Behavior and interaction imaging in early psychopathology

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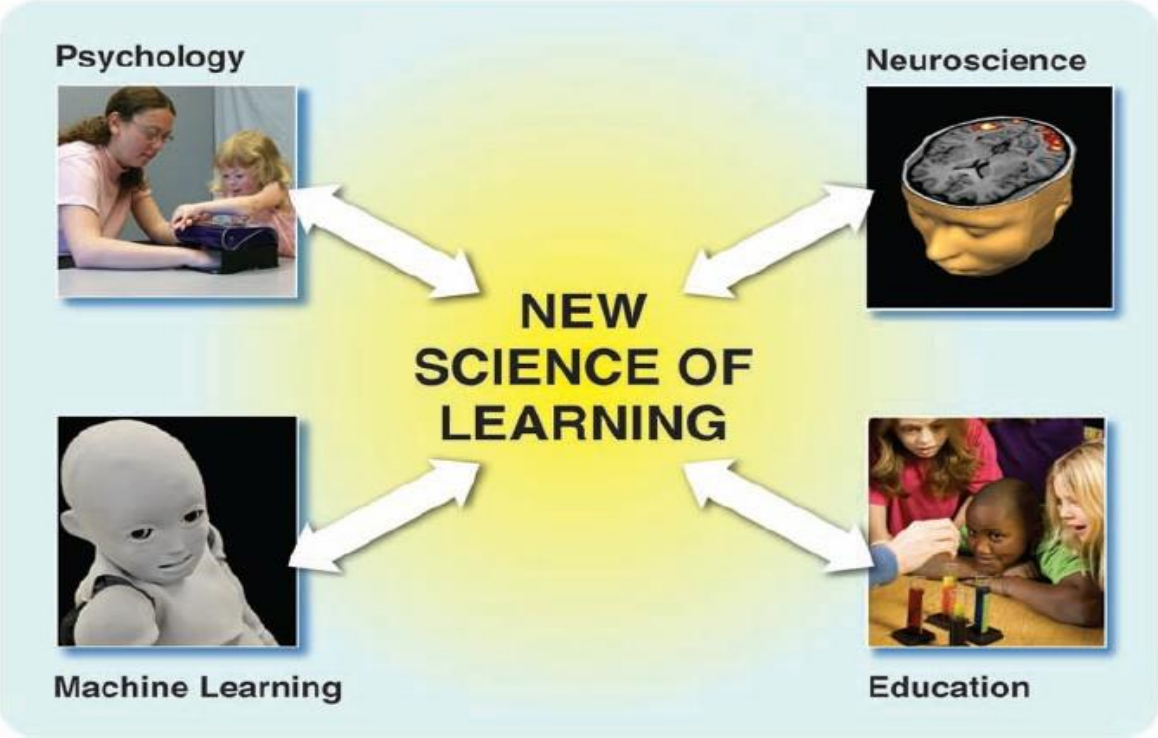


http//:speapsl.aphp.fr

Meltzoff et al, Science, 2009

Plan

Introduction

- Evolution of bonding
- Synchrony and social signal processing

Studying social cues during early interaction using SSP

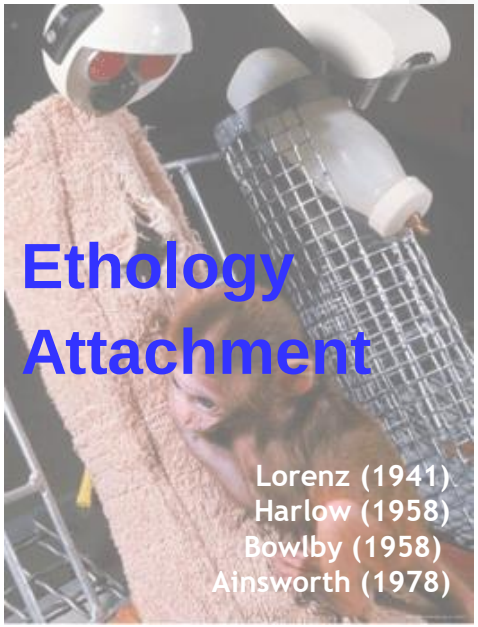
- ASD and home movies
- Motion and speeach turns during early interaction

Studying social cues anticipating signal capture

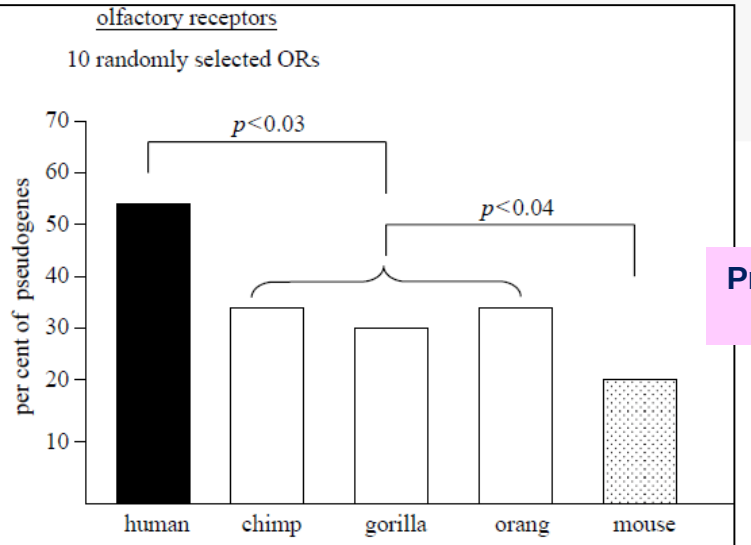
- Mothers showing severe neglect with their infants
- Studying the multimodality of stress

Modeling infant early development through developmental robotics

Early interaction



	RODENTS	NON-HUMAN PRIMATES	HUMANS
Context	Nest dependent	Social groups	Mothering, fathering, families
Timing	Immediate, short requires online infant cues	Social expectations, predictions of relationships	Past-informed and future projected Cross-generational
Sensory	Olfactory-based	Visual, multi-sensory	Visual, multi-sensory, association guided
Behavior	Touched-based	Touch and vision	Touch develops into face-to-face synchrony
Emotion	Negative emotion indicates danger	Facial mimic associated to both positive and negative emotion	Positive emotion (both audio and facial) are important social cues
Hormones	Primed by pregnancy hormones, triggered by birth hormones. Hormonally controlled bond	Hormone primed and triggered. Bond not hormone-dependent	Hormone primed and triggered. Bond formation ndependent from hormon control and pregnancy
Brain	Limbic network	Limbic network connected with neocortex	Limbic network connect via ascending and descending projections to empathy, mirror, mentalising, and emotion regulation networks

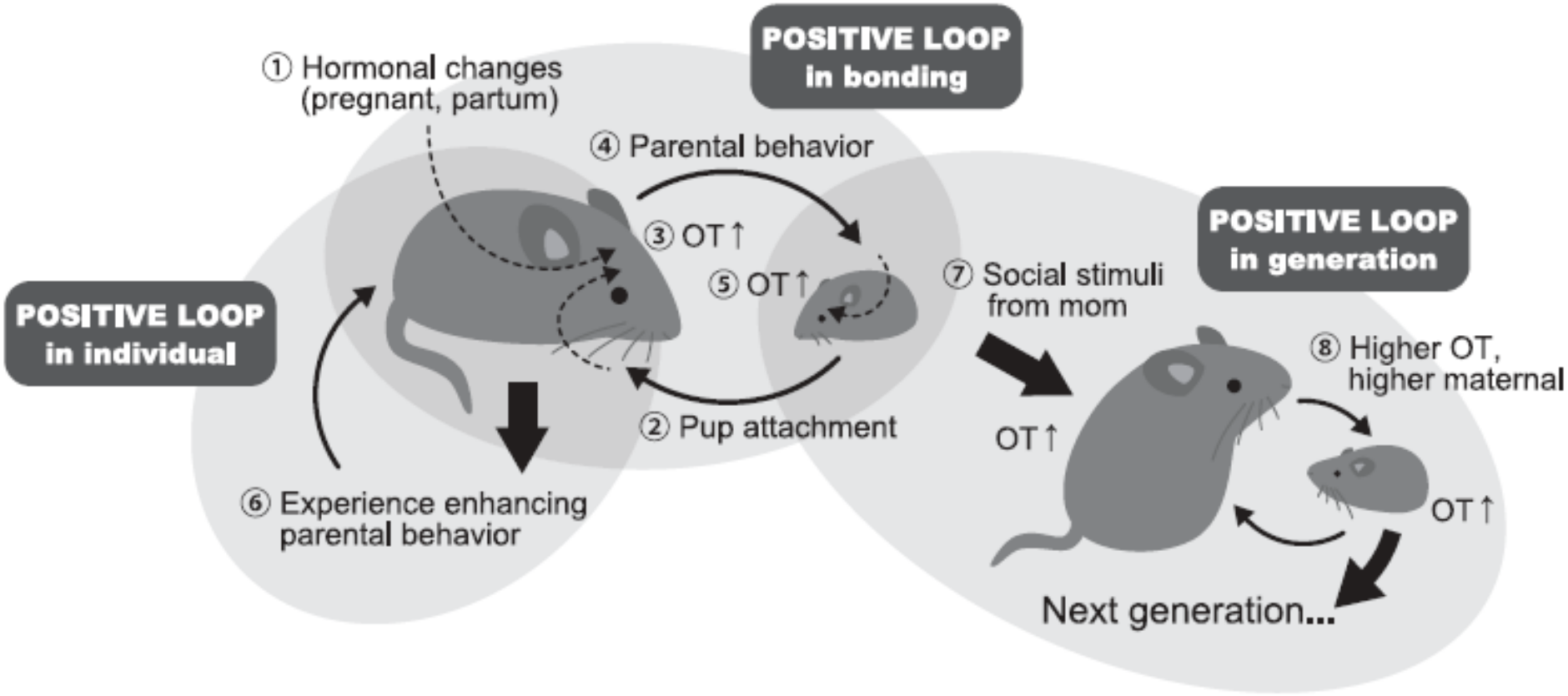


Promiscuous, olfactory-based, Nest-bound attachment

Exclusive, multi-sensory, associative, cultrure-based attachement

Feldman, Psychoendocrinology 2015

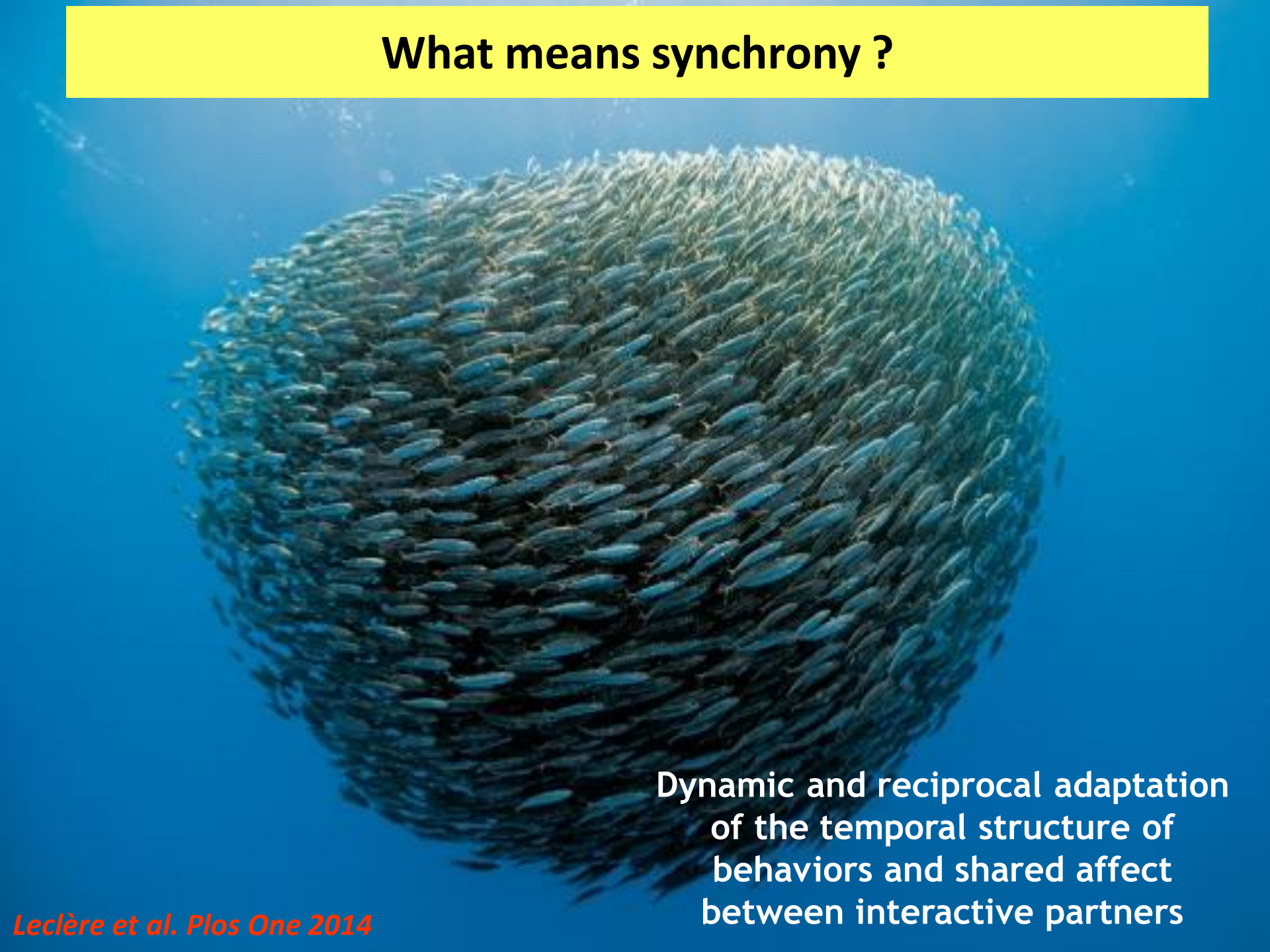
In sum: Oxytocin and mutual communication in mother-infant bonding (2)



A schematic illustrating the positive loop of social bonding controlled by oxytocin at ONE GENERATION BUT ALSO THE NEXT GENERATION through non genetic transmission of behavioral treats.

Nagazawa et al., Frontiers in Hum Neurosc 2012

What means synchrony ?

