F11

Cognitive Systems

2020 edition

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PSI 3560 – COGNITIVE SYSTEMS

class F11

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EVOLUTION AND DEVELOPMENT

Life and the emergence of cognition, developmental aspects of cognition

Session F11

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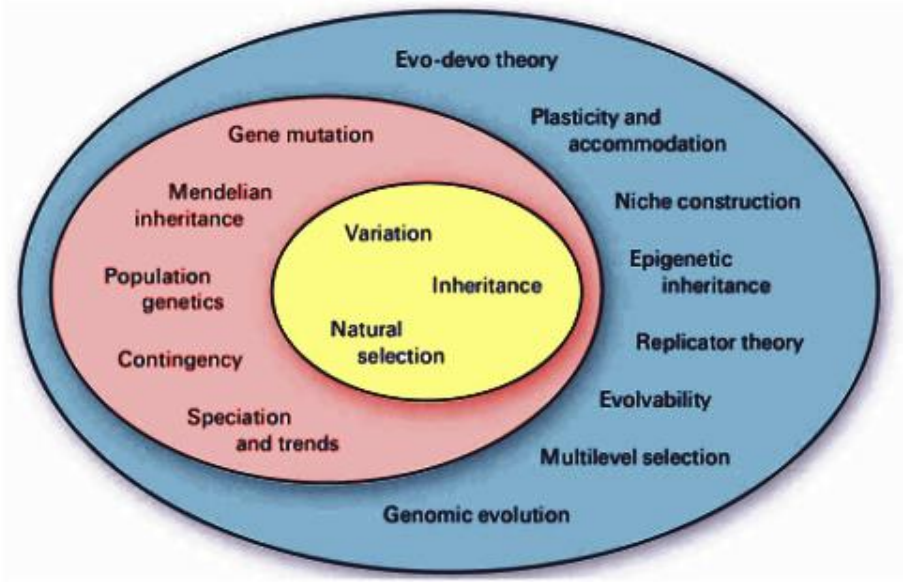
Summary

  - Second session (9:20 – 11:00)

- Evo-Devo
- Developmental aspects of cognition
  - Nativist models
  - Associationist models
  - Constructivist models
  - Sociocognitive models
  - Neural basis of cognitive development
  - Adolescent brain

Evo-Devo and Cognition

- The arise of cognition
  - Evolutionary questions
    - How did cognition begin (among species)
  - Developmental questions
    - How does cognition begin (in an individual)



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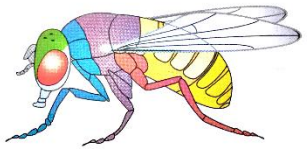
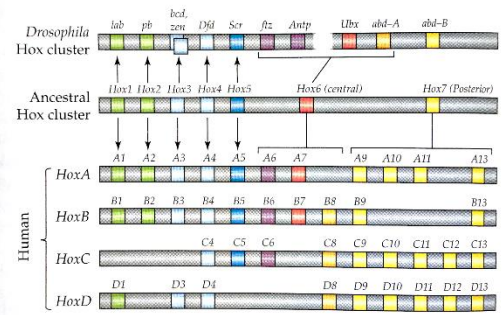
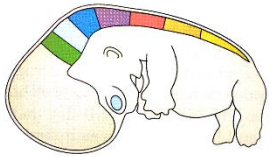
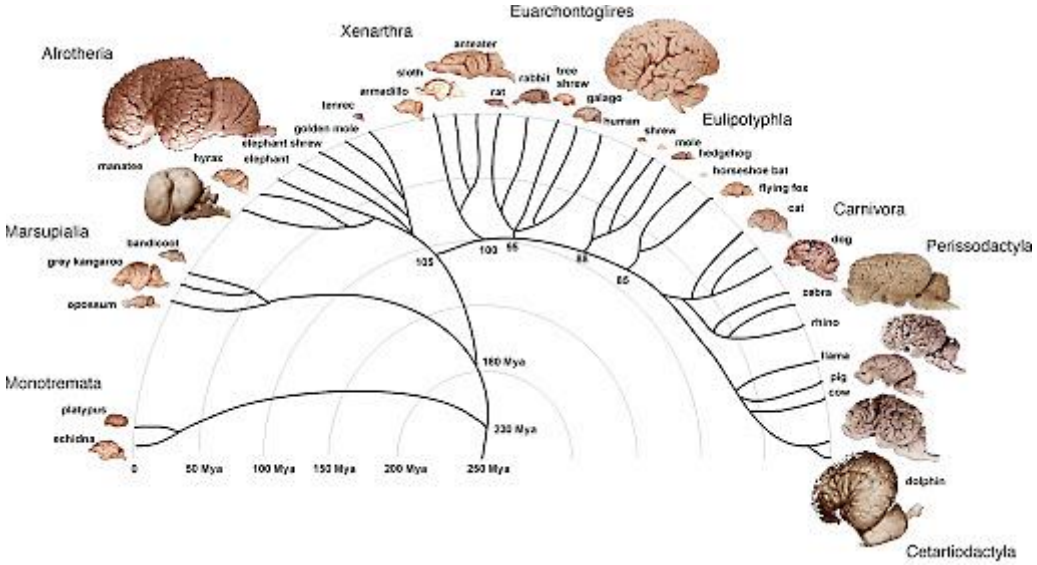
Evo-Devo and Cognition







- The arise of cognition
  - Evolutionary questions
    - How did cognition begin (among species)
      - Which currently existing animals have cognition ?
      - What past animals had cognition ?
      - How cognition appeared during the evolutionary process ?
      - How the results of evolution of cognition are expressed in our genes ?



Evo-Devo and Cognition

- The arise of cognition
  - Developmental questions
    - How does cognition begin (in an individual)
      - How genes regulate the unfolding of cognition ?
      - How the cognitive functions develop with the nervous system ?
      - How does cognition develop from infancy to adulthood ?

Developmental aspects of cognition

- Possibilities
  - Cognitive features are innate and just expand
  - Cognitive features emerge from experience
  - Cognitive features are constructed following steps
  - Cognitive features are acquired via social interactions

Developmental aspects of cognition

- Possibilities → Theories

  - Cognitive features are innate and just expand

    Nativist models
  - Cognitive features emerge from experience

    Associationist models
  - Cognitive features are constructed following steps

    Constructivist models
  - Cognitive features are acquired via social interactions

    Sociocognitive models

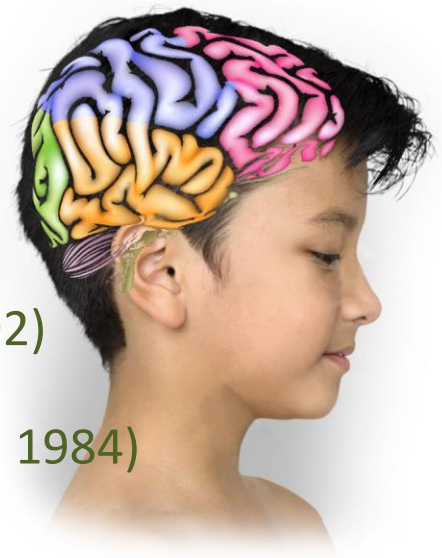
Nativist models

- Chomsky theories
  - Generative grammar (Chomsky, 1959)
    - Chomsky rejected the idea that the child learns grammar by imitating sentences heard
    - All the child's abilities in grammar must be inborn, in the form of
      - **Innate rules** coded in the genes
      - and biologically inherited
  - Cognitive competence theory (Chomsky, 1980)
    - Children must present early cognitive competency
      - Acquiring complex knowledge requires ability to restrict the range of hypotheses about the structure of what is learned
        - » Thus it implies that the child should be endowed with the competence to set the suitable *a priori* constraints

Nativist models

- Chomskian view
  - Based on Plato's argument: **poverty of stimulus**
    - Perception brings only contextualized information
    - Cognition must go beyond and transcend experience
      - Cognition must bring "**universals**" of structure and form
      - These were brought by natural selection
      - They play similar role as the idea of universal grammar for 'anguage
        - » "How could uniformity of structure arise from disparate experiences of children around the world ?" (Chomsky, 1980)

Nativist models



- Essential ideas on nativist models
  - Basic competences are innate
    - They manifest as a basic innate kernel (Klahr, 1992)

      or
    - They appear as multiple "intelligences" (Gardner, 1984)
  - Cognition (mind) is modular (Fodor, 1994)
    - The modules relate to the basic competences
    - The modules are innate
    - They just develop in the sense of growing, expanding
      - They don't undergo adaptations or structural changes
        - » The modules are like "mind organs"
      - Adult thinking is seen as qualitatively similar to that of the child
        - » Development is seen as just quantitative
          - Expansion of knowledge structures and
          - Increase in the efficiency of modules
    - They modules correspond to universals of structure and form in cognition

