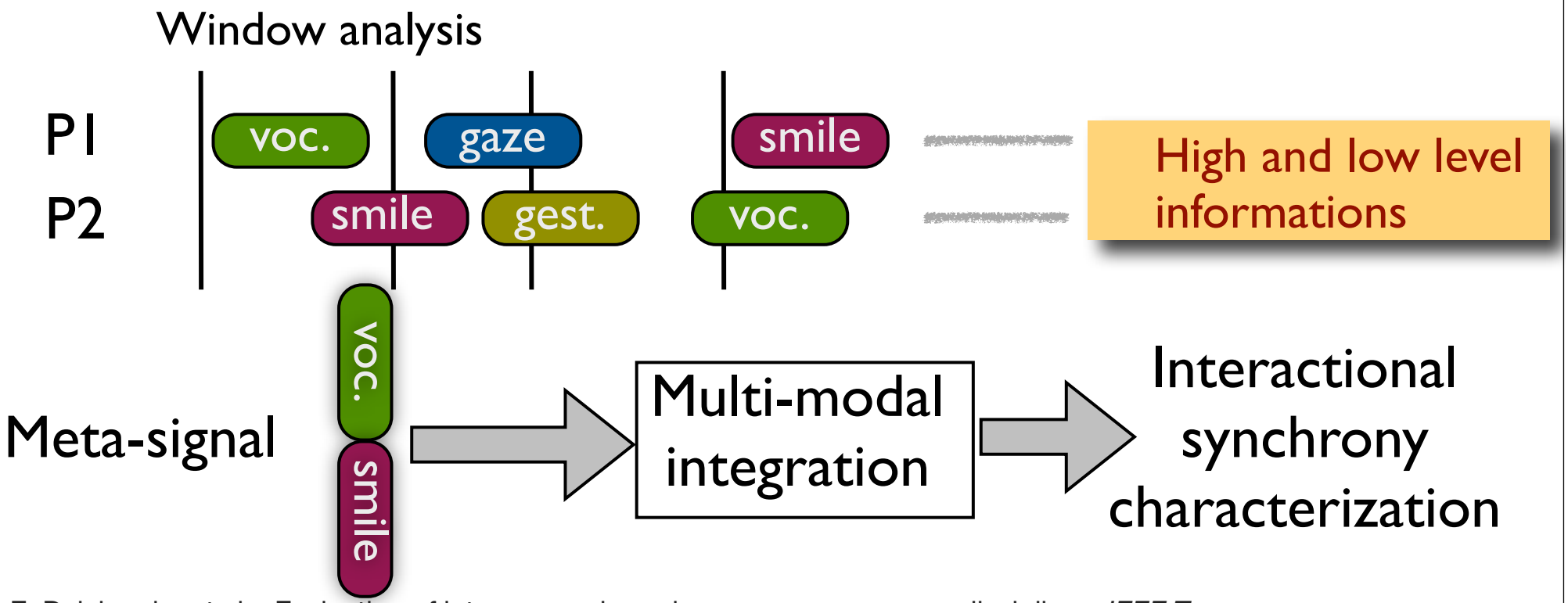

Weisman et al., 2012

# Outline

1. Role of social signals: motherese, motion, turn-taking and others...
2. Modeling synchrony: a focus on motor imitation
3. Synchrony and social intelligence for personal robots
4. Using social signal processing and developmental robotics for clinical investigations in autism

# Role of social signals in synchrony

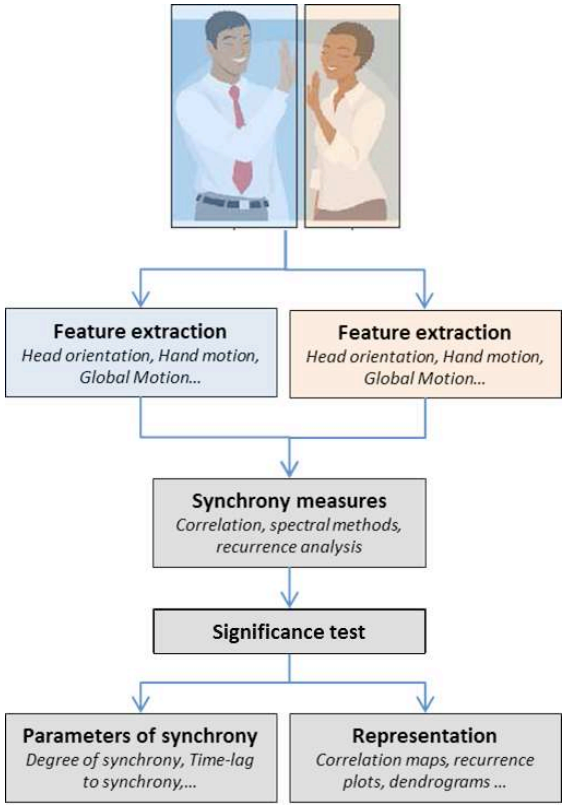
- Human communication dynamics
  - Nature of signals
  - Rhythm

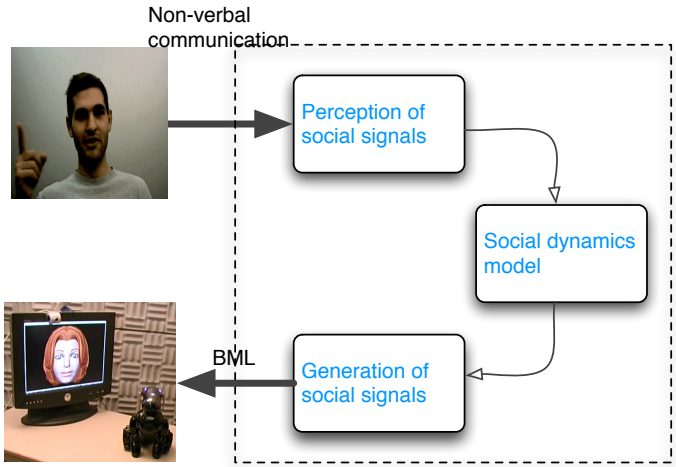



E. Delaherche et al. : Evaluation of interpersonal synchrony: a survey across disciplines. *IEEE Trans. on Affective Computing (2012)*

# Role of social signals in synchrony

- Toward a model of synchrony (Delaherche et al. 2012a)
  - General approach for characterization
  - From social perception to social interaction
  - Useful in various models



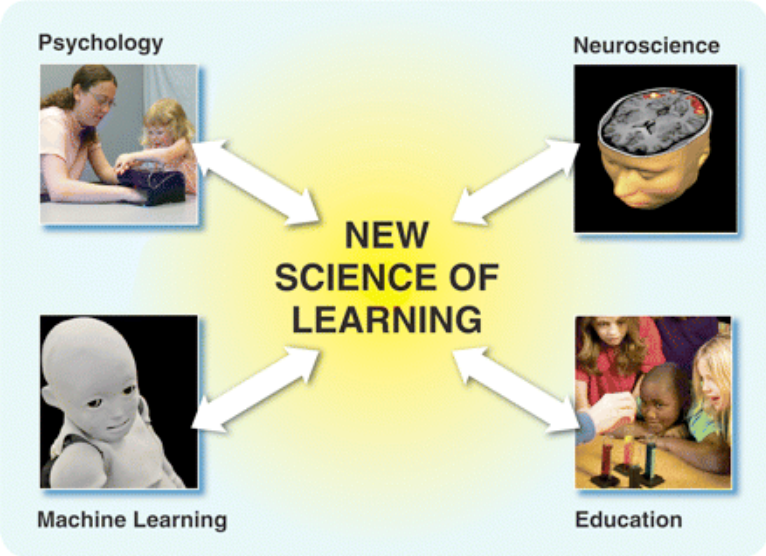

- Some examples
  - Developmental psychology: modeling parent-infant interaction (Saint-Georges et al. 2011)
  - Cognitive robotics: social engagement(Al Moubayed et al. 2009)

E. Delaherche et al. : Evaluation of interpersonal synchrony: a survey across disciplines. *IEEE Trans. on Affective Computing (2012)*

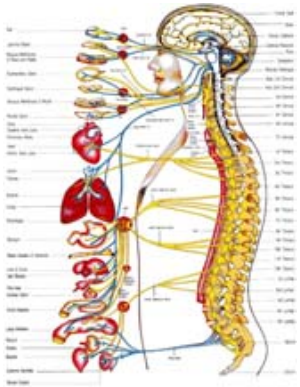
# Human communication dynamics

Social signal processing approach

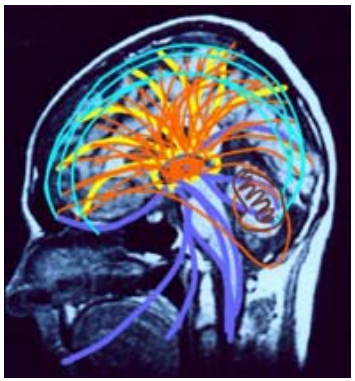
- « Low-resolution brain scanning» (Pentland)



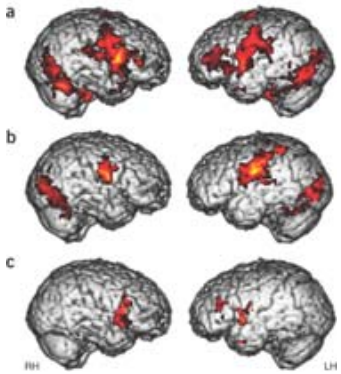

Social learning (Meltzoff et al., 2009)



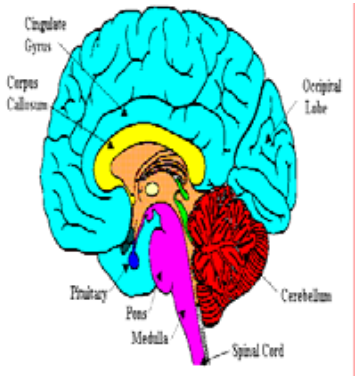
autonomic



thalamic attention




mirror neurons




cerebellar motor

ACTIVITY CHANGE

INFLUENCE ON TIMING

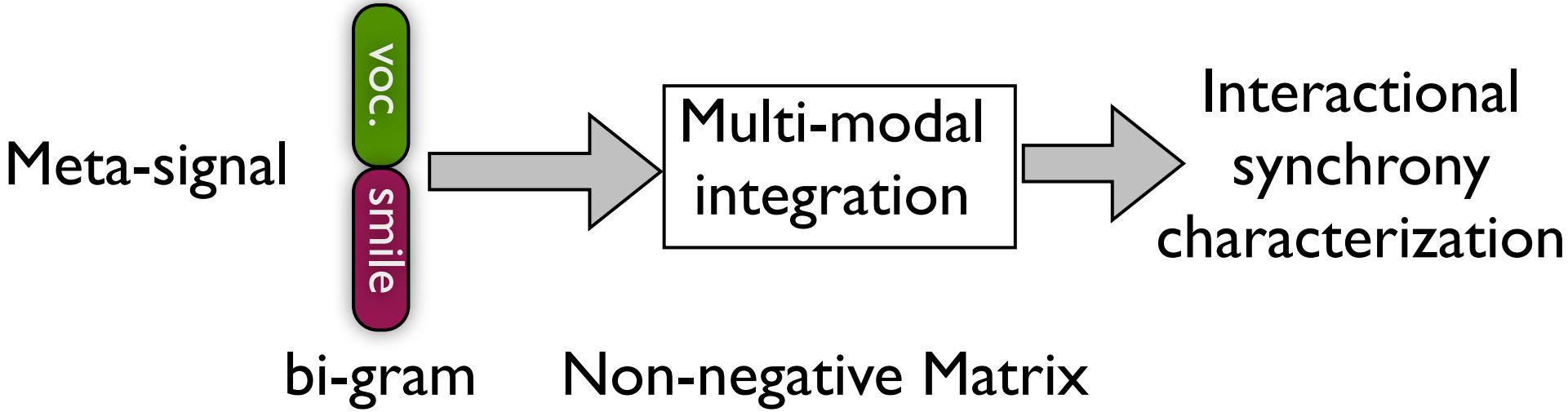
MIMICRY

CONSISTENCY OF MOVEMENT

# Human communication dynamics

Using high-level information:

- Real-life corpus: Family home movies
- Manually annotated by psychologist:
  - Infant behaviors: vocalization, behaviors with objects, orienting toward people...
  - Parent behaviors: vocalization, touching....

