De la navigation bio-inspirée au développement sensorimoteur d'un robot humanoïde

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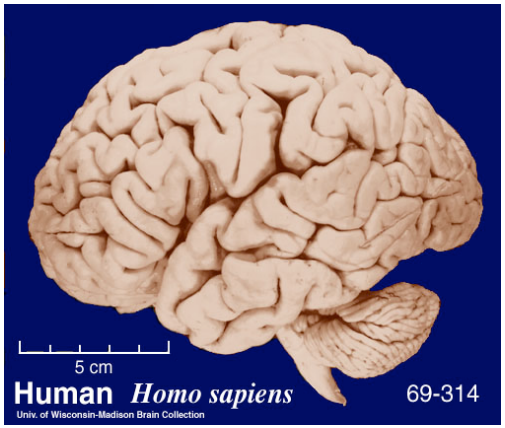
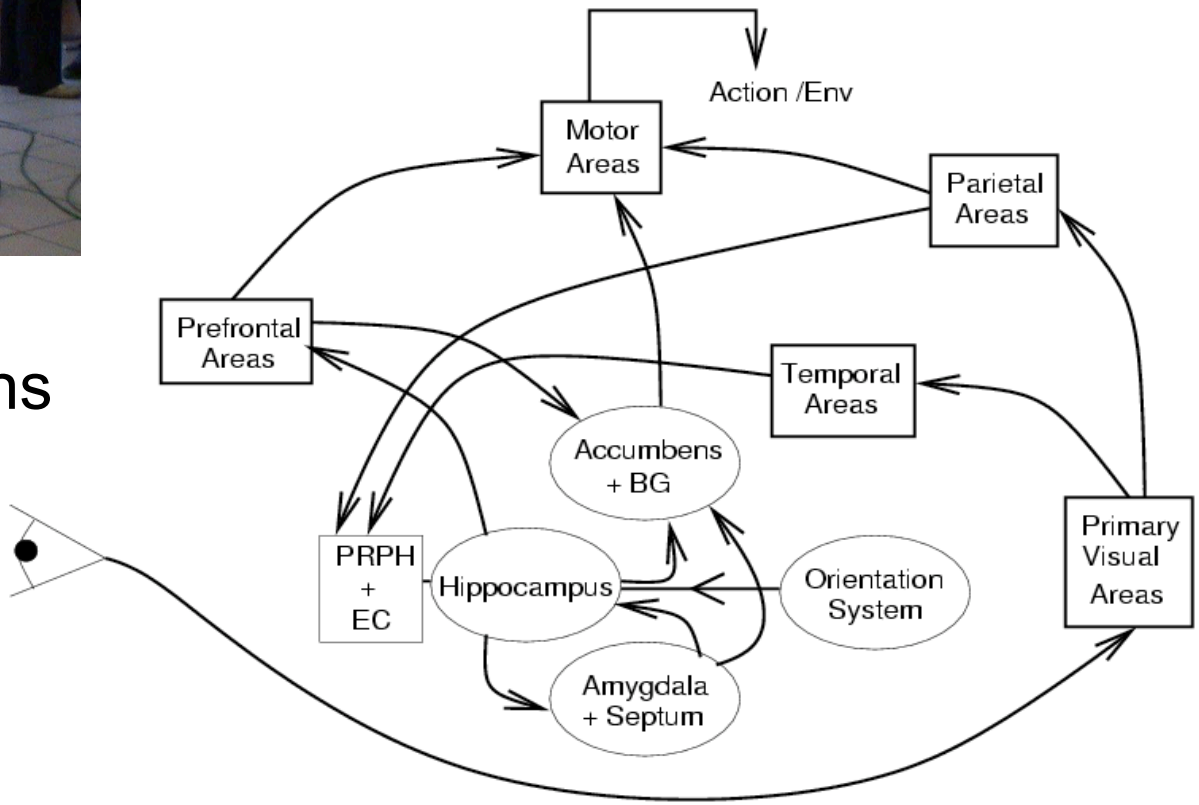
Cognition, brain, neurons...



-Development
-Social interactions



The limits of a reductionist approach…

Primate visual system

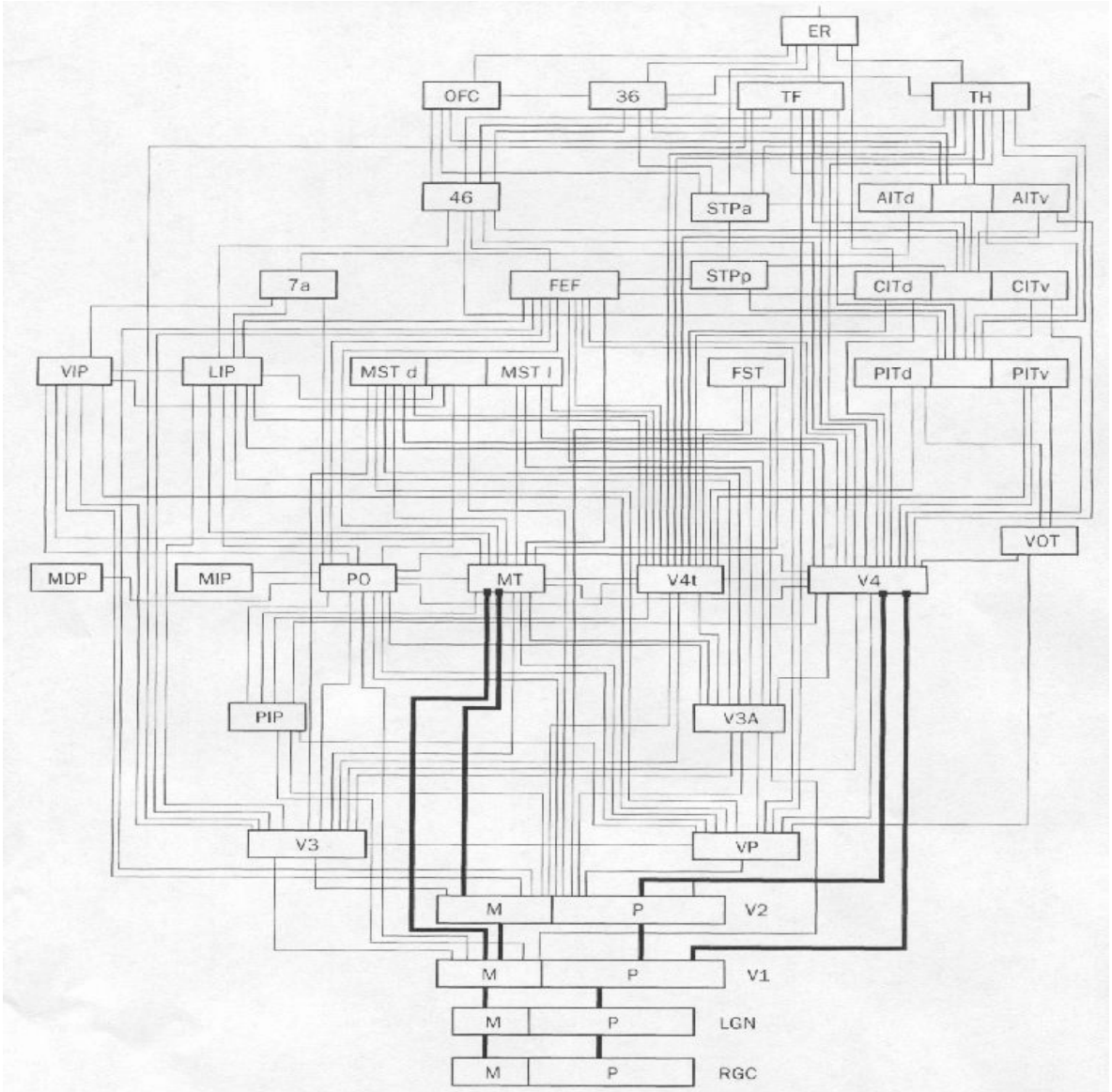


FIGURE 4.15 Diagram showing the hierarchical arrangement of visual processing stages, starting with the retina (bottom of diagram) and moving up through the multiple visual areas of the brain. The bold lines show the P and M pathways discussed in the text. (Adapted from Felleman and Van Essen, 1991.)

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(Van Essen 91)

Problem:

Knowing the neuronal activity is not always helpful
to understand the cognitive processing !

Solution:

Understanding the link between the link between the neuronal activity and the behavioral dynamics.

Our approach

- Find a minimal model justified by strong theoretical arguments:
  - single NN formalism and architecture AND several tasks
  - Taking into account a minimal number of biological structures,
  - Trying to understand what is brought by a new structure on the global behavior (otherwise do not take it into account),
  - Using robots to test the behavioral consequences of a given model (proof by failure!)

➔ Strong collaborations with neurobiologists and psychologists

« Virtual » Laboratory

Joint works with:

- Jean Paul Banquet : neurobiological modelling
- Bruno Poucet (Marseille 3C): exp. neurobiology
  + S. Wiener group (Paris) ANR Neurobot
- Jacqueline Nadel: developmental psycho pathology
  (+ inter-lab. association CNRS)
- Yann Coello, Yvonne Delevoye (URECA-Lilles)
  ANR INTERACT / SESAME TINO
- Lola Cañamero (**Feelix growing** UE STREP project)
  University of Hertfordshire, UK
  + K. Bard (Portsmouth)

Robotique et neurosciences
ou
Robotique et sciences cognitives?

Equipe neurocybernétique

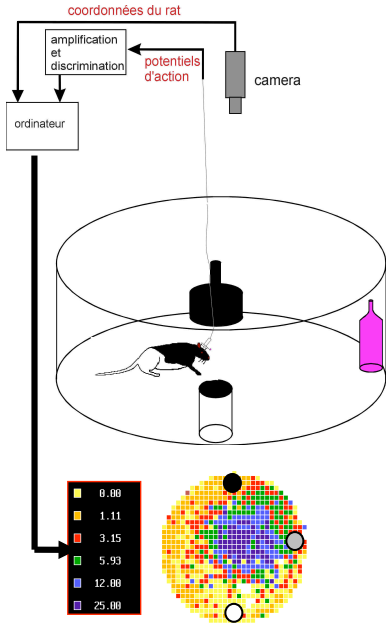
Enseignants/chercheurs: P. Andry, N. Cuperlier, L. Hafemeister, P. Gaussier, P. Laroque, G. Mostafaoui, F. Pirard, A. Pitti, M. Quoy

Associé: J.P. Banquet (neurobiologiste)

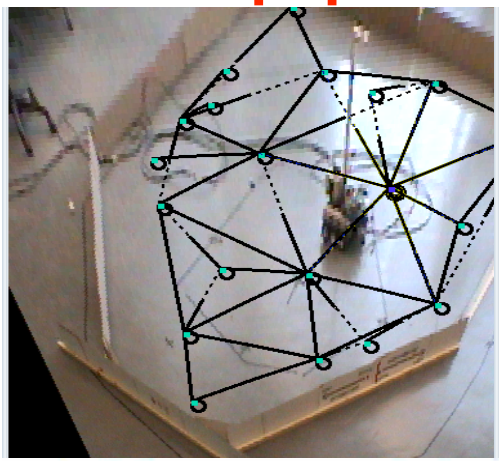
Doctorants: D. Bailly, A. Chatty, J. Hirel, A. Jauffret, R. Hasnain, A. de Rengervé (S. Boucenna, C. Hasson)

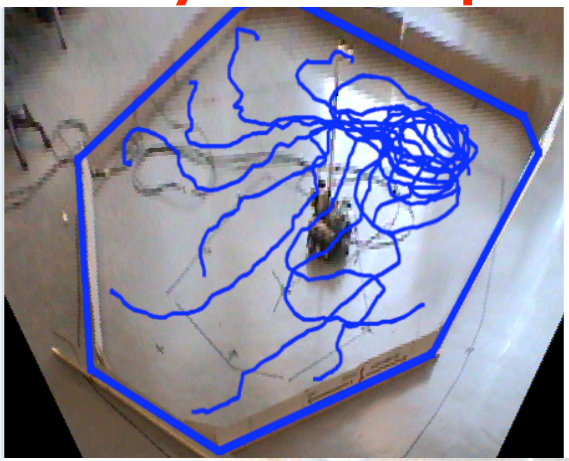
Ingénieurs: A. Blanchard, F. Demélo

ETIS - Equipe Neurocybernétique



Neurobiologie



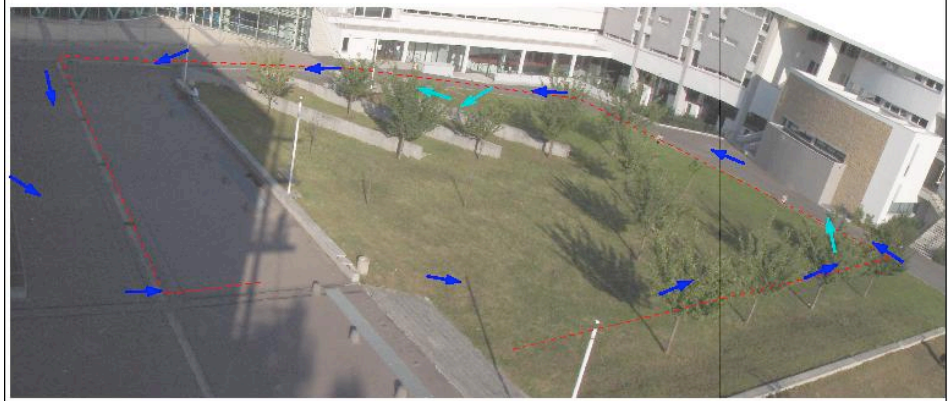


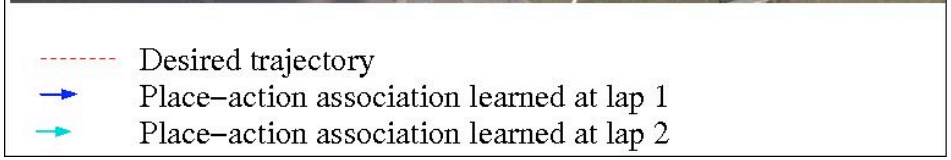
Apprentissage en ligne: associations sensori-motrices, carte cognitive et planification