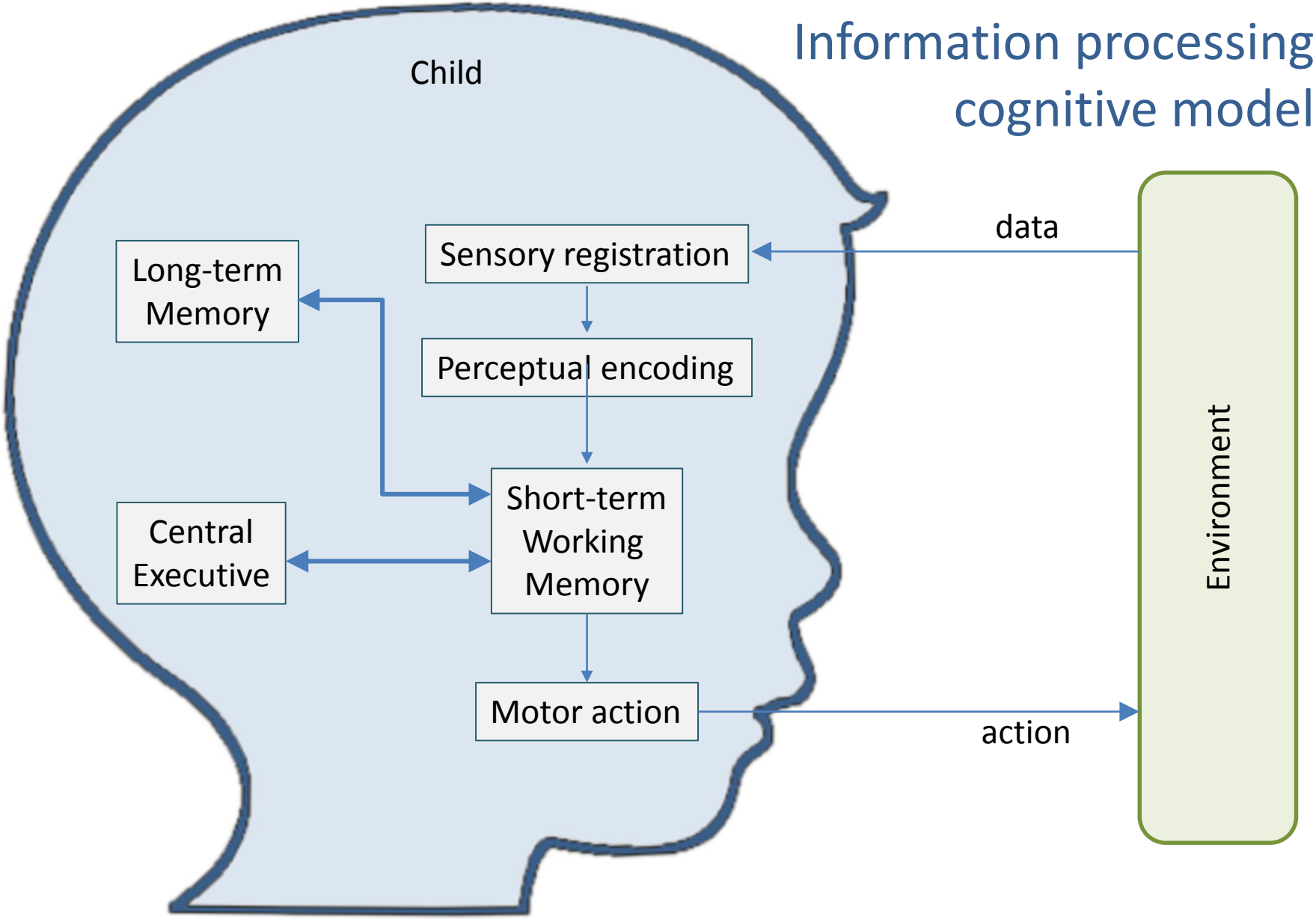
Nativist models

- The innate kernel (Klahr, 1992)
  - Taken as evolutionary product
  - Cognitive processes basic components
    - Encoding, mapping, evaluation, applying, response-production
    - Basic conceptualization: beliefs, recognition of kinds, categorization
    - Inference: logical rules, pragmatic schemas, mental models
  - Face processing / recognition
  - Voice recognition
  - Encoding images into vocalizations
  - Detection of causal relationships

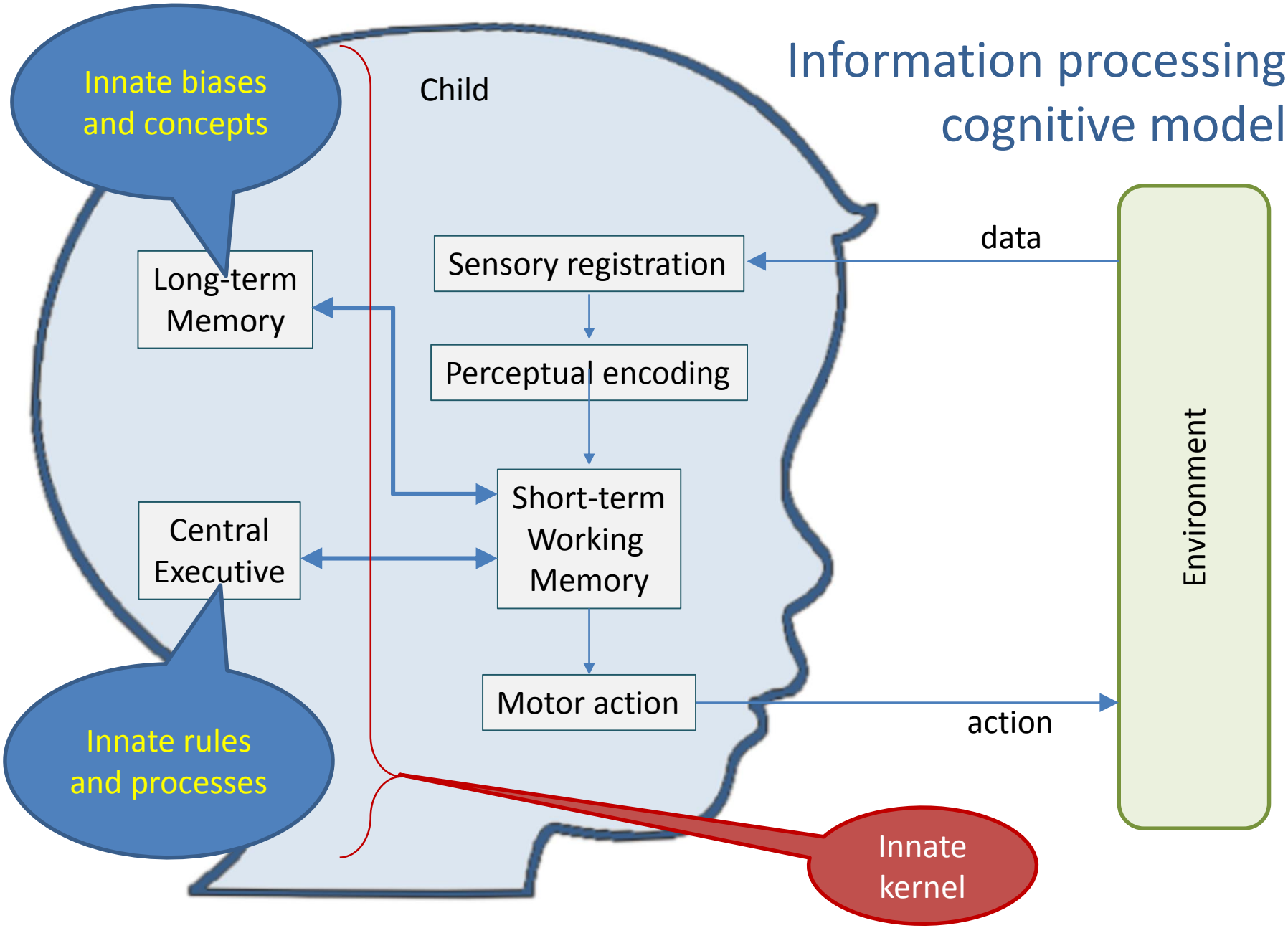
Nativist models

- Multiple intelligences (Gardner, 1984)
  - Genetically programmed modules
    - Activated or triggered by certain kinds of internally or externally presented information
    - Subject to some developmental flexibility
    - Amenable to cultural specialization
    - Capable of learning and accessible to education
  - Kinds of intelligences
    - Linguistic, musical, logico-mathematical, spatial, bodily kinesthetic, personal

