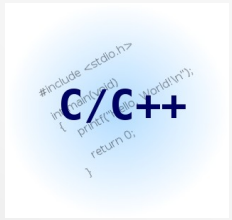
From early sensorimotor experience to object concepts, a developmental robotic study

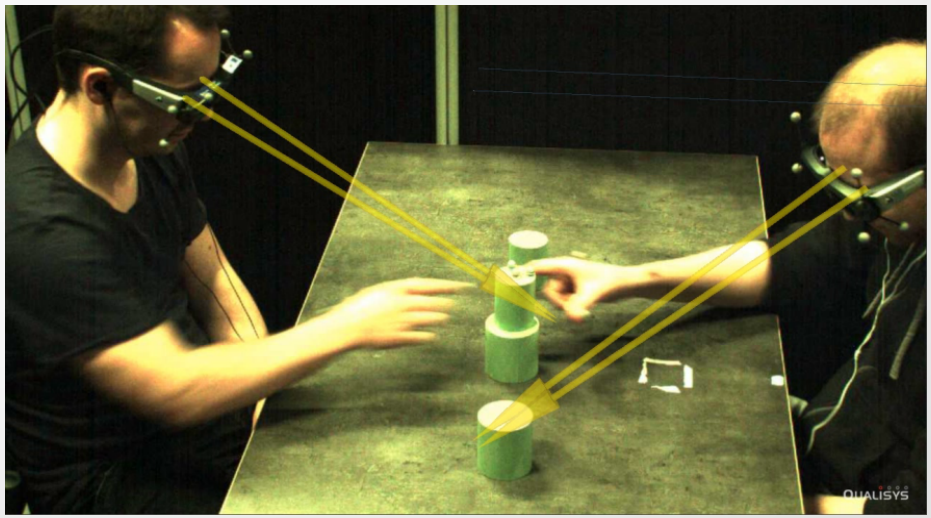
Project MoDeL

Daniel Lewkowicz

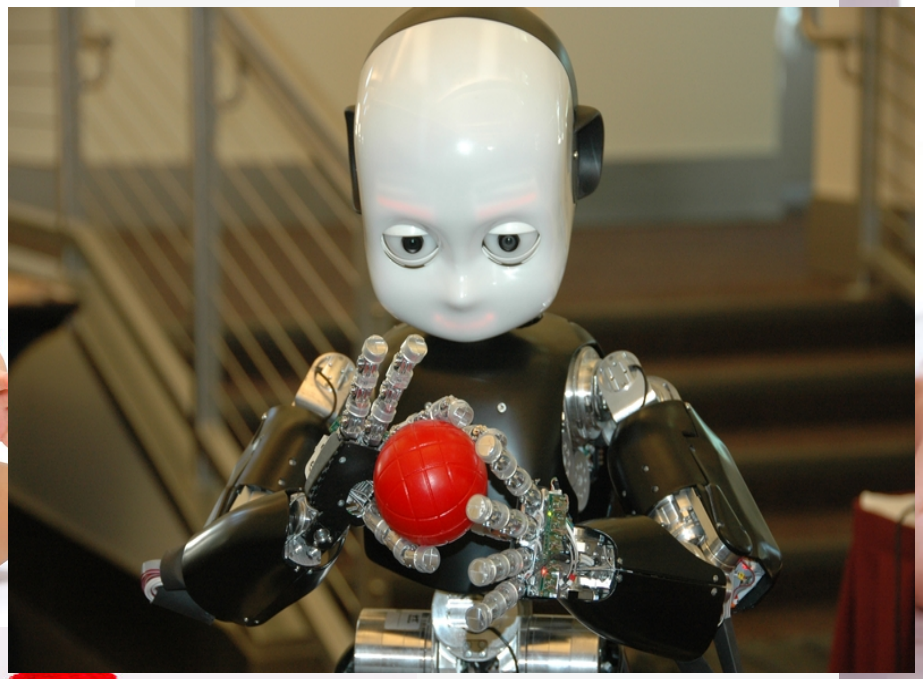
Background

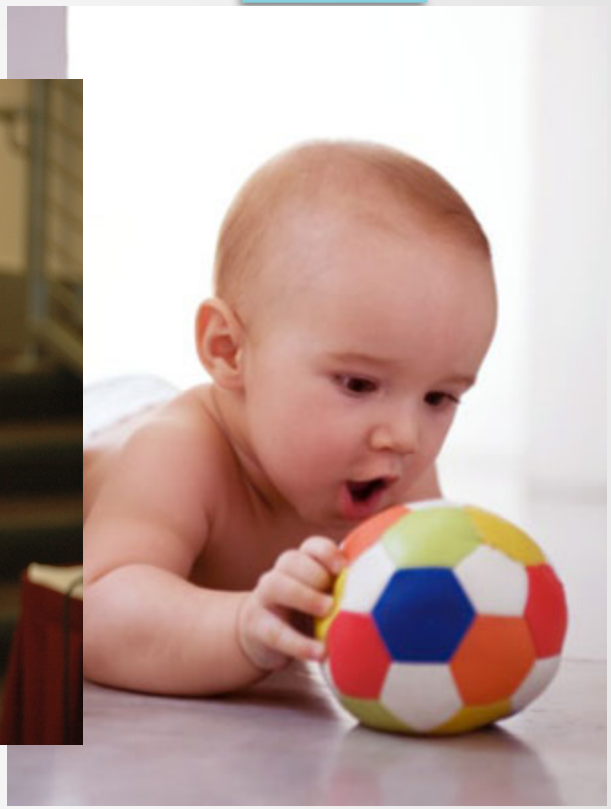
- MSc - Neuroscience
- PhD - Cognitive Psychology
- Post-Doc – Humanoid Robotics





Development of object concepts





How humans acquire and represent object knowledge ?

