ADAPT

IST–2001-37173

Artificial Development Approach to Presence Technologies

Deliverable Item 1.4
Periodic progress report

Delivery Date: October 1st, 2003
Classification: Public
Responsible Person: Dr. Giorgio Metta – DIST
Partners Contributed: ALL

Short Description:

Contributors:
DIST: Giorgio Metta, Giulio Sandini
CNRS: Jacqueline Nadel, Arlette Streri
UNIZH: Martin Krafft, Geoff Nitschke, Rolf Pfeifer

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Summary

1 Coordination and collaborative activities

The coordination activity for the past 6 months went on mainly through emails on the project discussion list and a formal meeting held in Genoa on September 15-16th. At the meeting we decided to address two main issues:

- address the reviewers' comments after the Venice May 2003 meeting
- finalize the theoretical aspects of the project

We firstly addressed one of the points raised by the reviewers, namely, how to achieve a common view and integration between the project's partners and how to smoothly merge the three lines of work proposed (see D1.3 and attached "additional document"). Further, we discussed if and how the experimental plan would allow achieving the goals of the project, or rather, actions are required to correct some of the experiments.

Generally speaking, we felt that we needed to finalize the theoretical/philosophical aspect of the project since it is proving to be a bottleneck (especially in terms of maintaining the planned scheduled of activity as in the project technical annex). A part of the experiments (and consequently continuation of the project) is in fact to be linked to the theory. The theory called a tentative theory of intentionality is described in D2.1.

The meeting didn't include formal presentations but was rather organized as an open discussion and small working groups to address specific issues. The meeting was attended by all partners. A copy of the agenda (of the general discussion) with the list of attendees is enclosed. During the management part of the meeting documents describing the procedures and format for the preparation of the first year report and the cost-statement (both due in September 2003) were presented. Also at the meeting, issues concerning the software and hardware architecture of the robot were discussed (DIST, UNIZH).

Actions to be taken include:

- Preparation/completion of the delayed deliverables that include details of the theory, experiments and experimental setups.
- More accurate definition of the experiments.
- Plan for coordination of the experiments and common analysis of the results within the framework.
- Preparation of one/two chapters for the "handbook on presence research" within Omnipres.

2 Research activity up to month 12

The research activity is proceeding as planned with the following exception: some of the deliverables have been delayed. We believe that the delay is to be expected in a project like this one and it is mostly due to providing definitions/experiments agreed by every partner. We would like to remark that the fact to have finally overcome this difficulty is an achievement of the project since it allowed creating a common basis (and language) bridging diverse disciplines such as philosophy, psychology and computer sciences. We are now in the process of finalizing most of the deliverables which are expected before month 14. We would like to remark again that this is more a delay in finding a common/unified theoretical basis for the project rather than in experimentation. On the other hand, preparing some of the experiments took less than planned. For instance, some of the developmental experiments in newborns and young infants are already started. The original plan foresaw about a year time for the preparation of the experimental setups.

2.1 Rationale of the approach

As described in the technical annex to the contract, exploration of Presence within Adapt addresses the problem of understanding what the constituents of representation are. This activity is going to proceed along a certain number of steps:

1. Since we believe that representation is unified and created by means of action,
2. and the best example of action is manipulation,
3. we decided to investigate how the multisensory representation of objects develops in children and in artificial systems which possess opportune structures.

These three steps have been justified already in the preparation of the project. Within this context the experiments have been devised to cover:

Theoretical umbrella of the theory of intentionality/development

ASPECTS/REQUIREMENTS – derived from the theory:

1. Learning invariance in the sensori-motor data (already fetuses can detect invariance)
2. Expectancy – top-down signals? The infant is expectant rather than simply reactive
3. Intermodal contingency. Contingency (including social) – causation
4. Short-term memory. Store temporary, memory traces
5. Value system. Primary values, what are the values, how can the system generate new values autonomously?
6. Perception-action coupling. Initial coupling. How to maintain the system within reasonable working limits.
7. Pattern recognition. Biases, for instance, towards human faces, human voice, smell, etc.
8. Morphology. Progressive maturation of the sensory systems.