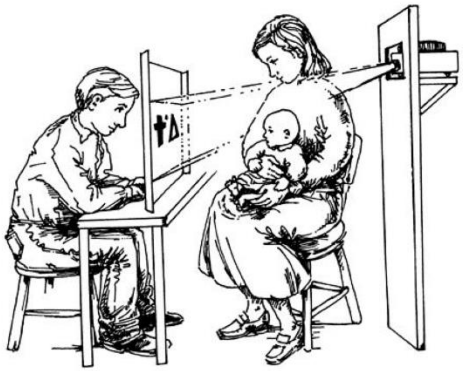
Information processing cognitive model



Information processing cognitive model



Nativist models



- Experimental studies

  (Gelman, Carey, Spelke, Ballairgeon, *et al*)

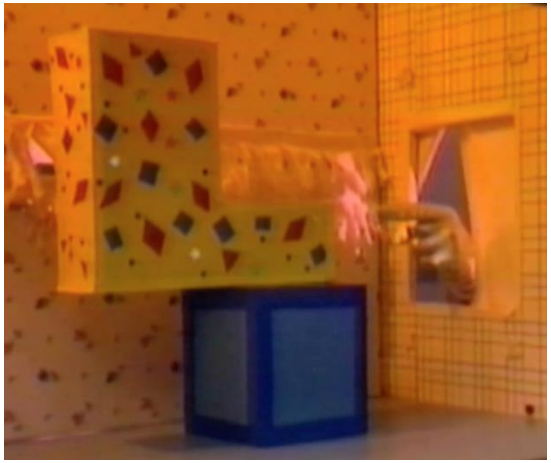
  - Investigations of deep ontological structures in concepts
  - Essentialism:
    - Humans are born with a bias for thinking that things that are superficially similar are alike in deeper, more principled ways, however are sensitive to the essential aspects
      - Ex (Carey, 1982,1985): humans have liver, so what has also:
        - » A mechanical monkey ?
        - » A worm ?
          - The essential aspect is to be alive

Nativist models

- Object permanence
  - Renee Baillargeon
    - Very young children are able to deal with object permanence laws
      - If the baby doesn't know that objects are permanent, she would not be surprised by the experiment of sudden disappearance of the doll
        - » But she is…

Nativist models

- Physical primitives
  - Renee Baillargeon
    - There are circuits in the brain that enable to deal with primitive physical properties
    - The resulting behavior cannot be explainable only in terms of nurture



Associationist models

- Origins
  - Ancient Greece
    - Plato (nativist) → knowledge is abstract ideas, derived from original concepts of divine origin
    - Aristotle (naturalist) → knowledge can be derived from experience
  - Empiricists (17th, 18th centuries)
    - Locke → *tabula rasa* (no innate a priori concepts or rules), just reasoning processes
    - Hume → rationalism: knowledge originated from reasoning and associations

Associationist models

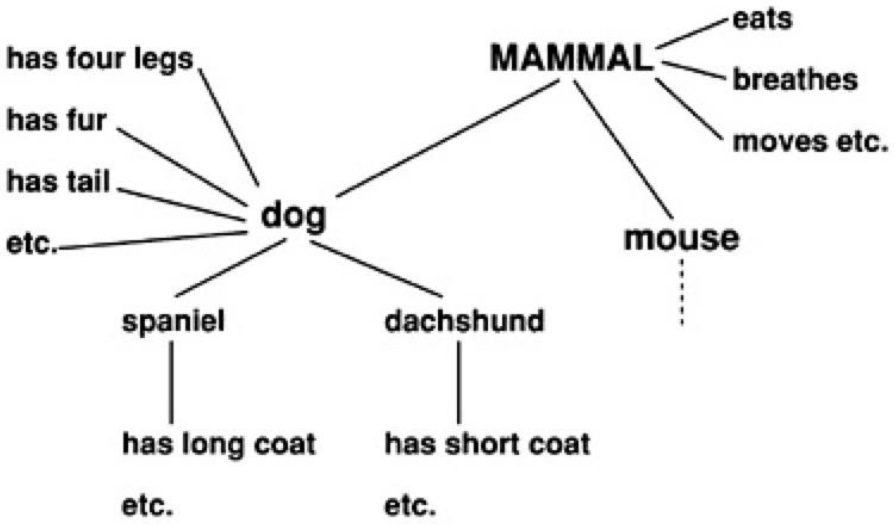
- Modern associationists
  - Dual systems
    - Innate faculties for abstracting information
    - The abstracted information consists of associations

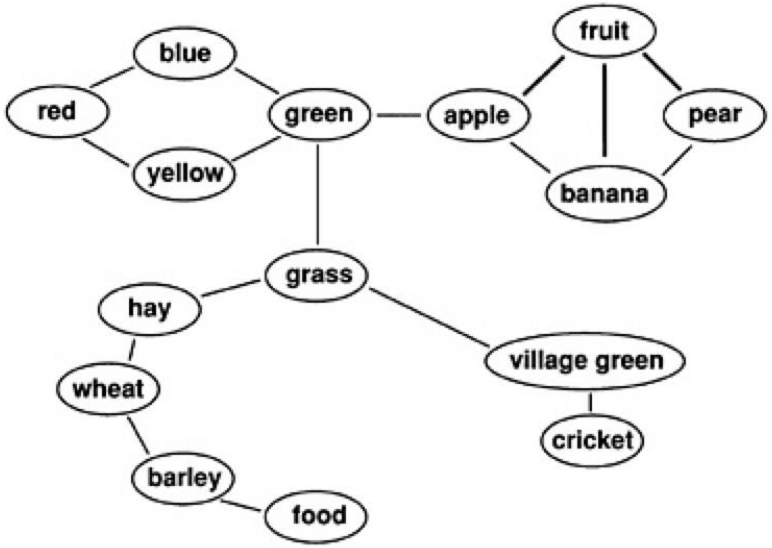
    - Associations between "sensory qualities" grounded in experience:
      - Images (mental imagery)
      - Symbols
      - Concepts
      - Propositions

    - Innate base → set of processes and primitive concepts to deal with sensory qualities.

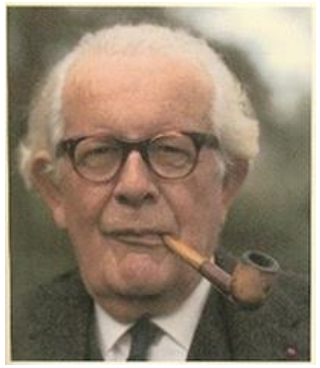
Associationist models

- Semantic networks (Quillian, 1969)
  - Co-occurring parcels of information are interconnected nodes in an abstract network
    - Development consists in the construction and expansion of the network, starting from the innate base