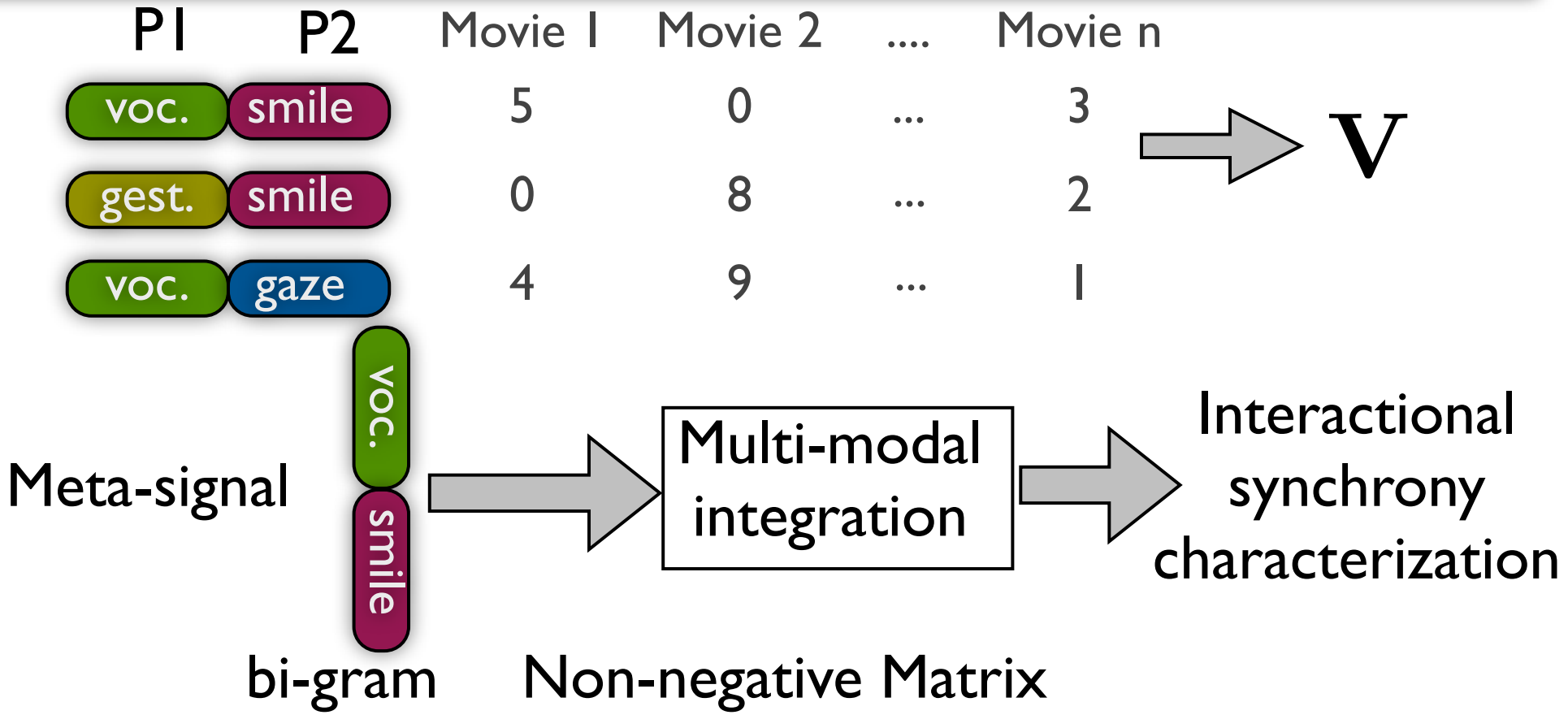



C. Saint-georges et al. : Do parents recognize autistic deviant behavior long before diagnosis? taking into account interaction using computational methods. *PLOS one*, 2011
A. Mahdhaoui and M. Chetouani: Understanding parent-infant behaviors using non-negative matrix factorization, 2011.

# Human communication dynamics

Non-negative matrix modeling of interactive situations

One of the first initiatives to employ data mining methods for understanding social interactions

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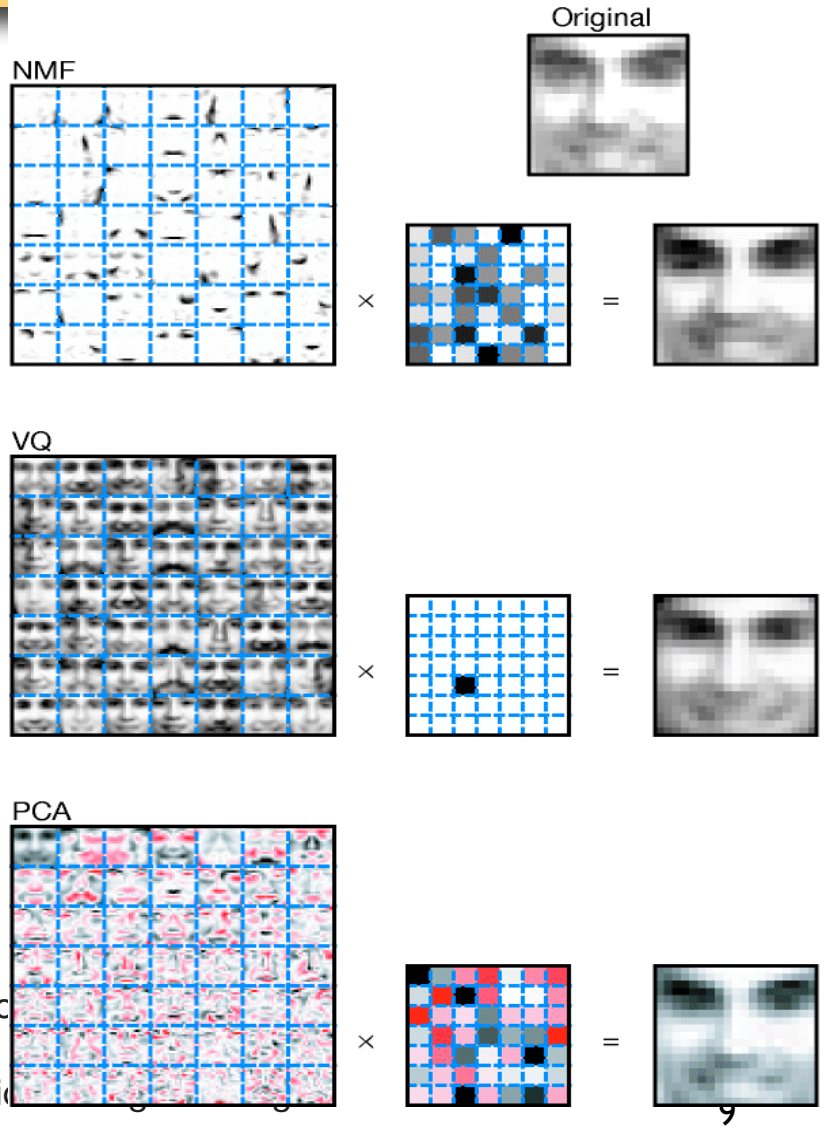
# Human communication dynamics

Non-negative matrix modeling of interactive situations:

Part-based representation

Lee and Seung, Nature, 1999




Data vector (nxm)

Expansion/ activation coeff. (kxm)

$$V \approx WH$$

Basis vectors «dictionary» (nxk)

Basis Interactive Behaviors vectors

C. Saint-georges et al. : Do parents recognize autistic deviant behavic
account interaction using computational methods. *PLOS one*, 2011
A. Mahdhaoui and M. Chetouani: Understanding parent-infant behavi
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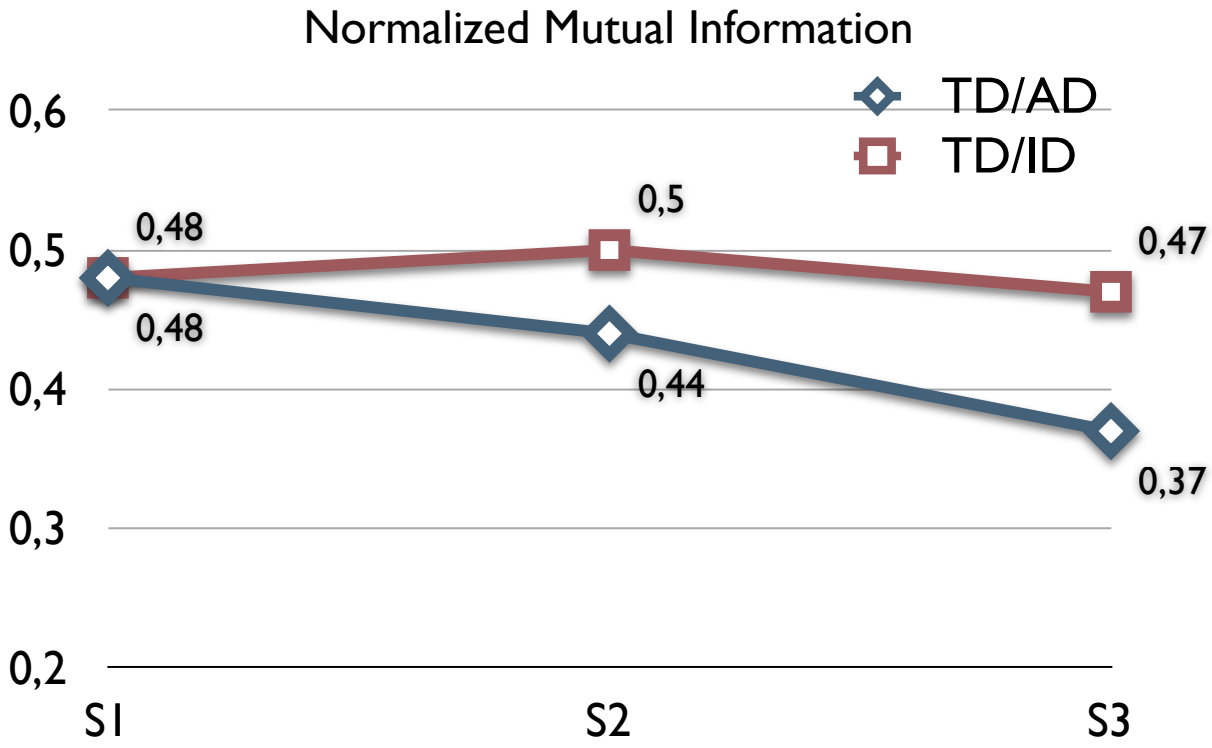
# Human communication dynamics