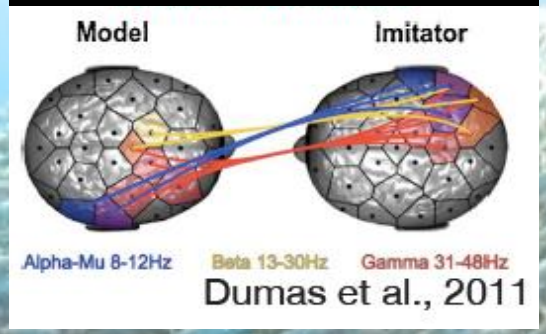


Dynamic and reciprocal adaptation of the temporal structure of behaviors and shared affect between interactive partners

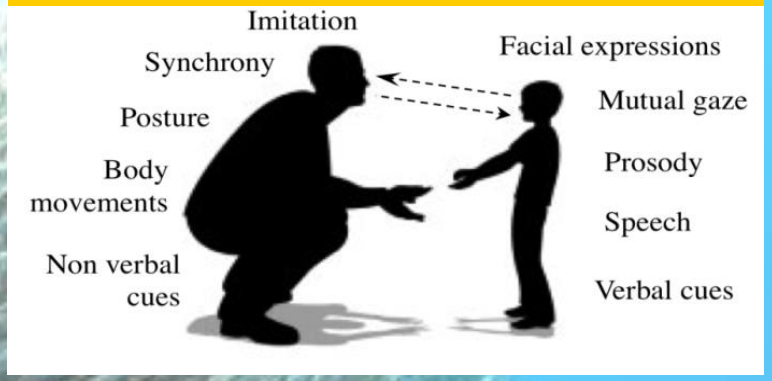
Leclère et al. Plos One 2014

Biological

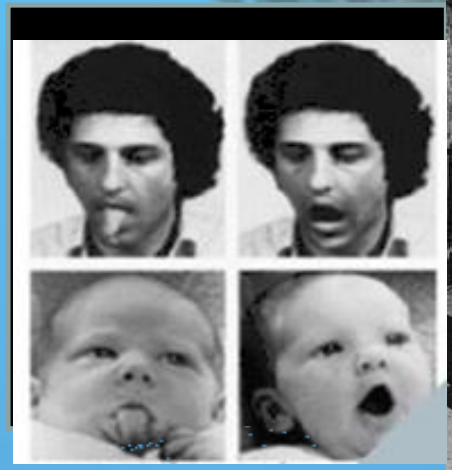
Neurophysiological

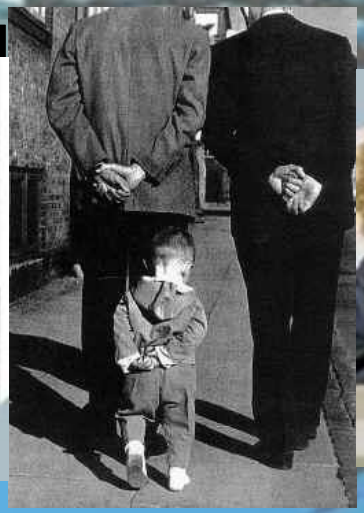


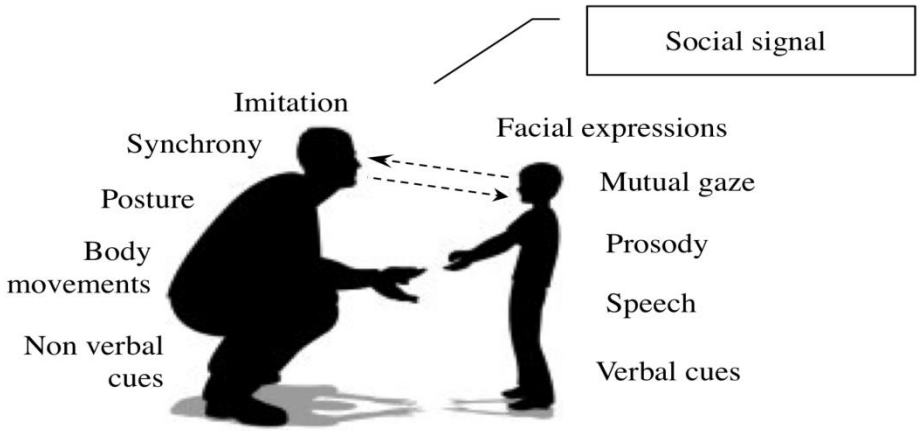
Social



(Feldman, 2007)







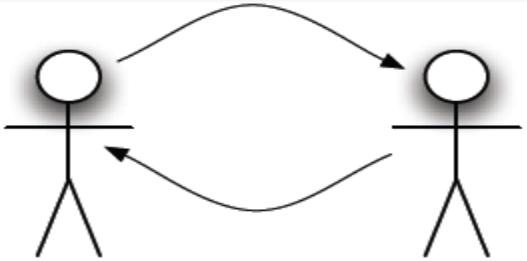
Human communication dynamics

Face-to-face communication is a highly dynamic process

Interpersonal dynamic (e.g. speech turns): interactional synchrony

Societal dynamic (e.g. large group)

Behavioral dynamic (e.g. gesture)



Individual dynamic (e.g. verbal and non-verbal communication): Intra-personal synchrony

Why this is so important?

- Indicator of engagement during interaction
- Can be used for clinical investigations of pathologies, social robotics...

Social cues and bonding: infant to mother

Audio signal

e.g. Ultrasonic vocalization in mice: Separation ⇨↗ infant USV ⇨↗ maternal behavior with EEG modification that are increased in experienced female

e.g. Crying in humans

Olfactory signal

e.g. Behavioral and neural response to pup odor in mice: Olfactory stimuli inhibit maternal behavior before parturation (neophobia). After parturation, ↗↗ response to olfactory cues and maternal behavior

Visual signal

e.g. gazing and eye contact in primates

Physical signal

e.g. stroking, nipple stimuli in primates

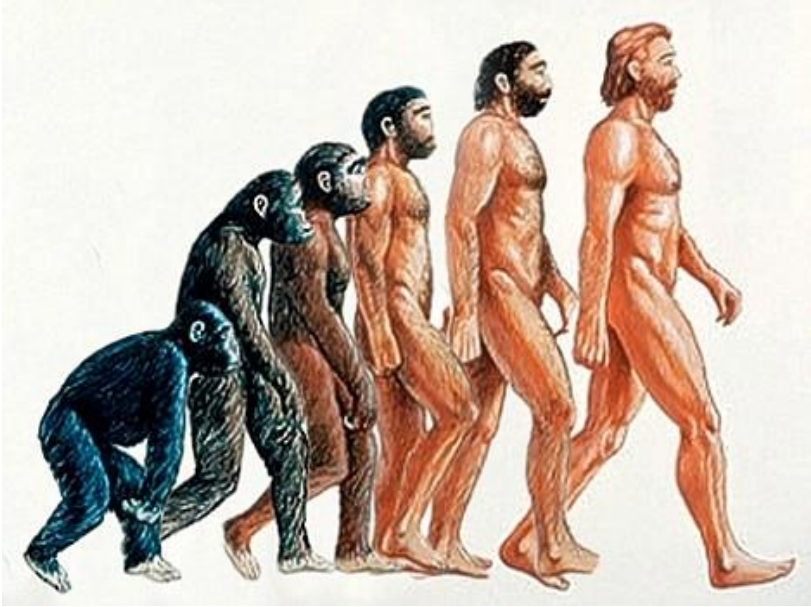
Delaherche et al., IEEE Trans Affective Computing 2012

Leclère et al., Plos ONE 2014

Nagazawa et al., Frontiers in Hum Neurosc 2012

An anthropological view
Prelinguistic evolution in early hominins: Whence motherese?

Comparison of mother-infant gestural and vocal interactions in chimpanzees and humans suggest:
(1)Prelinguistic vocal substrates that had prosodic features similar to contemporary motherese evolved as the trend for enlarging brains in late australopithecines/early Homo.
(2)This progressively increased the difficulty of parturition causing a selective shift toward females that gave birth to relatively undeveloped neonates.



In terms of human early interaction, this theory proposes touching, grasping, and skin-to-skin contact as old evolutionary moderators, and CG motherese, gesturing, and infant crying as recent evolutionary moderators.
Parents of infants who will develop AD change their interactive pattern of behaviour by recruiting both moderators (touching, as well as motherese and father involvement) for interacting with their infants.

Falk, BBS, 2004

Social cues and bonding: mother to infant

Audio signal

e.g. Motherese in humans

Olfactory signal

e.g. from the nipple area in mice

Visual signal

e.g. motion in birds

e.g. imitating and synchronizing in humans

Physical signal

e.g. licking and grooming in mice.

e.g. holding and physical contact in primates

Data mostly obtained from experimental and developmental studies and from studies assessing consequences of early separation

Delaherche et al., IEEE Trans Affective Computing 2012

Leclère et al., Plos ONE 2014

Nagazawa et al., Frontiers in Hum Neurosc 2012

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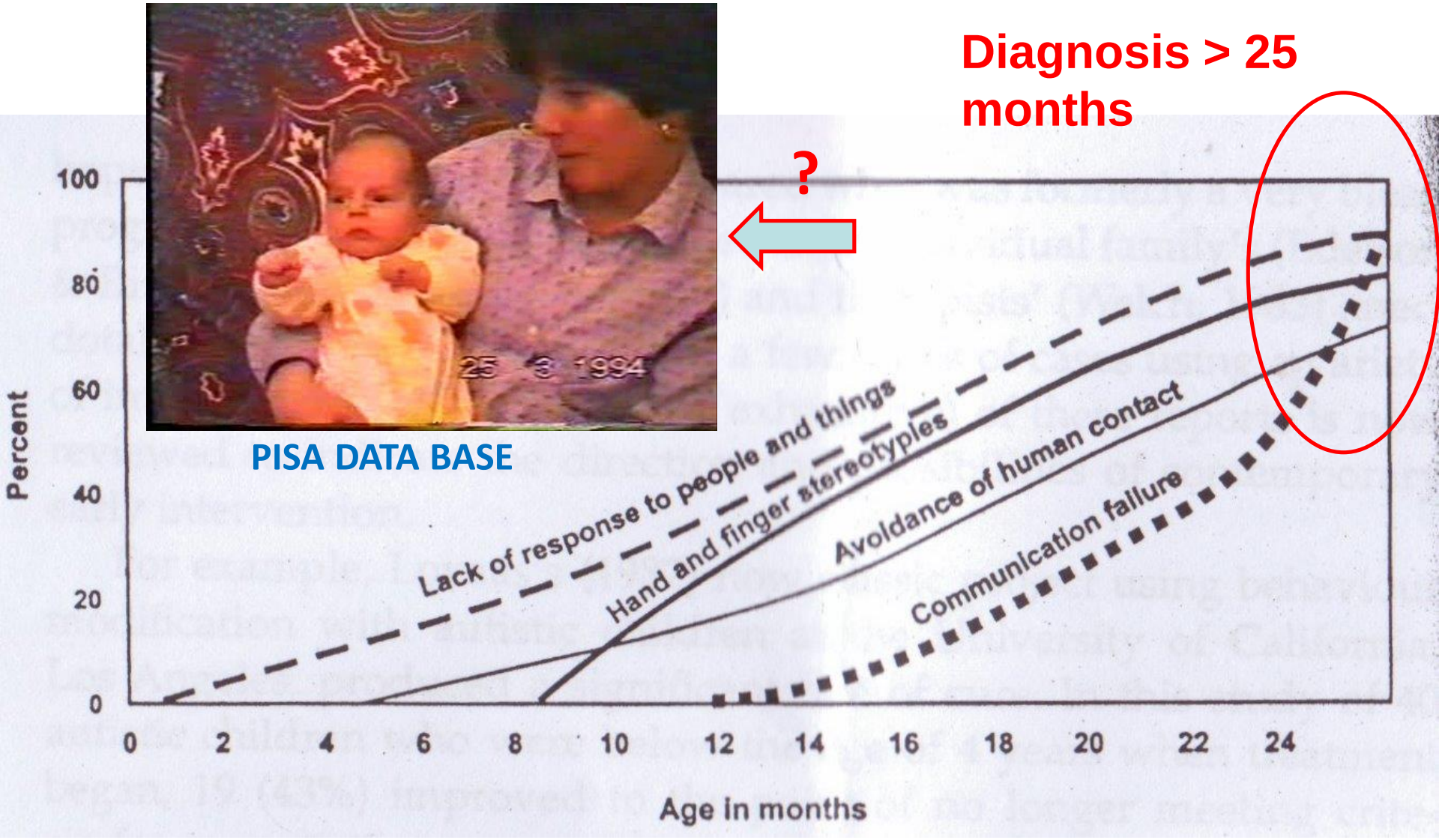
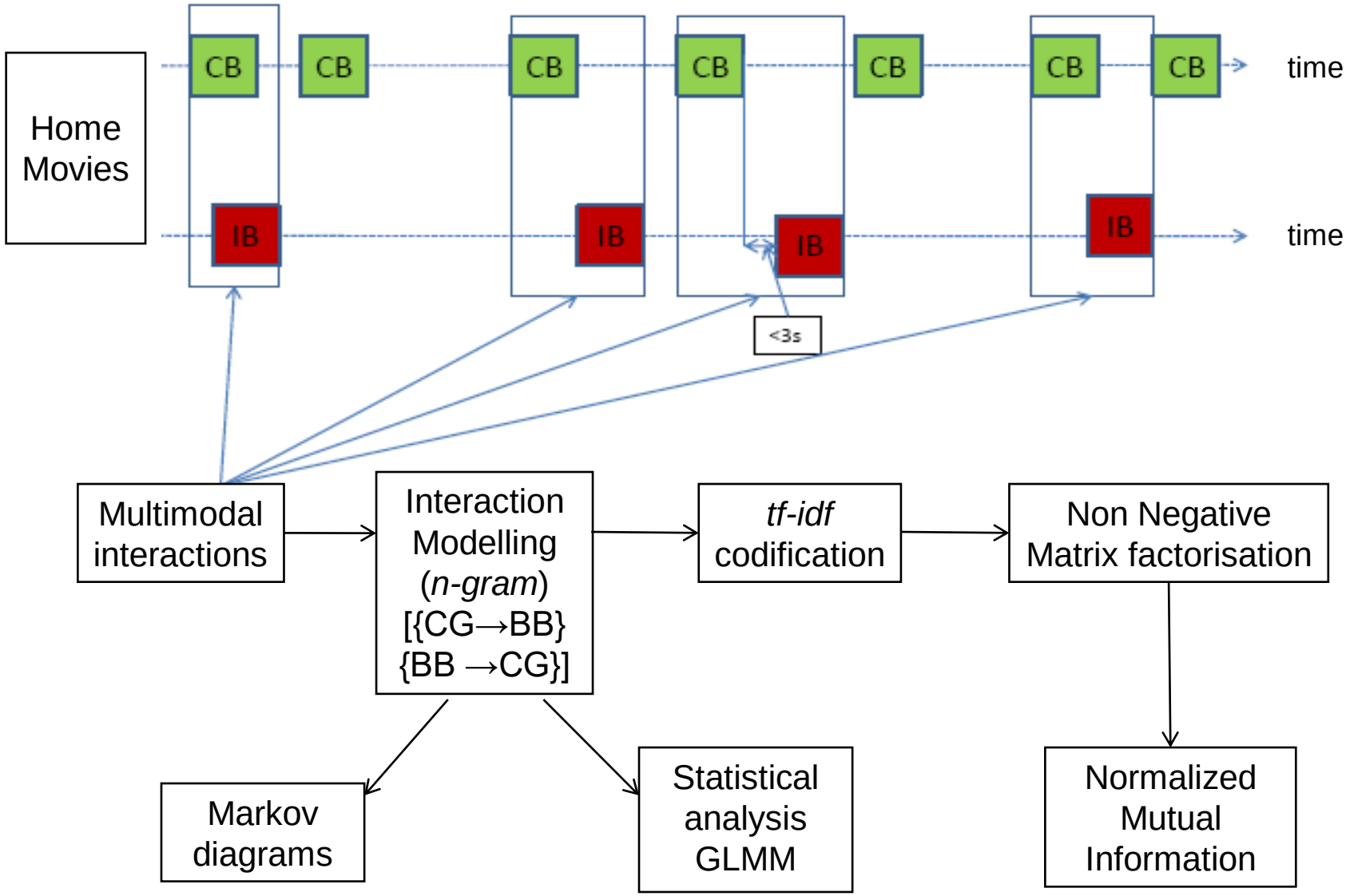
Studying interaction in infants who will subsequently develop autism