Constructivist models

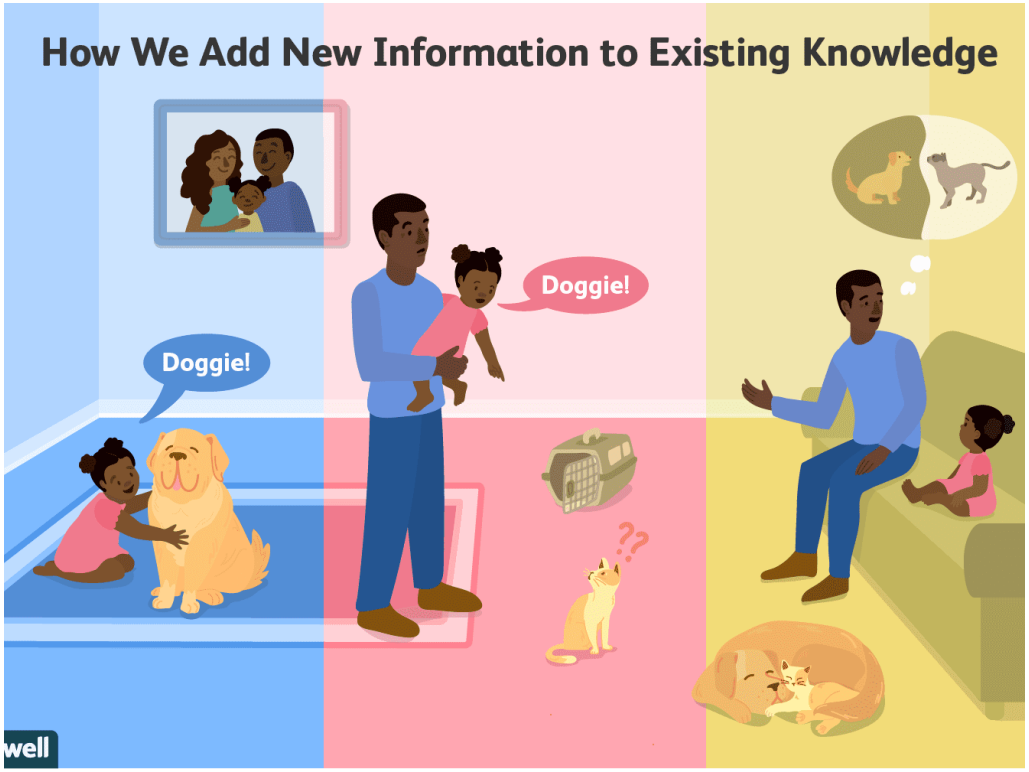


- Piaget's theory
  - Genetic epistemology
    - Development proceeds through qualitative changes that occur in well defined ordered stages
    - Piaget defended that the stages occur at characteristic ages of the child
    - The qualitative changes take place by means of transformations on schemas
      - Schemas
        - » Schemas are categories of previous knowledge or proto-knowledge, that help understanding the world.

Constructivist models

– Schemas

- Schemas are categories of previous knowledge or proto-knowledge, that help understanding the world.
  - – Ex: early conception of quadrupeds as dogs
    - » Dog is a proto-knowledge, a previous knowledge the child had.
    - » Then cat appears as a kind of dog, until the schema is updated to differentiate cats and dogs.
    - » Then the idea of quadruped starts to emerge.



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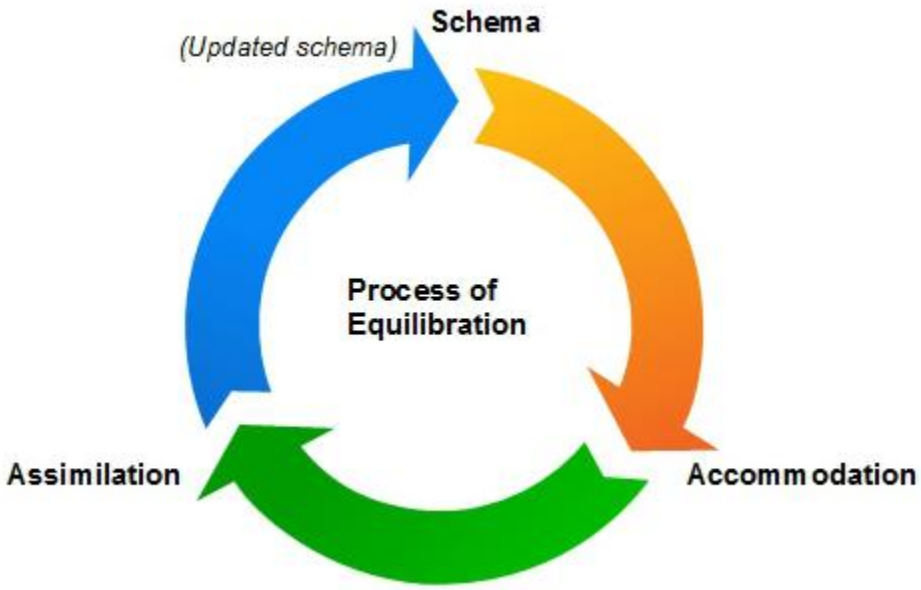
Constructivist models

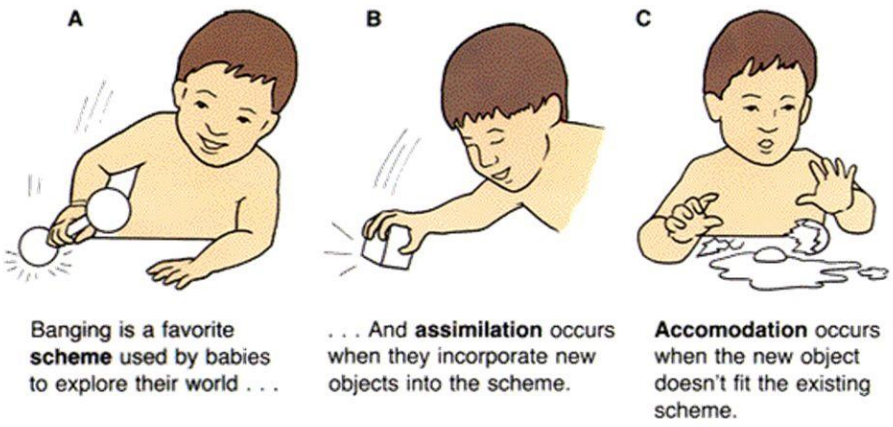
- Piaget's theory
  - Genetic epistemology
    - Processes on schemas
      - Assimilation
      - Accommodation
      - Equilibration



Constructivist models

- Piaget's theory
  - Genetic epistemology
    - Processes on schemas
      - Assimilation
        - » The process of taking new information into already existing schemas
          - Ex: seeing a new dog and assimilate it in the dog schema
        - » Adapt the experiences to fit into preexisting beliefs
      - Accommodation
      - Equilibration

Constructivist models

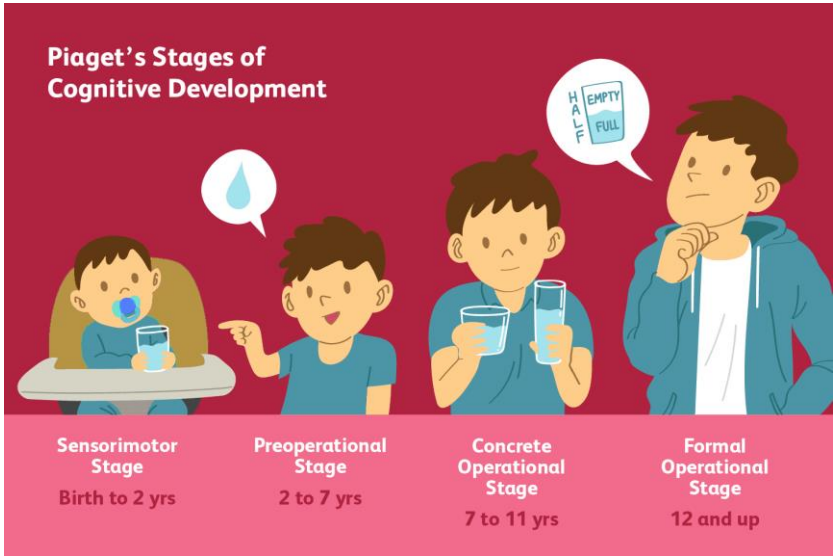


- Piaget's theory
  - Genetic epistemology
    - Processes on schemas
      - Assimilation
        - » The process of taking new information into already existing schemas
        - » Adapt the experiences to fit into preexisting beliefs
      - Accommodation
        - » The process of changing or altering schemas when the new information doesn't fit the belief
        - » Instead of adapt the experience, it changes behavior.
          - Ex: including the dog and cat schema in a new category of quadrupeds.
      - Equilibration