Apprentissage perceptif ?

Gibson « Ambiant optic arrays »: Nous ne percevons pas la lumière de manière aléatoire. Le monde visuel humain est fait de surfaces et de dispositions (layouts) dont les structures sous-jacentes déterminent en grande partie nos capacités de reconnaissance.

A la recherche des invariants du monde visuel

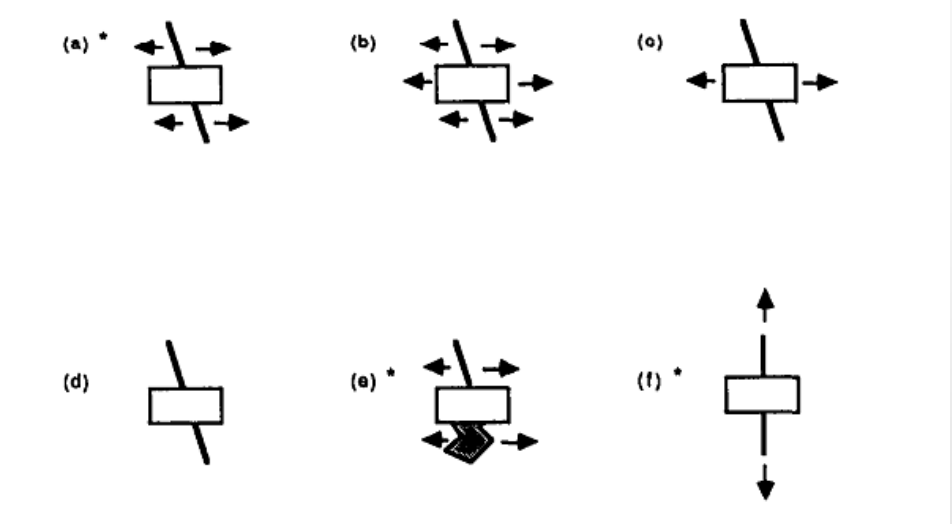
⇒ Aspect sensorimoteur: « conscience » visuelle, O' Regan & Noë (2001) « *ce que ça me fait de voir* »

⇒ Construction d'une représentation stabilisée.

- ⇒ Du *percept* au *concept*.
- ⇒ J. Mandler (1992) « Conceptual primitives »

Heuristiques d'apprentissage

- Spelke: Core knowledge – Principles of Object perception (1990)
  - *Bornés* (limites ne changent pas)
  - *Unitaires* (ne se séparent pas – les parties bougent ensemble)
  - *Solides* (non liquides/non sableux, ils occupent un espace)
  - *Persistants* dans l'espace et le temps (ne se transforment pas spontanément – pas de contrôle sur le movement sans contact)



General Method

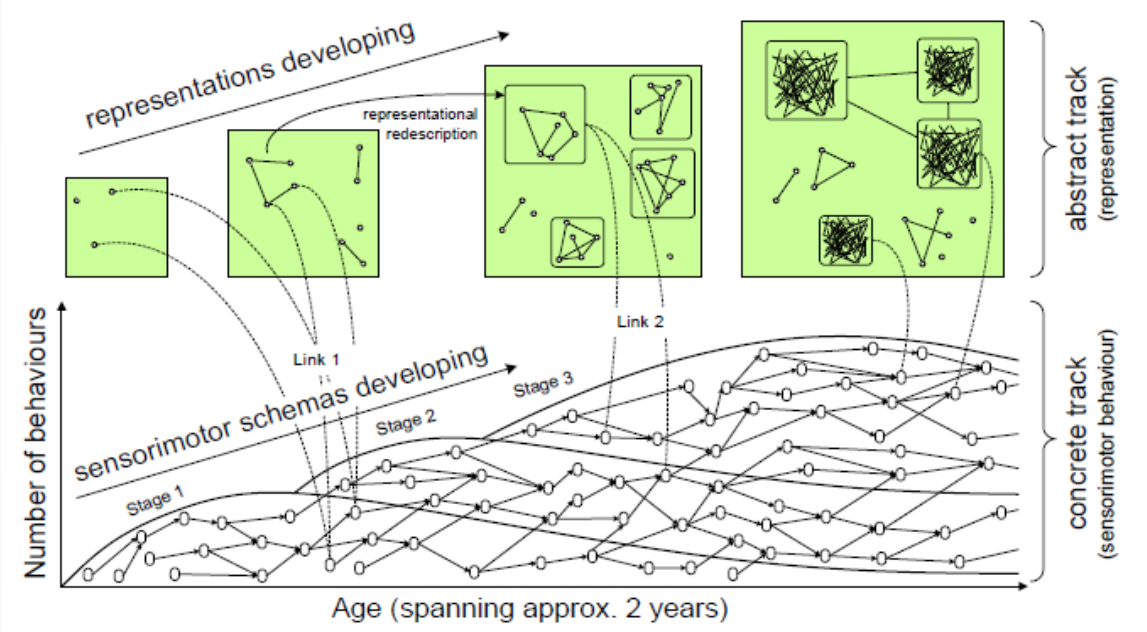
- Reproduce the cognitive mechanisms at a **functional level**
- Connect them to form an appropriate abstraction of their biological counterparts

The model :

- Longitudinal (to study developmental *trajectories*)
- Unsupervised, incremental, continuous and cumulative
- Driven by intrinsic motivations (autonomous activity)
- Self calibration
- Real-time: training, learning and performing
- Efficient: Very fast generalizations and adaptations