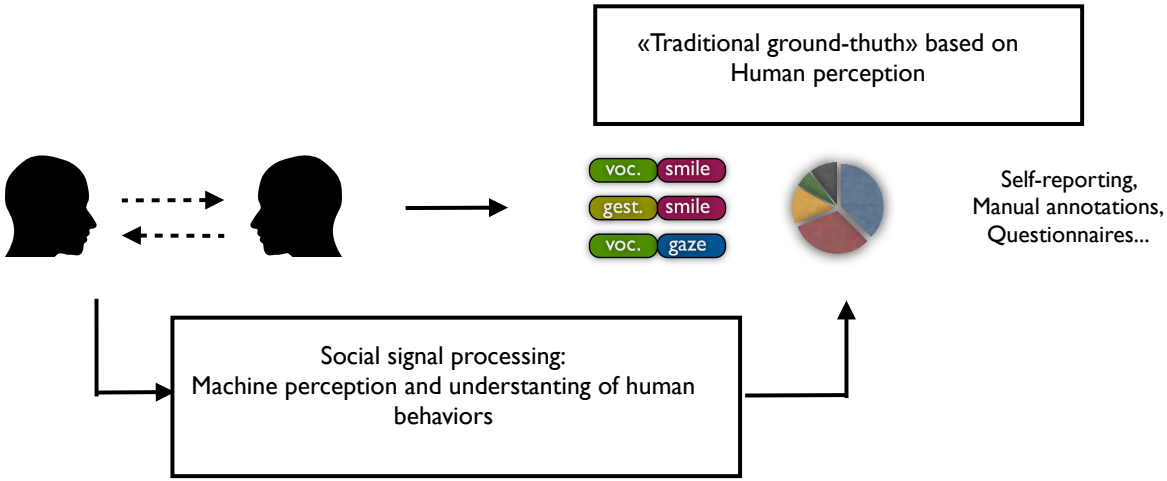
Application to investigations on early signs of autism:

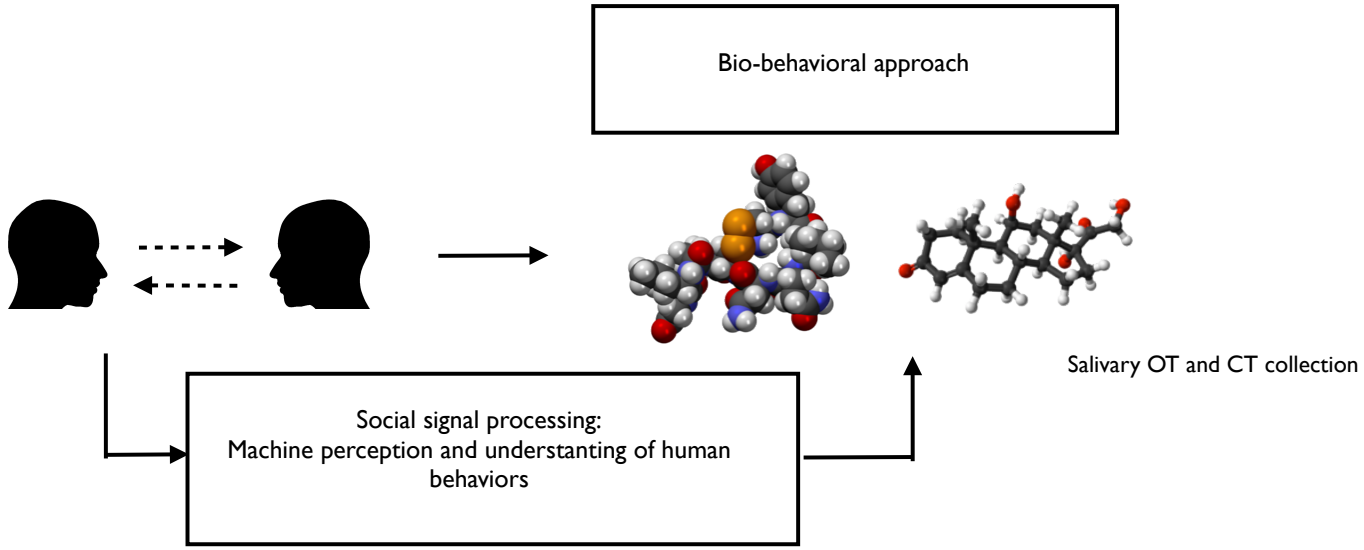
- Diagnostic > 36 month
- Developmental issues: Semesters S1 (0-6 months), S2 (6-12) and S3 (12-18)
- Comparisons of clusters obtained by NMF: Typical development, Intellectual disability, Autism




«Deviant behaviors»:
✓Reality mining method used by clinicians
✓Coherent with qualitative impressions of clinicians

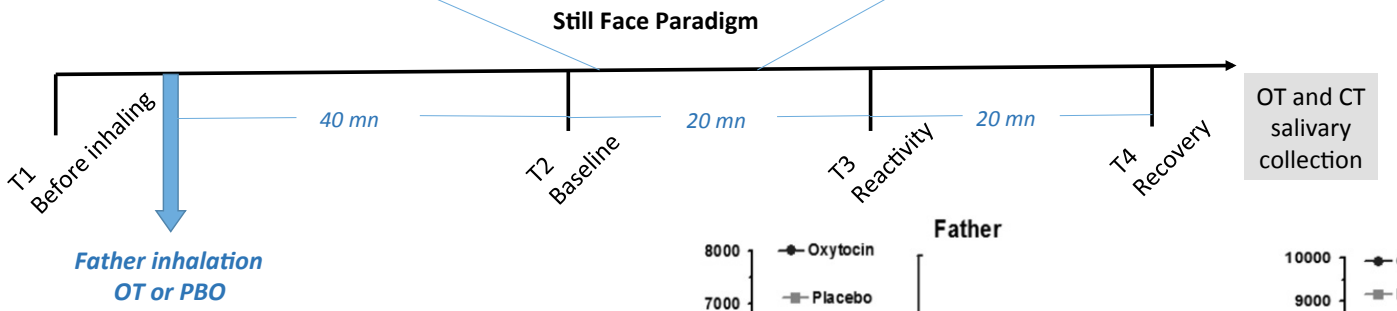
# Role of social signals in synchrony

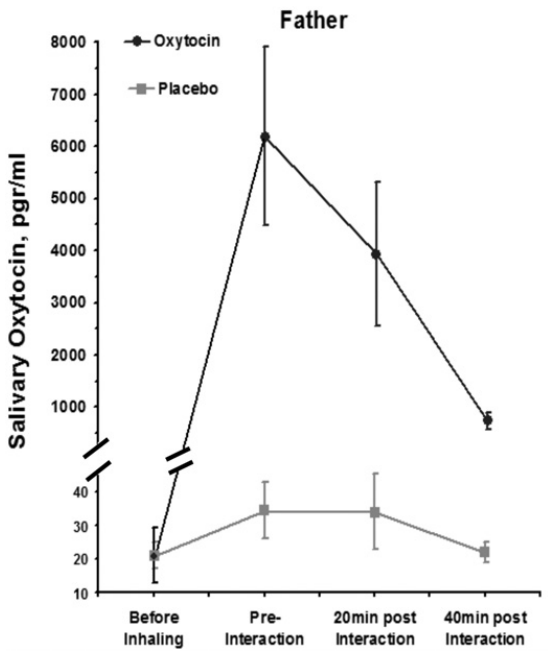


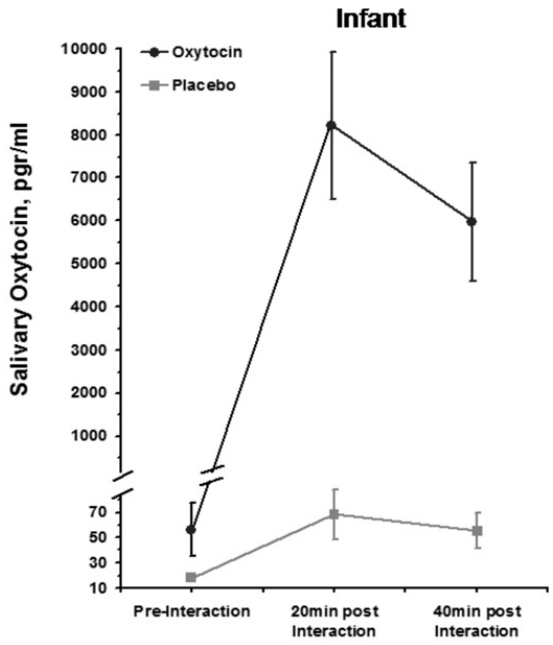




Weisman et al. : Oxytocin shapes parental motion during father-infant interaction . *Biology Letters (2013)*
Chetouani et al. : Beyond traditional ground-truth labeling: A bio-behavioral synchrony approach for social bonding characterization . submitted