Constructivist models

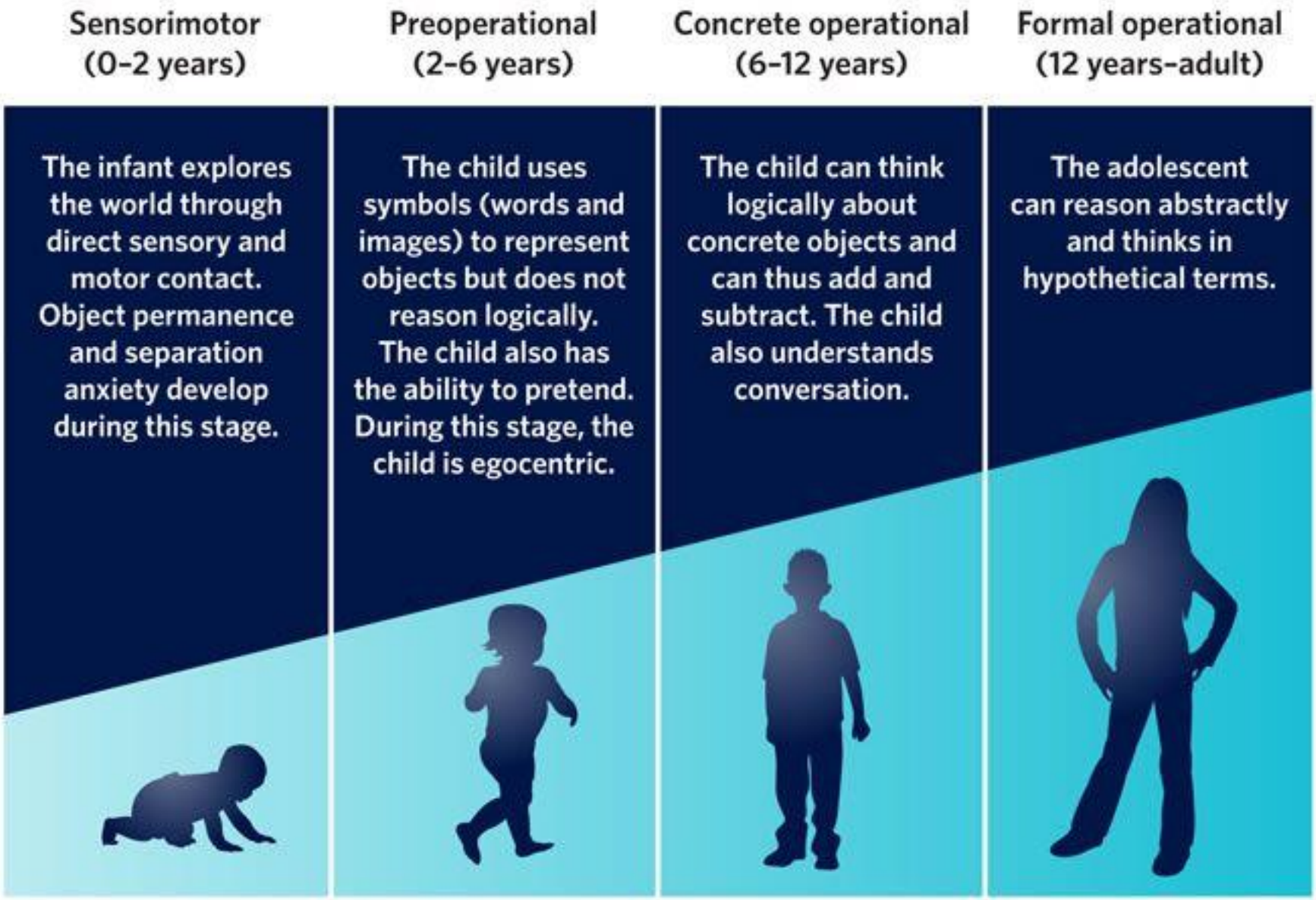
- Piaget's theory
  - Assimilation
    - » The process of taking new information into already existing schemas
    - » Adapt the experiences to fit into preexisting beliefs
  - Accommodation
    - » The process of changing or altering schemas when the new information doesn't fit the belief.
      - Ex: including the dog and cat schema in a new category of quadrupeds.
  - Equilibration
    - » The process of providing a balance between applying previous knowledge (assimilation) and changing behavior to account for new knowledge (accommodation).
    - » Equilibration helps explain how children can move from one stage of thought to the next.

Constructivist models



- Piaget's theory
  - Jean Piaget's theory of cognitive development suggests that children move through four different stages of mental development:
    - Sensorimotor stage: birth to 2 years
    - Preoperational stage: ages 2 to 7
    - Concrete operational stage: ages 7 to 11
    - Formal operational stage: ages 12 and up
      - The theory focuses not only on understanding how children acquire knowledge, but also on understanding the nature of intelligence.

Constructivist models



1-Piaget Theory: Sensorimotor Stage (children 0-2)

- This developmental stage is characterized by how the child understands the world, bringing together sensory experience with the physical activity.
- This is the period where the child improves innate reflexes.
  - Children at this age like bright, shiny, moving stimuli with lots of contrast.
  - They construct schemes by trying to repeat an action with their own body, like making noise by hitting their toy, throwing something, or moving a blanket to get something that's on top of it.
  - At this age, children repeat actions randomly, experimenting with their own bodies.
  - During the first few months of life, their communication will be primarily pre-linguistic, using smiles and crying involuntarily. These actions will later become voluntary when they learn to use them in a communicative manner. However, the parents are able to understand a cry or a smile from their baby, making it an unintentional form of communication. At about 6 months, the baby will learn to babble and make consonant-vocal sounds like "da da da". The first appearance of words is at about 12 months.

1-Piaget Theory: Sensorimotor Stage (children 0-2)

- Piaget Theory during this stage establishes six sub-stages that are:

1. Simple reflexes: From birth to 6 weeks the baby will have three primary reflexes (sucking of objects in the mouth, following moving or interesting objects with the eyes, and closing of the hand when an object makes contact with the palm) As time goes by the reflexes will become voluntary actions.
2. First habits and primary circular reactions: From 6 weeks to 4 months the child is now starting to be more aware and classical and operant conditioning begins in this phase. Imitation or reproduction of certain reactions with his own body begin.
3. Secondary circular reactions: From 4 to 8 months the child starts to develop habits, they are more object-oriented, repeating actions with a purpose that bring pleasurable results. He can now reproduce certain reactions but with external objects.
4. Coordination of secondary circular reactions: From 8-12 months the child consolidates hand-eye coordination and intentionality. His actions are now goal-oriented.
5. Tertiary circular reactions, novelty, and curiosity: From 12-18 months, the infant start exploring and investigating objects that intrigue them. It's the stage of discovery to meet new goals. Piaget called this stage the young scientist.
6. Internalization of schemas: From 18-24 months the infant can now use primitive symbols to form lasting mental representations. It is when the creativity stage begins and gives passage to the preoperational stage.

2- Piaget Theory- Preoperational Stage (2-7 years-old)

- Schooling generally starts at about 3 years-old, which brings about an important social change and causes significant social development.
- The child will start relating to other children and people, especially peers. Before this age, the interaction was generally with family.
  - While between the ages 3-7 the child will largely expand their vocabulary, they are still guided by an "egocentric thinking", meaning that the child will think according to their individual experiences, which makes their thinking and thoughts starts, intuitive, and lacking logic. This is why children until the age of about 6 will misunderstand events and will have trouble expressing them.
  - Talking in the third person is very common in this stage because children still don't fully understand the concept of "I" or "me" that separates them from the rest of the world.
  - Children between 2-7 will be curious and want to learn, which is why they so often as "why".
  - Children of this stage often give human characteristics or feelings to objects. This is called personification.

3- Piaget Theory: Concrete Operational Stage (7-11 years)

- The second-to-last stage of Piaget Theory is when children start to use logic thinking, but only in concrete situations.
- It is at this stage that the child will be able to do more difficult and complex tasks that require logic, like math problems.
- However, while their ability to use logical thinking has advanced, their logic may have certain limitations during this period: the “here and now” will always be easy.
- Children at this age will still not use abstract thinking. In other words, they will be able to apply their knowledge to a subject that they don’t know, but it’s still difficult at this age.

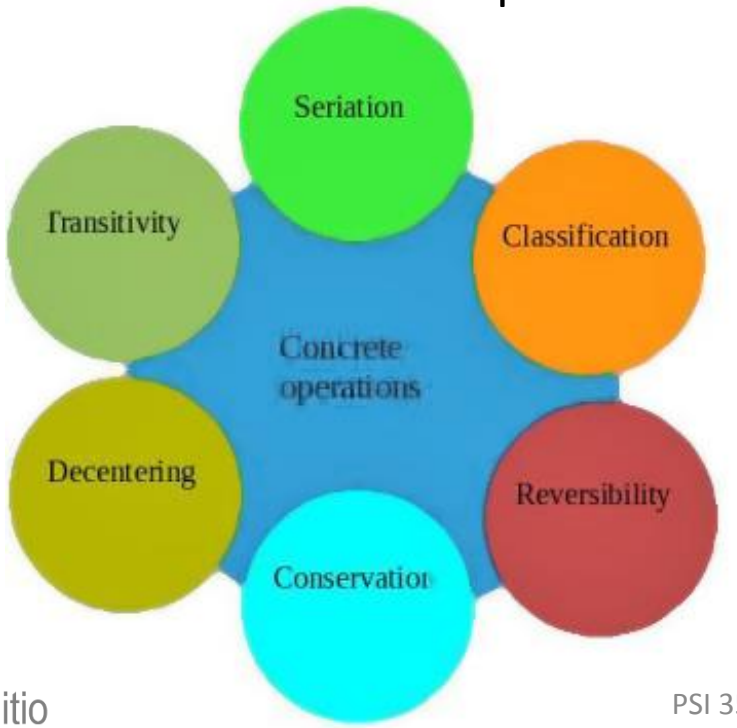
3- Piaget Theory: Concrete Operational Stage (7-11 years)