Methodology (LCAS)

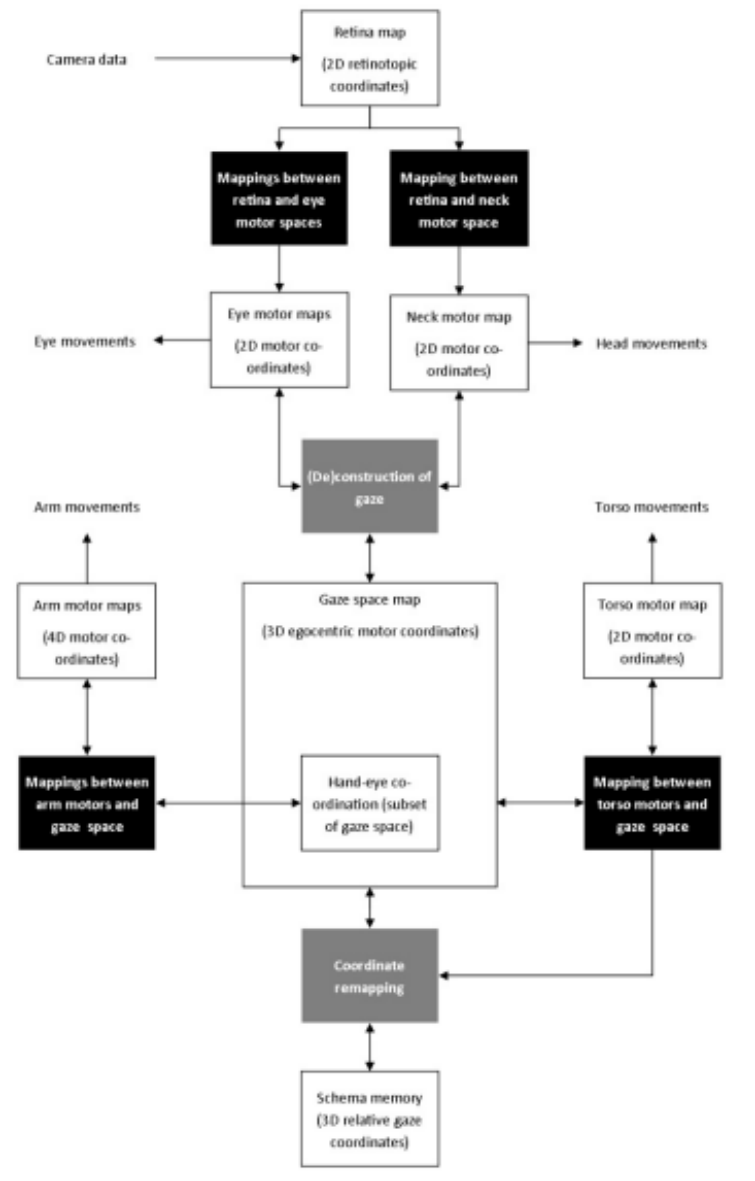
- “Lift” the previous constraints and proceed to next stage
- “Constraints” to structure the stages (developmental timeline)
- “Act” within the constraints to increase competence and knowledge (play generator)
- “Saturate” the learning at this developmental stage (bidirectional links)



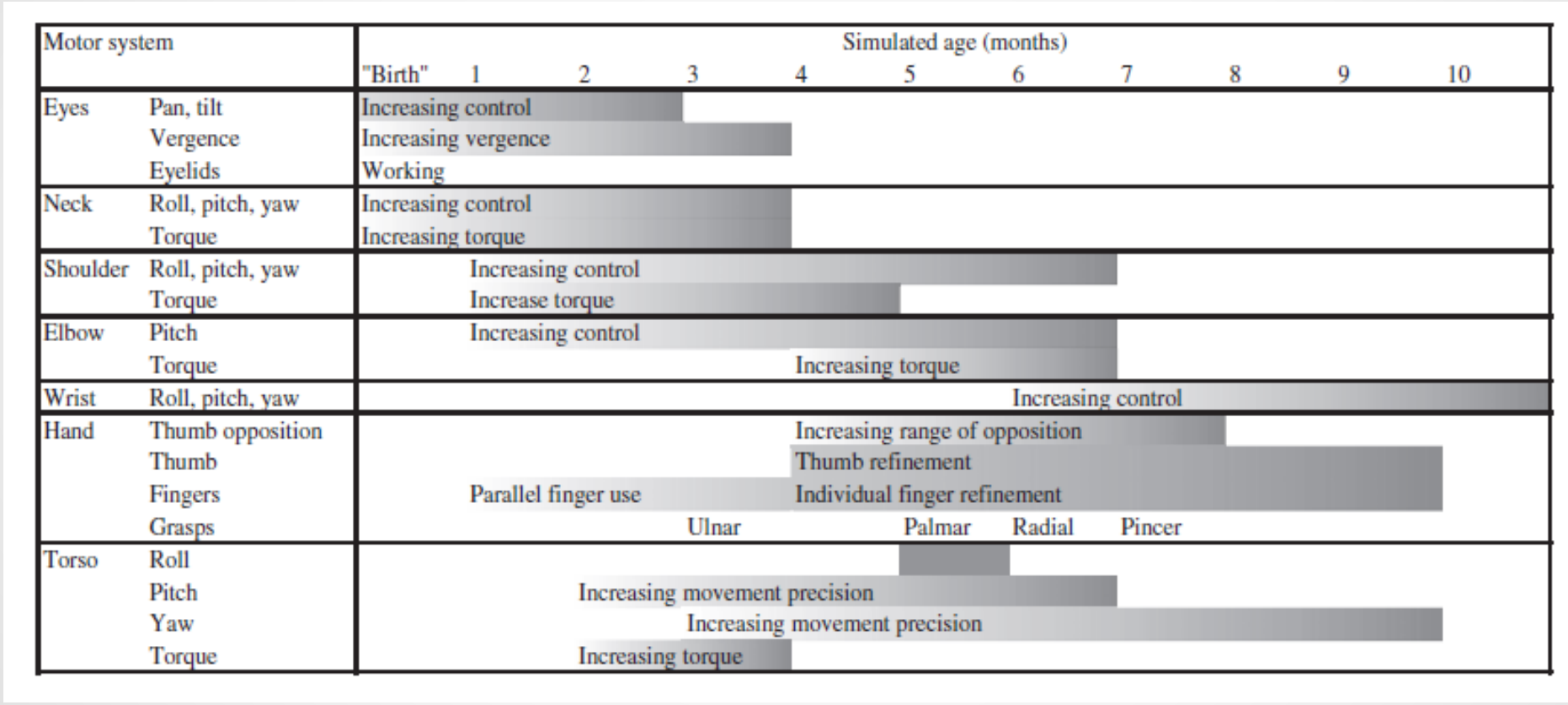
From a limited repertoire of stereotyped behaviours to complex refinement, compositions, differentiation, modularisation of sensorimotor schemas
(from Guerin, Krüger and Kraft, 2013)