# Role of social signals in synchrony

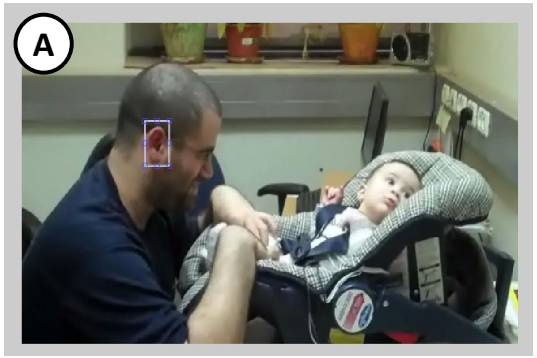



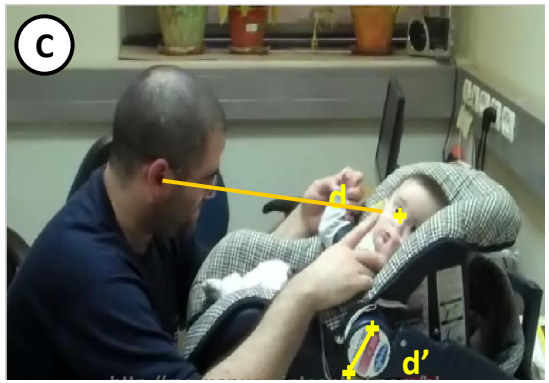



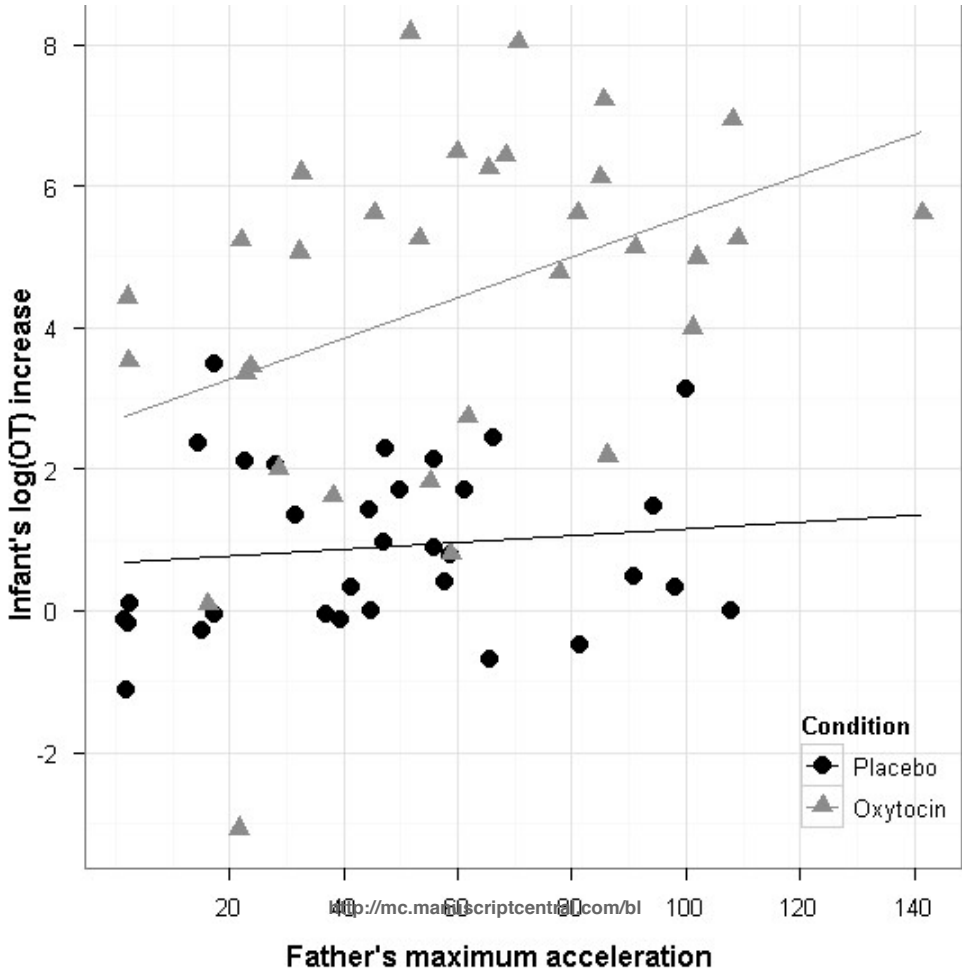

Weisman et al. : Oxytocin administration to parent enhances infant physiological and behavioral readiness for social engagement. Biol. Psychiatry (2012)

# Role of social signals in synchrony

- Low -resolution brain scanning
  - Oxytocin modulates proximity (kind of motionese)
  - Infant's OT reactivity  positively correlated with father's head acceleration

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# Outline

1. Role of social signals: motherese, motion, turn-taking and others...

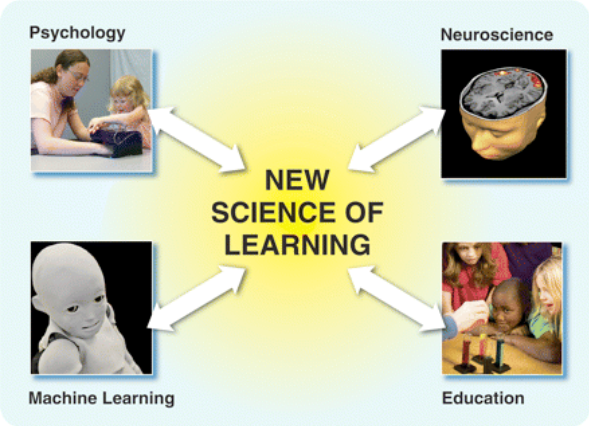
2. **Modeling synchrony: a focus on motor imitation**

3. Synchrony and social intelligence for personal robots

4. Using social signal processing and developmental robotics for clinical investigations in autism

# Imitation characterization through social signal processing

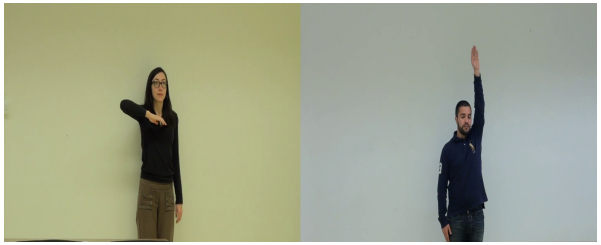
- Social learning
  - Infant's development
  - Learning in robotics




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)

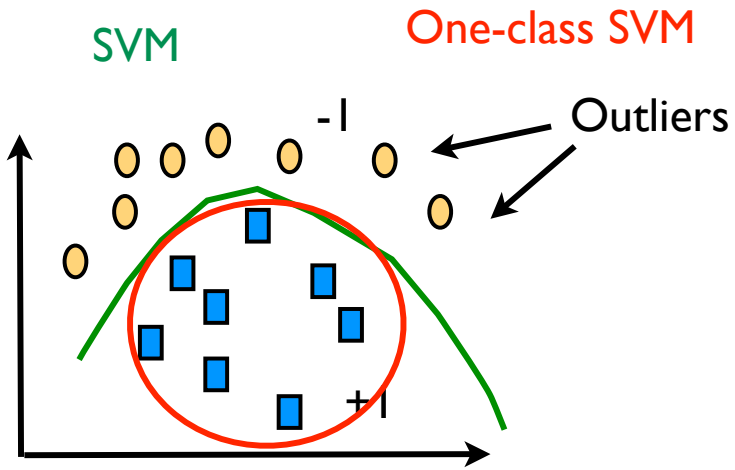
Unsupervised learning of a model A

Unsupervised learning of a model B

Evaluation of model B on data of A

Evaluation of model A on data of B

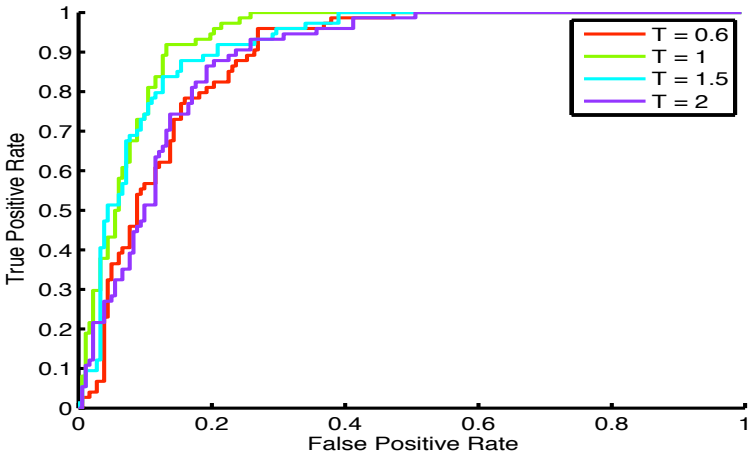
Metrics in the model space




Feature space

Interpretation:

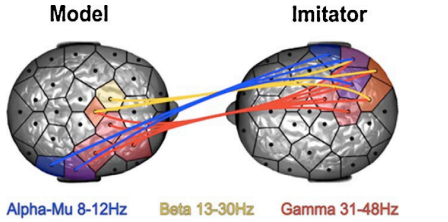
Novelty detection

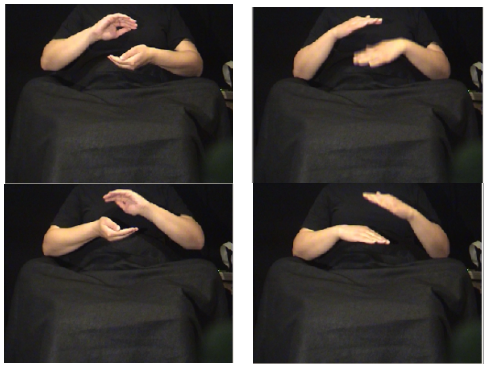



(a) Influence of window size. k=64.

# Imitation characterization through social signal processing

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



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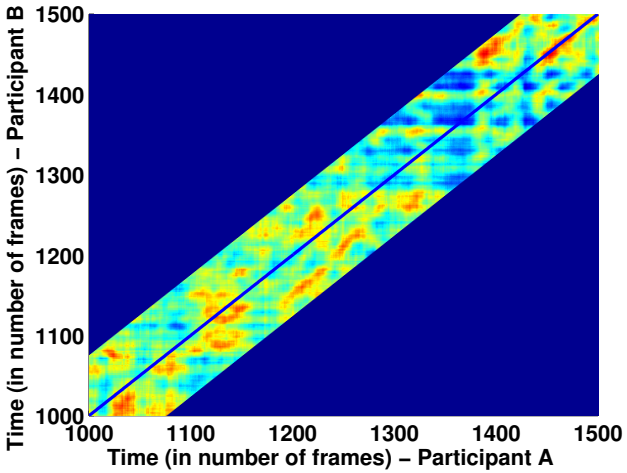
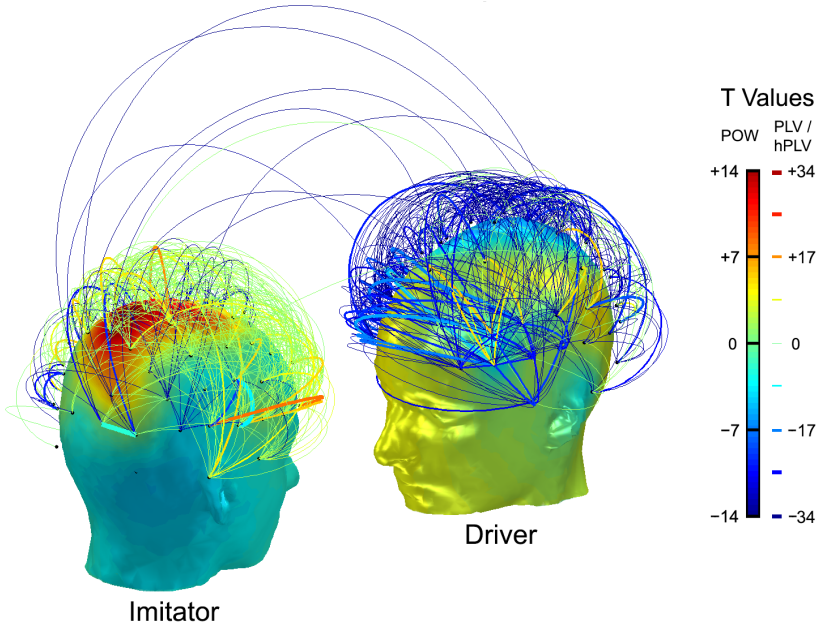
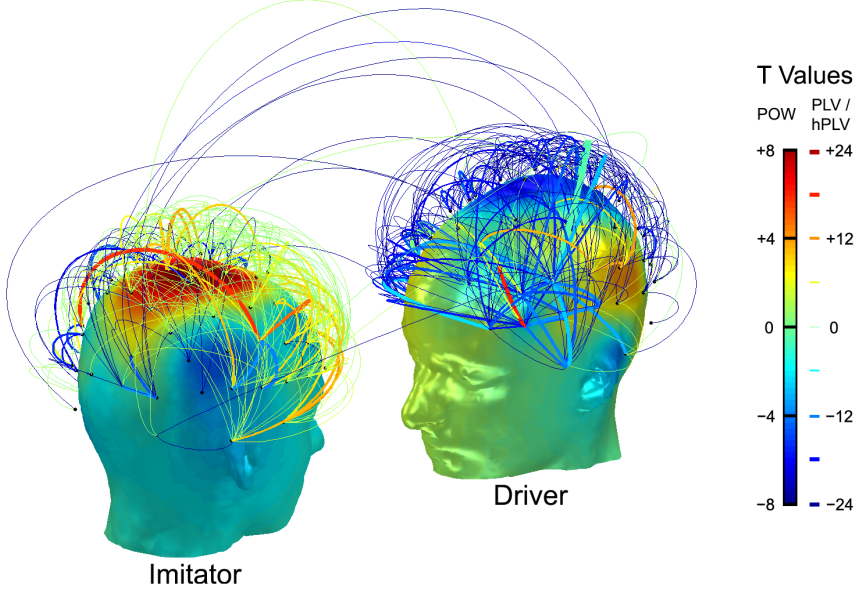
Linking behaviors and brain activities