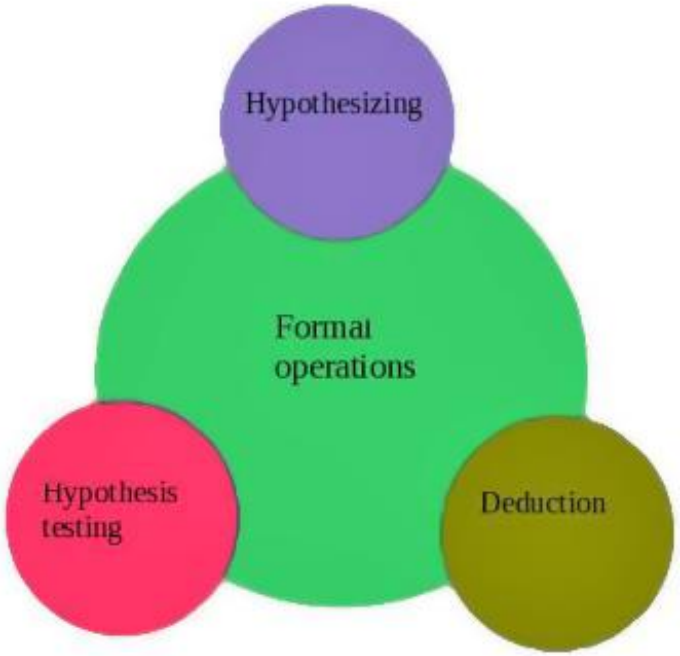
- Conservation: it is the understanding that something stays the same quantity even though its appearance changes. Watch the following video for examples on how to test conservation.
- Classification: It is the ability to identify the properties of categories, to relate categories or classes to one another, and use the categorical information to solve problems. For example, group objects according to some dimension they share.
- Seriation: The ability to mentally arrange items along with a quantifiable dimension, such as height or weight.
- Reversibility: The ability to recognize that numbers or objects can be changed and returned to their original condition. For example, during this stage, a child understands that a favorite ball that deflates is not gone but can be filled with air again and put back into play.
- Transitivity: The ability to recognize relationships among various things in a serial order. For example, when told to put away his books according to height, the child recognizes that he starts with placing the tallest one on one end of the bookshelf and the shortest one ends up at the other end.
- Decentering: The ability to consider multiple aspects of a situation. For example, a child is given the chance to choose between two candies, he chooses one according to his favorite flavor regardless of the fact they were both the same size and color.

- video

4- Piaget Theory: Formal Operational (11 years and older)

- This last period is characterized by the acquisition of logical reasoning under all circumstances, including abstract reasoning.
- The new aspect of this last period in relation to intelligence is, as Piaget mentions, the ability to hypothesize about something that they haven't learned specifically.
- This is where learning starts to take place as a "whole", rather than a concrete form like in the previous stage.





Developmental aspects of cognition

- Possibilities → Theories

  - Cognitive features are **innate and just expand**

    Nativist models → Cognitive competence theory
  - Cognitive features **emerge from experience**

    Associationist models → Semantic networks
  - Cognitive features are **constructed through stages**

    Constructivist models → Epistemological genetics theory
  - Cognitive features **are acquired via social interactions**

    Sociocognitive models

Sociocognitive models

- Characteristics
  - Non-social models:
    - Focus on autonomy → cognition
      as a mean to improve **autonomy**
    - Explanation of internal processes without the need of the social component
    - Grounding on physical contexts

  - Social models:
    - Explicit dependence on social interactions:
      - » The social interactions explain cognitive development
        - "Think and reason together"
        - Learn through communication
          - Meaning is taken from social contexts

Sociocognitive models

- Social nativism
  - Sociobiological standpoint (Wilson, 1975)
    - Social and cultural scaffoldings coded in the genes
    - Ideal social-Platonism
      - Children mature into the very role that their genetic lot can express for their structuring (programmed developing) socio-cultural scaffoldings
    - Criticism: adaptations on scaffoldings based solely in genetic information tend to be dysfunctional with rapidly changing environments, like social ones.

Sociocognitive models

- Social associationism
  - Social learning theory (Bandura, 1989)
    - Learning by observation, development by imitation
      - Children gain self-knowledge by interaction with others

        - » Perceptions of their own competence
        - » Self-efficacy
          - Disjunction between what a child can do and what she think she can do
            - Children with different levels of self-efficacy belief perform markedly different on the same tasks.
    - Criticism: lack of theoretical sufficiency

      - Can the simple process of association formation explain complex social behavior ?
        - » The evidence of central processes cannot be ignored
      - Brainwashing process → shaping young people so that they can function effectively and constructively in social settings
        - » It would be easily achievable via suitable associations

Superficiality of pure associative social networks

Sociocognitive models

- Social constructivism
  - Developmental dialogic (Vygotsky, Luria, Leontiev)

  - Social tools → patterns of social interaction elicited by tangible instruments or physical interactions
  - Development is from the "outside in"
  - **Dialogical** process (frequently taken as "dialectical" process)
    - » The social interaction leads to confrontation of representations and conceptualizations and an internal conflict as reaction to the patterns currently being internalized.
      - Dialogical processes occur via dialogs → speech
        - First the dialogs occur via acts of pure movement
        - Then actions become interposed with vocalizations
        - Attention is coordinated with vocal actions starting speech
        - Speech is central to Vygotsky's theory

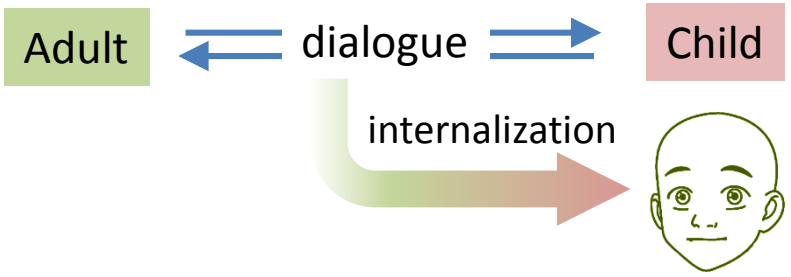
Sociocognitive models

- Vygotsky, language and speech
  - Vygotsky and Luria (1993)
    - Speech behavior in pre-operational children
      - Piaget: no speech (babbling) → egocentric speech → social speech
      - Vygotsky: Instrumental speech → speech as a cognitive tool
        - » Speech is required to carry on a task
        - » Speech is an auxiliary symbol system that helps in representation, interposing between other actions of the child.
        - » Babbling is a proto-language, and has some representative power as other actions.
        - » It's not egocentric. It's thinking out loud and develops as a proto-conversation.
        - » Instead of being an egocentric speech, is a private speech.
        - » It doesn't disappear. It's becomes internalized.

    - Internal speech → builds from "outside in"
      - It's verbal thinking (inner reflection or self-reflection, self-talking).

Sociocognitive models

- Vygotsky's ZPD
  - zone of proximal development
    - Domain between autonomous and assisted performance
      - Depends on the task difficulty and versus child age and competence
        - Assistance must lead to autonomy in the long term
        - The shared knowledge through social interaction must reduce the degree of intersubjectivity

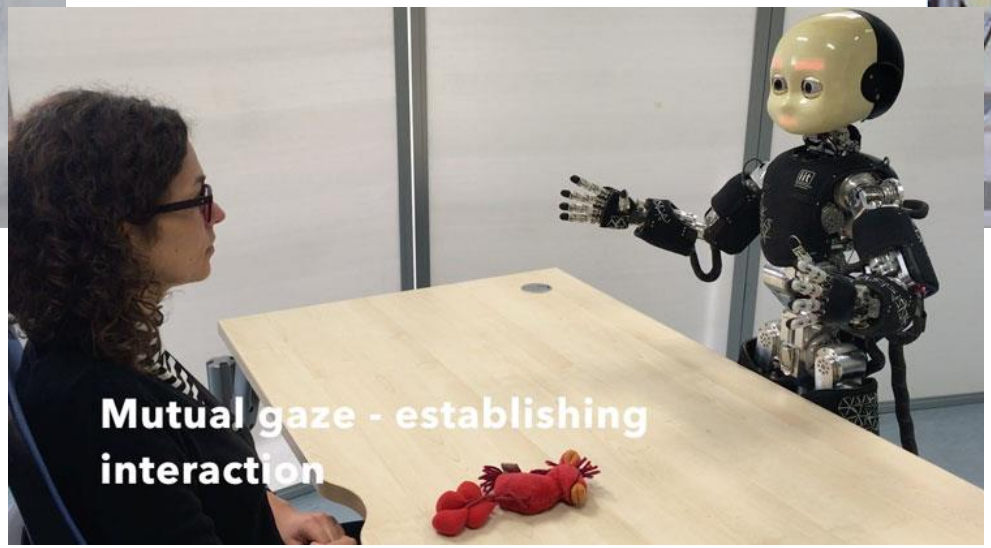


Sociocognitive use of robots with children

- As an intelligent toy, capable of high level of interaction
  - Can be used with protocols based on developmental theories like
    - Vygotsky's zone of proximal development
    - Piaget's tracking of behavioral circularity
  - Applications go from therapy assistance to general health attendance.
  - Future applications consider educational uses at home and in schools.