=> Cost: Sub-optimality
=> Benefit: Tractability / Transparent

Incremental learning of space representation



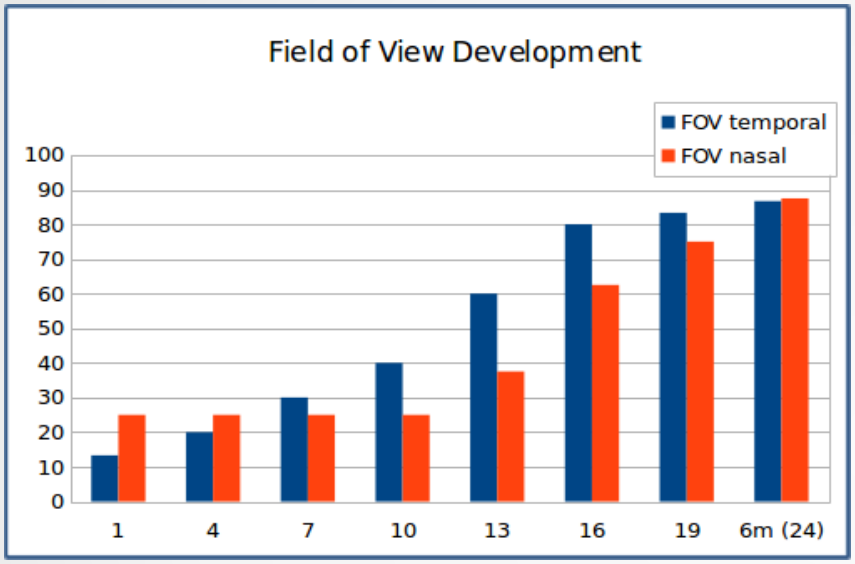
Motor constraints

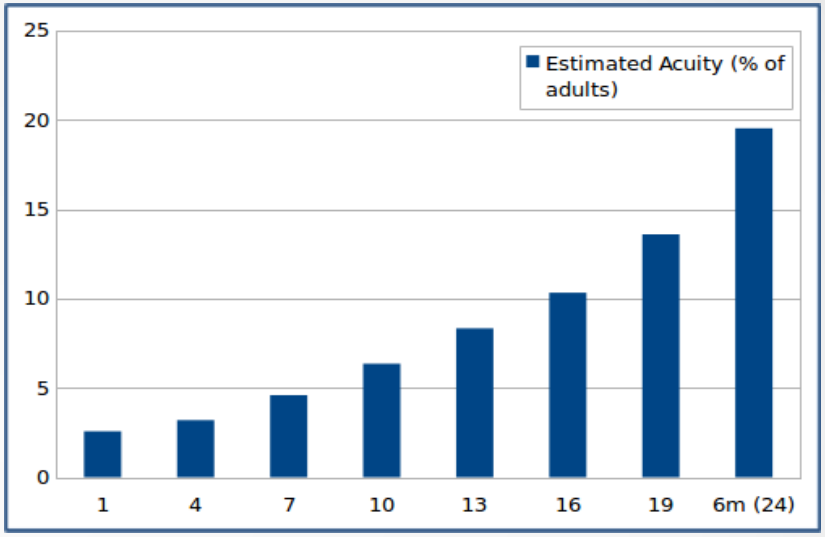


Incremental learning of space representation

body relative to world

Sensory constraints for perceptual development





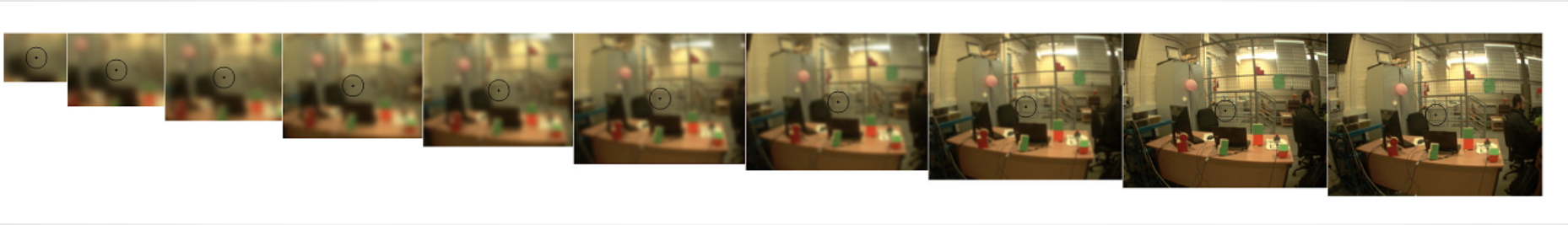