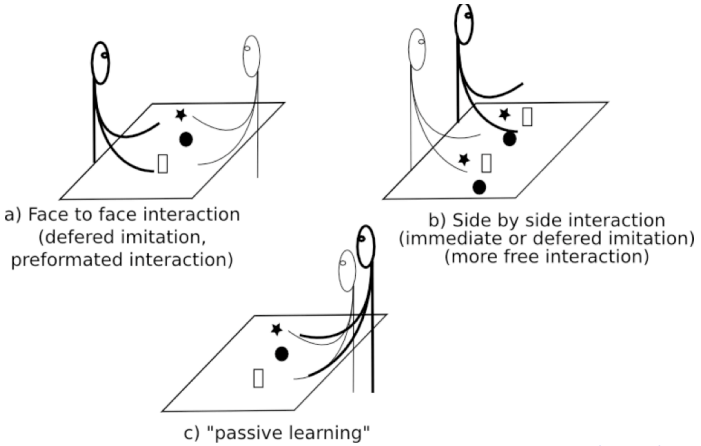
modélisation en neurosciences computationnelles

Expérimentation en exterieure
➔ navigation visuelle / syst neuromimétique

Perception visuelle / mécanismes attentionels

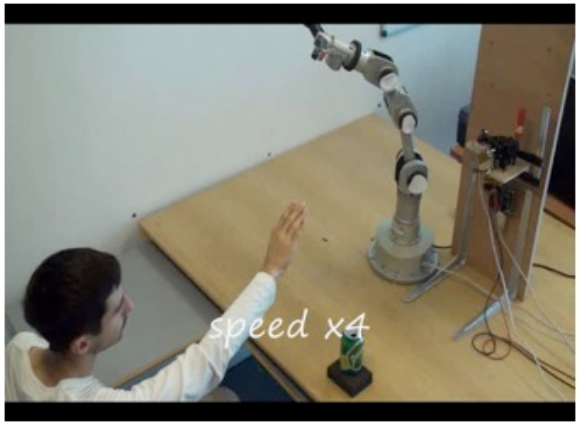




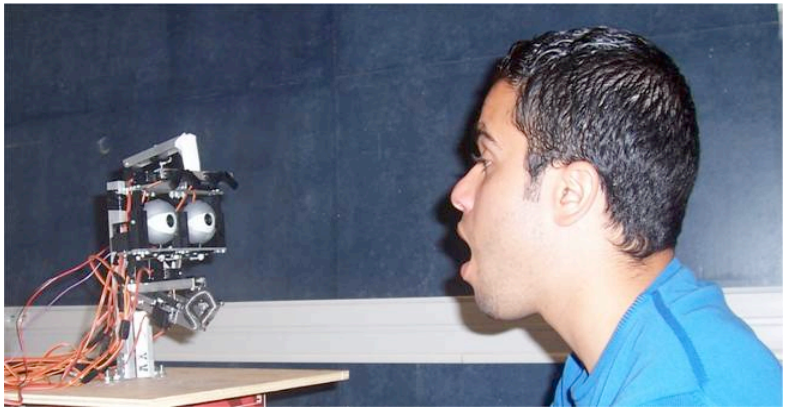


INTERACTIONS

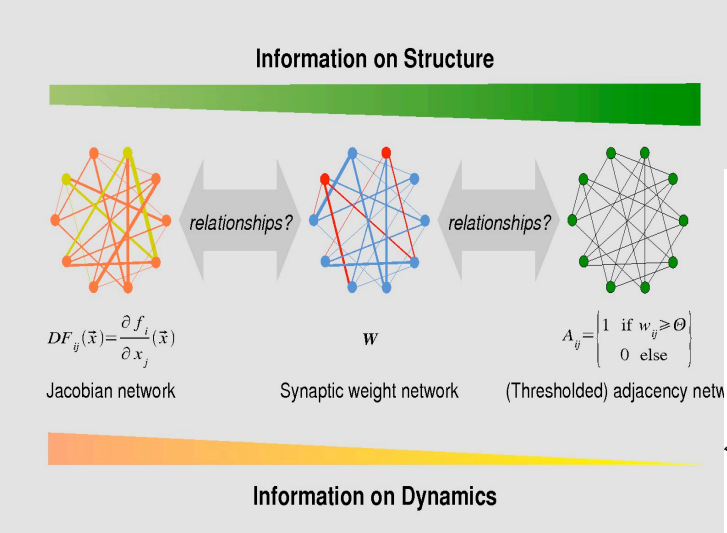
Psychologie developpementale
➔ Interactions sociales + IHM
➔ Apprentissage par imitation

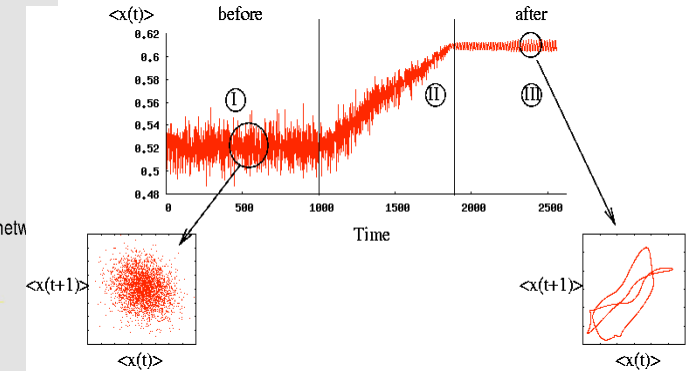


Robot hydraulique Interactif
Lien mécanique & cognition
(compliance physique)



Modèle des émotions / référencement social





Systèmes Multi-Agents

- Solutions émergentes
- Optimisation collective
- Spécialisation des agents

Modèles dynamiques neuronales ➔ dynamiques d'interactions

Plan

1. Navigation autonome bio-inspirée

2. Apprendre en interagissant

3. Emotions et interactions sociales

➔ **une même architecture neuronale pour des applications très différentes**

1st part

Navigation bio-inspirée

Hipp-BG-PFC loop

Navigation and the building of attraction basin

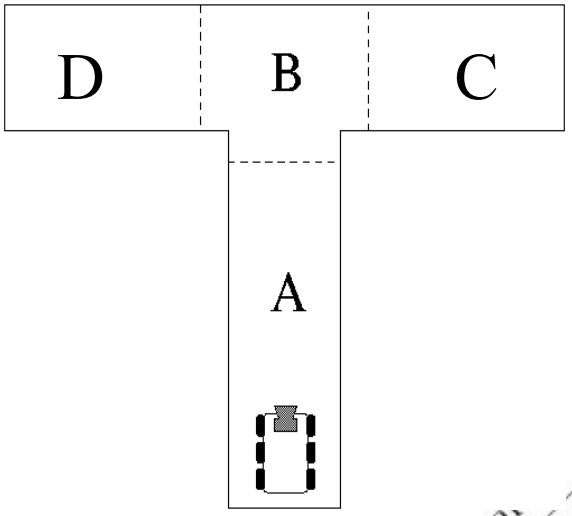
(+ transition building, novelty detection, frustration…)

Training mobile robots to perform path following by an intuitive human–robot interaction

C. Giovannangeli
P. Gaussier

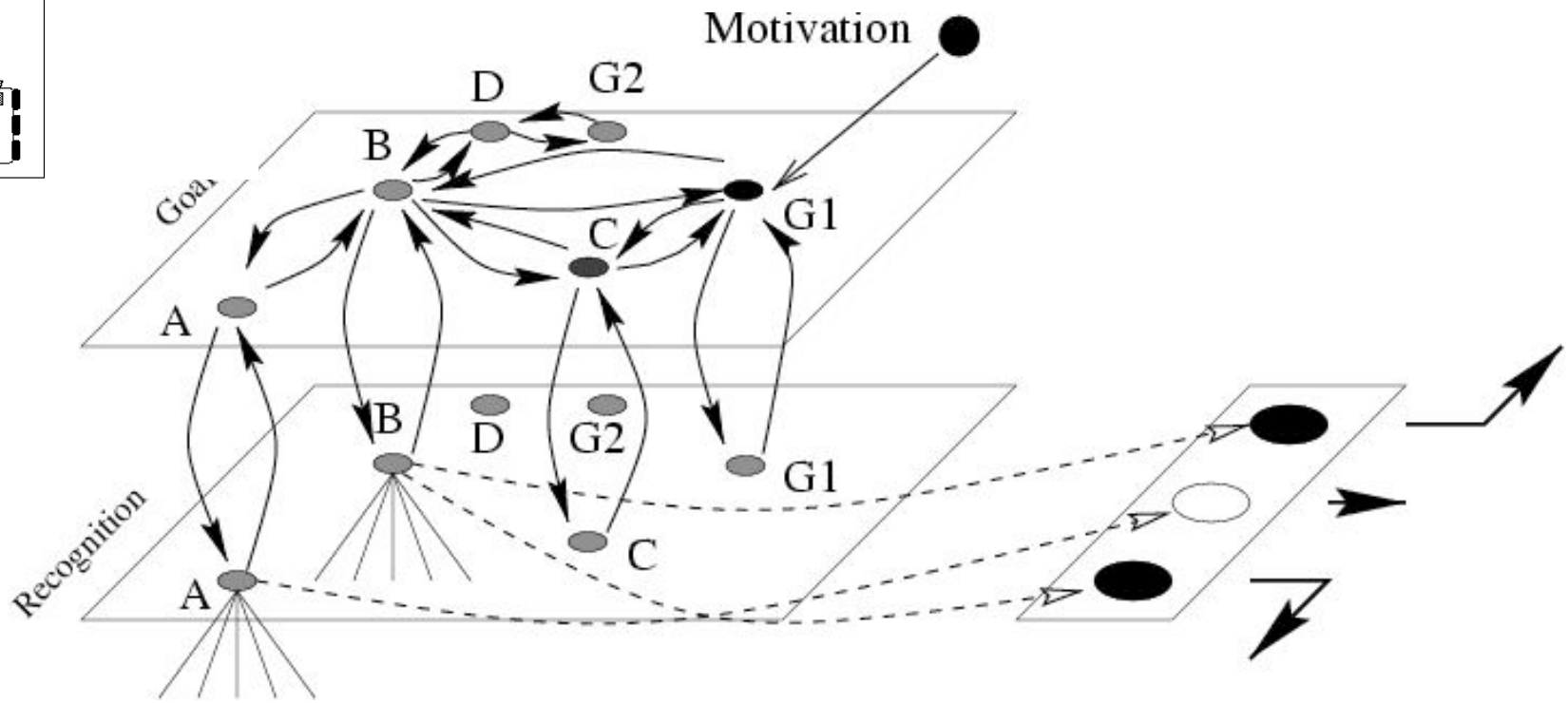
ETIS Laboratory
CNRS UMR 8051
Cergy–Pontoise University

Action selection problem



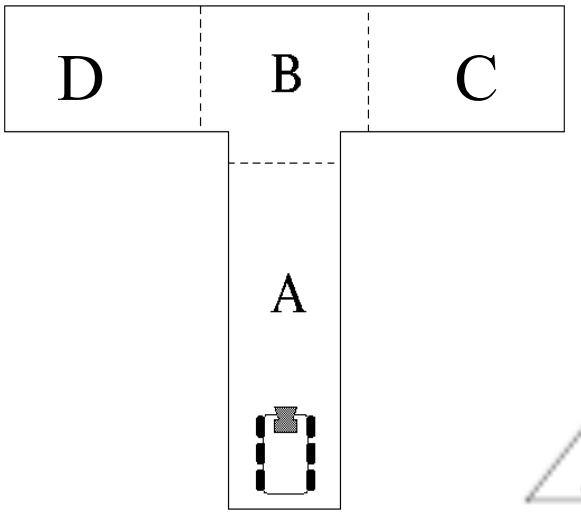
Goal

Diffusion ⇔ Ford – Bellman alg.