EXPERIMENTS

Age	Developmental experiment	Robotic experiment
Birth: our initial state of the system: time=0.	The very initial step of the development of the representation (newborns <3 days of age). We would like to answer to the question of what is the significance of the intermodal transfer (visuo-haptic) observed in newborns. The instability of such transfer at later age: e.g. it changes from haptic to visual (at birth) into visual to haptic by about 5 months of age.	Investigating the initial formation of the representation by haptic exploration of generic shapes. What is the language of touch for the robot made of? How does the sense of touch correlates with motor action? What is the meaning of having an initial transfer of information from haptic to vision? What does it buy us? Learn multimodal representation.
	To what extent the intermodal transfer is selective to certain cues. Previously, testing has been carried out only with respect to the shape of objects. Next step is to repeat the same protocol but test texture rather than shape.	What features can possibly be embedded into the robot representation?
6-9-12 months	Consistency of intermodal integration: Ambiguous objects (transfer of information). What action is elicited when an object with ambiguous visual/haptic features is presented?	Experimenting includes learning (discovering) affordances of objects. An important aspect is the strategy of exploration of the environment.
	Non-affordant use of objects (embedding of motor information into the unified representation). What would an infant imitate when shown a non-affordant use of object?	How does the motor information contribute to the construction of the representation? What happens if we embed motor information into the representation of objects? See previous experiment.
2-6 months	Early detection of social contingency: Presentation of non-contingent situations by for example delaying speech vs. video.	Clarify what is the role of the detection of contingency into the architecture. What happens if we change the delays of different sensory cues?

2.2 Assessment and analysis of results

The experimental plan presented in **section 2.1** presents a parallel between developmental and robotic experiments that explores different aspects of the representation of objects. In particular, we envisaged at least three "sampling points" along the developmental pathway when to test for the representation of objects. The experimental line will in fact investigate the representation at birth, the consistency of the representation (with affordant vs. non-affordant components) longitudinally from 6 to 12 months, and the role of contingency in building unified representations (2 to 6 months).
The assessment and comparison of results is always a difficult enterprise in a project like Adapt. Results coming from developmental psychology will necessarily be punctuated: i.e. for practical reasons not all different possibilities could be investigated; there's a finite small set of results aimed at elucidating some particular aspect of the problem. The level at which we can conduct experiments with the robot is different since, in this case, we are the designers of the mechanism and not just the analyzers of the results. The plan (now better explained in D2.1, D5.1, and in part in D3.1) is to build first of all a theoretical umbrella where to cast the developmental psychology results and, subsequently, to make informed choices on the architecture and supporting learning machinery of the robot. We expect to succeed at building a computational model that is simultaneously biologically plausible and explanatory of the structure of representations in the brain [under opportune simplifications].
In particular assessing the structure of the representation in the robot allows a detailed analysis of what information is retained into the artificial neural structure.
Specific effort will be devoted in the next 6 months in defining a procedure for the assessment of results and comparison of different experimental data. In particular, the consortium is expected to meet again in about 5 months' time.

2.3 Status of the project and prospect of research

At month 12 various aspects of Adapt are getting to a more definite form. In particular considering **workpackage 2** (theory of intentionality), the consortium produced a document (also D2.1) where the basic elements of the theory of intentionality have been defined. This effort is the minimum core from which Presence-related specifics will be derived during the prosecution of the project. Also, the validation of the theory[1] or at least a certain degree of congruence (agreement) is expected between the developmental experiments (WP4) and the theory. As in a good scientific practice, the theory will be validated in terms of the strength of the prediction that would reveal to be true from the experiments on young infants. To a different degree the experiments on the artificial architecture will contribute along the same direction. According to our schedule, further prosecution of this part of the project is only due towards the end of the project (last 6 months or so).

We will dedicate some effort from WP1 to try to harmonize these different strains (development, theory and robotics) into a more coherent multidisciplinary one. More

[1] Perhaps a much wider validation effort should be envisaged. Clearly a single set of experiments could not possibly validate completely the theory given its broad and far looking scope.

importantly, part of this effort will go into a clearer assessment and evaluation procedure of the results of the project. Additional documentation will be produced later during year 2.