(a) Recurrence matrix




(a) Manual indexing




(b) Automatic indexing

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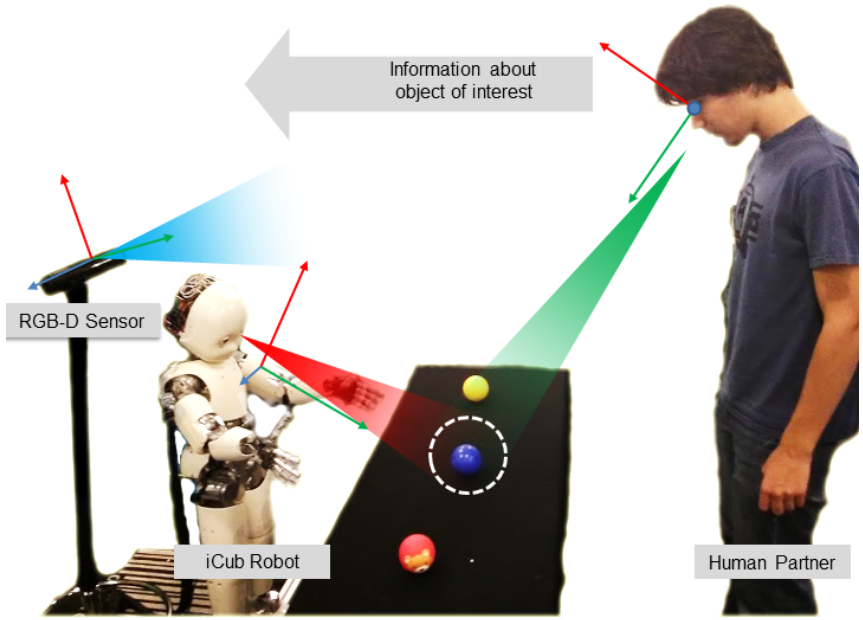
# Social intelligence for personal robots

- Social intelligence influences (shared) task performance:
  - Second-perspective taking
  - Dynanmics of interaction (synchrony)

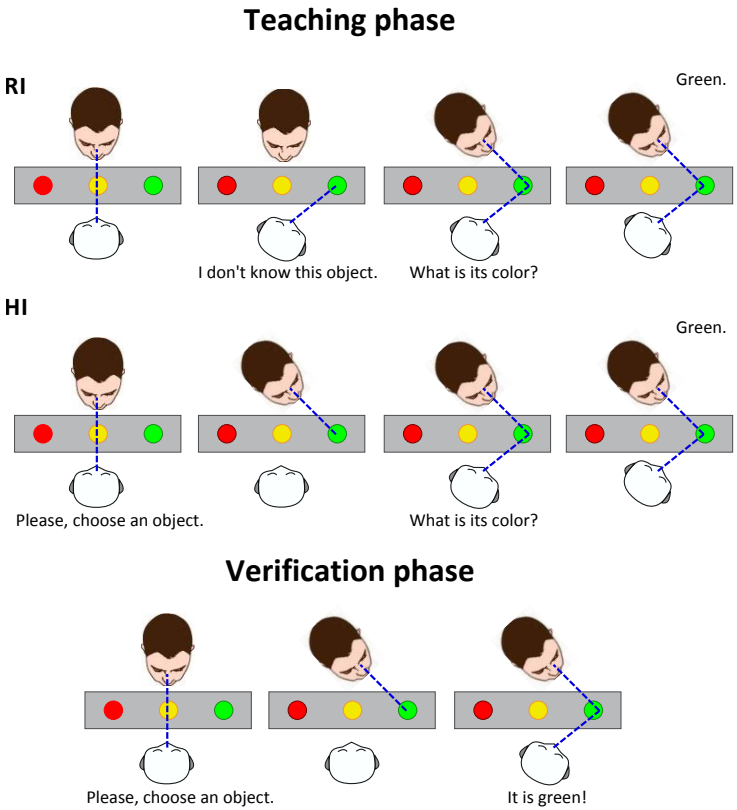
- Experiment :
  - Object learning through human interaction




Ivaldi et al. : Robot initiative in a team learning task increases the rhythm of interaction but not the perceived engagement , *Frontiers in Neurorobotics (2014)*

# Social intelligence for personal robots

- Protocol:
  - Robot initiates the phase
  - Human initiates the phase





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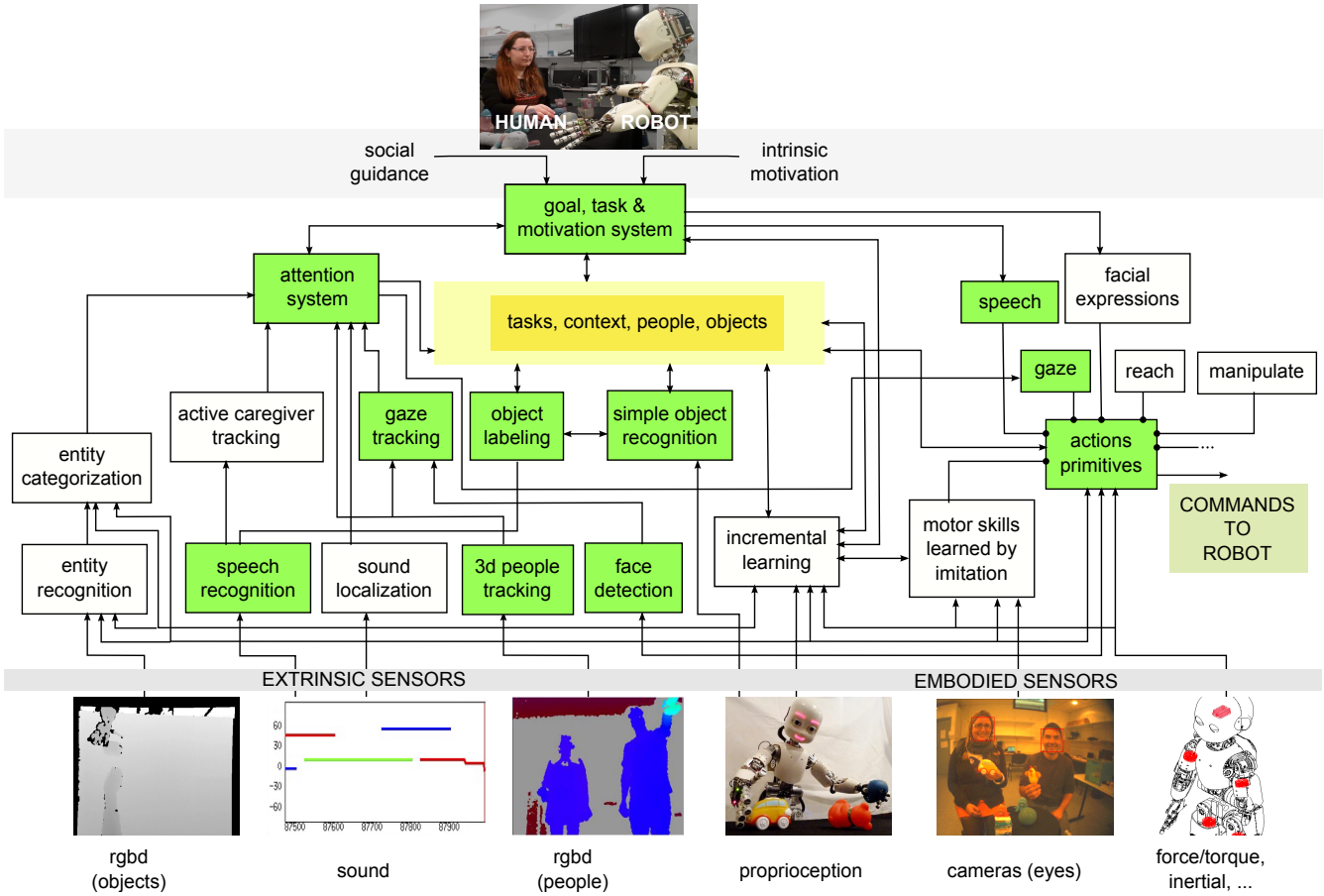
# Social intelligence for personal robots

- Complex architectures are required:

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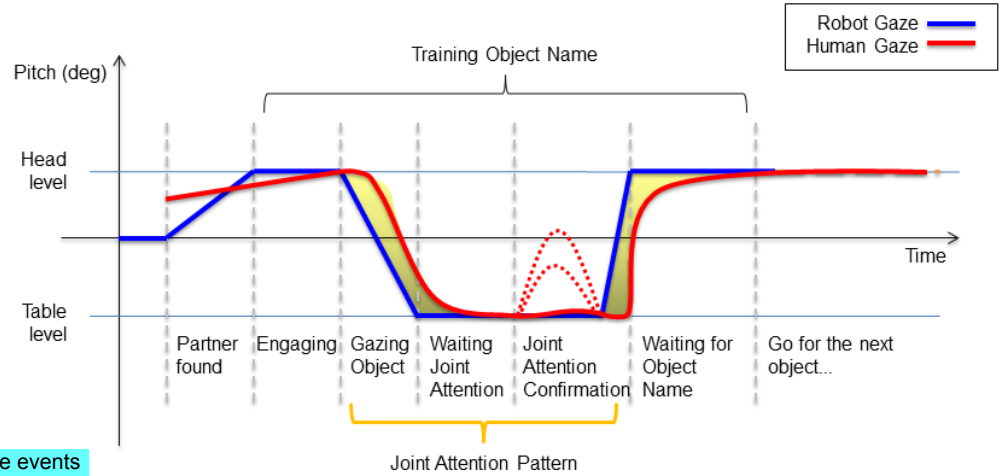
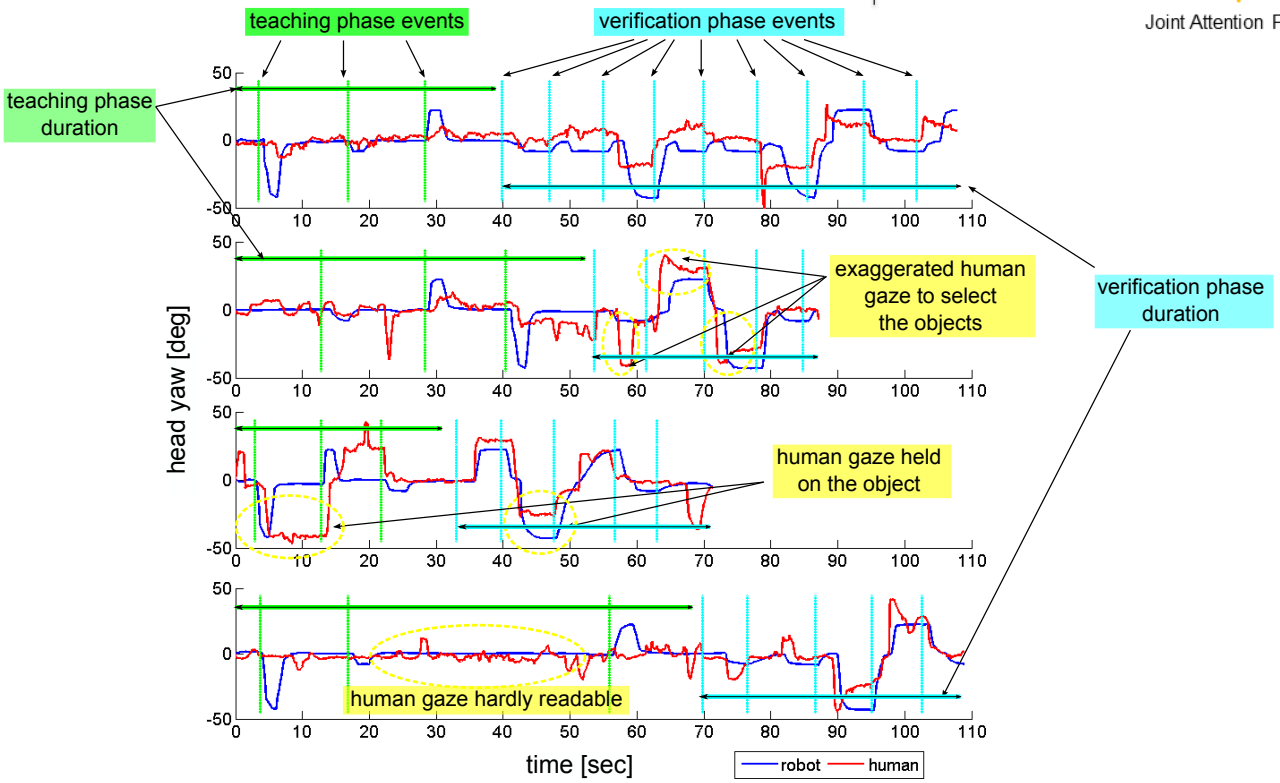
# Social intelligence for personal robots

- Some results:

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# Social intelligence for personal robots

- Subjects in the RI group react faster than the ones of the HI group, and the interaction with the robot has a higher rhythm

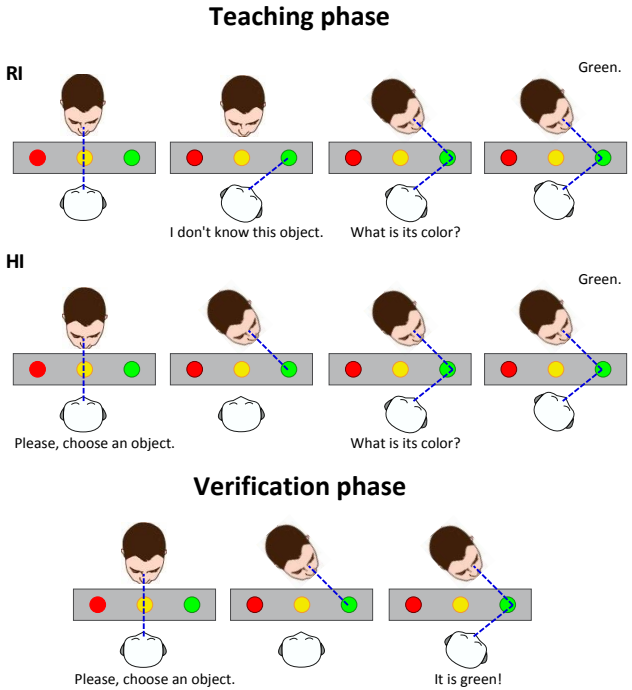



**Table 2.** Reaction time (seconds) in response to robot attention stimuli (utterances) during verification phase

| Group | mean | std | median | Wilcoxon's test |
|---|---|---|---|---|
| HI | 1.932 | 0.711 | 1.917 | W=418, |
| RI | 1.296 | 1.145 | 1.106 | p-value=0.005 |

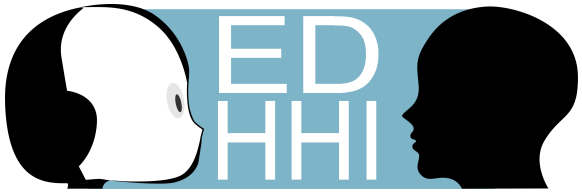
**Table 3.** Time interval (seconds) between consecutive robot attention stimuli (utterances) during verification phase

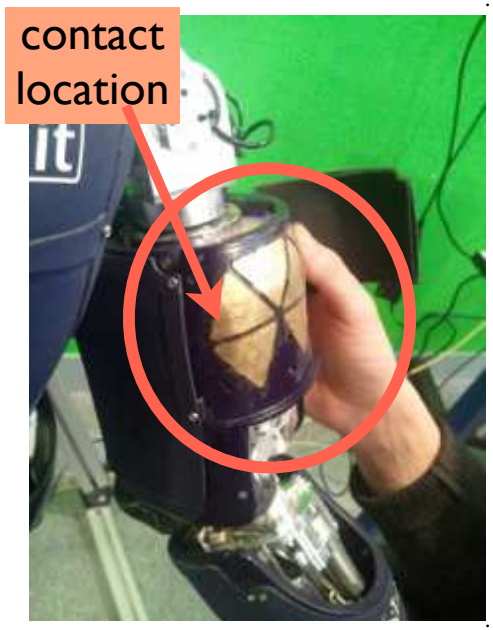
| Group | mean | std | median | Wilcoxon's test |
|---|---|---|---|---|
| HI | 9.524 | 1.515 | 8.588 | W=447; |
| RI | 7.287 | 1.653 | 7.257 | p-value=1.6e-5 |

Ivaldi et al. : Robot initiative in a team learning task increases the rhythm of interaction but not the perceived engagement , *Frontiers in Neurorobotics (2014)*

# Social intelligence for personal robots

- Combining social and physical interaction
- Engagement during Human Humanoid Interaction




1) acceptance test

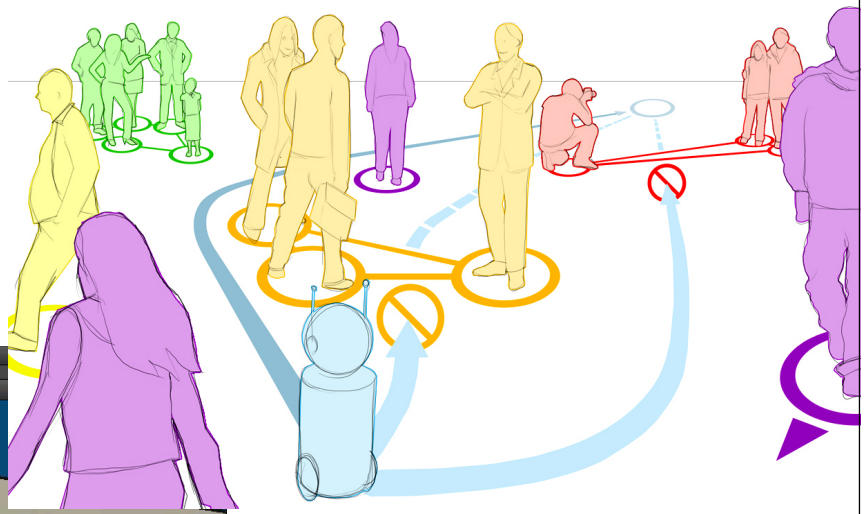
2) teaching through physical interaction

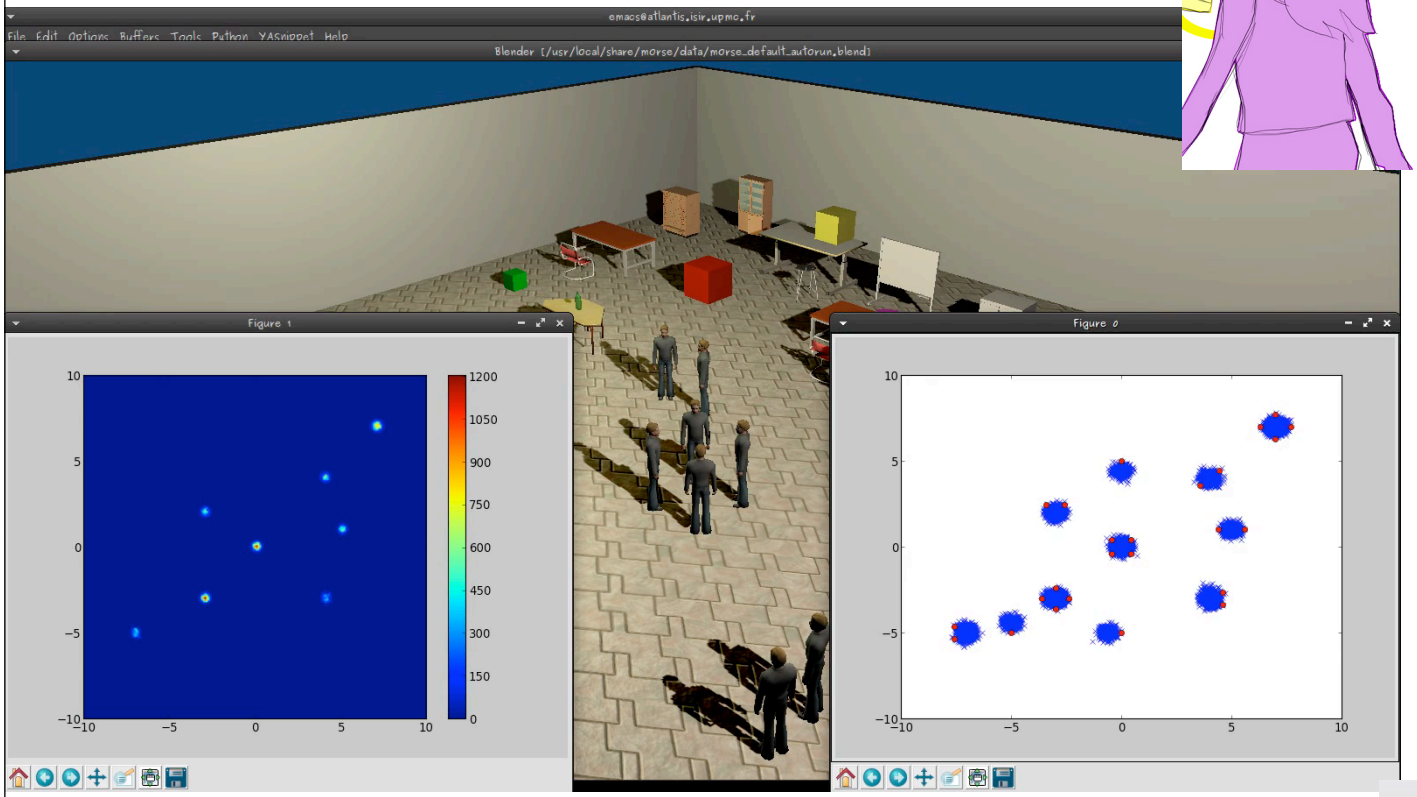
3) functional acceptability

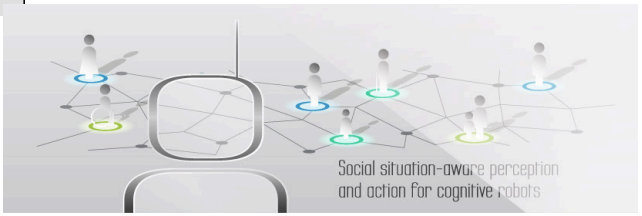
4) social acceptability

# Social intelligence for personal robots

- How to engage with people? group of people?
- Use case navigation with group of people