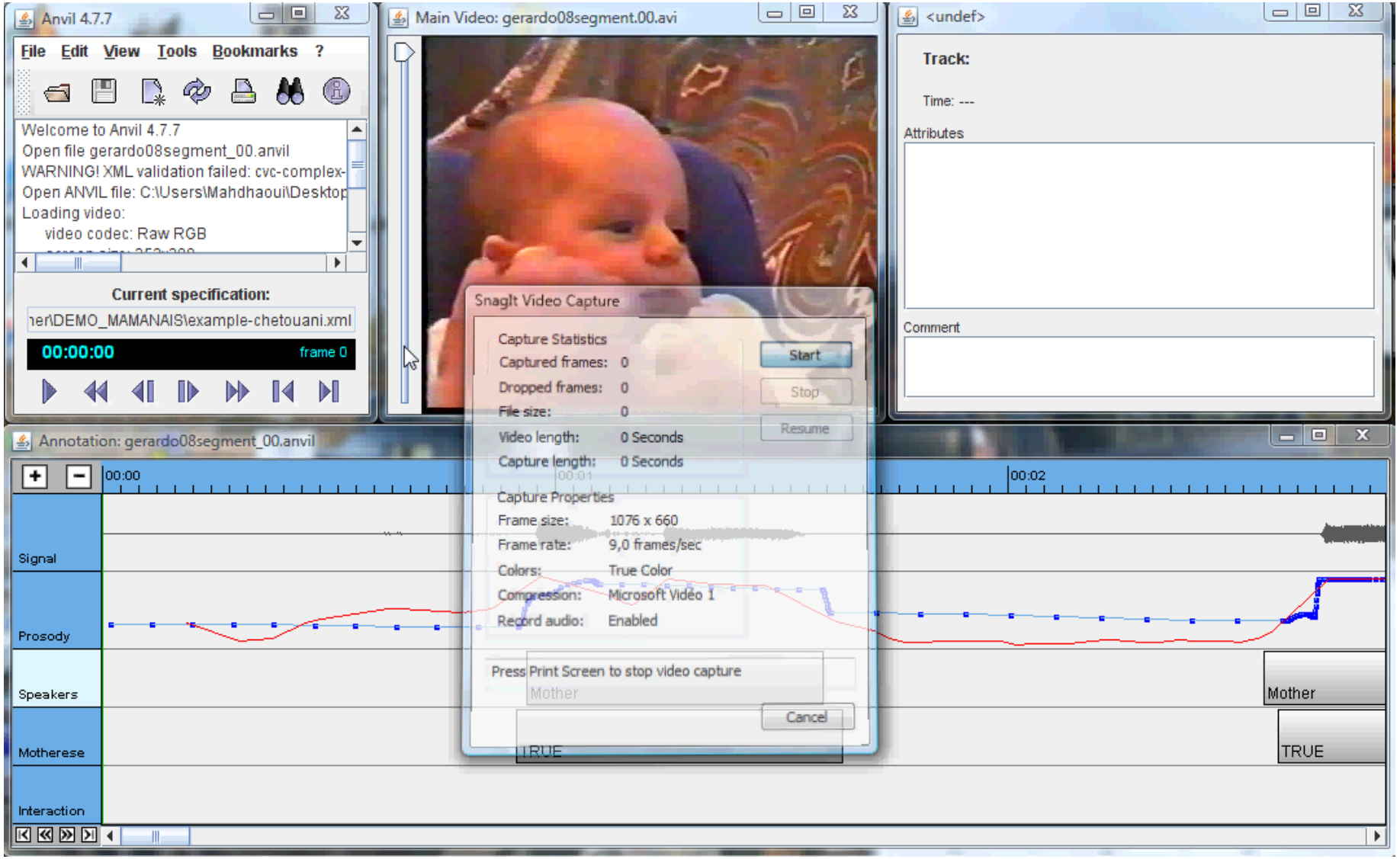


Massie, 2007

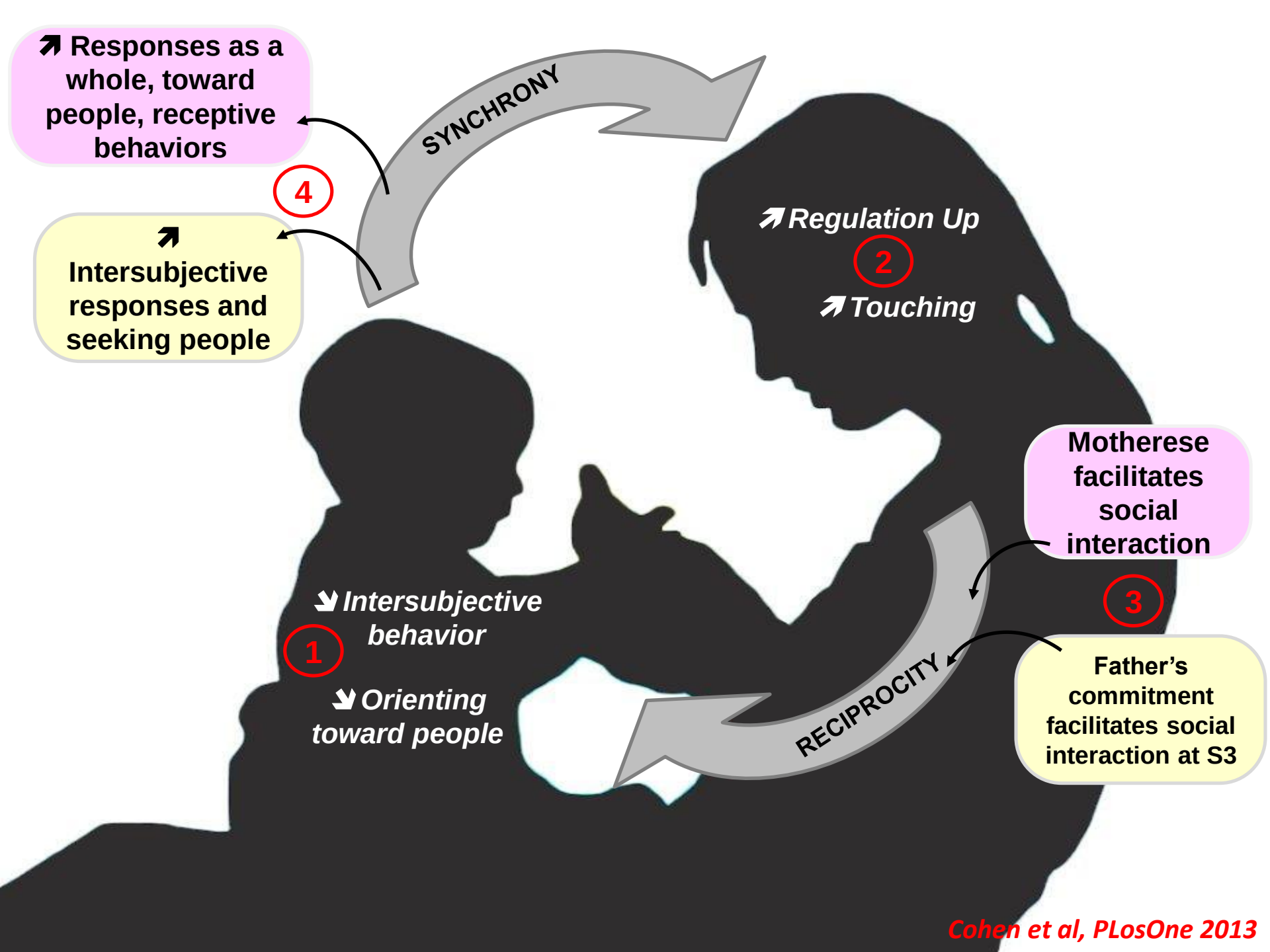


Saint-Georges et al, PlosONE, 2011

Motherese-Extractor-Video-Demo



Mahdhaoui et al, Int J Method Psy Res, 2011



Cohen et al, PLosOne 2013

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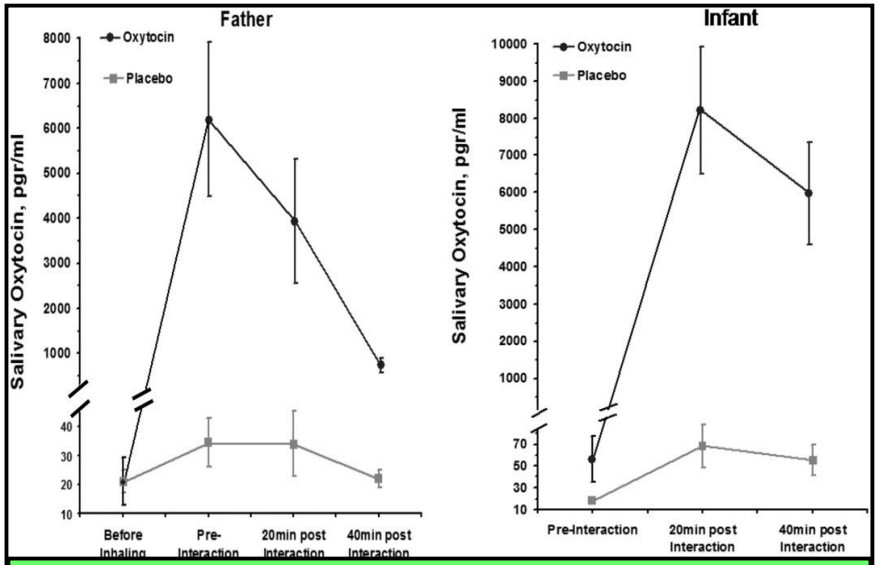
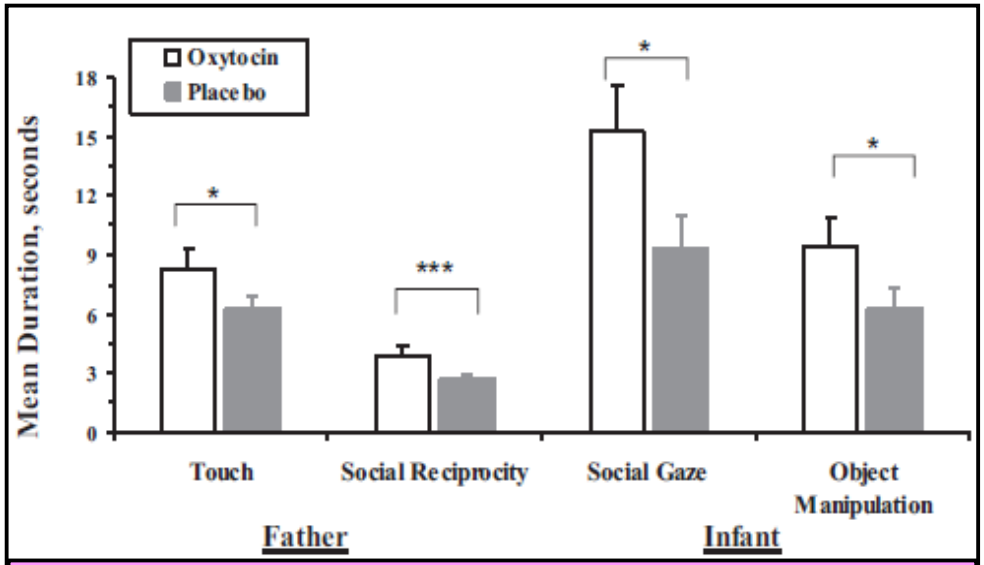
Oxytocin Administration to Parent Enhances Infant Physiological and Behavioral Readiness for Social Engagement



Oxytocin inhalation to father enhances oxytocin levels in infants

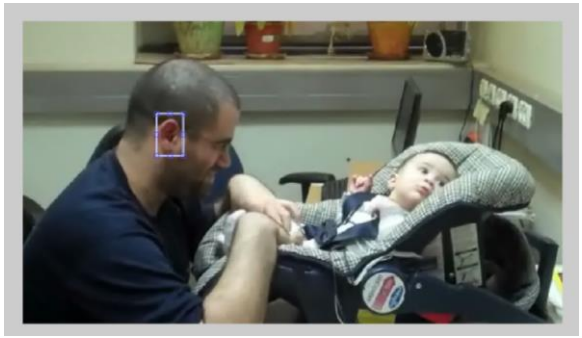


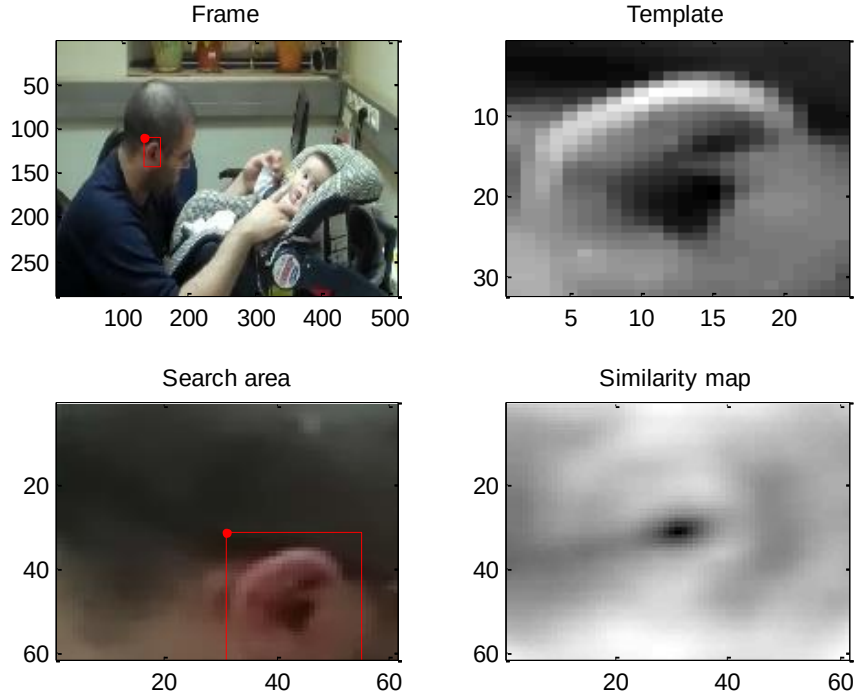
Father and infant social engagement in the oxytocin and placebo conditions

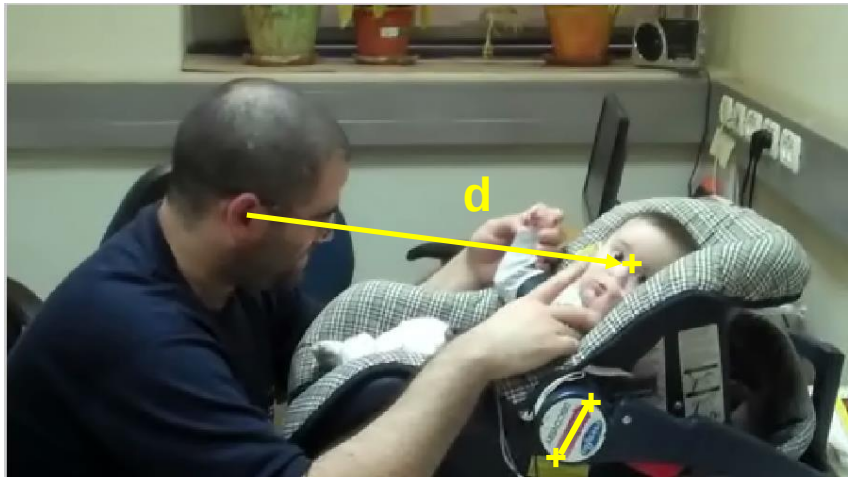
Oxytocin administration to one attachment partner can have parallel effects on the other and underscore the role of oxytocin in the cross-generation transmission of human social participation