How to deal with the bifurcation points?

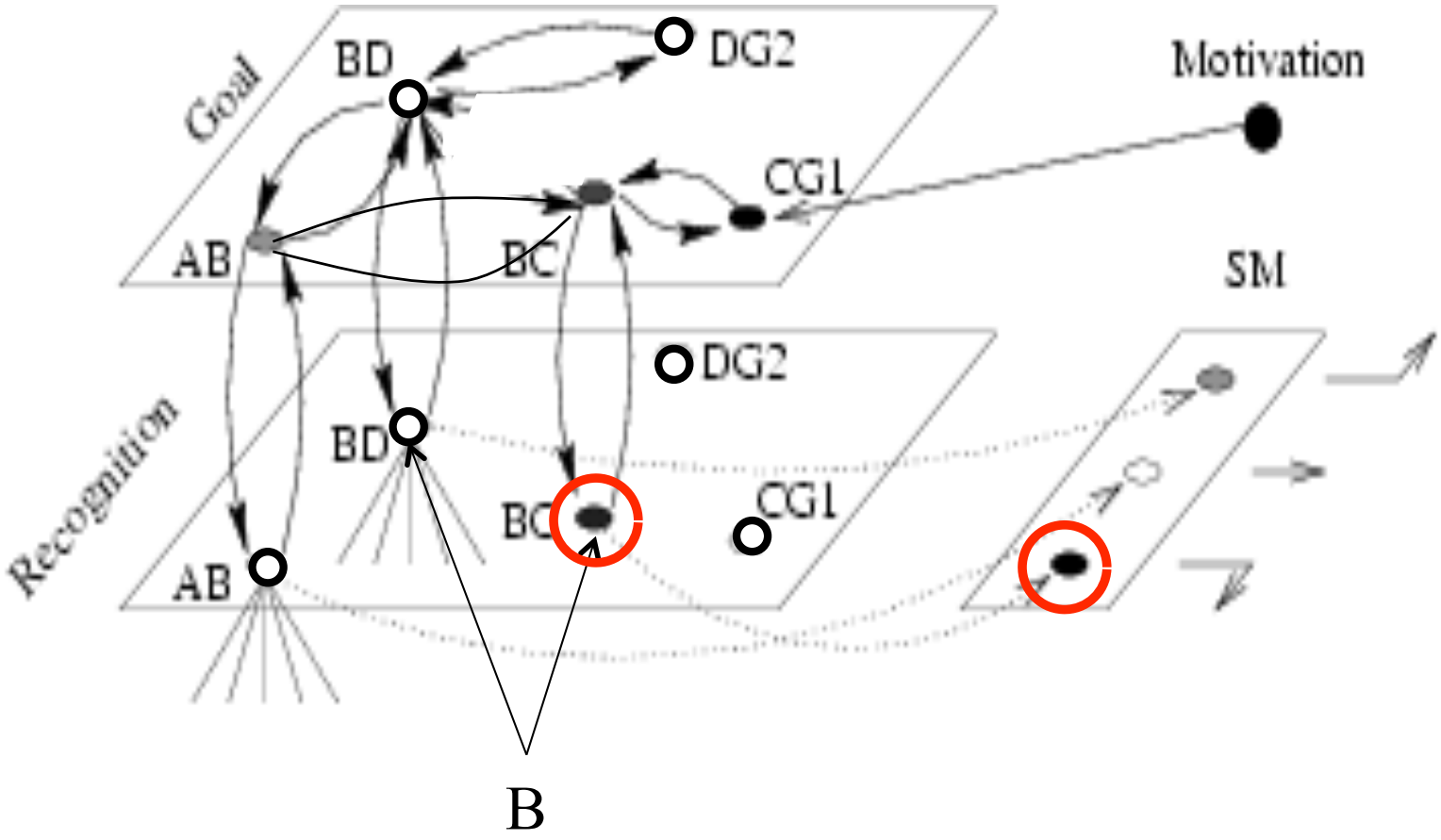
Solution: “transitory states”



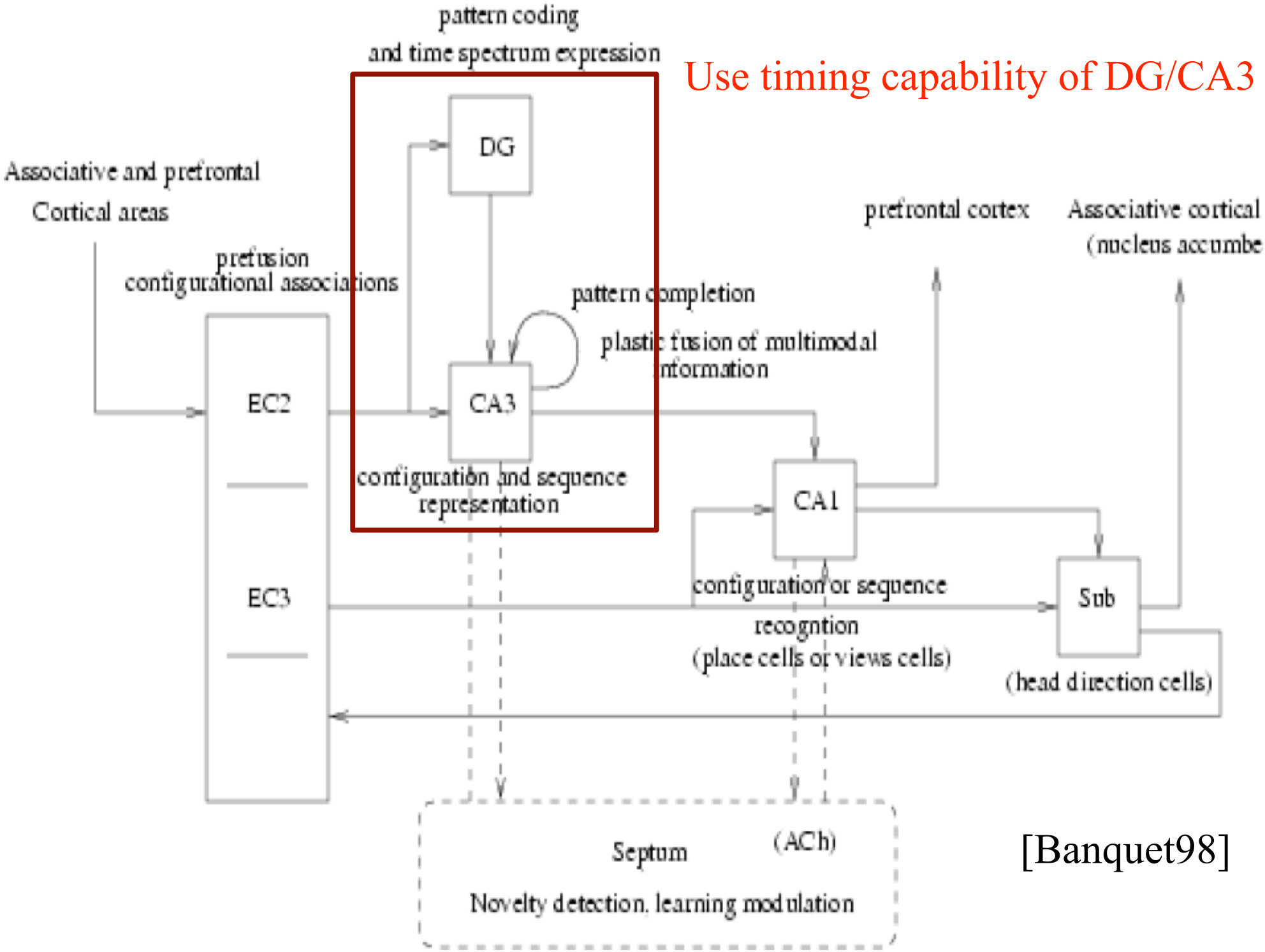
Goal

[Revel98,Gaussier01]

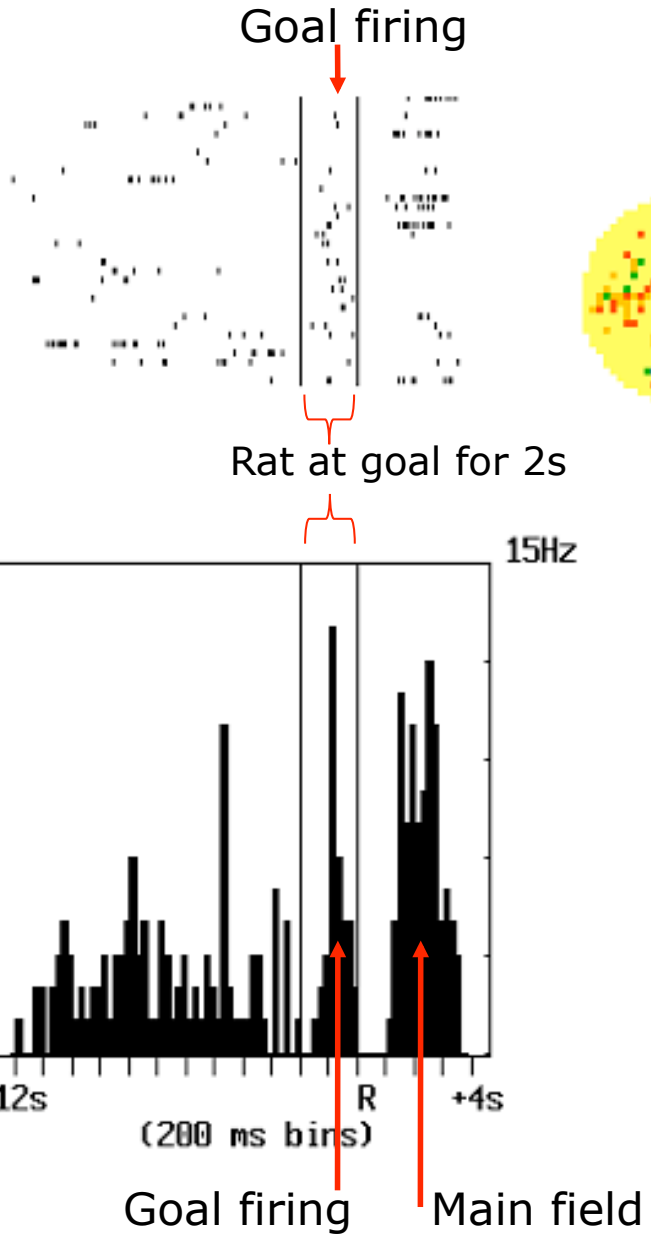
[Hok2007]

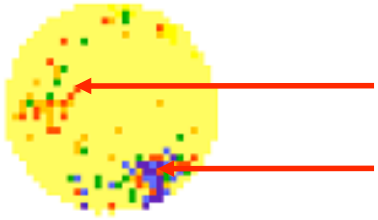


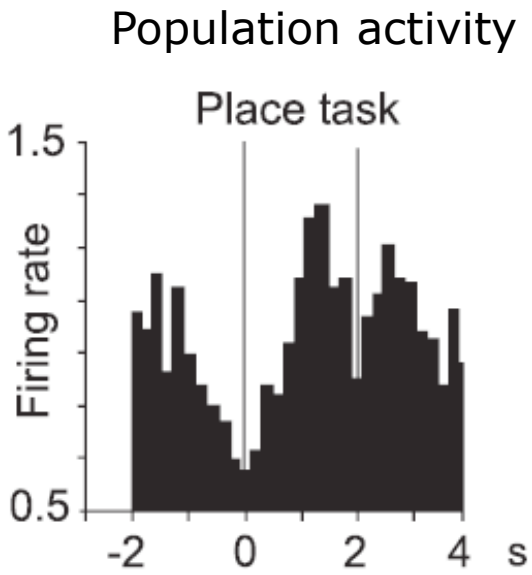
One transition is always associated to a single action


pattern coding
and time spectrum expression
Use timing capability of DG/CA3
DG
Associative and prefrontal
Cortical areas
prefusion
configurational associations
pattern completion
plastic fusion of multimodal
information
prefrontal cortex
Associative cortical
(nucleus accumbe
EC2
CA3
CA1
configuration and sequence
representation
EC3
configuration or sequence
recogntion
(place cells or views cells)
Sub
(head direction cells)
Septum
(ACh)
Novelty detection. learning modulation
[Banquet98]