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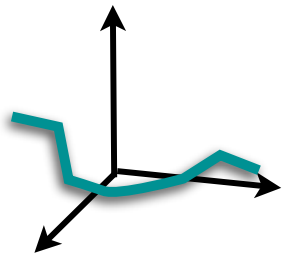
# Extraction of social signatures during Human-Robot Interaction

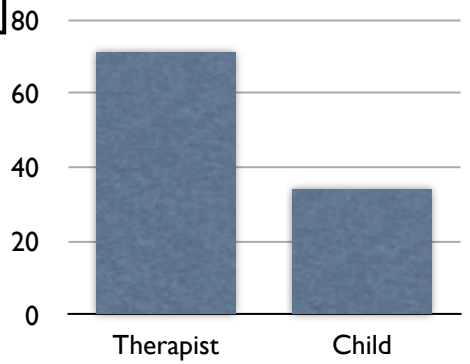
- Case of Human-Human Interaction
  - Mutual influence of partners
  - Paradigm-shift Looking at partner A to analyze partner B!

Continuous space

Speech turns, Gestures, Interpersonal synchrony...

SVM regression



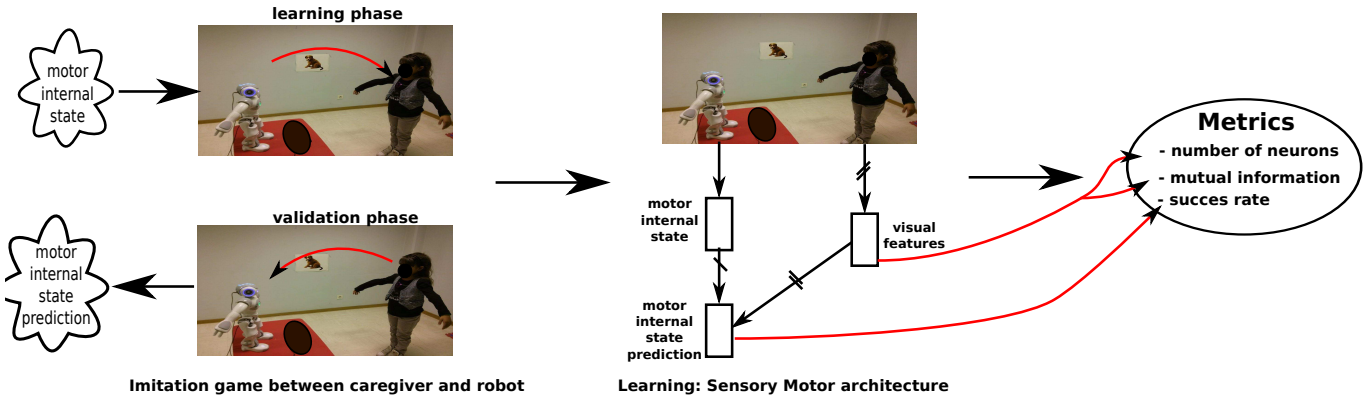


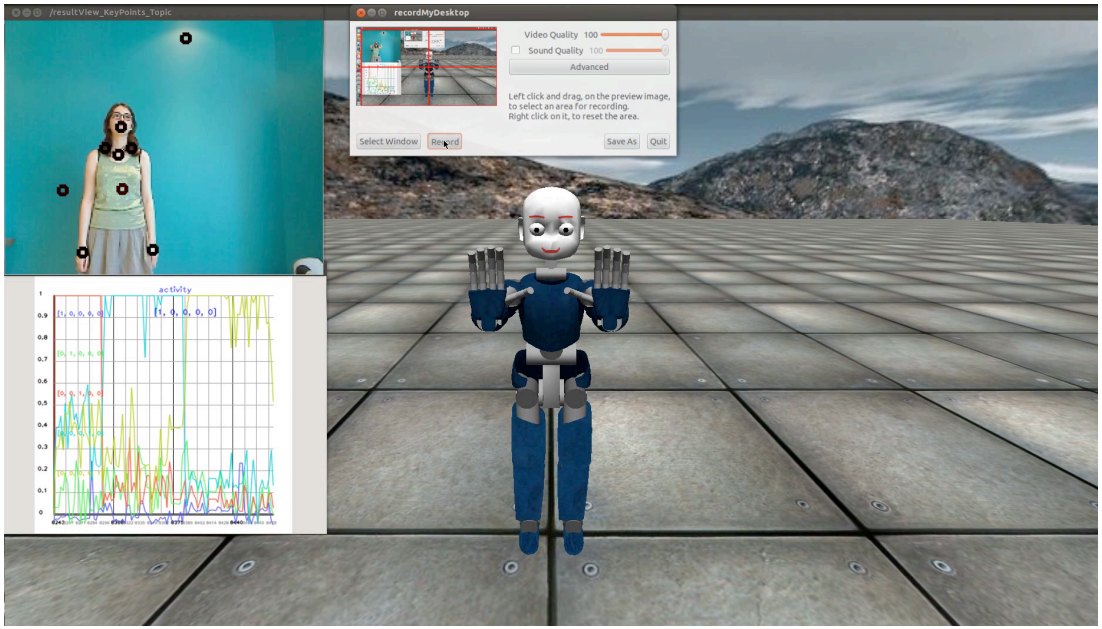

Correlation between speech turns and developmental age of child

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)*

# Extraction of social signatures during Human-Robot Interaction

- Social learning (Boucenna et al. 2014)
  - Proposition: Evolution of computational model's parameters inform us about the human partner



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

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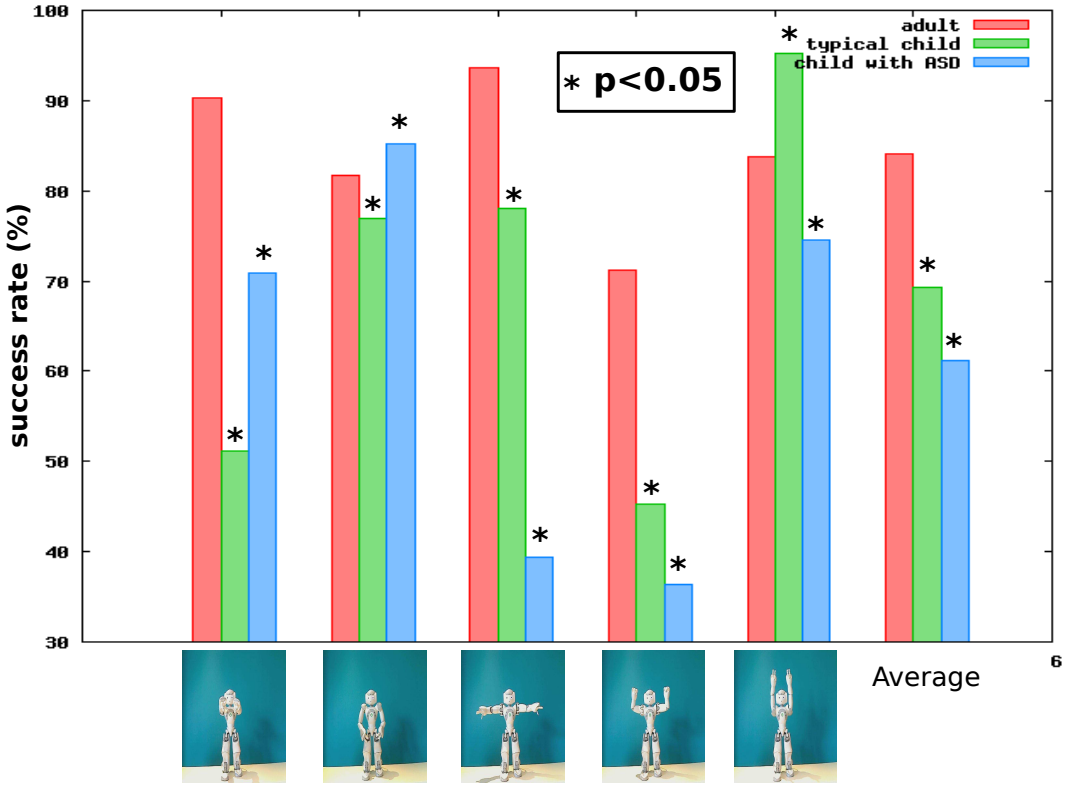


Recognition rates for adults, typical and autistic children

| | ASD (N=15) | TD (N=15) |
|---|---|---|
| Age, mean (± SD), year | 9.25 (± 1.82) | 8.06 (± 2.49) |
| Male - Female | 13-5 | 9-6 |
| ADI-R, current, mean (± SD) | | |
| Social impairment score | 10.77 (± 5.3) | Not relevant |
| Verbal communication score | 7.72 (± 4.22) | Not relevant |
| Non verbal communication score | 4.3 (± 3.5) | Not relevant |
| Repetitive interest score | 2.5 (± 1.88) | Not relevant |
| Developmental score | 3.3 (± 1.5) | Not relevant |
| Total score | 31.1 (± 5.46) | |
| ADI-R, 4-5 years, mean (± SD) | | |
| Social impairment score | 17.33 (± 8.47) | Not relevant |
| Communication verb score | 13.75 (± 5.72) | Not relevant |
| Communication non-verb score | 8.08 (± 4.4) | Not relevant |
| Repetitive interest score | 5.25 (± 3.52) | Not relevant |
| Developmental score | 3.83 (± 1.47) | Not relevant |
| Total score | 48.25 (± 7.34) | |
| Developmental age | 7.47 (± 2.9) | 8.06 (± 2.49) |
| IQ* | 73 (± 14) | All controls > 80 |
| GAF score | 40.27 (± 9.44) | All controls > 90 |
| Imitation score / therapist** | 18.0 (± 3.46) | 19.66 (± 1.29) |
| Imitation score / Nao** | 17.27 (± 5.24) | 19.53 (± 1.81) |