Weissman et al., Biol Psychiatry 2012

Study on proxemics between father and infant



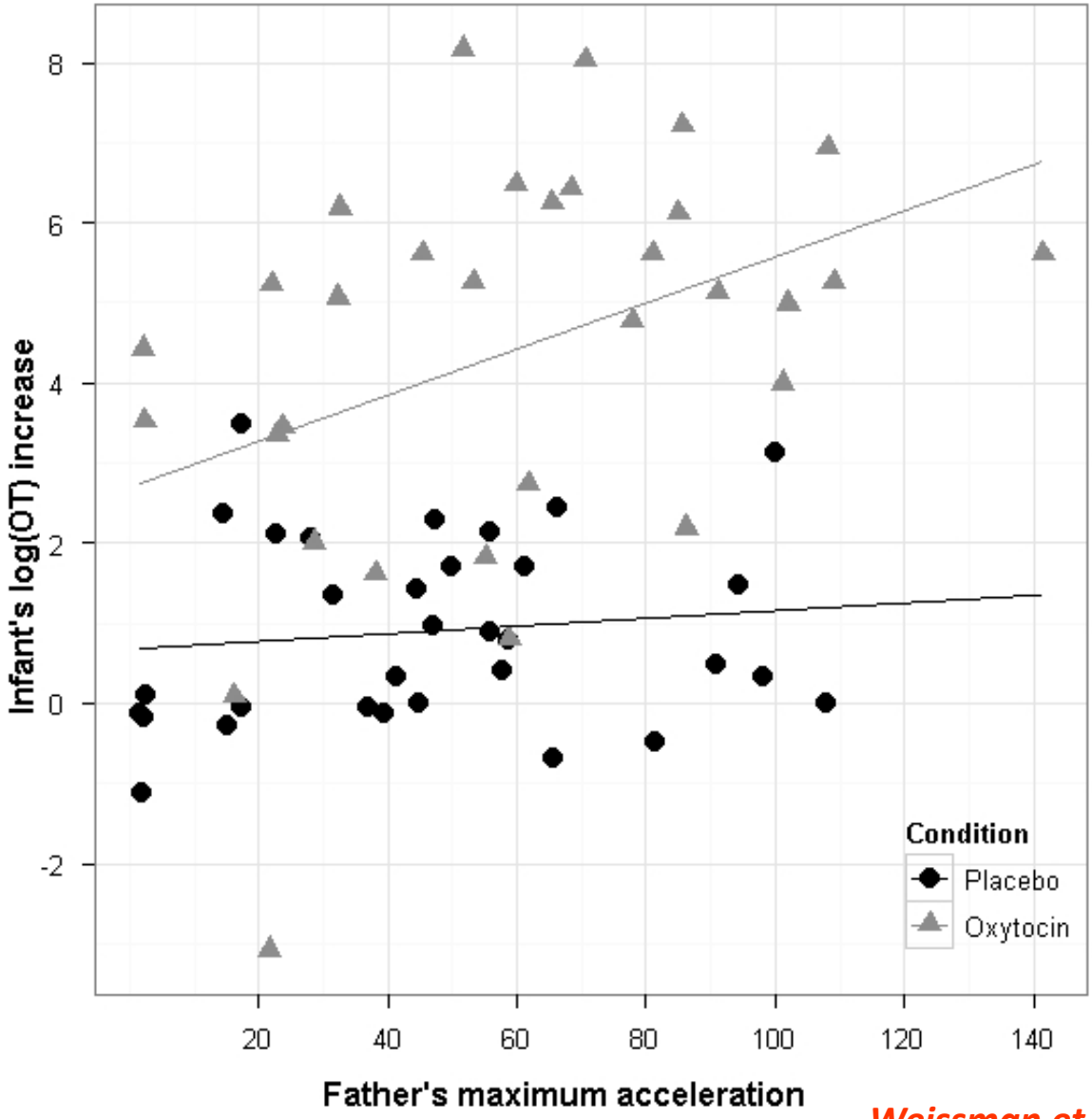




Normalisation of d

Parameters: d, speed, acceleration

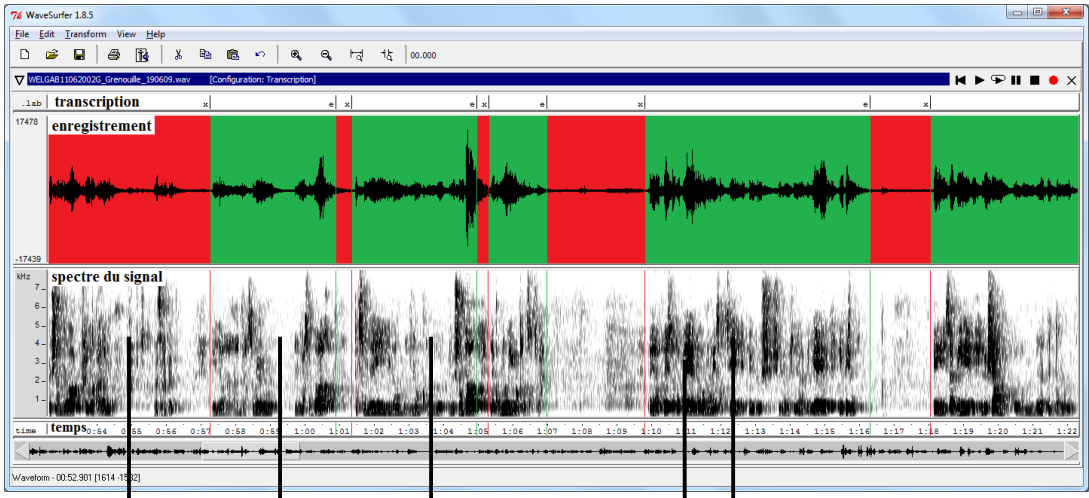
Father head acceleration correlates with infant OT increase



Weissman et al., Biol letters (2013)

SF+TOUCHING vs. SF vs. SF+ARM BLOCKING

3 MONTHS vs. 6 MONTHS



Infant ... Infant

Mother Mother ... Mother

Manual segmentation with ELAN

Mother audio line
Infant audio line

a

Extraction of parameters of dialog acts and speech turn taking using MATLAB

Mother Vocalization, Infant Vocalization, Mother Pause, Infant Pause,Silence, Overlap Ratio, Synchrony Ratio
(Mean, SD, Min, Max, Range)

b

Classifier applied on mother vocalization

c

Motherese

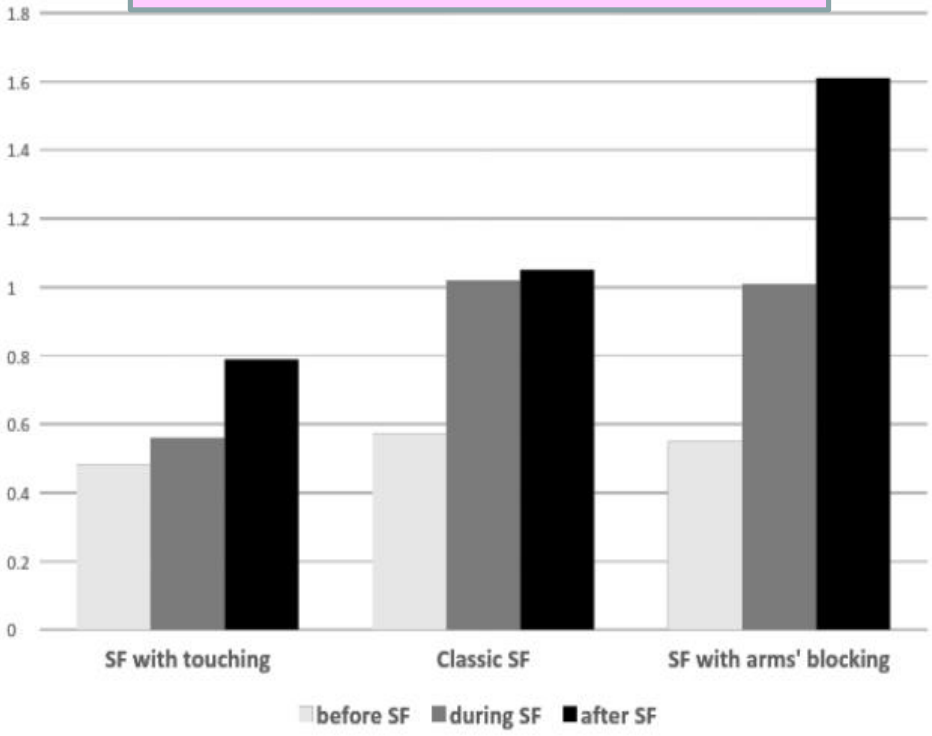
Other speech

Table 3 : Linear Mixed Model of speech turn taking and motherese during mother infant interaction using a still face paradigm

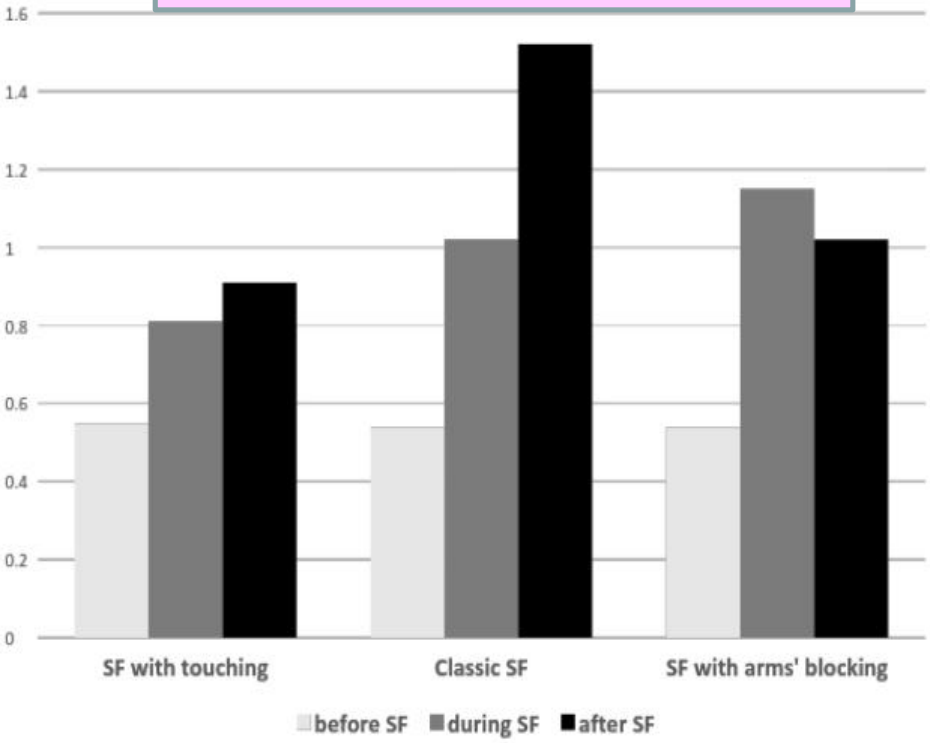
MOTHER PARAMETERS					
	Age effect	Type of SF effect		Gender effect	Time effect
		Touch vs. Classic	Arm vs. Classic		
Mother Vocalization Mean	**0.09 (p=0.005)**	0.005 (p=0.96)	0.04 (p=0.67)	0.01 (p=0.86)	-0.027 (p=0.53)
Mother Pause Mean	-0.028 (p=0.07)	-0.09 (p = 0.12)	-0.07 (p=0.16)	-0.069 (p=0.13)	**0.09 (p= 0.003)**
Motherese Ratio	**0.028 (p=0.01)**	-0.018 (p =0.65)	0.034 (p=0.37)	0.033 (p=0.32)	-0.010 (p=0.34)
Non Motherese Ratio	-0.011 (p=0.26)	-0.025 (p=0.50)	0.025 (p=0.45)	-0.030 (p=0.31)	**-0.038 (p<0.001)**
INFANT PARAMETERS					
	Age effect	Type of SF effect		Gender effect	Time effect
		Touch vs. Classic	Arm vs. Classic		
Log(Infant Vocalization) Mean	0.03 (p=0.44)	-0.05 (p=0.67)	-0.04 (p=075)	**0.27 (p=0.008)**	**-0.45 (p<0.001)**
Log(Infant Pause) Mean	0.067 (p=0.078)	0.027 (p=0.85)	0.11 (p=0.39)	**-0.29 (p=0.012)**	**0.59 (p<0.001)**
SPEECH TURN TAKING SYNCHRONY					
	Age effect	Type of SF effect		Gender effect	Time effect
		Touch vs. Classic	Arm vs. Classic		
Silence Ratio Mean	**-0.015 (p=0.035)**	-0.01 (p=0.62)	-0.02 (p=0.47)	-0.04 (p=0.07)	**0.11 (p<0.001)**
Overlap Ratio Mean	0.001 (p=0.99)	0.32 (0.23)	0.16 (p=0.51)	**0.52 (p=0.02)**	**-0.86 (p<0.001)**
Synchrony Ratio	-0.01 (p=0.44)	**0.1 (p=0.04)**	0.06 (p=0.14)	**0.10 (p=0.009)**	**-0.14 (p<0.001)**
Synchrony Motherese Ratio	0.005 (p=0.73)	**0.13 (p=0.01)**	0.10 (p=0.04)	**0.12 (p=0.003)**	**-0.15 (p<0.001)**
Synchrony Non Motherese Ratio	-0.006 (p=0.66)	0.08 (p=0.09)	0.06 (p=0.17)	**0.10 (p=0.01)**	**-0.15 (p<0.001)**