The importance of constraints

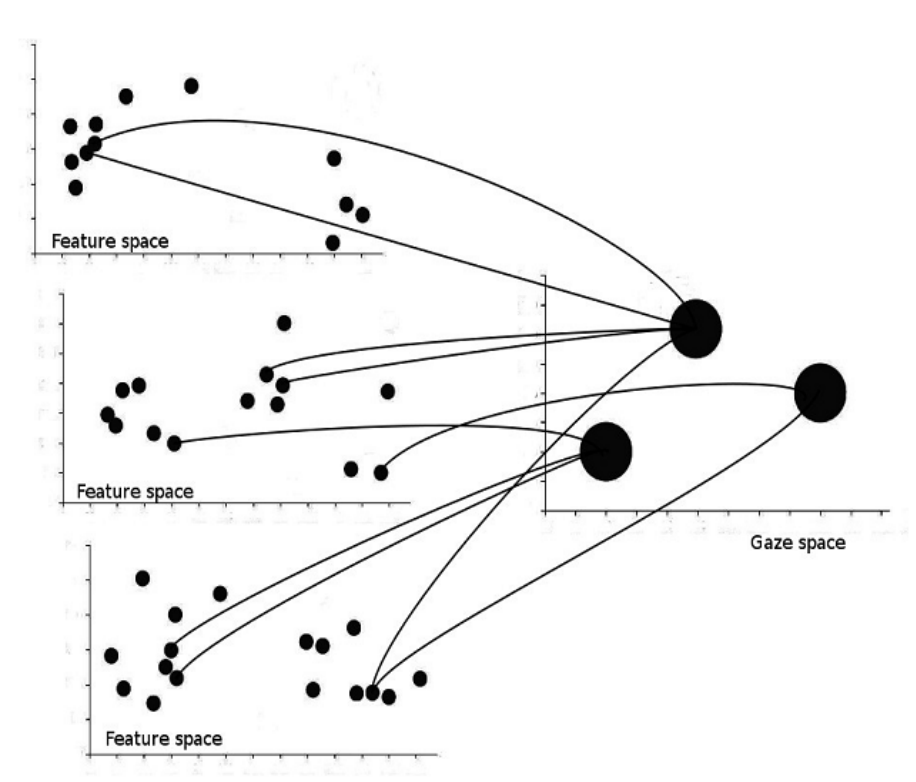
- Scaffolding
- Bandwidth reduction
- Degrees of freedom reduction

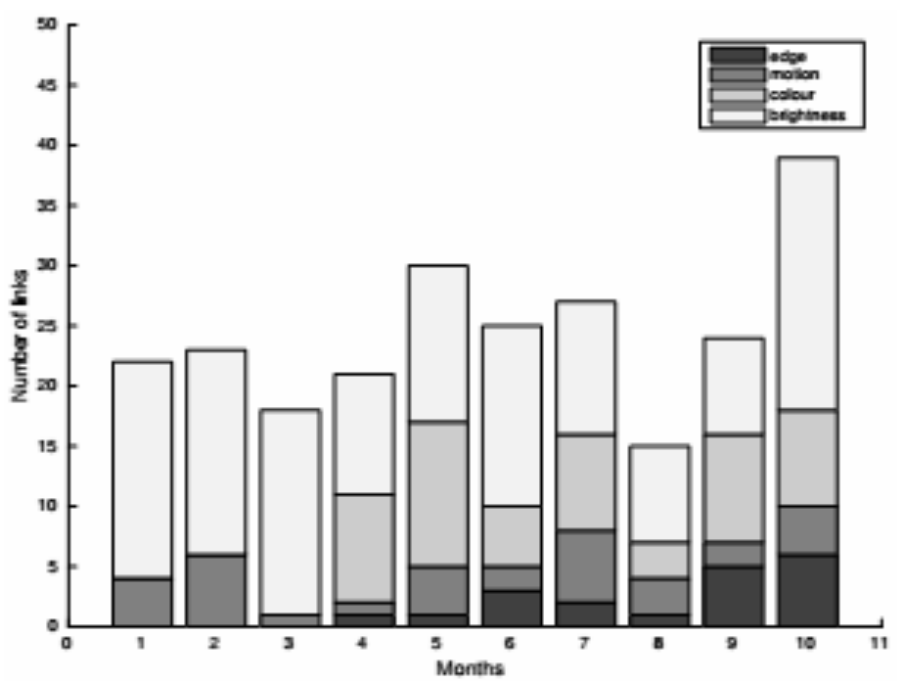
Many forms of constraints are possible:

- Physical - morphology, mechanical, motor
- Internal - cognitive, sensory, neural, maturational
- Environmental - external, scaffolding, social.