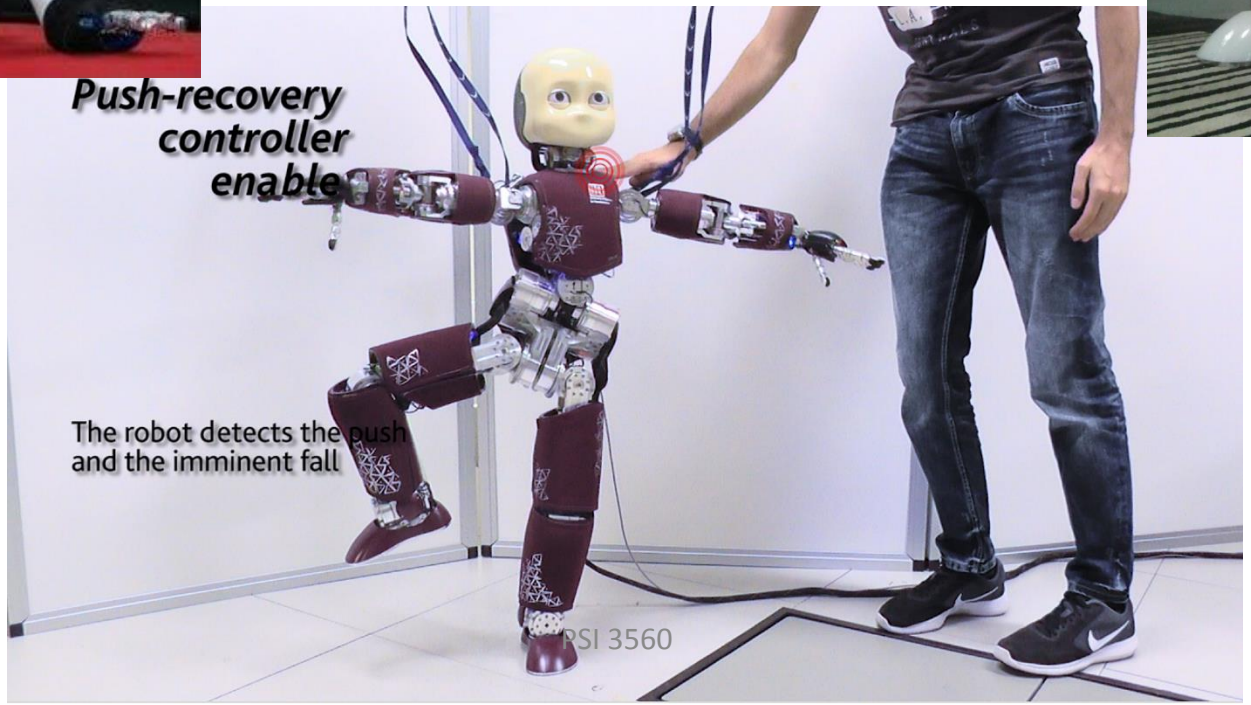
Developmental social robotics

- Social cognitive development in robots

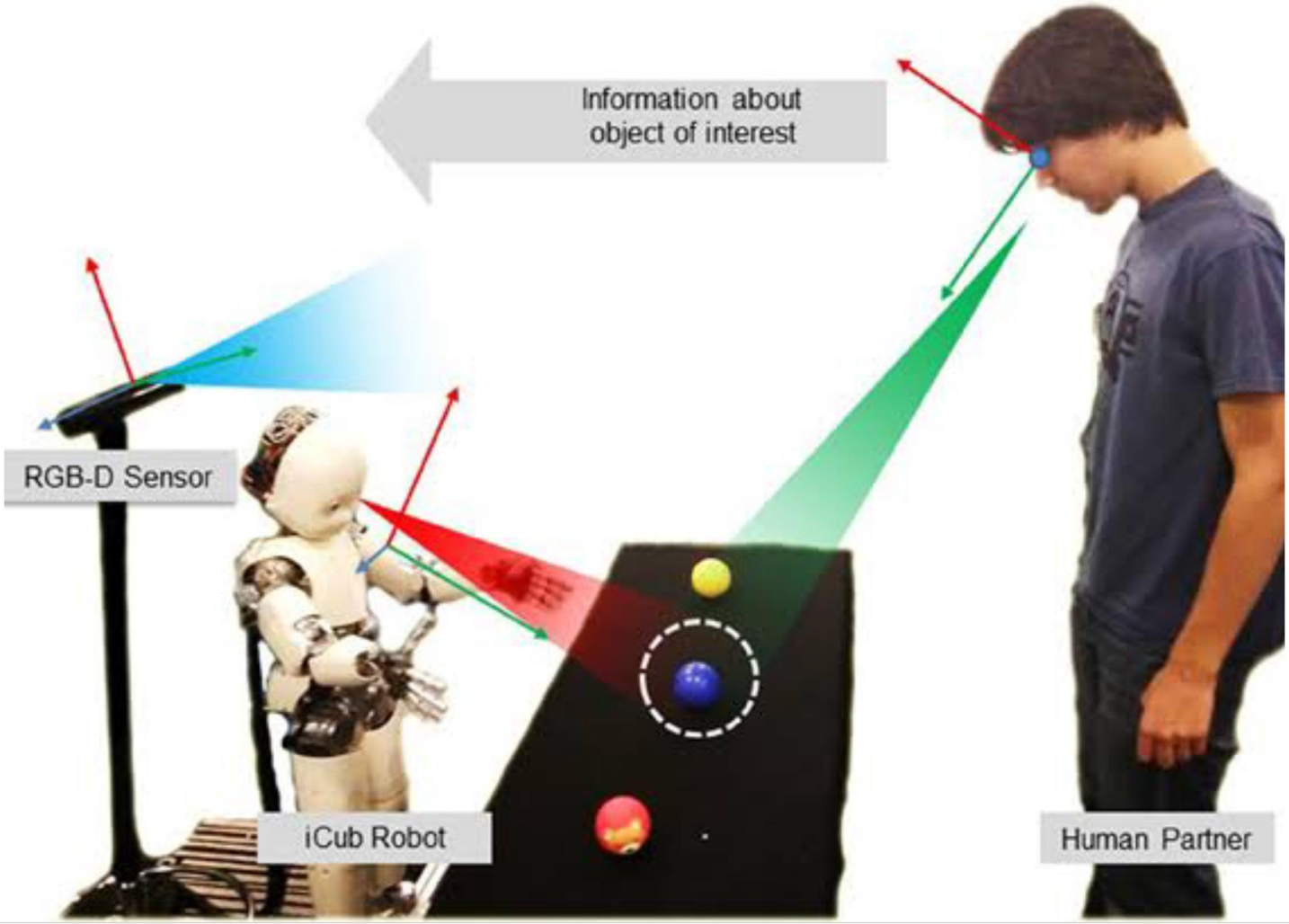


Developmental robotics

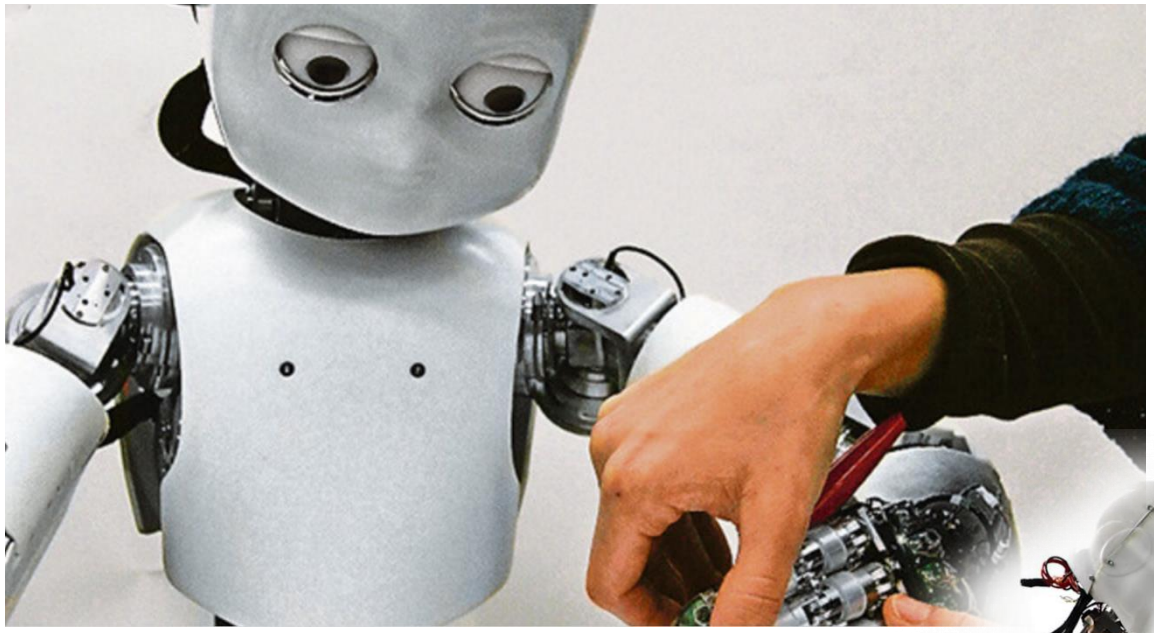