The first stage of **workpackage 3** (morphology) came to a conclusion after the first 12 months of the project. We have made a number of major and somewhat minor improvements to the two existing robotic setups: the Babybot in Genoa, and the active vision system and industrial robotic arm located in Zurich.
The most natural major upgrade was the realization of a five-finger robotic hand. As described in D3.1 the robot hand fits nicely to the existing humanoid setup in Genoa. We completed a full testing of the hand electronics and mechanics. Sensors include tactile elements (FSR at the moment of writing – see discussion below) and Hall-effect sensors to measure the position of all joints. The setup in now completed. Along the way, a major revision of the (software) control architecture of the robot has been carried out. Some elements of the motor behaviors are not yet integrated back into the system but things are proceeding at a reasonable pace.
In parallel, the group in Zurich designed a new robotic head to address the limitations of their current active vision system. The plan is to duplicate to a certain extent (functionally) the setup in Genoa so that experiments could be performed independently or jointly on both sites. The head, which already features 6 degrees of freedom and stereo vision, is soon to be extended with audition and a gyroscope. Furthermore, the design of an anthropomorphic torso-shoulder-arm-hand combination has been commenced. Four people are working on the computer interface for the robot. The design of the robot as well as the interface is done with flexibility and modularity in mind, so as to allow for later replacement of physical and logical parts, as required for morphology research.
After completion of the arm design, our focus for the prosecution of WP3 will be the study of the morphology of the haptic modality. We have completed initial studies on FSR sensors but we are now looking at an improved method employing the same technology at a higher density. Furthermore, we are going to investigate strain gauges and a combination of those with FSR sensors. Finally, we are strengthening the cooperation with Zurich's AMOUSE team, which is exploring whiskers as a sensory modality. Our goal is to be able to detect both, pressure and texture. Part of this investigation shall be concerned with the material used for the fingers, which has to be suitable for gripping as well as the integration of appropriate haptic sensors. We expect additional experiments on morphology further down the road.

Workpackage 4 is devoted to the study of the developmental time course underlying the acquisition of the multimodal representation of objects. Unfortunately, collecting data about newborns' and very young infants' capacities is not a matter that can be settled in a short time. When designed, any project involving infants has to be examined by an ethical committee for approval. When this first step is successfully done, then the project has to be accepted by the director of the hospital and the caregivers, then by each mother and father concerned. This explains why the experiment cannot start as soon as the contract starts.
Research of WP4 is aimed at testing two hypotheses: the hypothesis of a primitive unity of senses at birth, and the hypothesis of a later access to a general intersensory integration through perception-action coupling, and in particular through experiencing the specific properties that objects afford to action. In-line with the project plan, we are now involved in testing further the first hypothesis. This is the staring point of development (time zero) and it is clearly required in defining the initial state of any developmental model. Experiments planned are described with

more detail in section 2.1. Part of experiment 1 (early integration) and experiment 3 (social contingency) has been completed.

Workpackage 5 is devoted to the realization of the control architecture for the artificial implementation of the developmental model. The results are still fragmentary although early testing and partial results have been collected into D5.1. We expect, now that also the experimental setups are fully available, to quickly further the implementation. Particularly useful it has been a discussion between our computer science and psychology sides on what properties the intentional architecture should lay on. Some of these ideas are reported above. For a more detailed description see D5.1 and the forthcoming D5.2, D5.3. Part of the activity of workpackage 5 is aimed at creating a common base (software) for performing experiments both in Genoa and Zurich.

3 Deliverables

The following table lists all the deliverables due at month 12. We included also the list of deliverables that were delayed. The status, at the moment of writing, is reported below:

Number	Title	Type	Due month	Expected
D1.1	Project presentation	Docs + web site	3	N.A.
D1.2	Dissemination and use plan	Document	6	12
D1.3	Management report	Document	6	6 (rev1) 12 (rev2)
D1.4	Periodic progress report	Document	12	12
D2.1	A tentative theory of intentionality and the sense of being there	Document	7	12-13
D3.1	Definition and implementation of a human-like robotic setup	Document	12	12
D4.1	Definition of experimental paradigm	Document	12	13
D4.2	Definition and implementation of setup for the investigation on child development	Prototype	12	13
D5.1	System's architecture specifications and design	Document	6	12-14
D5.2	Basic unit design and implementation	Prototype	9	12-14
D5.3	Initial implementation of the integration model	Prototype	12	12-14
Additional document	Plan of experiments	Document	-	N.A.

Submitted [yellow]. This document [cyan]. To be delivered [white].

D1.3 has been revised according to the reviewers' observations and it's being submitted together with this one (D1.4). We are also submitting the deliverable 3.1 – description of the robot setup. The hardware and software components of the setup have been completed.