Collecting object data during sensorimotor learning







The Team

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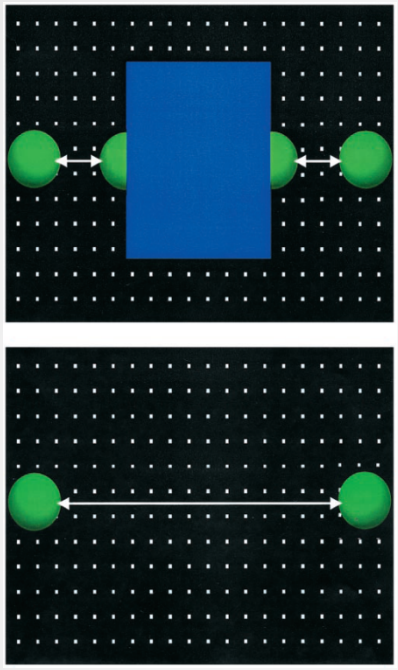
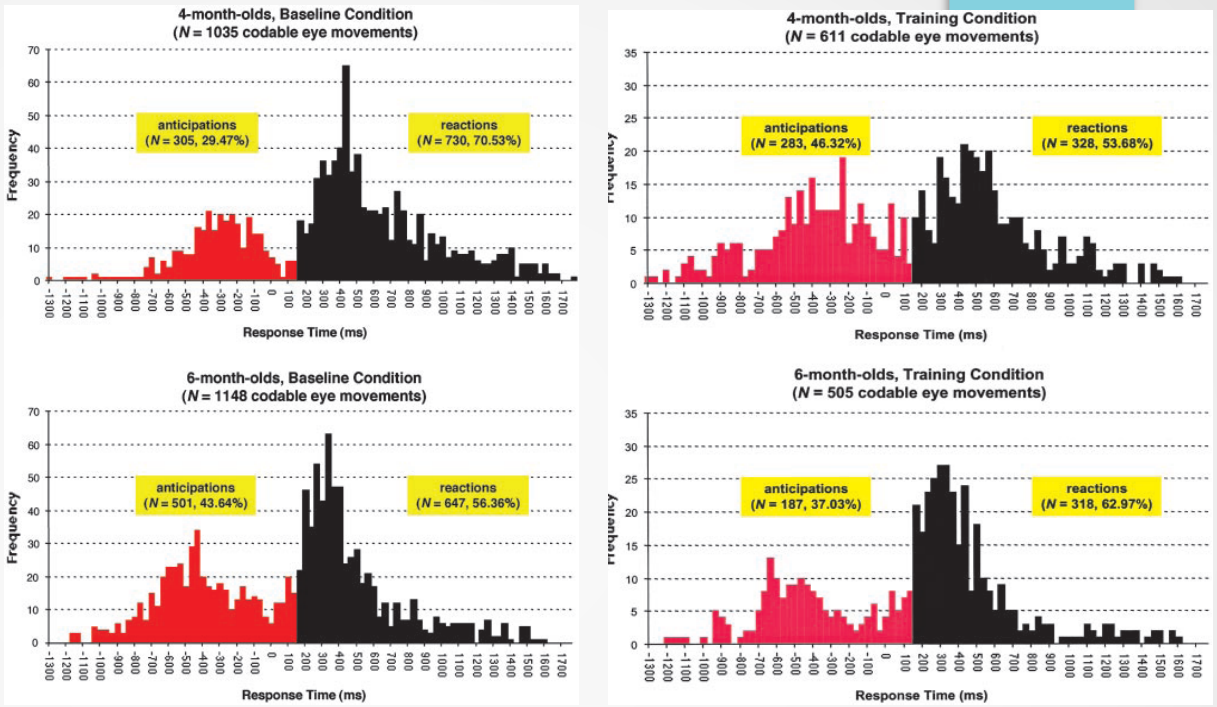
PRIFYSGOL ABERYSTWYTH UNIVERSITY

Thanks !

Variations in developmental trajectories





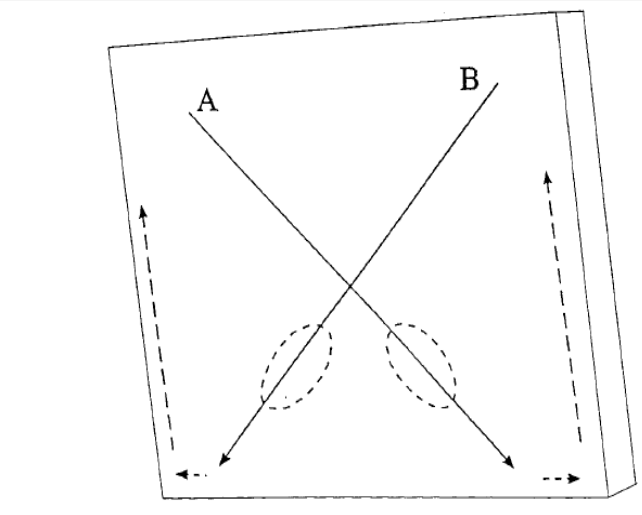
Johnson, Amso & Slemmer (2003)

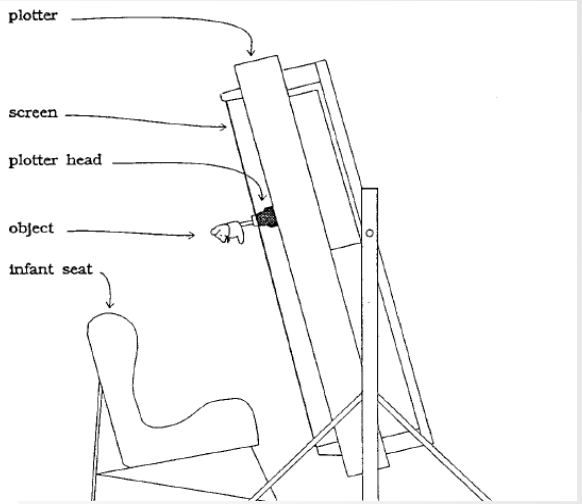
Anticipations can be learn through associative mechanism (similarity of fully visible and occlu