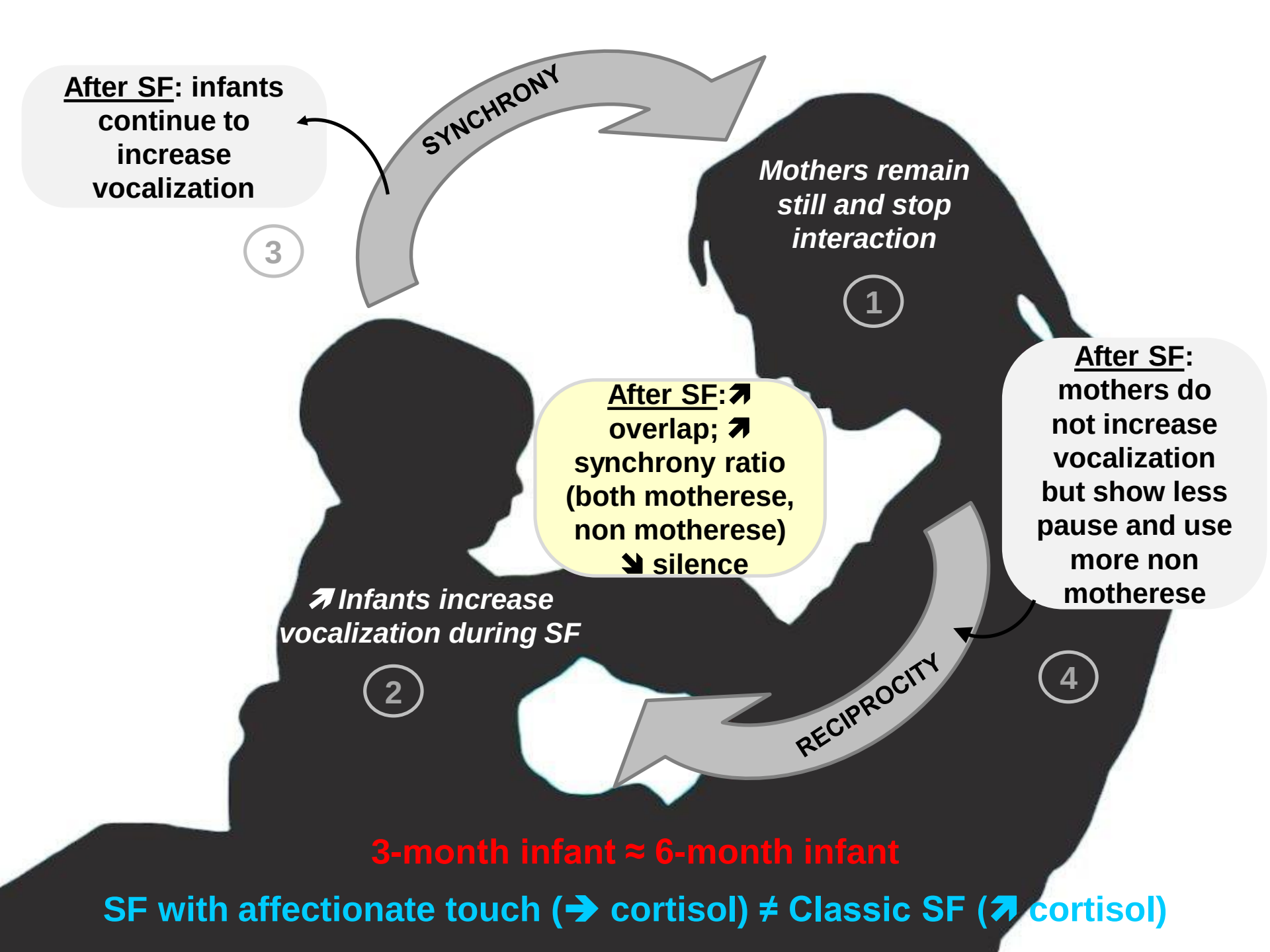
Infant Vocalisation, before, during and after SF

3 months



6 months




After SF: infants continue to increase vocalization
3
SYNCHRONY
Mothers remain still and stop interaction
1
After SF: ↗ overlap; ↗ synchrony ratio (both motherese, non motherese) ↘ silence
After SF: mothers do not increase vocalization but show less pause and use more non motherese
↗ Infants increase vocalization during SF
2
4
RECIPROCITY
3-month infant ≈ 6-month infant
SF with affectionate touch (→ cortisol) ≠ Classic SF (↗ cortisol)

Social cues for bonding

Audio signal

- Motherese as it appears to be recruited when intersubjective interaction is lacking (autism)
- Infant vocalization and speech turn taking after still face

Visual signal

- Motion like birds as its derivative appears to be correlated with infant OT increase during free interaction in a double blind placebo crossover experiment

Physical signal

- Touching like in Chimps and Apes as it appears to be recruited when intersubjective interaction is lacking (autism)

Cultural signal

- Fathers' commitment as it appears to be recruited when intersubjective interaction is lacking (autism)

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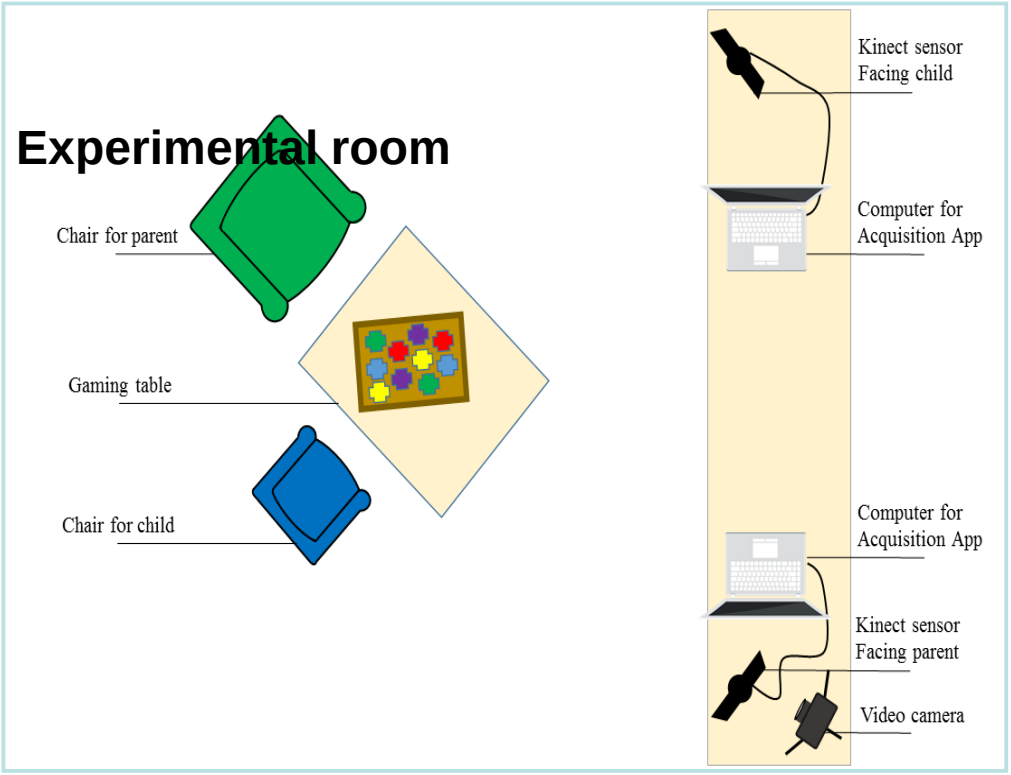
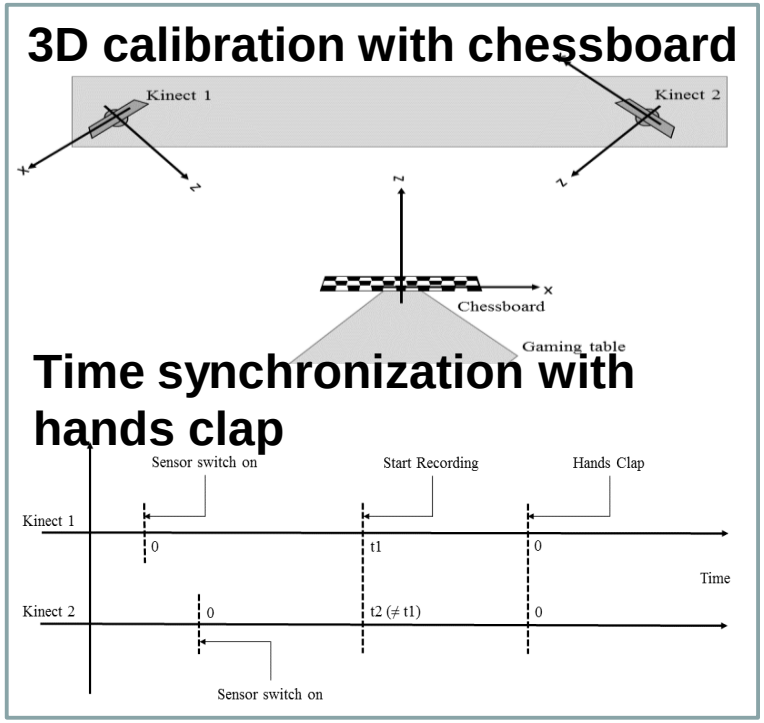




3D Image reconstruction

Automatic extraction of individual *(quantity of movements; motion activity)* **and synchrony** *(contribution to heads distance change; time spent face to face; time spent gazing at the game)* **motion features**

10 neglect mothers vs. 10 control mothers

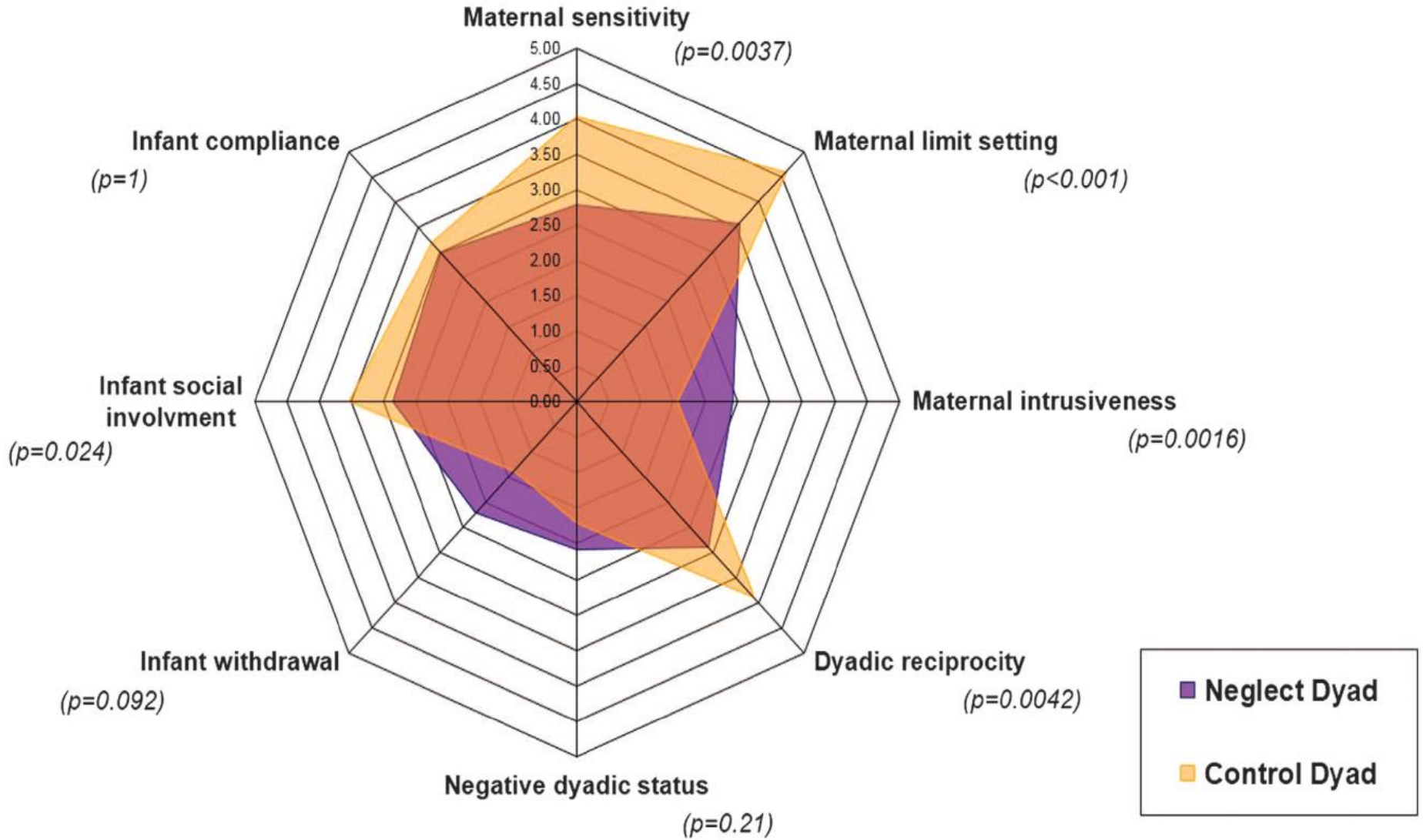
Demo of video 2D + 3D features

Translational Psychiatry

Chloë Leclère, Marie Avril, Sylvie Viaux-Savelon, Nicolas Bodeau, Catherine Achard, Sylvain Missonnier, Miri Keren, Ruth Feldman, Mohamed Chetouani, David Cohen

Leclère et al., Trans Psychiatry, 2016

Video clinical rating (CIB): Mothers showing severe neglect show less reciprocity, sensitivity, express less limit setting, and are more intrusive



	CIB interactive composites							
	Maternal sensitivity	Mother limit setting	Mother intrusiveness	Dyadic reciprocity	Negative dyadic status	Infant avoidance	Infant engagement	Infant compliance
Individual parameters								
Mother quantity of movement	-0.44 p=0.06	**-0.54 p=0.018**	**0.58 p=0.009**	**-0.44 p=0.06**	**0.15 p=0.53**	0.22 p=0.37	-0.44 p=0.06	-0.35 p=0.14
Mother ratio activity	**-0.6 p=0.007**	**-0.65 p=0.003***	**0.59 p=0.008**	**-0.53 p=0.02**	**0.47 p=0.044**	**0.59 p=0.008**	-0.44 p=0.06	-0.24 p=0.32
Infant quantity of movement	-0.26 p=0.28	-0.35 p=0.147	0.48 p=0.038	-0.27 p=0.26	-0.08 p=0.74	0.15 p=0.54	-0.2 p=0.41	-0.05 p=0.84
Infant ratio activity	**-0.48 p=0.037**	-0.36 p=0.13	0.31 p=0.19	**-0.47 p=0.04**	**0.4 p=0.088**	**0.47 p=0.044**	-0.37 p=0.12	-0.36 p=0.13
Synchrony parameters								
Dynamics of partners heads distance								
Mother contribution to heads distance	-0.09 p=0.71	0.23 p=0.34	0.18 p=0.47	-0.14 p=0.56	-0.21 p=0.39	-0.28 p=0.25	-0.12 p=0.63	0.34 p=0.15
Infant contribution to heads distance	0.1 p=0.67	-0.22 p=0.37	-0.19 p=0.43	0.16 p=0.52	0.2 p=0.42	0.26 p=0.28	0.14 p=0.58	-0.33 p=0.17
Focus of engagement								
% of time spent face to face	0.41 p=0.08	**0.51 p=0.026**	-0.34 p=0.15	**0.44 p=0.057**	**-0.44 p=0.057**	**-0.61 p=0.005**	0.42 p=0.076	0.37 p=0.12
% of time spent looking together at the table	-0.2 p=0.4	-0.14 p=0.57	0.06 p=0.8	-0.25 p=0.29	-0.06 p=0.81	0.03 p=0.9	-0.26 p=0.275	-0.13 p=0.59
Dynamics of motion activity								
Synchrony ratio: Parent response to Infant	**-0.54 p=0.017**	**-0.62 p=0.004***	**0.61 p=0.005**	**-0.48 p=0.039**	**0.48 p=0.038**	**0.59 p=0.008**	-0.41 p=0.08	-0.22 p=0.38
Synchrony ratio: Infant response to Parent	-0.2 p=0.4	-0.12 p=0.62	0.09 p=0.7	-0.23 p=0.34	0.22 p=0.37	0.28 p=0.24	-0.26 p=0.28	**-0.46 p=0.047**
Overlap ratio	**-0.56 p=0.012**	**-0.53 p=0.02**	**0.46 p=0.049**	**-0.5 p=0.03**	**0.5 p=0.028**	**0.6 p=0.007**	-0.38 p=0.11	-0.18 p=0.46
Pause ratio	**-0.66 p=0.002***	**0.64 p=0.003***	**-0.63 p=0.004***	**0.61 p=0.005**	**-0.55 p=0.014**	**-0.63 p=0.004***	**0.52 p=0.023**	0.44 p=0.06