4 Effort and cost

Participants Code	One person-month corresponds to N hours
C1 - DIST	141
P2 - UNIZH	179
P3- CNRS	135
P4 -UPMC	

Work-Package ID	Title	Reporting period
WP1	Project management	1.04.2003 – 30.09.2003

Participants Code	Spent (person-months)	Planned (person-months) Total	Start date / End date Month 1 / Month 36
C1 – DIST	**0.5**	3	
P2 – UNIZH [1]	0.2	1 (1)	
P3/P4 –CNRS/ UPMC	0.2	1.2	

Work-Package ID	Title	Reporting period
WP 2	**Theory of intentionality and the sense of being-there**	1.04.2003 – 30.09.2003

Participants Code	Spent (person-months)	Planned (person-months) Total	Start date / End date Month 1 / Month 36
C1 – DIST	**2**	12	
P2 – UNIZH [1]	2.0	10 (5)	
P3/P4 –CNRS/ UPMC	1.2	4	

Work-Package ID	Title	Reporting period
WP 3	Embodiment and body morphology	1.04.2003 – 30.09.2003

Participants Code	Spent (person-months)	Planned (person-months) Total	Start date / End date Month 1 / Month 30
C1 – DIST	**2**	12	
P2 – UNIZH [1]	4.0	24 (10)	
P3/P4 –CNRS/ UPMC	2.4	12	

Work-Package ID	Title	Reporting period
WP 4	Development of Coherent Representations	1.04.2003 – 30.09.2003

Participants Code	Spent (person-months)	Planned (person-months) Total	Start date / End date Month 1 / Month 31
C1 – DIST	**2.5**	14	
P2 – UNIZH [1]	4.0	25 (10)	
P3/P4 –CNRS/ UPMC	6.6	26	

Work-Package ID	Title	Reporting period
WP5	System's architecture	1.04.2003 – 30.09.2003

Participants Code	Spent (person-months)	Planned (person-months) Total	Start date / End date Month 1 / Month 33
C1 – DIST	1.5	12	
P2 – UNIZH [1]	2.0	12 (3)	
P3/P4 –CNRS/ UPMC	1	4	

The number between brackets report the persons/month spent by permanent staff at UNIZH and not charged to the project.

Title	Reporting period
Cumulative effort	1.04.2003 – 30.09.2003

Participants Code	SPENT HOURS	Spent (person-months)	Planned hours 1st year	Planned person-months 1st year	Planned hours (TOTAL)	Planned person-months (TOTAL)
C1 – DIST	**1248**		**2496**	**17.7**	**7488**	**53**
A2 – UC	**2184**	**12.2**	**4296**		**12888**	
A3 - UP	**1565**	**11.4**	**3388**	**25.1**	**6372**	**47.2**

5 Publications

1. Giorgio Metta, Giulio Sandini, Lorenzo Natale, Riccardo Manzotti. *Artificial Development Approach to Presence.* In Presence 2003. Aalborg, DK. Oct 6-8th, 2003.

2. Max Lungarella, Giorgio Metta, Rolf Pfeifer, Giulio Sandini. *Developmental Robotics: A Survey.* Accepted for publication in Connection Science. Special Issue on Epigenetic Robotics. 2003.

6 Activity within Omnipres

A representative from Adapt attended the Omnipres board of directors' meeting held during the Presence 2003 conference in Aalborg. Two aspects of the involvement of Adapt within the Presence initiative are worth noting:

1. A view of the future of presence elaborated by the consortium.
2. The proposal for two chapters for the handbook of presence.

6.1 View on Presence

PROJECT*:** ADAPT ***WWW: http://www.liralab.it/adapt

COORDINATOR: Giorgio Metta, Giulio Sandini ***E-Mail:*** pasa@dist.unige.it

PRESENCE RESEARCH AFTER 2005?

Vision: What is your vision for the future of Presence?	Vision: **[To be there requires] Direct connection between the human [brain] and the world by means of neural interfaces.** Three layers: i) The **machine**, ii) the **human**, and iii) the **interface**. • **The machine.** Recreation of the sense of being there requires not only the perceptual side but the motor aspects altogether (active perception, etc.). Two possibilities: a virtual or a real world conveyed to the user. In case the real world is presented, the "probe" needs to be a robotic one (avatar). In case we're talking about a virtual world the machine is simply simulating the world: what is important to simulate and what can be neglected should be determined by studying the "human layer". Mixed reality situations are also possible. • **The human:** understanding of Presence by investigating specifically the modeling and artificial implementations of how perception develops during ontogenesis, and *inter alia*, getting to grips with consciousness both as a general scientific challenge and, in particular, with respect to Presence. • **The interface.** Direct neural interfaces. Moving from the peripheral external interfaces to the direct connection to nerves and eventually to the brain. For smell and taste this could be the only feasible approach. We see a world where the machine gets closer to the brain. Let's call it the "100% pure-Presence" scenario.
Objetives: What significant achievements in R&D would be possible to make your vision come true by 2007?	➢ **Machine:** a new generation of robotic artifacts. Human shape, agile, partially autonomous, etc. How much intelligence do we put into the artifact? ➢ **Human:** understanding of what are the constituents of perception. What sort of cues do we actually need to recreate/communicate? ➢ **Interfaces:** new technology of silicon-neural interfaces is required. We really need a breakthrough in technology if we'd like the vision come true.