6month old already have it (sufficient exposure to occlusions and generalisation to new obje

Evaluate against psychological benchmarks (6month)

- Predictions for tracking and reaching
- Linear vs sudden change in direction or stop





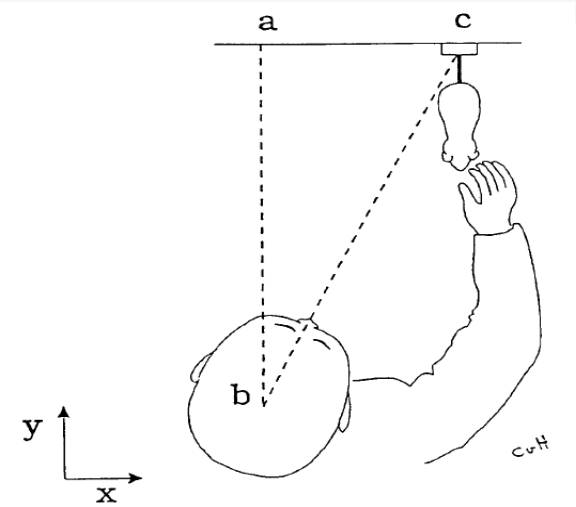
Results :

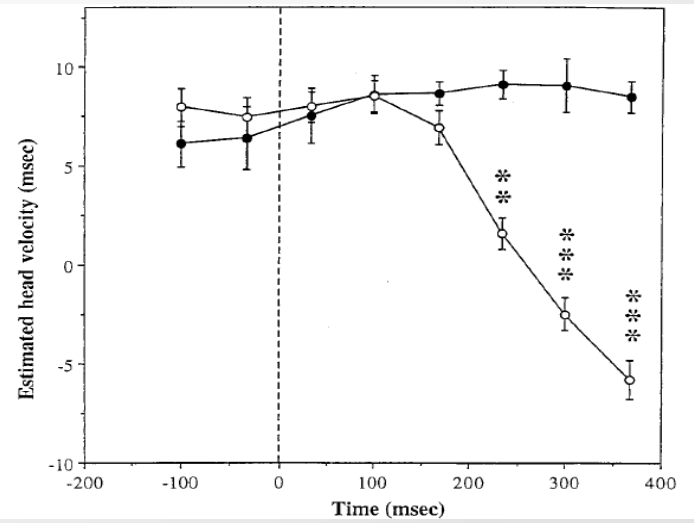
Head continue to move 200ms after stop

Reaches to the side of the display where the object would enter reaching space up to 300ms after the object stopped and turned

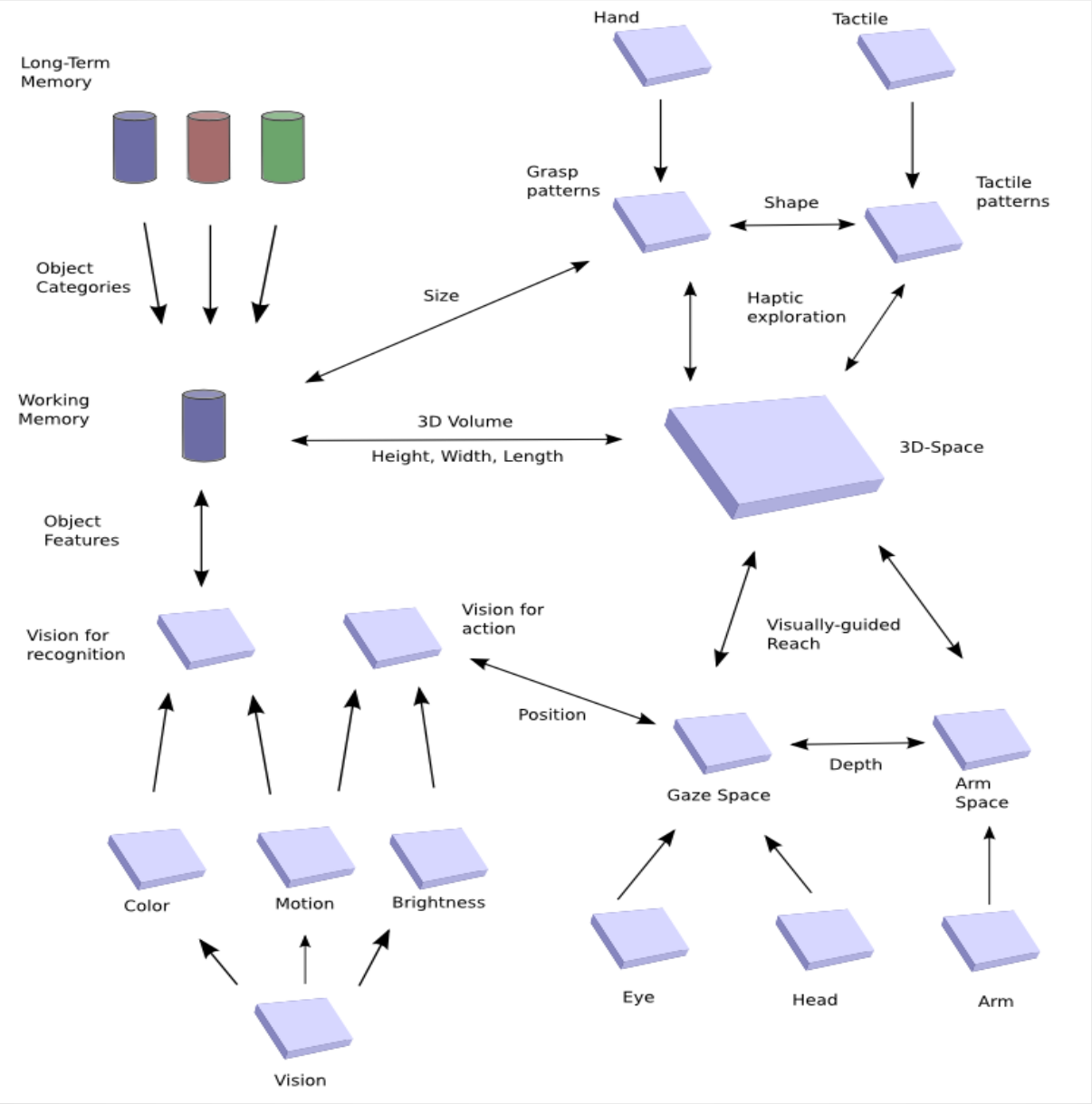
=> actions are prospective by extrapolating object motion on linear paths.