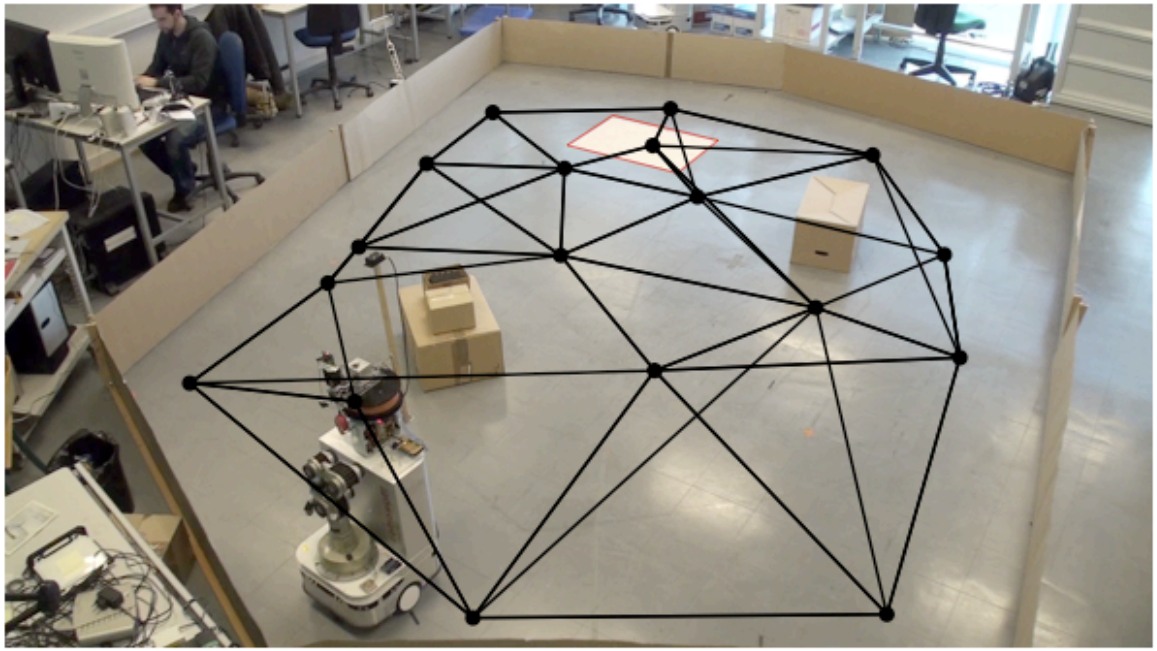
Analyse de l'activité des cellules de lieu dans la période d'attente au but

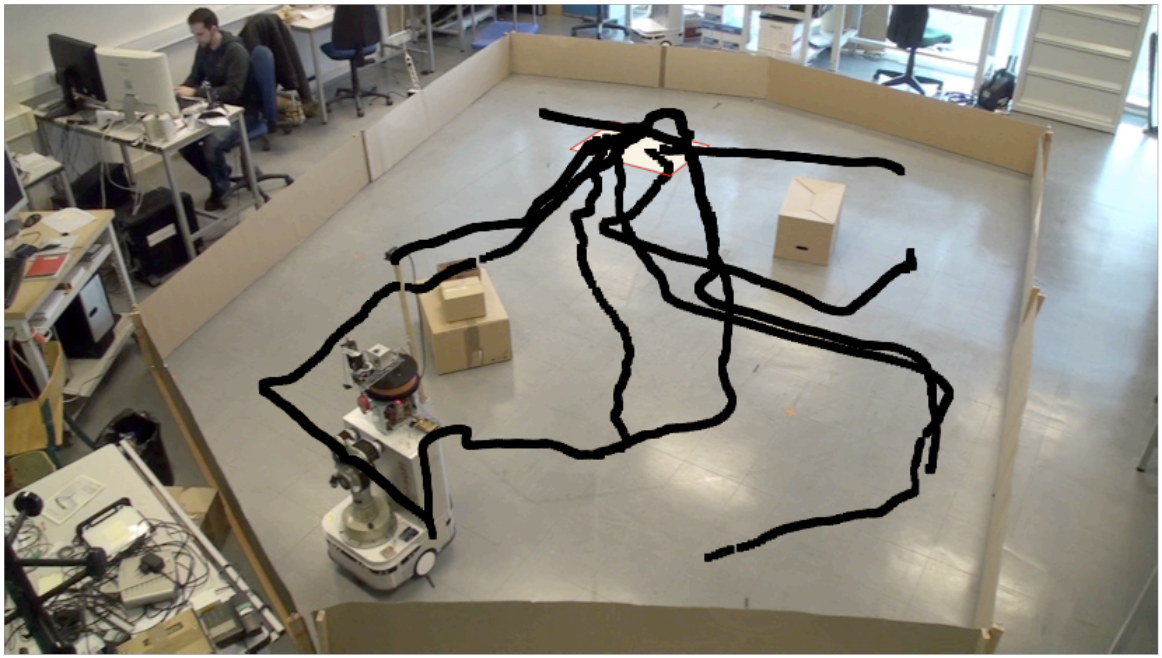






Hok et al. (2007)





[Cuperlier 2006, Hirel 2010]

Latent learning of the cognitive map.

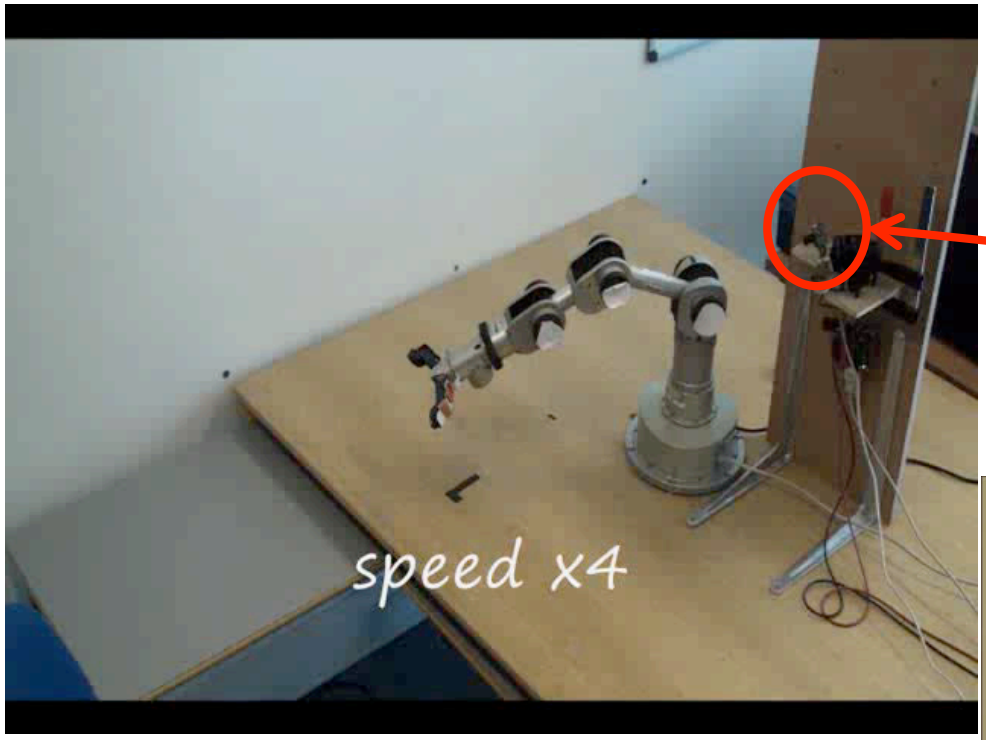
Return path to the goal place from random departure points.

Stay for 7s at the goal place.

2d part

Interactions capabilities

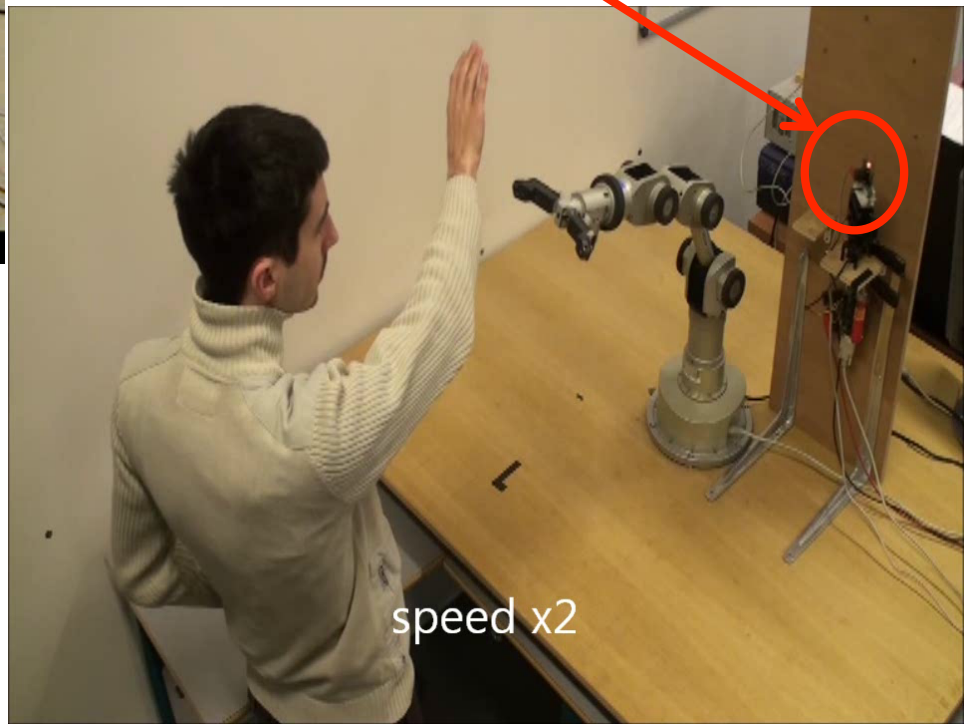
Immediate imitation



Sensori-motor learning (robot alone)

Control of a 4DOF arm

Pan-tilt camera



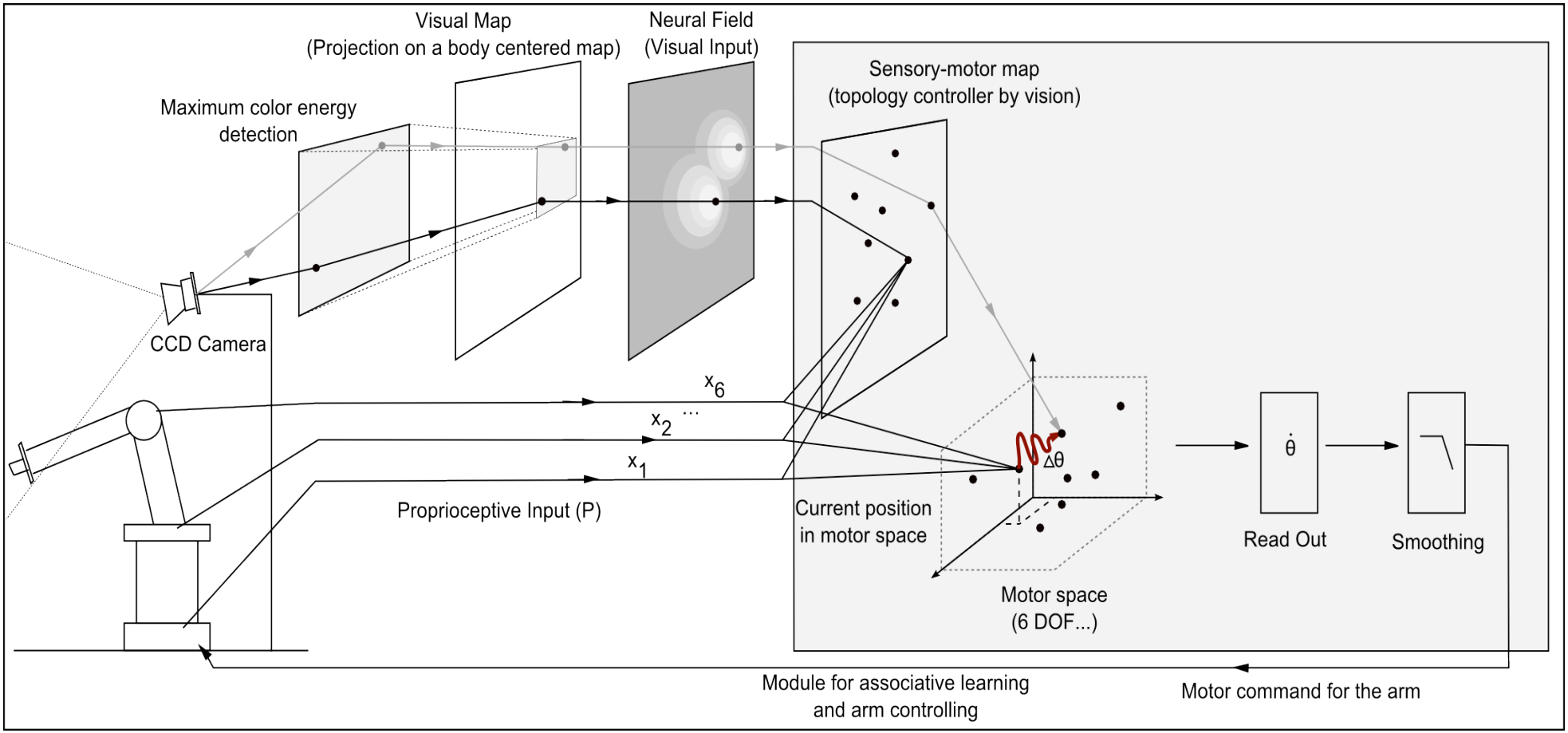
Immediate imitation

Minimal mechanisms:

- Ambiguity of perception
- Homeostatic control

→ **emergence of immediate imitation** [Andry et al 2002 & 2004]

Sensori-motor controller



→ learning of visuo-motor associations (online learning)

→ visual activation of motor attractors

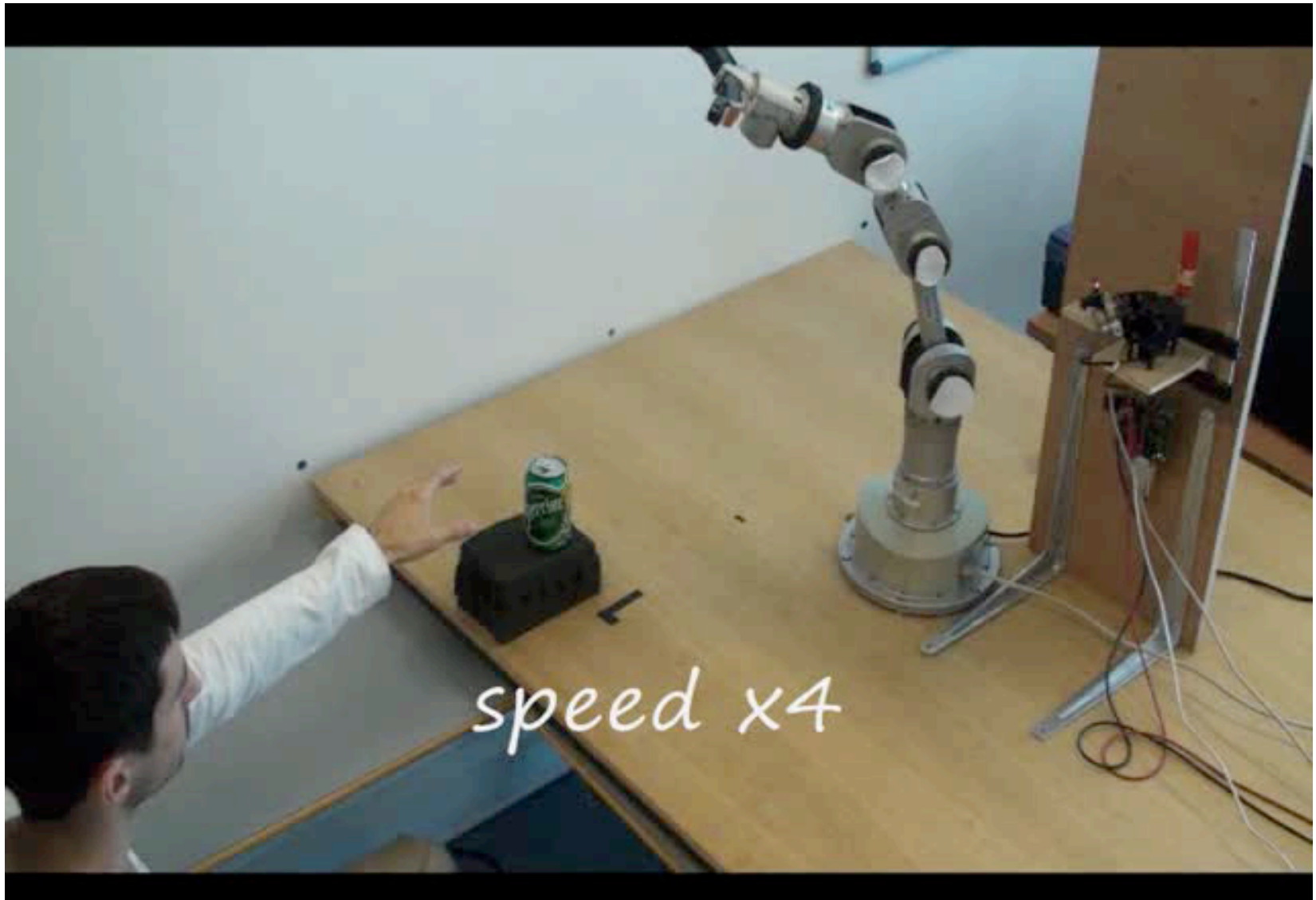
→ extraction of the command on the basis of the selected attractors [Fukuyori 2008]

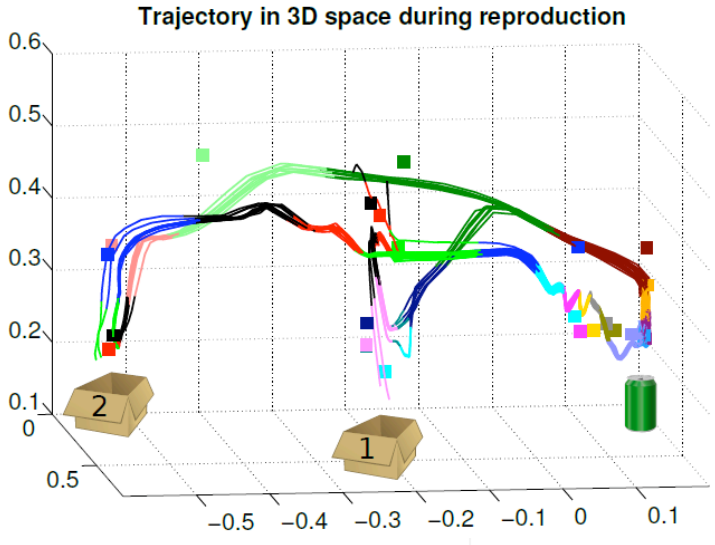
Minimal mechanisms necessary to the bootstrap of imitation ?

Observational learning

1. Autonomous learning of visuo-motor associations (babbling)
2. Inhibition of the motor command during human display (but sequence learning)
3. Reproduction of the sequence from one item to the next (first item is either triggered by human or by robot position)

[IROS2010]



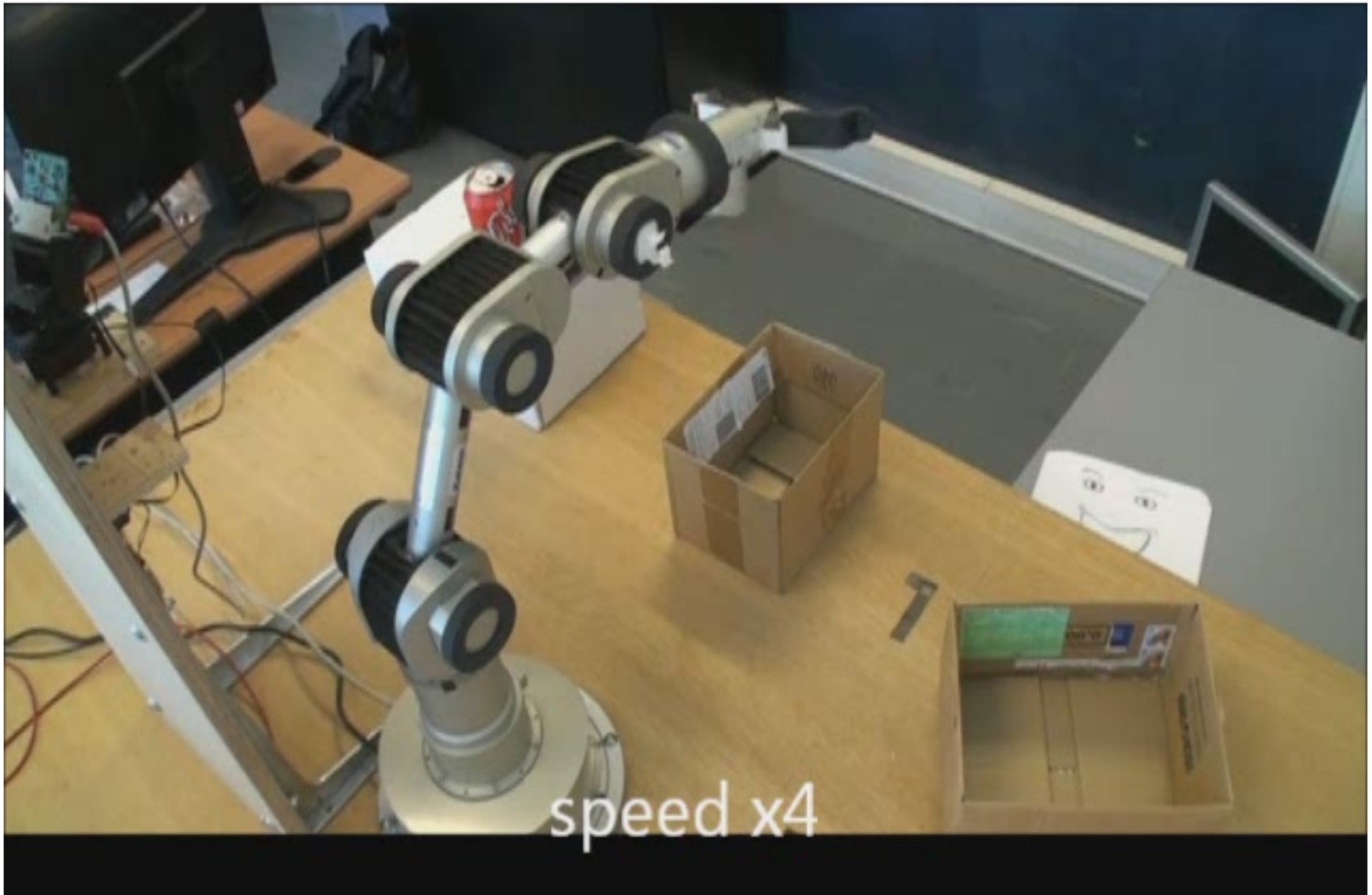


Learning by demonstration more complex tasks

Categories: proprioceptive states, transition detected and coded as new states (same as nav.)

Addition of the planning capabilities used for navigation (latent cognitive map learning)

- Cognitive map encoding the sequences of transitions
- Visual categorisation to generate the goals
  ➔ planning



Preliminary conclusions

- « Mirror neurons » can emerge from the sensori-motor learning.
- « mirror neurons » may be the consequence of the sensori-motor learning (not the cause!)

- Is imitation so much important for learning?

3d part

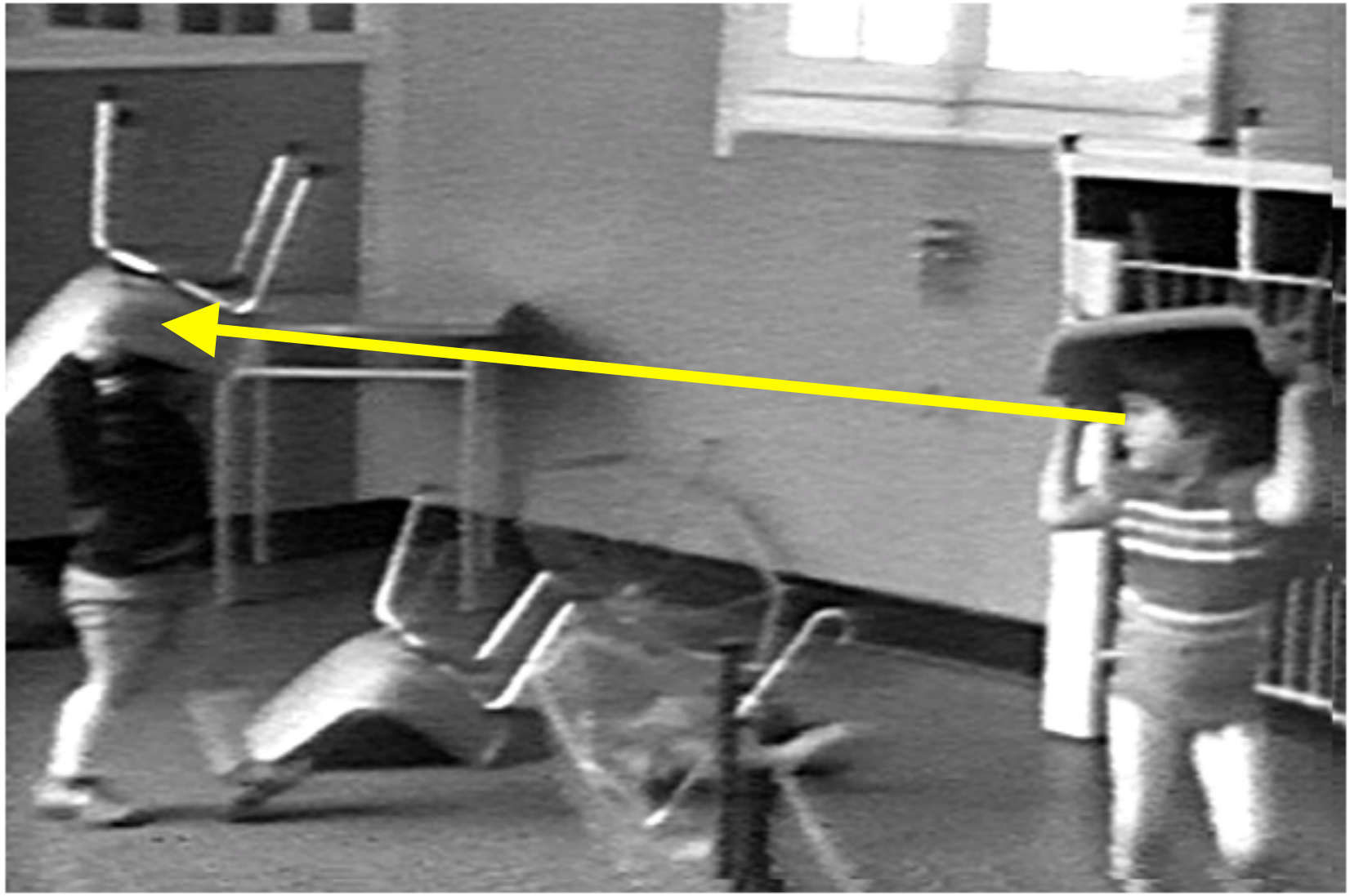
Emotions and social interactions

A solution to build a developmental sequence bootstrapped from emotional resonance…