Aalborg October 2003

6.2 Tentative contribution to the handbook of presence

These are two tentative titles/abstracts of the contribution of Adapt to the handbook of Presence. They are likely to change as the project progresses since new experimental results and ideas might be available. We might also decide to work on a single rather than on two separate chapters/documents. This depends on the results of the experiments and/or the organization of the handbook itself. Another possible contribution (not covered here) is on the use of humanoid robots to convey the sense of presence - there's something in this direction happening in Japan - it's a likely field where Adapt could contribute although it's not our specific focus at the moment.

1) A developmental theory of intentionality and the sense of being there
Authors: J. Nadel, R. Manzotti, G. Sandini

Drawing on developmental psychology evidence and on philosophy of mind theories this chapter/section presents a novel theory of intentionality founded on development, embodiment, and explicitly takes into account the interaction of the agent with the environment.
The feeling of being there is only conceivable in a conscious being. A conscious being is a system that experiences (feels) something. This capability of feeling something depends on what is called the aboutness of phenomenal states, a property which is related to the intentionality of mental states. In order to understand the feeling of being there [or Presence] we need to understand the nature of aboutness and intentionality in a conscious being. This task can be profitably approached if we leave behind the dualist framework of traditional Cartesian substance metaphysics and adopt a process-metaphysical stance. We begin by sketching the outline of a process-ontological scheme whose basic entities are called ’onphenes’.
From within this scheme a set of constraints defining the architecture capable of intentionality and aboutness is formulated. An architecture abiding by these constraints is capable of epigenesis driven by onphenes. Since an onphene is a process in which the occurrence of an event creates the conditions for the occurrence of another event of the same kind, an onphene-based architecture allows for external events to provoke the repetition of other events of the same kind. In an artificial system, this propensity to repeat events can be considered as a functional reconstruction of motivation.
The theory is used to devise a sound experimental plan aimed on the one hand at supporting and validating the theory itself, and, on the other, at casting a set of experiments conducted on young infants in a broader framework.

2) Sensori-motor learning and object representations [robotics]
Auhtors: H. Valpola, M. Krafft, G. Metta, G. Sandini

Based on some of the theoretical premises [see above] we designed and implemented a neural network based developmental architecture. The goal is to generate a general-purpose system that [with some limitations] develops following an epigenetic pathway similar to the one observed in human infants. In particular we will analyze how the robotic system can learn to manipulate different types of objects and what sort of [multimodal] representation would emerge when the robot is free to interact with the environment.

The robotic system is shaped as a humanoid. It consists of a head, arm, hand, and it is equipped with vision, audition, proprioception, and touch.
The experiments presented here are aimed at validating some of the questions emerged during the investigation on small infants. Our goal was to uncover some of the mechanisms of development by employing a "synthetic methodology". This chapter would integrate evidences from different disciplines starting from philosophy of mind through developmental psychology and terminating in a robotic implementation.
Examples of the experiments we have in mind are "learning about object properties", affordances, and uncovering how a multi-modal representation [autonomously developed by the robot] could be used in solving simple cognitive task (e.g. how to grasp a hammer to properly toll a bell).

7 Agenda of the meeting held in Genoa –Sept 15-16th, 2003

Program:

Open discussion

Attendees:

LIRA-Lab: Giorgio Metta, Lorenzo Natale, Sajit Rao, Giulio Sandini, Riccardo Manzotti, Carlos Beltran
UPMC/CNRS: Jacqueline Nadel
University of Zurich: Harri Valpola, Martin Krafft, Geoff Nitschke

7.1 Minutes of the meeting

Things said at the meeting in random order:

Jacqueline pointed out that one reason for a late start of the project (at least the experiments) is due to the necessary preparation of experiments with young children and especially newborns. Ethical committees have to be contacted. Plan for experiments has to be submitted and approved. Concerning methodology of experiments on development, Jacqueline remarked that the experiments are carried out following the habituation paradigm (this should be clarified in replying to the reviewers).