(from von Hofsten and al. 1998)





General Overview



Propriétés du système visuel

- Modèle

Développement d'une mémoire de travail visuelle

Propriétés prospectives

Propriétés retrospectives

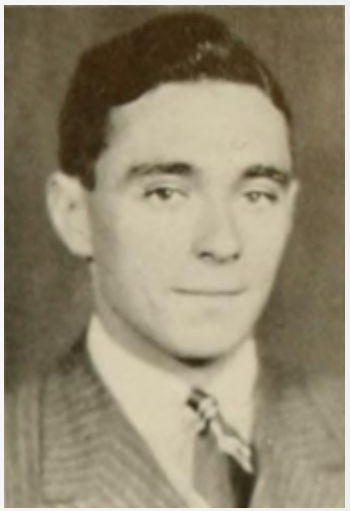
Why “Developmental” Robotics ?

Jean Piaget (1896 – 1980)
“Constructivist theory of knowing”

=> Each child is different

Lev Vygotsky (1896 – 1934)
“Zone of proximal development”

=> Difference between what you can do and what you can do with help



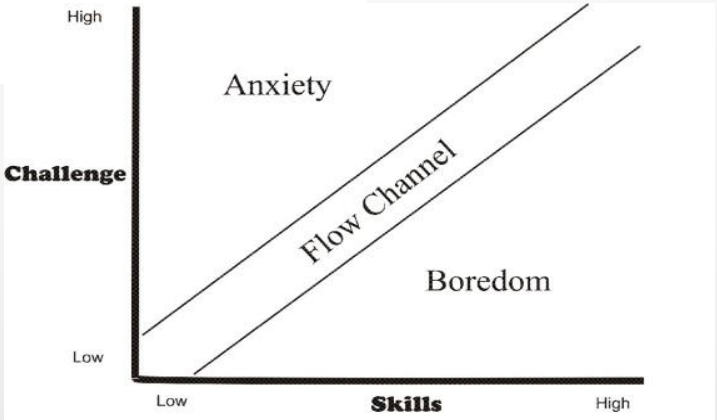
Jerome Bruner (1915 - ?)
“Instructional Scaffolding”

=> Concepts exists before you (cultural heritage)
=> from enactive to iconic to symbolic

How to “improve” learning ?

Direction Maintenance (support students' metacognitive activities)	Keeping the learning on target and maintaining the learner's active engagement with a particular goal
Explanatory and belief structures (support students' cognitive activities)	The teacher provides the underlying complexity of the structure
Reducing the degrees of freedom (support students' cognitive activities)	taking over the parts of the task that are more complex so the student can complete the task.
Recruitment (support of student affect)	getting students interested in a task and helping them adhere to the requirements of the task
Contingency management (support of student affect)	using a system of rewards and punishments to facilitate student performance and keeping students motivated

Feedback	providing information regarding the student's performance to the student him or herself.
Giving hints	providing clues or suggestions but deliberately does not include the full solution
Instructing	the teacher tells the students what to do or explanation of how something must be done and why
Explaining	provision of more detailed information or clarification by the teacher
Modeling	offering behavior for imitation, including demonstrations of particular skills
Questioning	asking students questions that require an active linguistic and cognitive answer.



The Flow. After Mihaly Csikszentmihalyi, *The Flow (1990)*, p. 74

But...

Piaget's stages

PIAGET'S HIERARCHICAL THEORY OF SENSORIMOTOR DEVELOPMENT

Stage I: Reflexes
Age: Birth to 6 weeks
e.g. sucking

Stage II: Primary circular reactions
Age: 6 weeks to 4 months
First acquired habits, e.g. thumb sucking

Stage III: Secondary circular reactions
Age: 4 to 8 months
Goal-directed behaviour, e.g. visually guided reaching to objects

Stage IV: Co-ordinated secondary circular reactions
Age: 9 to 12 months
Differentiation of means and ends in intentional acts, e.g. searching for a hidden object

Stage V: Tertiary circular reactions
Age:12 to 18 months
Application of established means to new ends, e.g. in the bath, baby squeezes water from a sponge, pours water from a can, holds water carefully in a basin, and studies the water falling under different conditions

Stage VI: Symbolic representation
Age: From 18 months
Mental combinations of means and ends
Insightful discovery of new means through active experiment, e.g. toddler pulls an object through playpen bars using a stick. Toddler has concepts of object, space, time, and causes

Typical errors

- Conservation tasks (focus on a single dimension)
  - Number
  - Length
  - Liquid
  - Mass
  - Area

Some interesting proprierties