Imitation and social interactions

(J. Nadel et al 2004, Interactive Studies)

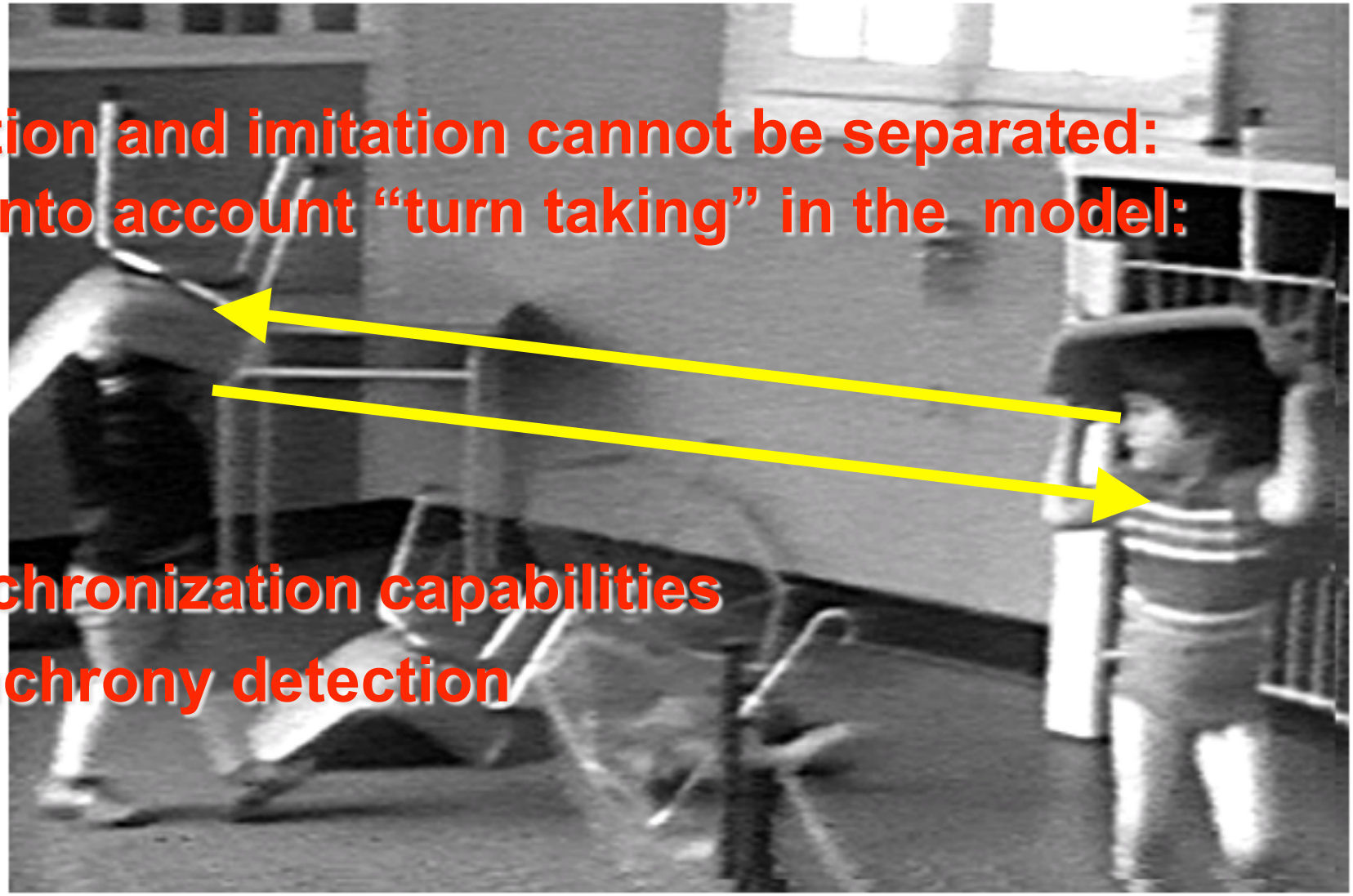
Imitation and social interactions



(J. Nadel et al 2004, Interactive Studies)

Imitation and social interactions

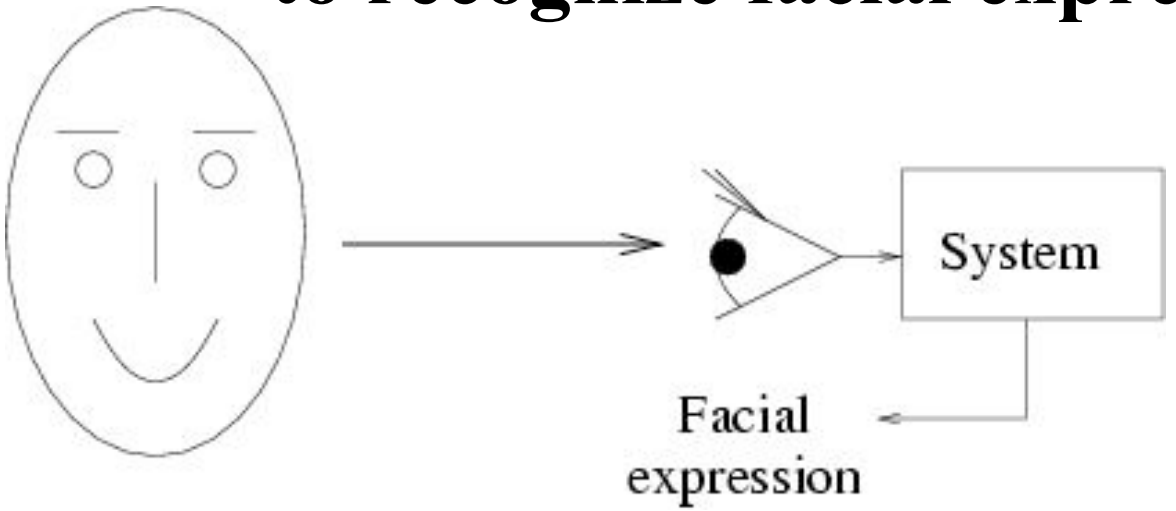
Interaction and imitation cannot be separated: taking into account "turn taking" in the model:

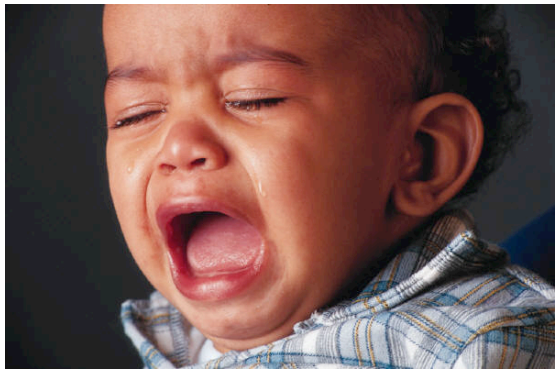


- **Synchronization capabilities**
- **Synchrony detection**

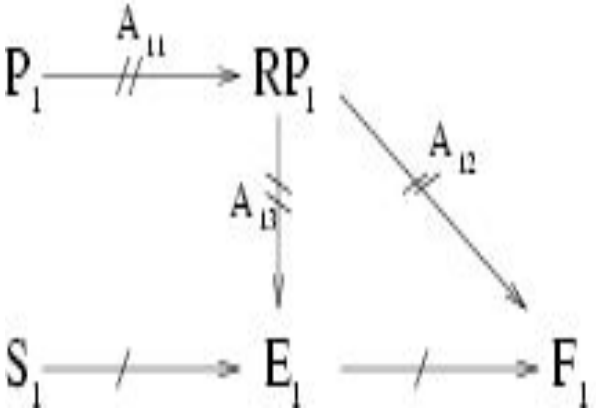
(J. Nadel et al 2004, Interactive Studies)

A toy problem: How to model baby learning to recognize facial expressions?

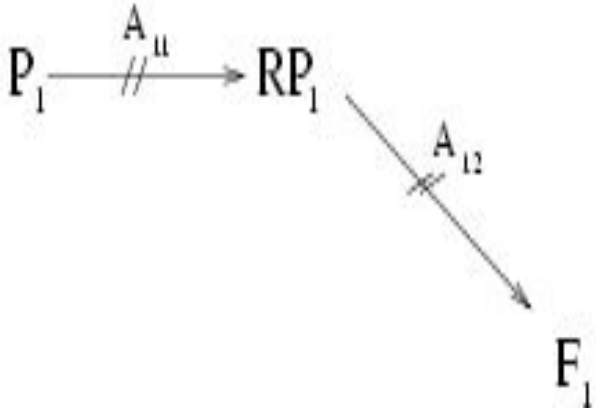


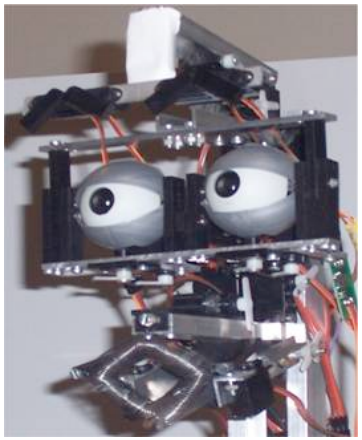


One possible architecture:



Desired solution:





(based only on sensori-motor loops)

After only 2 min of online learning

(SAB04, Epirob 06, 08)

Social referencing

- Toward complex behaviors (manipulation, interactions between behaviors at different levels…)
- Modeling emotions (metacontrol /communication)