Recognizing human postures

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

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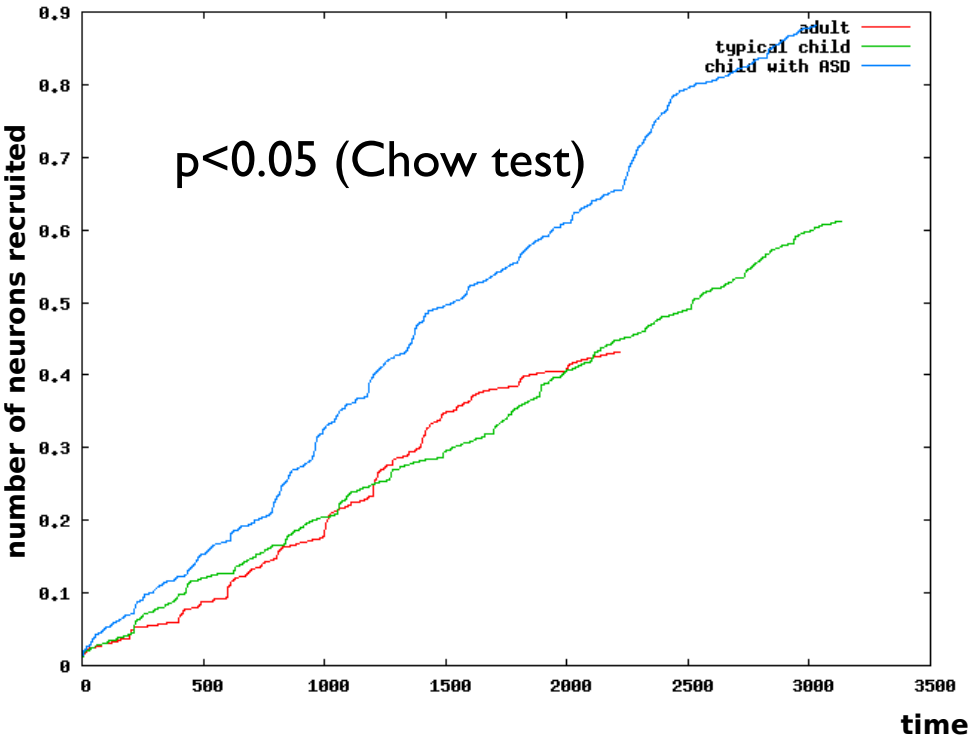
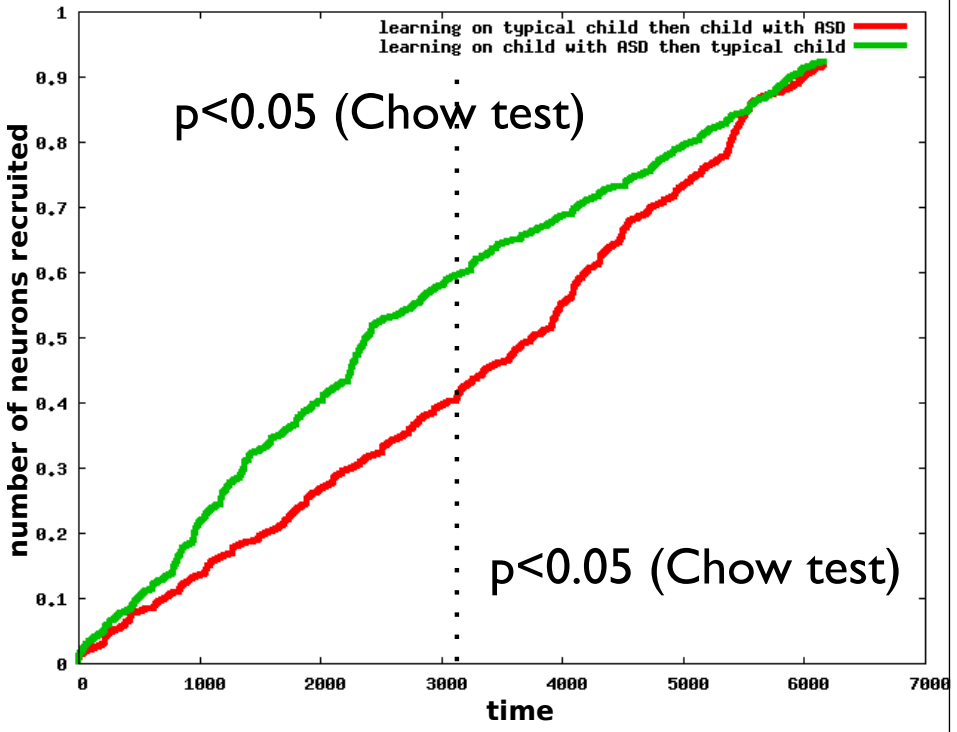



Evolution of parameters for differents groups during learning

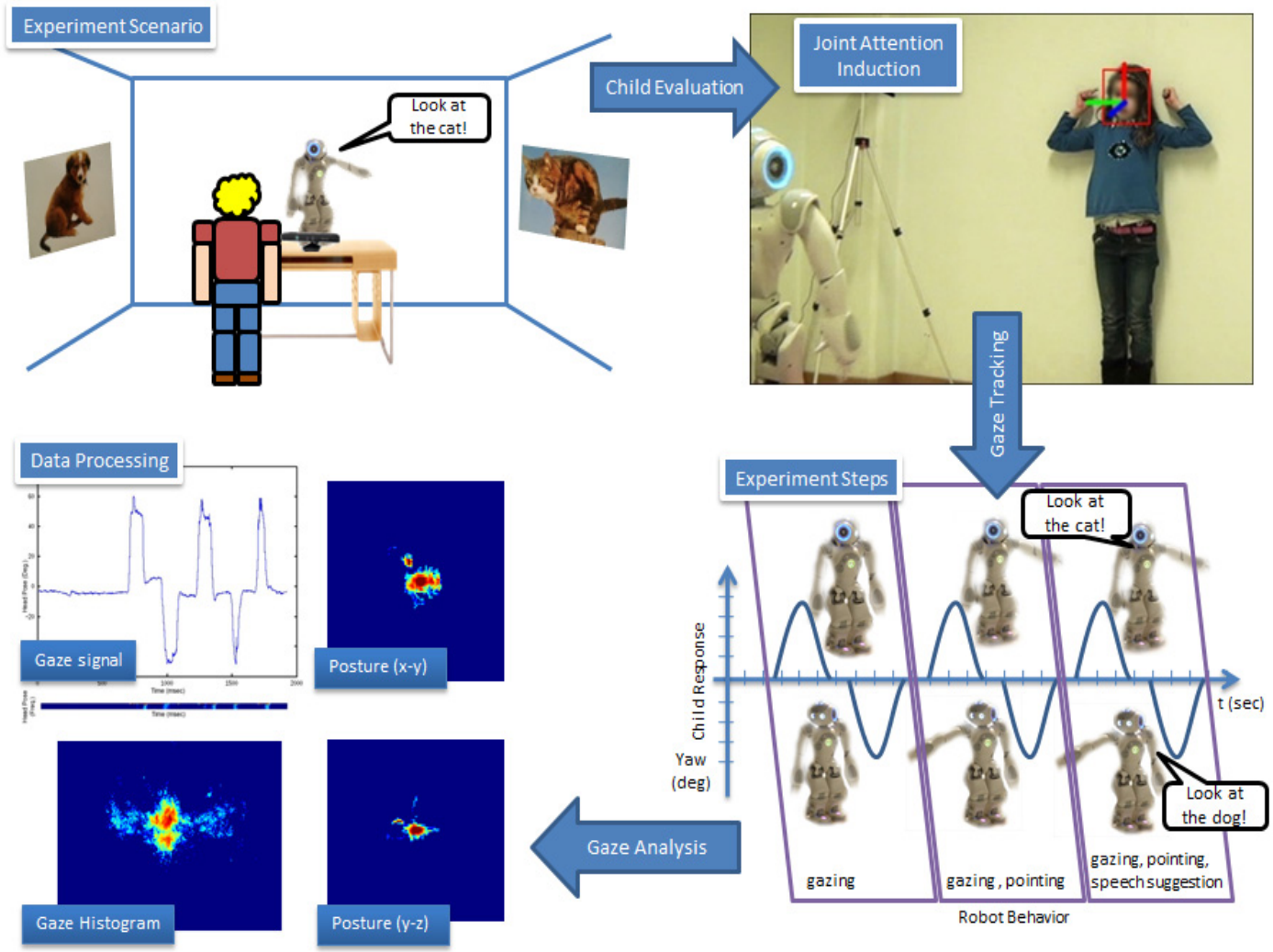



Changing group during learning

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 Interaction

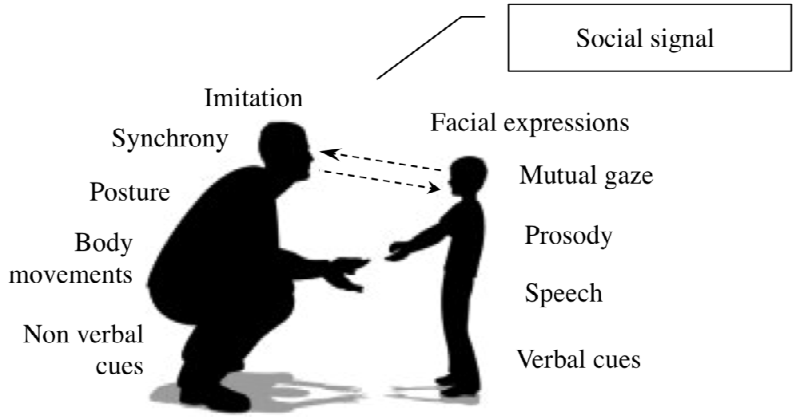
- Joint attention (Anzalone et al. 2014)
  - Proposition: How to extract social cues of joint attention during interaction?

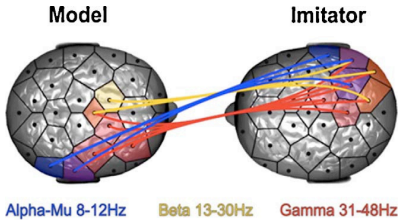



Anzalone et al. : How children with autism spectrum disorder behave and explore the 4-dimensional (spatial 3D+time) environment during a joint attention induction task with a robot. *Research in Autism Spectrum Disorders (2014)*

# Conclusions

- Modeling and characterizing human communication dynamics
- Robot is employed as a tool for both stimulation and clinical investigation
- New ways to study social interactions

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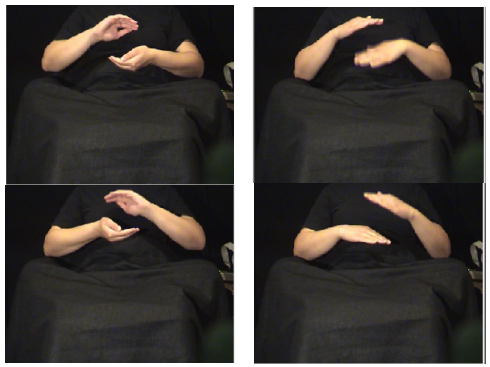
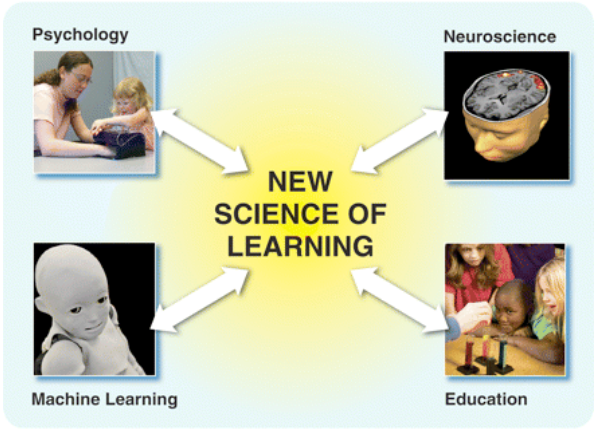


Linking behaviors and cerebral activities



# Thank you for your attention

# Questions?

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