How 2D and 3D motion SSP relates to clinical data

Clinical rating correlates with video 2D + 3D motion features

Using SVM classifiers based on learning with motor characteristics of the dyads, we obtain 100% of dyads correctly classified

Mothers showing severe neglect are very significantly different in terms of motor interaction with their baby during free play

Leclère et al., Trans Psychiatry, 2016

Plan

Introduction

- Evolution of bonding
- Synchrony and social signal processing

Studying social cues during early interaction using SSP

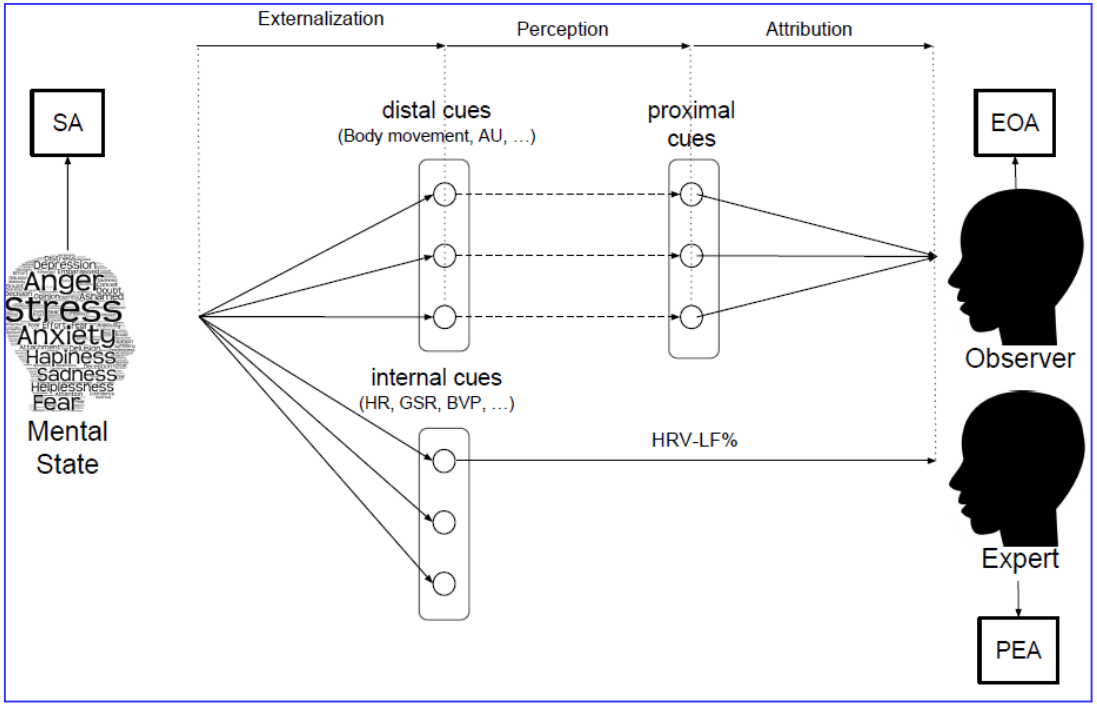
- ASD and home movies
- Motion and speeach turns during early interaction

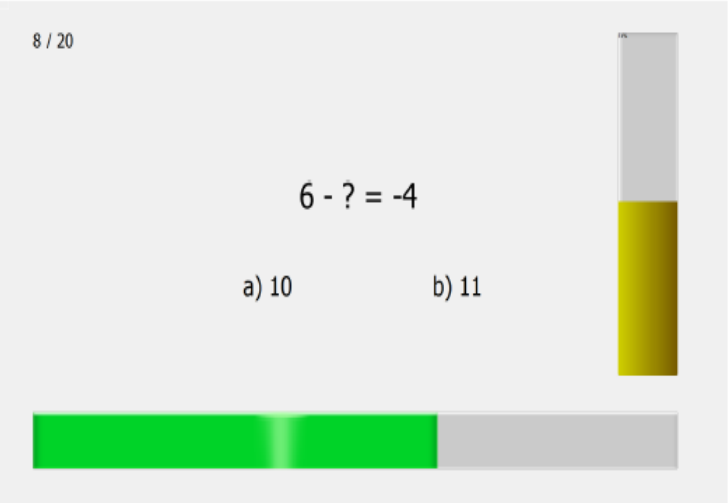
Studying social cues anticipating signal capture

- Mothers showing severe neglect with their infants
- Studying the multimodality of stress

Modeling infant early development through developmental robotics

Multimodal assessment of stress in borderline adolescents





Physiological features (Blood pressure, skin conductance)

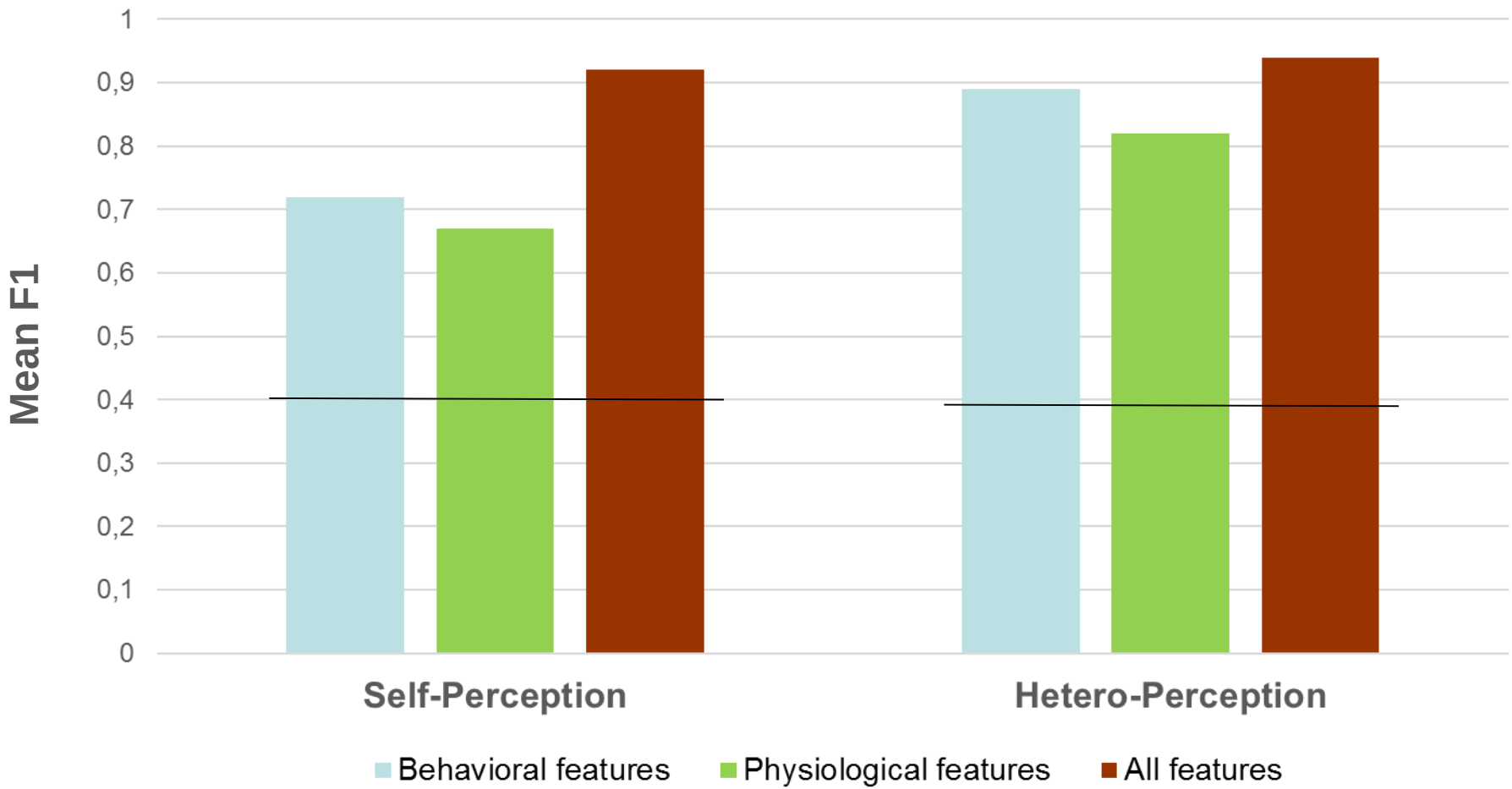
Self touching

Posture change

Multimodal assessment of stress

Nearly 90% prediction

Best features prediction through machine learning methods (SVM-linear kernel)



Aigrain et al, IEEE TAMS, in revision

Behavioral and physiological characteristics of self-perceived and hetero-perceived stress: common features detected through machine learning methods

	F1	Self-Perception	Hetero-Perception	F1
		COMMON FEATURES		
Behavioral features	0.48	Face Action Unit 12 (Lip Corner Puller): standard deviation		0.62
	4.43	Face Action Unit 4 (Brow Lowerer): mean		0.46
	0.52	Face Action Unit 6 (Cheek Raiser): mean		0.61
	0.62	Quantity of Movement		0.73
	0.60	Right Hand Movement		0.67
Physiological features	0.51	Blood Volume Pulse Amplitude: maximum		0.69
	0.51	Chest and Abdominal Respiration Rate: maximum		0.53
	0.56	Level of coherence between the Respiration and the Heart Rate: maximum		0.56
	0.43	Electromyographic activity of the sternocleidomastoid and upper trapezius channel 1: minimum		0.49
	0.50	Galvanic Skin Response: variance		0.48
	0.50	Chest and Abdominal Respiration: variance		0.64

Behavioral and physiological characteristics of self-perceived and hetero-perceived stress: specific features detected through machine learning methods

	Self-Perception	Hetero-Perception
Behavioral features	5	10
Physiological features	13	3

Behavior is more associated with hetero-perception

Physiology is more associated with self-perception

Stress has eveloved during evolution to serve in humans at least two functions:

1. Survival and defense to threat
2. Communication with peers

This method may help disentangle the differences between the two functions of stress and between what is self-perceived and what is communicated (and seen) by others

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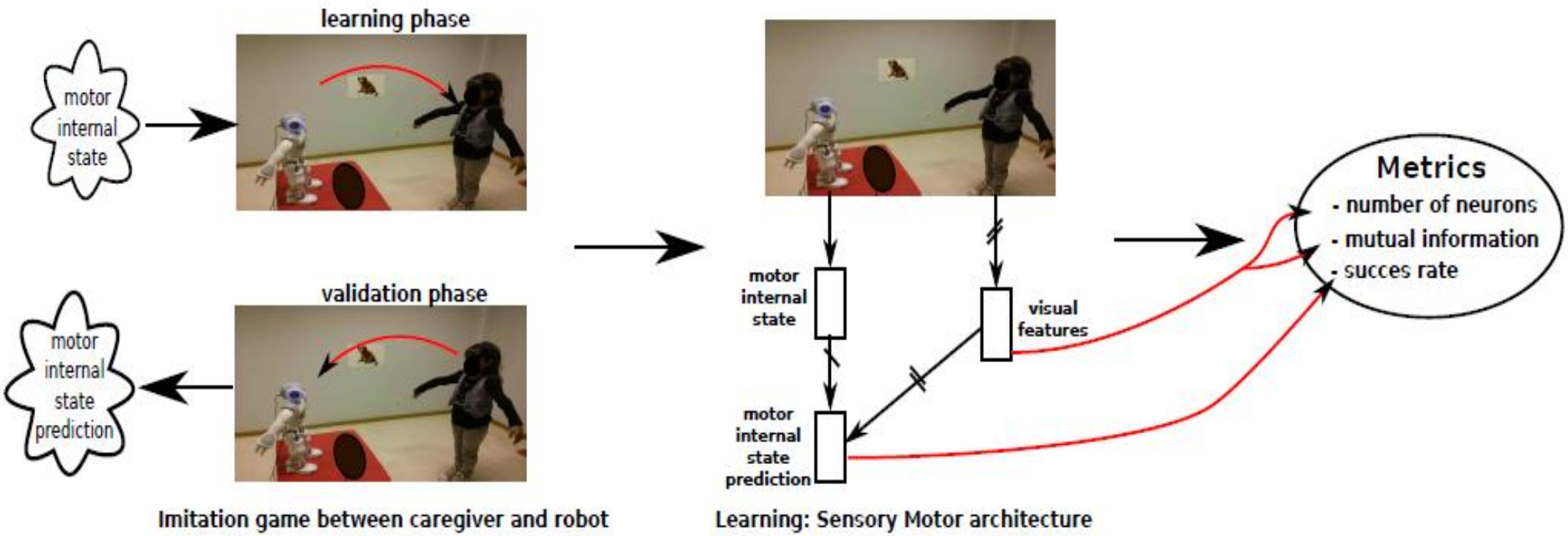
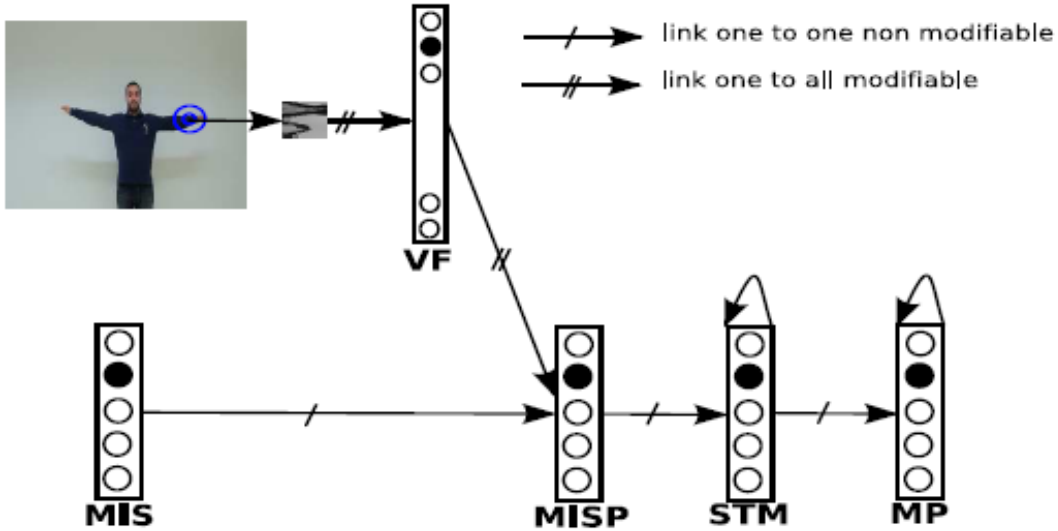
Modeling infant early development through developmental robotics