Harri: mentioned the fact that the robots must have "agency". Agency is the fact that the robot is performing action itself. This is perhaps included into the representation the robot builds of the world. The fact that the system is acting.

Jacqueline: Representation requires action (what we experience is ours, created by our own acting). This allows building a causal link between what "you're doing" and what "someone else is doing". It leads to imitation.
Contingency: very young infants can detect non-contingent events (see Russell).

Contingency is a precursor of intentionality (in what sense?).

Infants are stimulus expectant (not only reactive). The difference being in the expectations infants have about what is going to happen? Stimuli have meaning because they're expected (coupling – process – between the agent and the stimulus).

Martin: Memory/Body Image. How do we include them into the framework?

Jacqueline: Hedonic aspects and motivations:

Repeat past experience? Why?
Rather novelty seeking/experience expectant (Hedonic too).
Newborns expect novelty → motivations.
Selection of stimuli.
Seek among all available stimuli.
Don't like the "repetition" thing.

Manzotti: motivations (2 aspects):

Looking for novelty (this was missing).
Result of experience (motor aspects connected to pleasant experience).

Harri: mentioned embodiment and unsupervised learning.

Jacqueline: development, example: myopic aspect of visual/retina development.
Multimodal transfer: why is it important?
Experiment:
At birth: tactile -> visual is ok, while visual -> tactile is not.
At 4/5 mo: visual -> tactile is ok, while tactile -> visual is not.
Explained as:
At birth the hand in mainly used for grasping. Motor control aspects co-opt the system. At 4/5 mo, the hand/arm is mainly used for reaching (transport). There's a new function which uses vision. Immaturity: grasping and reaching functions cannot be carried out simultaneously.

Jacqueline: interaction with humans.
You change the other, and the other changes you.
Special feature of dynamical interaction with other agents.
There might be something new emerging from the interaction.

For the experiments:
Detecting agency.
Learning from the interaction.
Objects + agents.
Ability to build relationships between events.
Attraction to movement -> agency

Dynamic -> object
Dynamic -> dynamic

Communication: two dynamical systems involving changes in the state of mind of the agents as a consequence of communication.

Manzotti: mental picture of the other (communication).
Jacqueline: Expectancy of contingency.

Unity of perception would develop from action: that is, action unifies perception.
Definition:
Cross-modal transfer: external sensory source (when action is involved)
Intermodal transfer: internal sensory sources (e.g. haptic to vision).

Somebody correlated the degree of novelty seeking to pathologies such as autism. E.g. lack of novelty seeking -> autism.

Experiments:
Before learning:
General exploration, non-object specific.
It's not yet multimodal, hand exploration.
How do we build a representation? What if this is explained by measuring some global signal of the neural representation (Harri)?

First learn, then test:
Habituation accounts to learning?
Habituation gets the information specific to objects
Exploration specific to objects.
Test representation into intermodal transfer: e.g. visuo-haptic

Jacqueline distinguished between:
Affordance and familiarity of use
- Affordance: proper to the dorsal stream

- Familiarity of use requires the object identity (ventral stream?)

Affordances are perhaps represented by some amodal property (e.g. size). Familiarity of use just requires the memory of use of the particular object.

Jacqueline experiment on affordant vs. non-affordant use.
  Experimenter pretend a grasp on an object
  The grasp can be affordant or not
  See what the child imitates
  Anticipation, computing the grasping?
    Ambiguous objects
    Non-affordant use of objects

Early imitation

Neonates
  We need to go step by step (what does it mean?)
  Integration -> audition, vision, touch
  Associate sound + texture in a 6 mo old child

Harri's concept of architectural design
Learning system

Requirements:
  Invariance(s) (already fetuses can detect invariance)
  Expectancy -> contingency
  Intermodal contingency
  Short-term memory

For a tabula-rasa (very bad):
  Prerequisites:
    Morphology (e.g. increasing resolution, myopia, etc.)
    Reflexes -> call them perception/action coupling
    Pattern recognition
    Primary values

Also Harri mentioned Imagination and working memory as two higher level elements forming a cycle (feedback) into the agent.

Jacqueline comments:
  Goal directed actions -> 6 mo
  Working memory -> short term>\?
  31st month infantile amnesia -> redescription, rebuilding of what has been learnt
  deferred imitation on learning -> memory involved

My Q:
  Can we express any of the learning modules as detecting causal relations?

Harri: ICA/neural ICA.