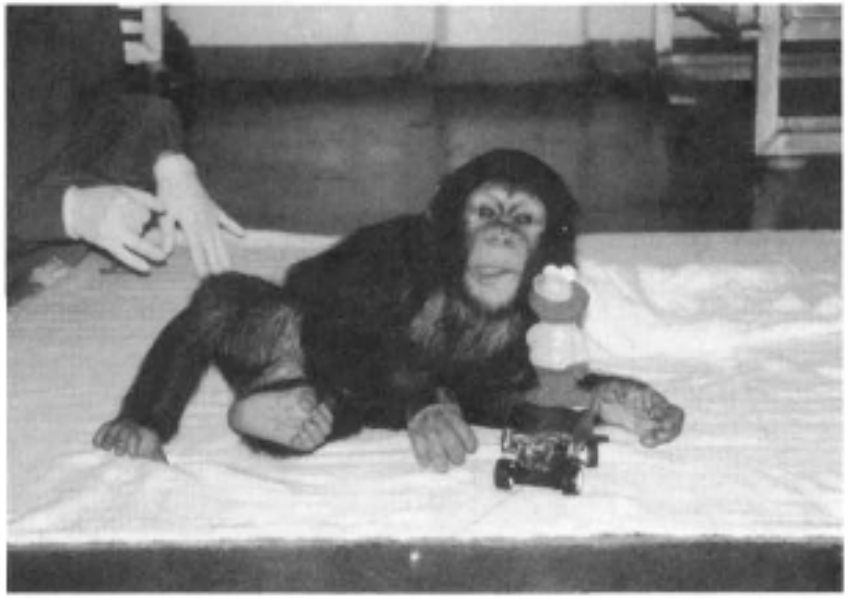
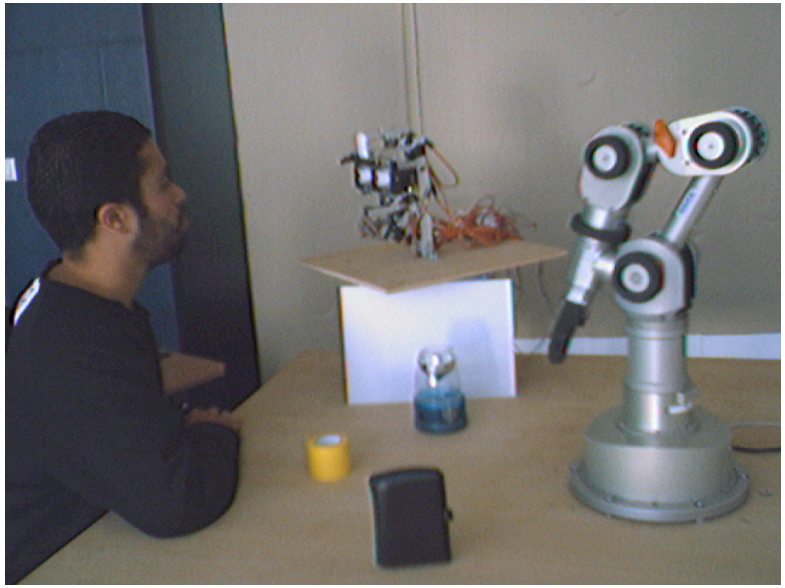
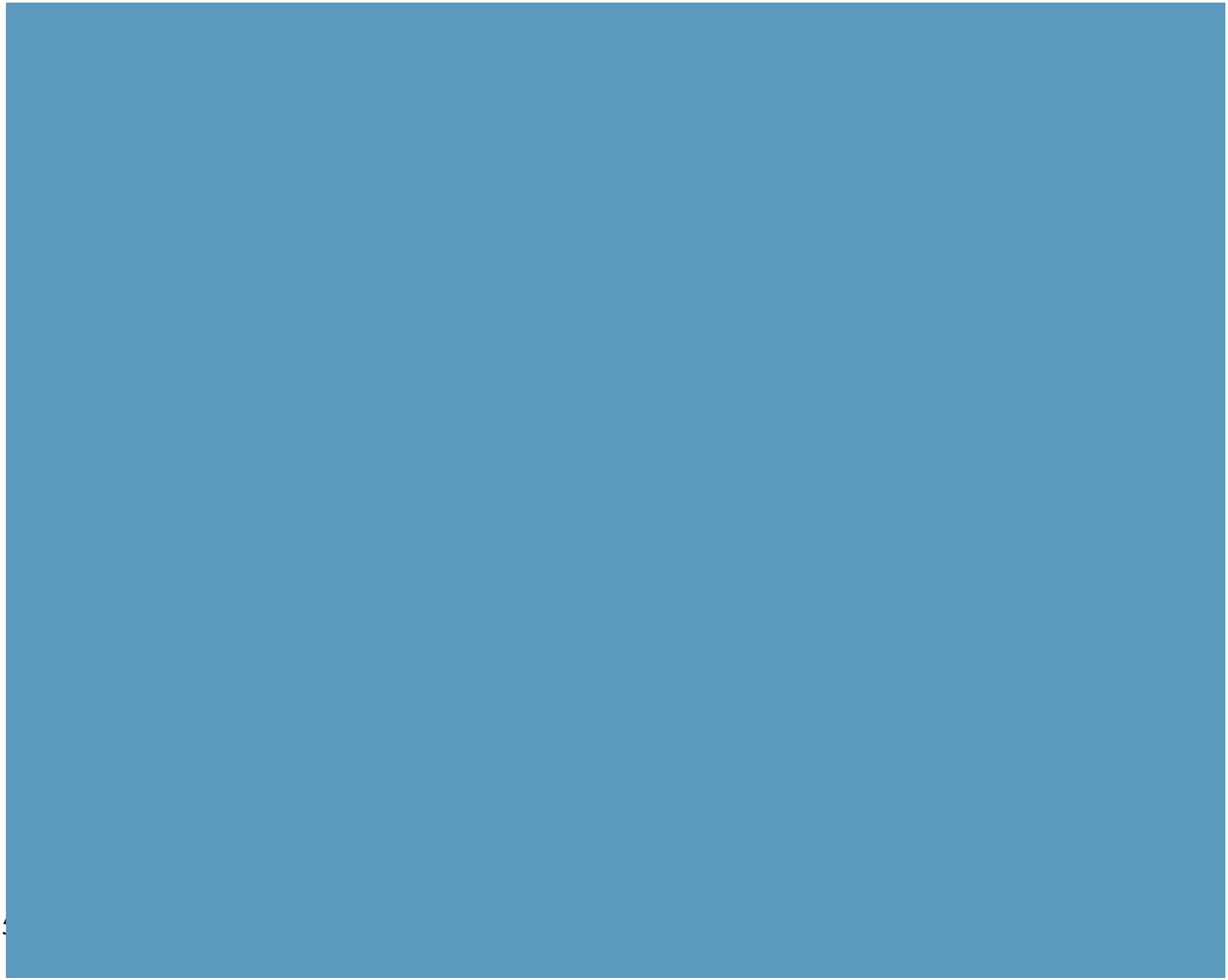


Figure 1. Experimental room with chimpanzee, caregiver, and object.

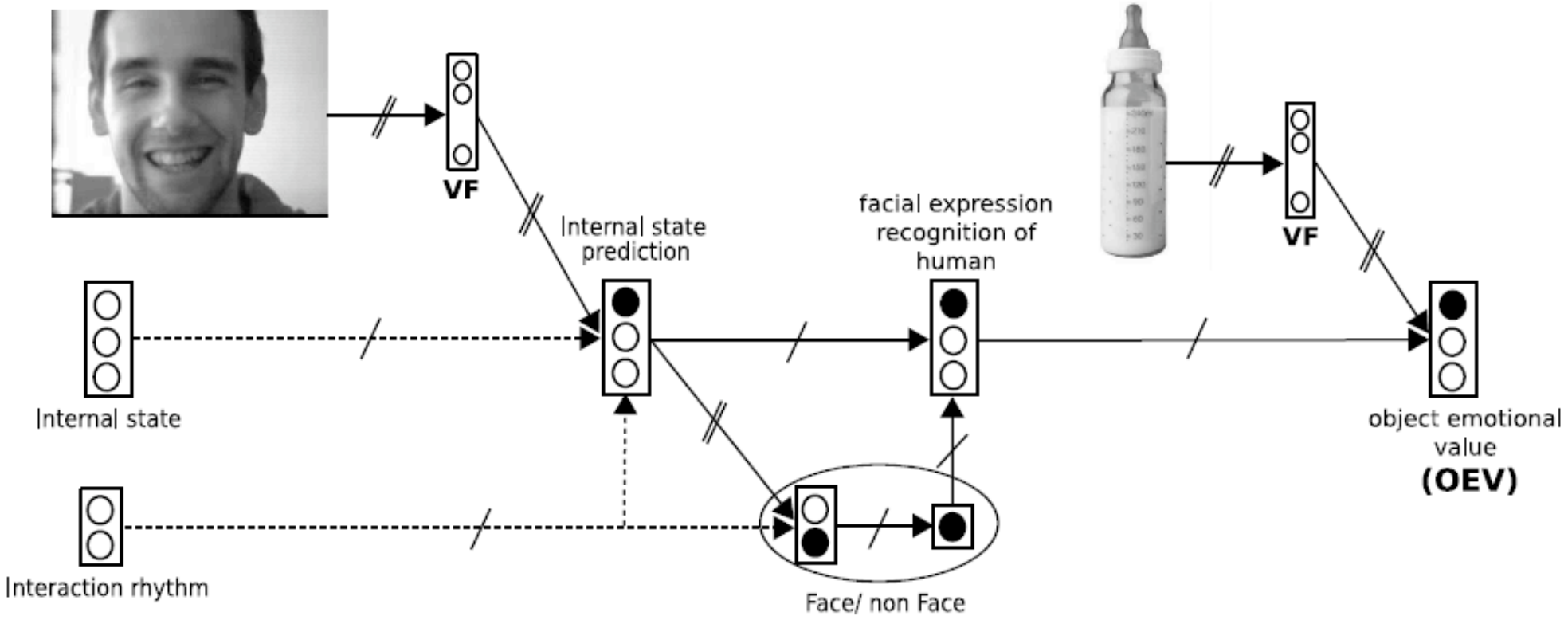
[Russel97]

Exp. on the devel.
of the social referencing
(associate a value to an
object)





Social referencing for object manipulation



Providing an emotional value to an object

Behavior: take-and-deposit or avoid

Discussion
&
conclusions

Conclusion

Les aller-retour neurobiologie/psychologie ⇔ robotique prennent du temps:

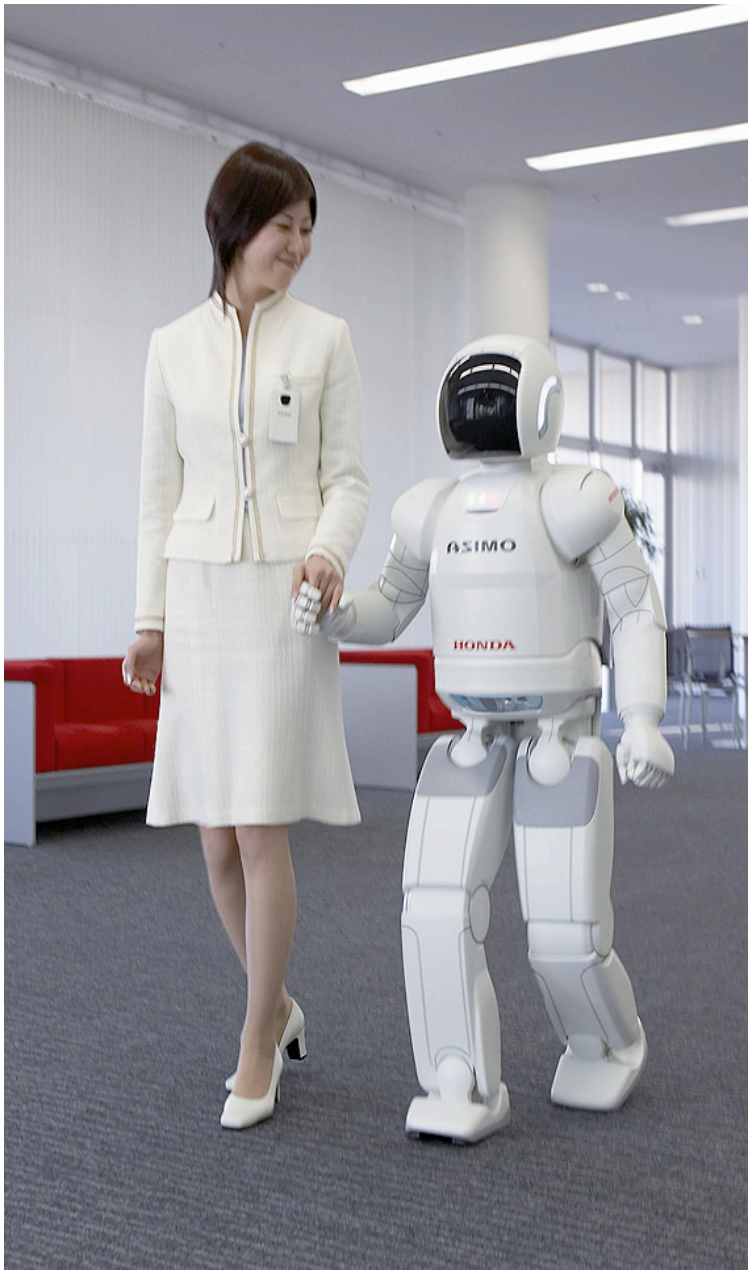
temps de boucle 6/7 ans minimum…

(modèles falsifiables / intérêt des doubles fonctions)

➔collaboration sur du long terme

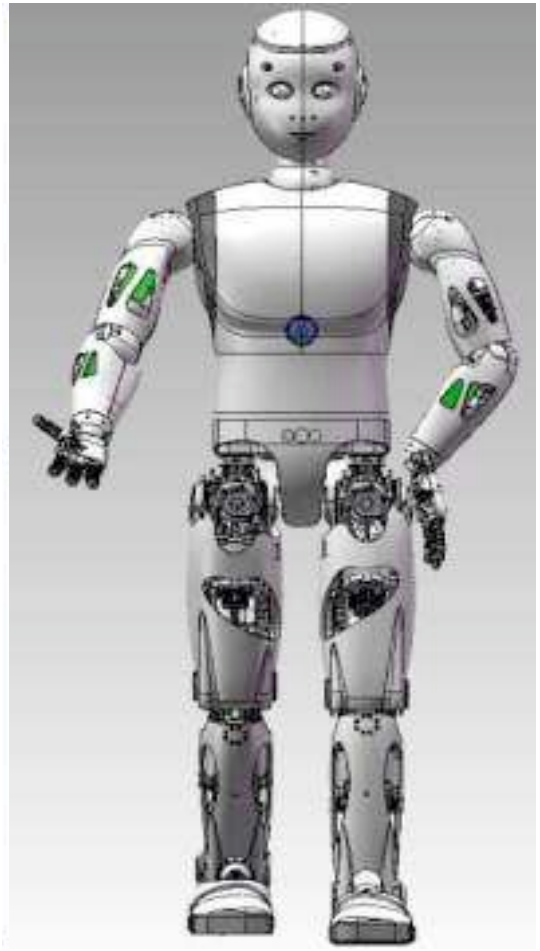
➔management délicat / projets sur 3 ou 4 ans (ANR, Europe…)

Nouveaux outils pour les sciences cognitives



Tester des modèles du cerveau en conditions réelles !