Global architecture of the experiment

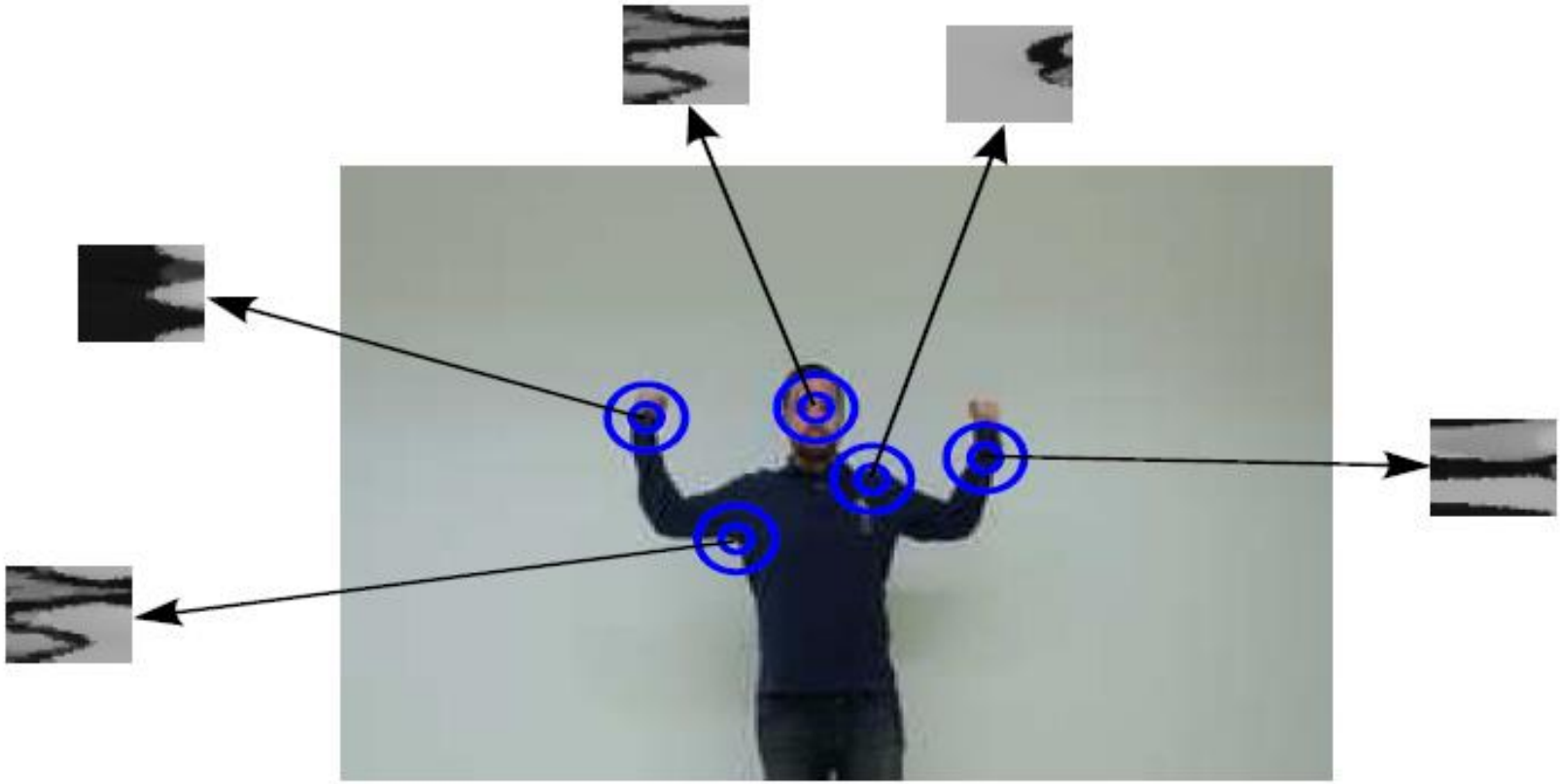




The computational architecture is able to learn by imitation when a robot interacts with a partner who imitites the robot

Posture to imitate during the learning phase

Learning is due to automatic extraction of specific points of interest



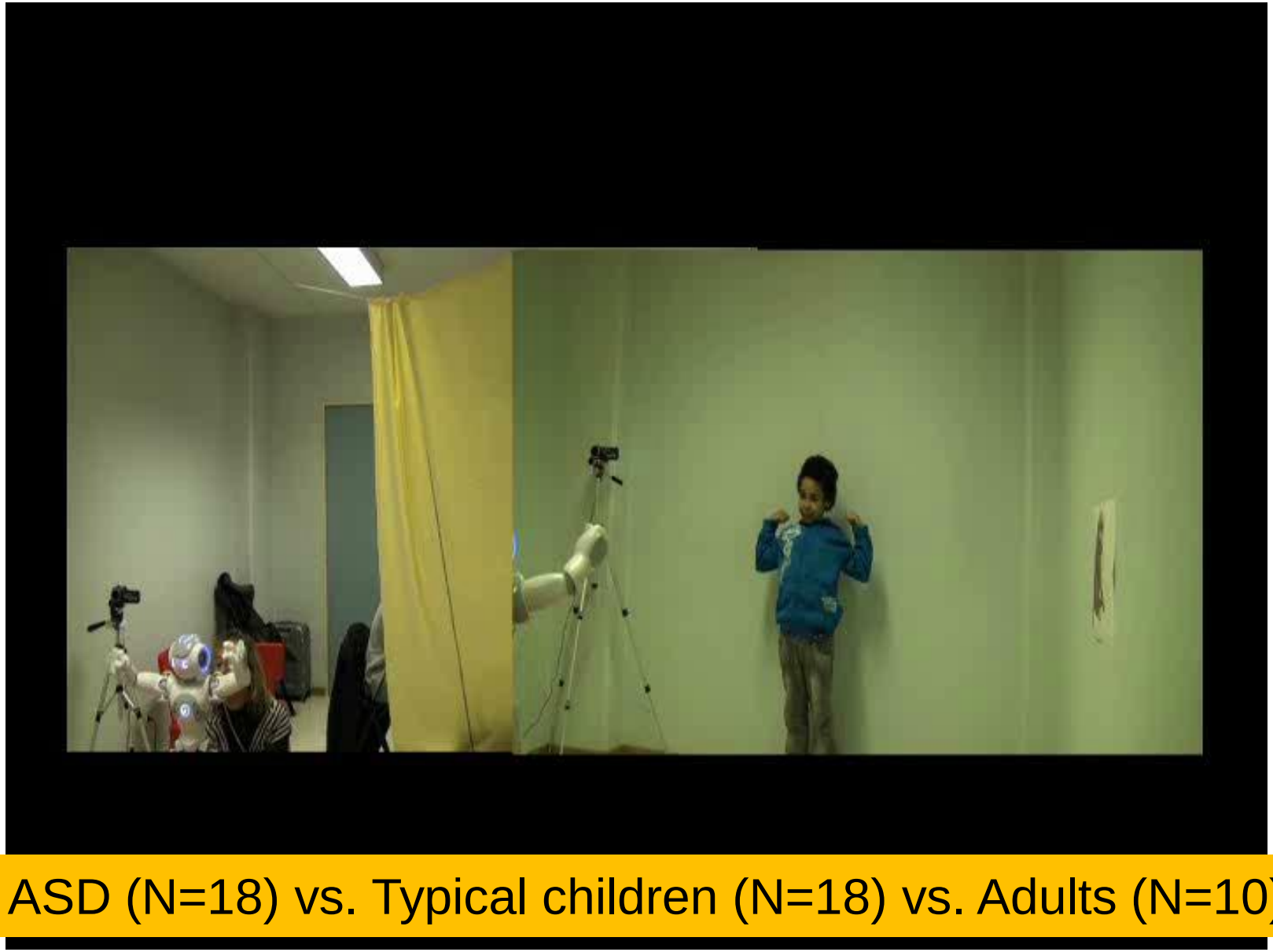
$$\Delta W_{ij} = \delta_j{}^k (a_j(t) I_i + \epsilon (I_i - W_{ij})(1 - VF_j))$$

Similar to k-means with a vigilence mechanism

Online learning

Boucena et al, IEEE TAMS, 2014

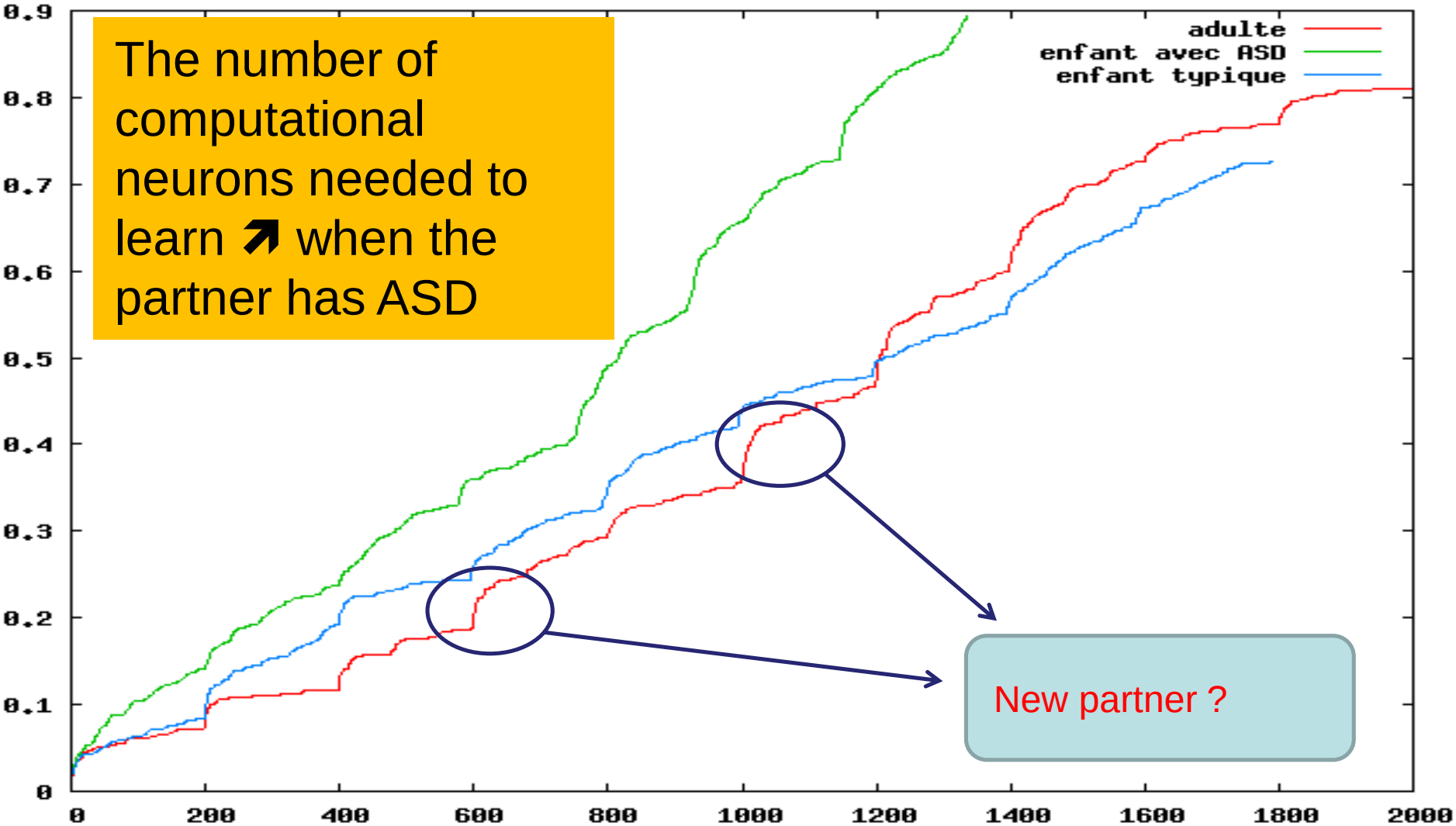
How Nao perceives his partner during the imitation task interaction?



ASD (N=18) vs. Typical children (N=18) vs. Adults (N=10)

Boucena et al, IEEE TAMS, 2014

How Nao perceives his partner during the imitation task interaction?

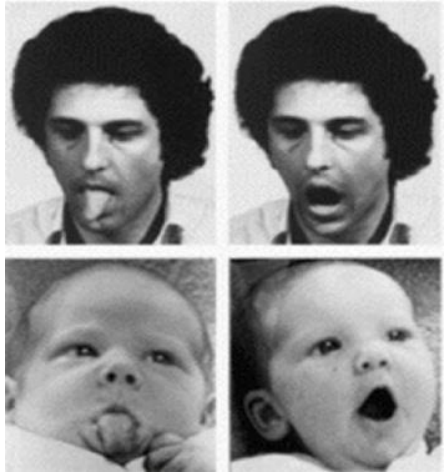


The number of computational neurons needed to learn ↗ when the partner has ASD

New partner ?

Boucena et al, IEEE TAMS, 2014

Testing Meltzoff's hypothesis for the emergence of the self: 'Like me' hypothesis



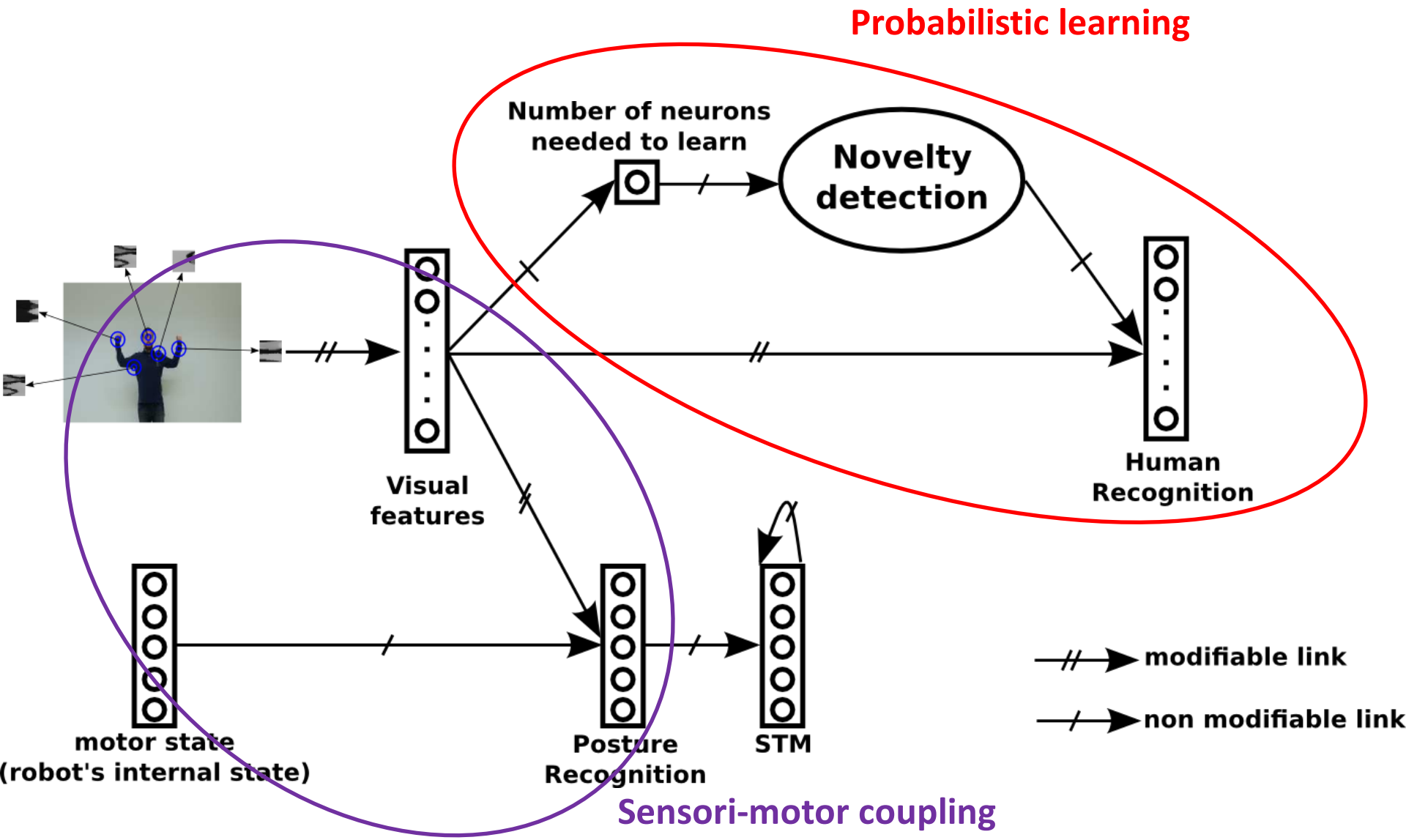
The 'Like me' hypothesis postulates that imitation is a key ability of early development with neural plasticity and statistical learning

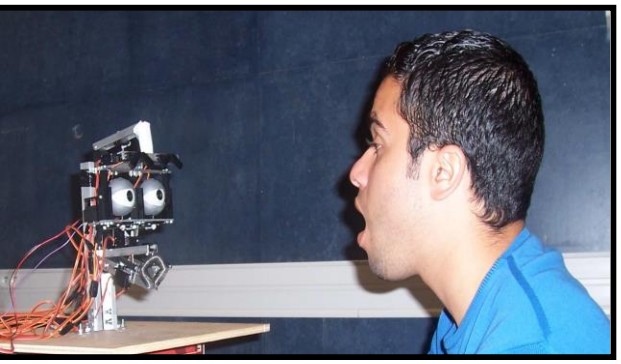
When a neonate imitates, he understands that his partner is imitating and that he is imitating in return

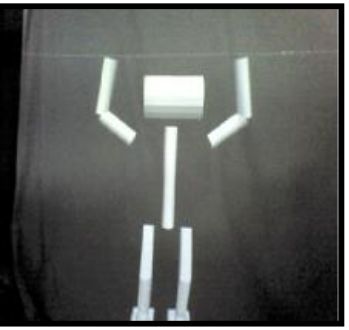
These early interactions constitute the first step of human recognition and the emergence of the self

Melzoff, Dev Science, 2007

Testing Meltzoff's hypothesis with developmental robotics







SAME LEARNING ARCHITECTURE

Same experimental design

Learning phase

The robot does a movement → The partner imitates the robot

Validation phase

The robot → The partner

Recognition phase

The partners are presented a second time an the robot (the architecture) has to recognized him

Experiment 1

Nao learns through a motor imitation task (5 arms positions) with:

- 11 adults
- 15 typical developing children

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

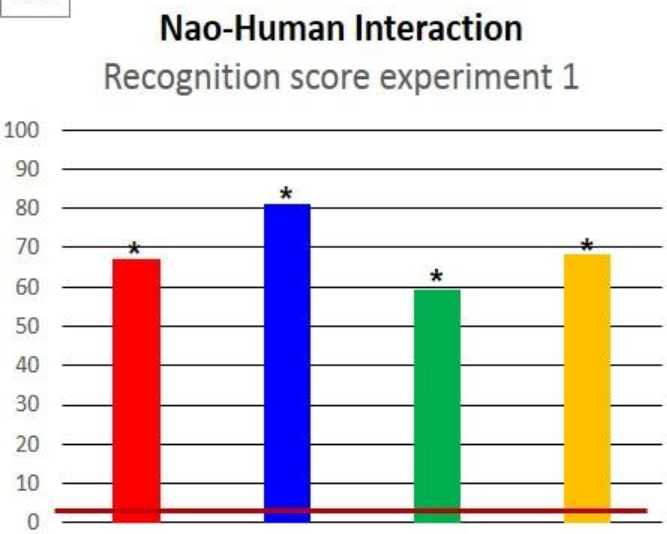
Nao learns through a motor imitation task (5 arms positions)

To control for visual features independant of motor task

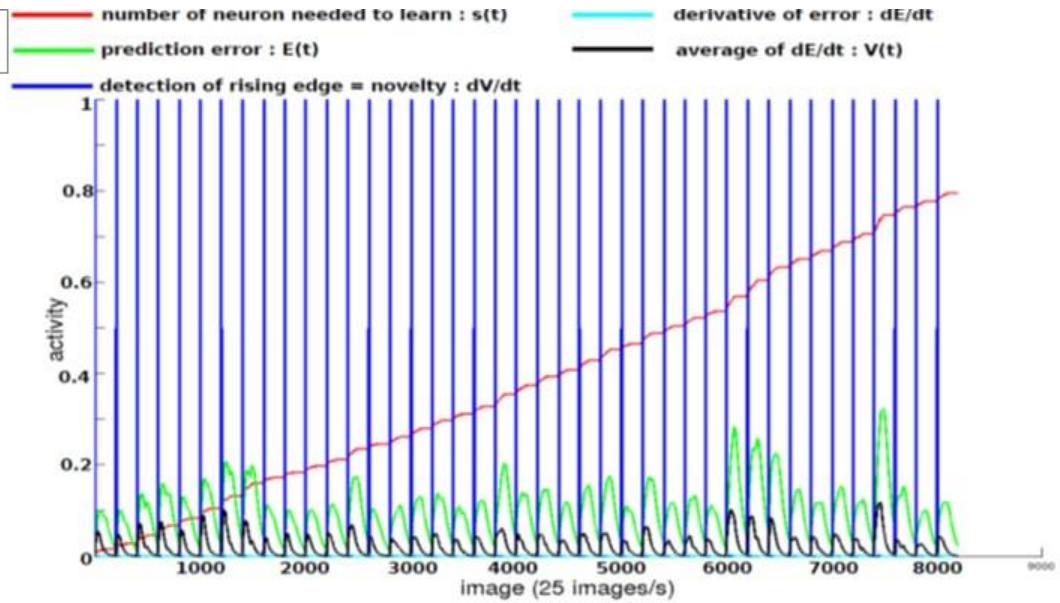
Boucenna et al, Scientific Report, 2016

Robots Learn to Recognize Individuals from Imitative Encounters with People and Avatars

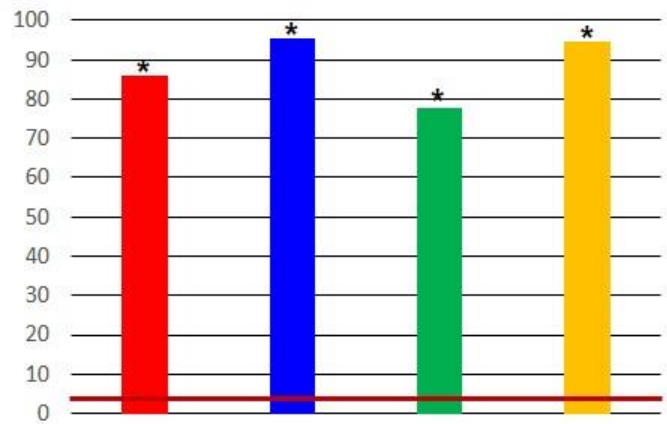
3a



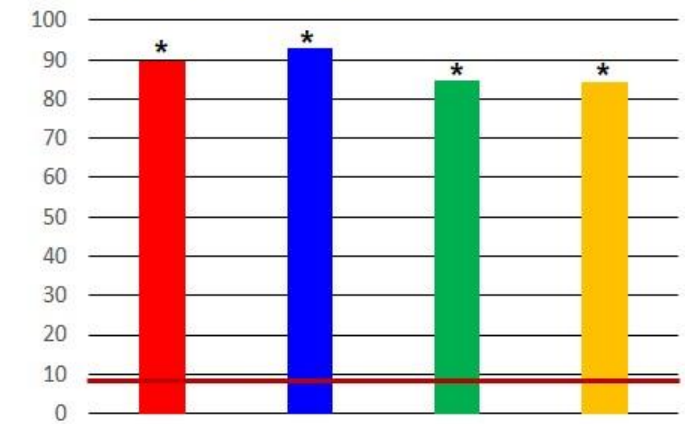
3b



3c



3d



3e

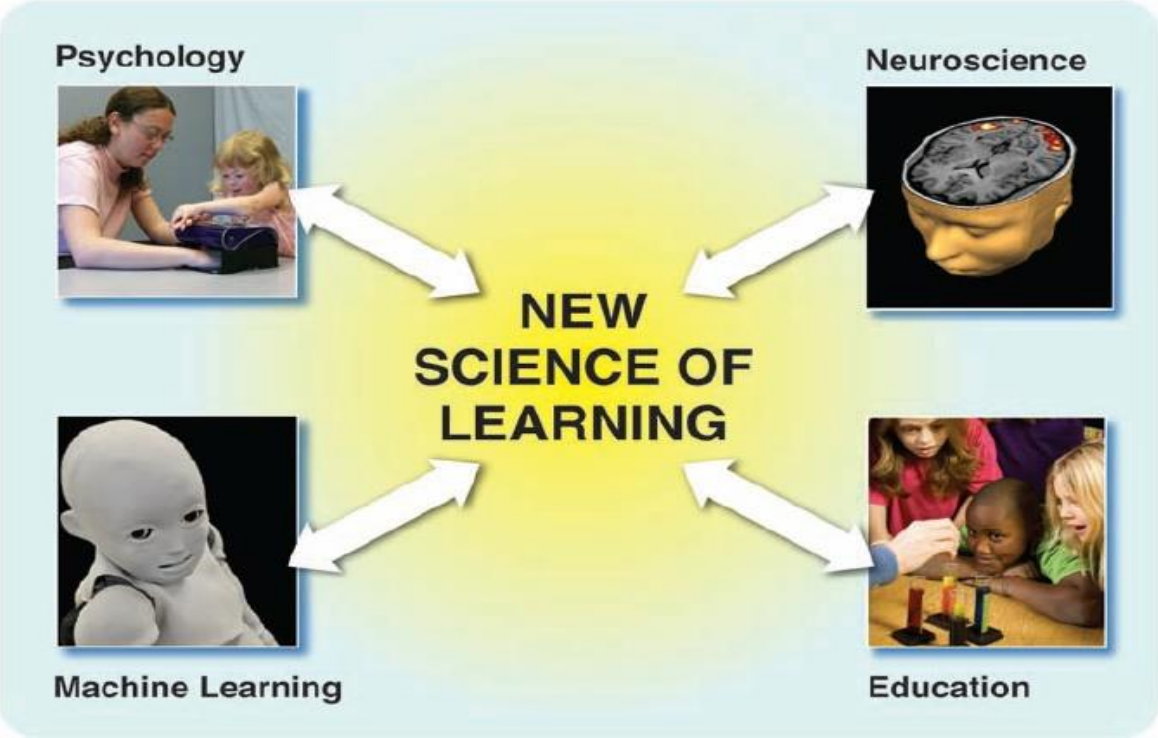
Correlations

ρ	red	blue	green
blue	0.93		
green	0.79	0.81	
yellow	0.92	0.83	0.88

unknown/non random
known/non random
unknown/random
known/random
score by chance

Conclusion

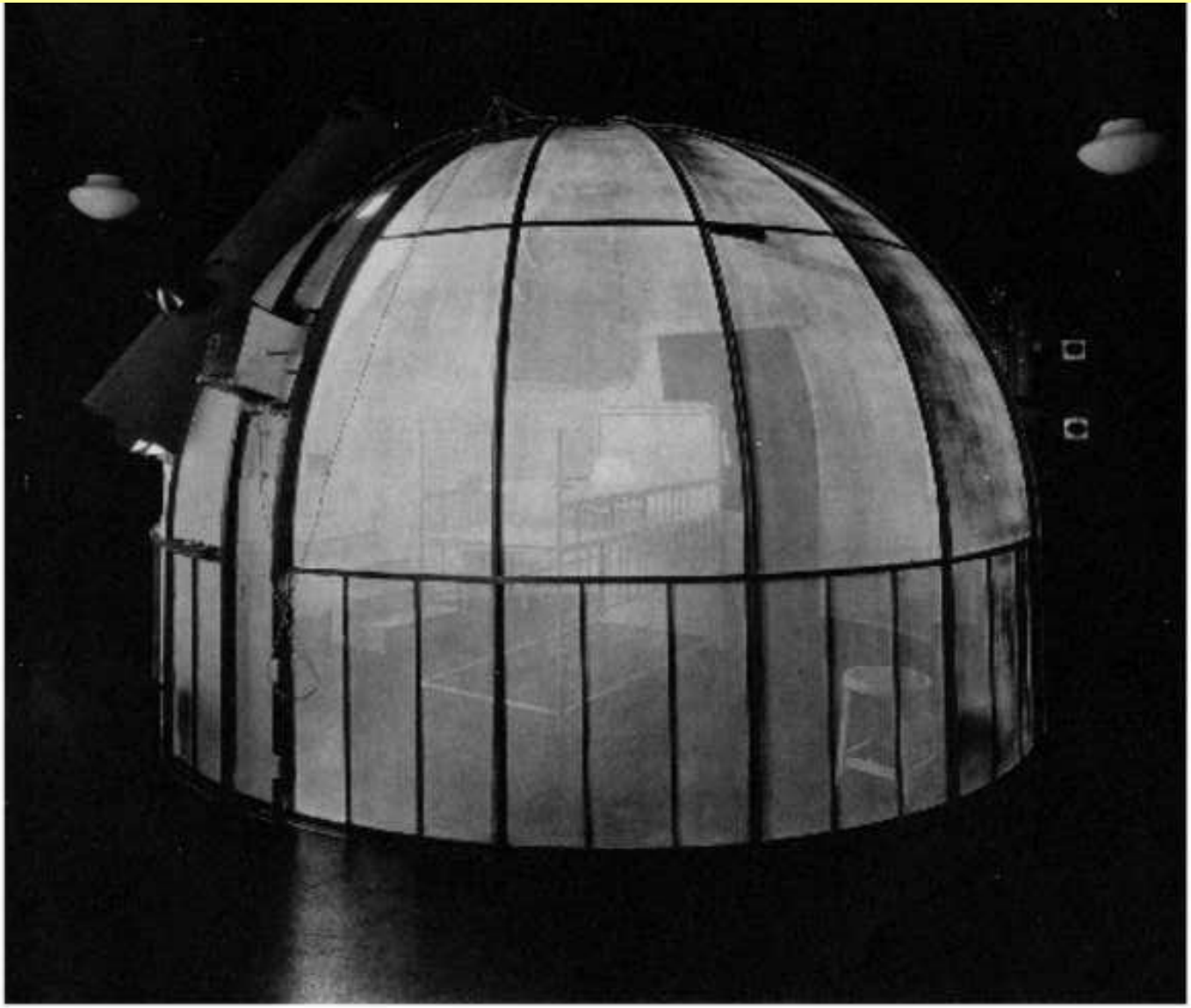
SSP and developmental psychopathology should bond together



http//:speapsl.aphp.fr

Meltzoff et al, Science, 2009

Gesell construit une cloche d'observation du bébé fournissant des images de haute qualité grâce à plusieurs caméras et à un dispositif d'éclairage special (Yale University, 1930-1940)



Rietman, Neurospchytr Enf Adol (in press)

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J Nadel
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