Robotex



Emotions as a way to structure learning

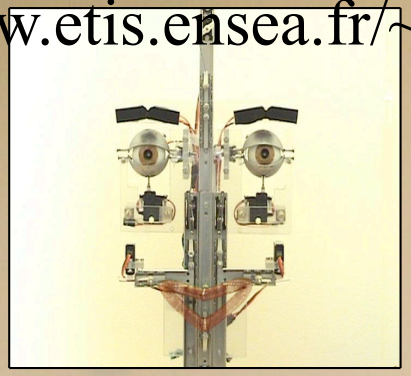
- Learning to recognize facial expression can precede the learning of face / non face recognition !

- The emotion **communication/interaction** may be used as a way to shape and trigger more and more complex learning when no explicit reinforcement signal can be used (➔**bootstrap**).

➔Importance of social feedbacks

- Taking into account the emotional development opens new doors for autonomous learning

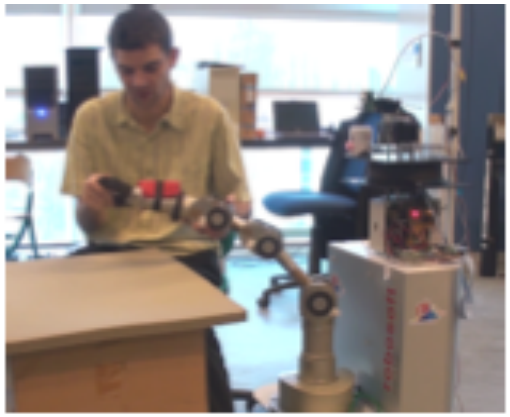
Videos on: www.etis.ensea.fr/~neurocyber/Videos/

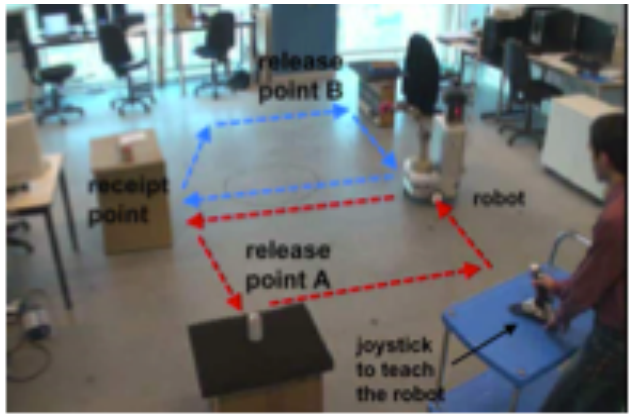


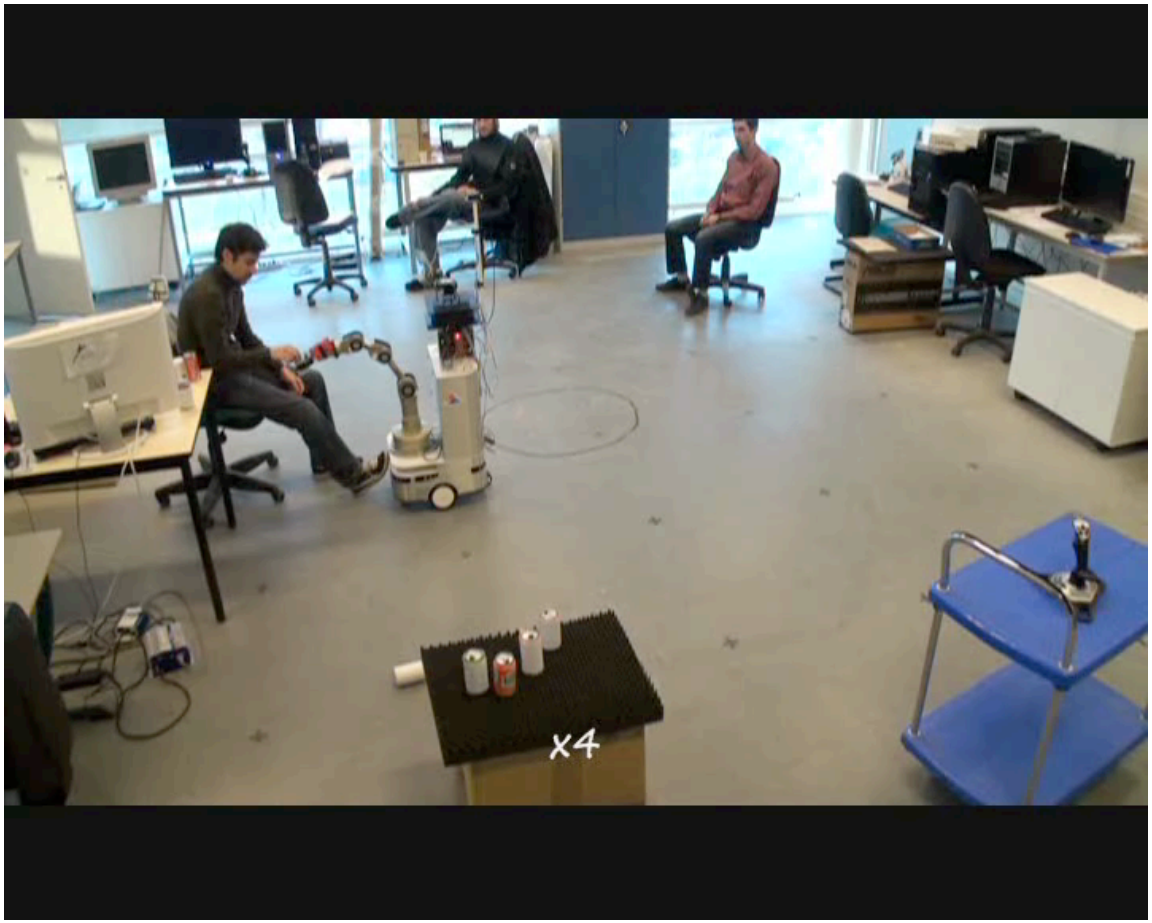
Thanks to: P. Andry, J.P. Banquet, D. Bailly, S. Boucenna, A. Chatty, N. Cuperlier, F. Demelo, L. Hafemeister, J. Hirel, A. Jauffret, R. Hasnain, C. Hasson, P. Laroque, B. Miramond, G. Mostafaoui, F. Pirard, M. Quoy, A. de Rengervé

(J.-C. Baccon, C. Giovannangeli, C. Joulain, M. Lagarde, S. Leprêtre, S. Moga, S. Moga, K. Prepin, A. Revel)

Visual navigation + arm control (SM level)







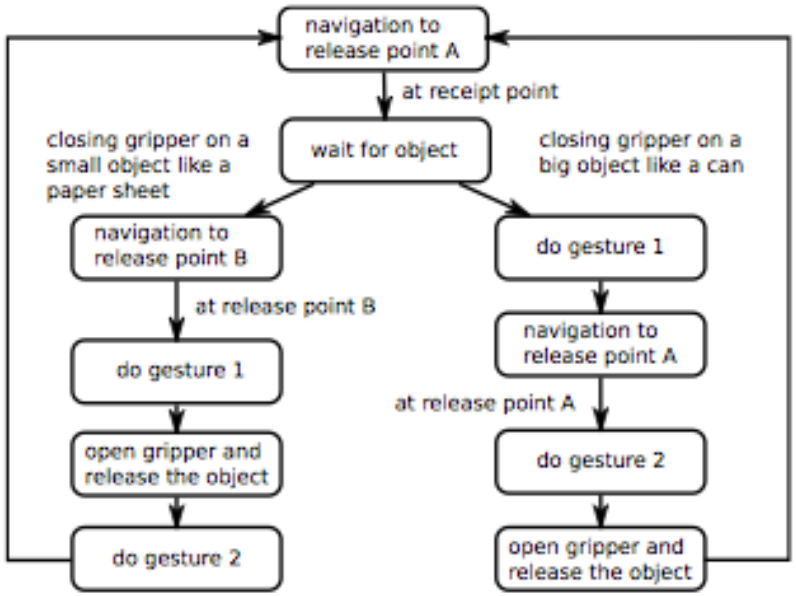
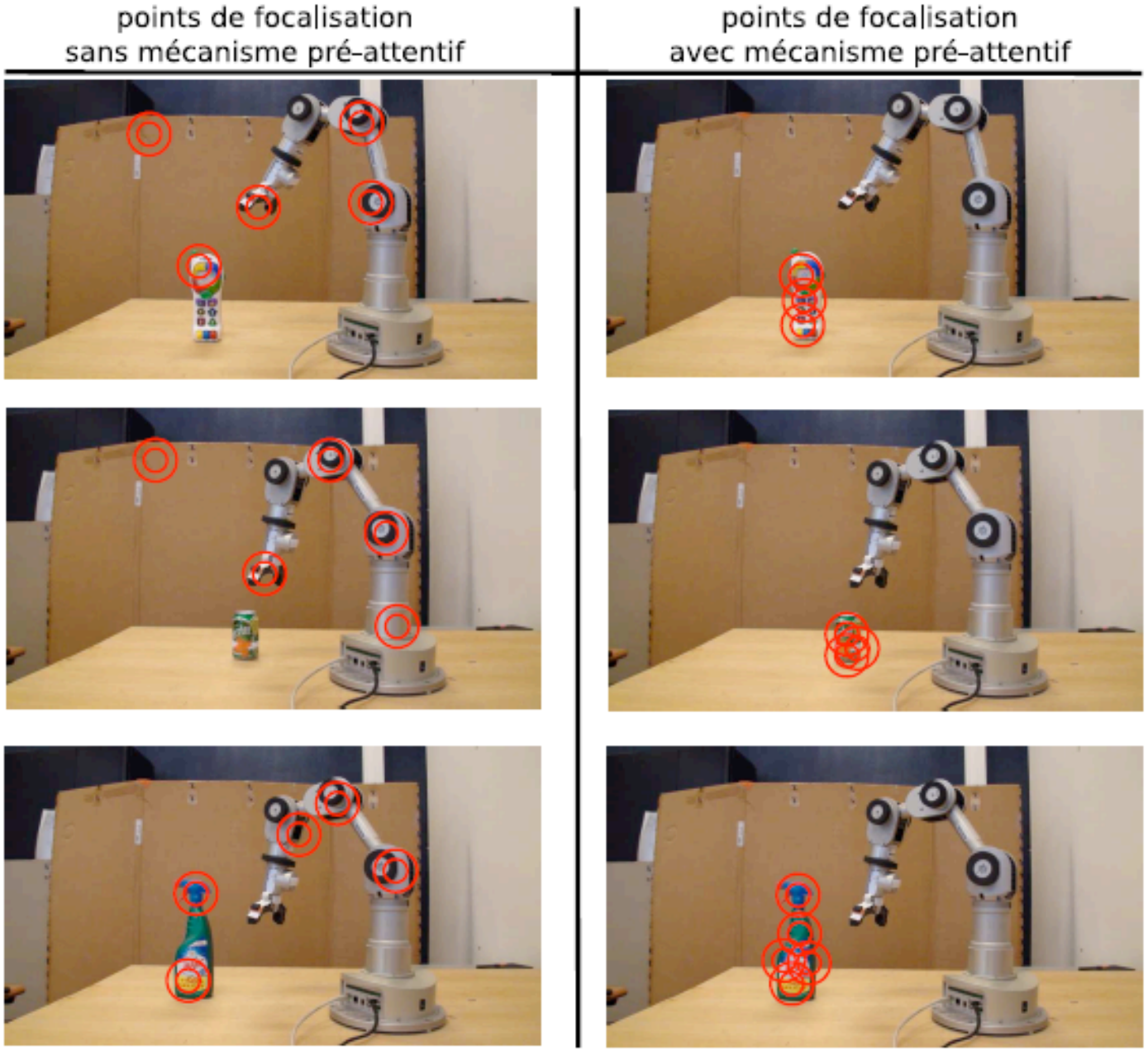


Fig. 3. Flowchart of the desired behavior for the experiment

[Epirob 2010]
Joint work with EPFL

Use of a saliency map to speed-up learning

Saliency map
Inspired from
[Itti & Koch]



C. Giovannangeli (IROS 06, EPIROB 06)

web site: www.etis.ensea.fr/~neurocyber/
Videos/