- Simulate cognitive development in robots

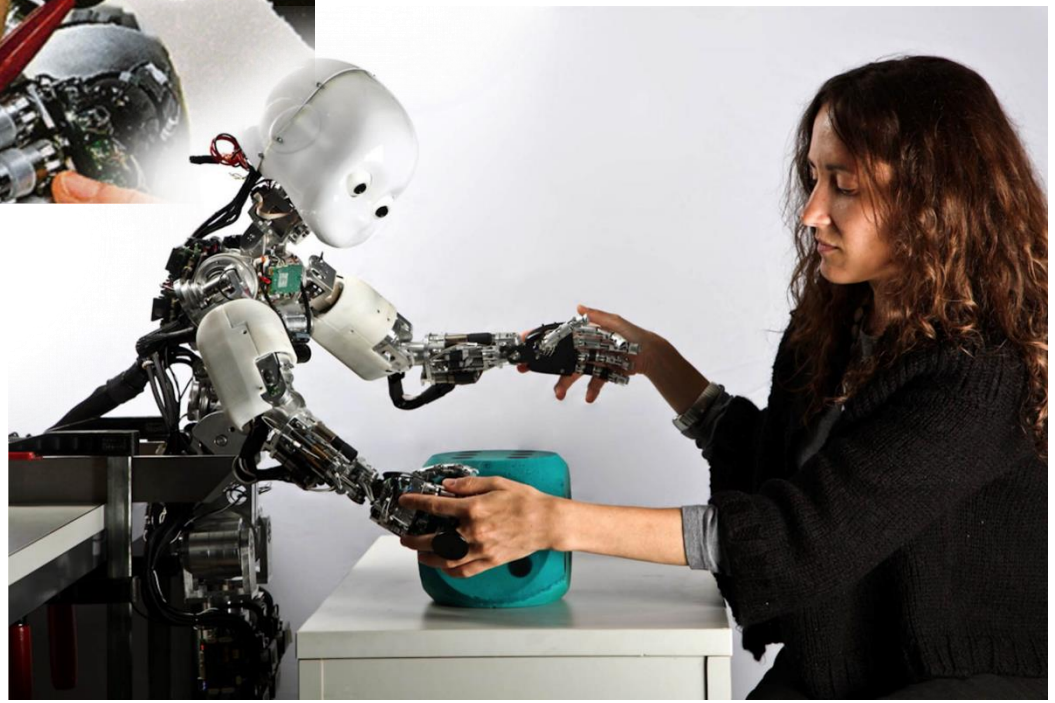


Developmental social robotics

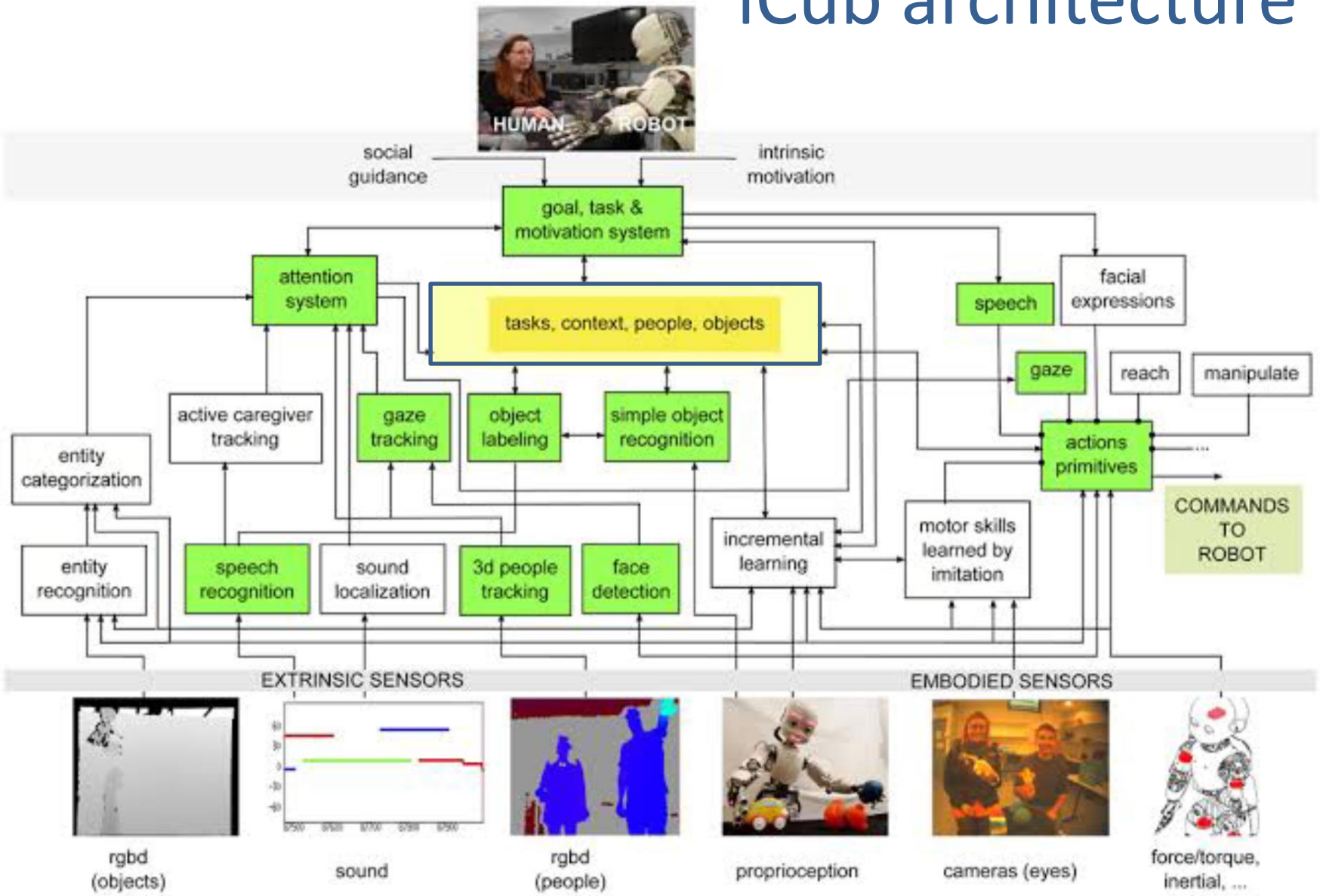


Social learning in robotics





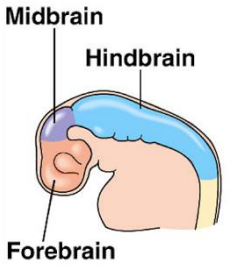
iCub architecture



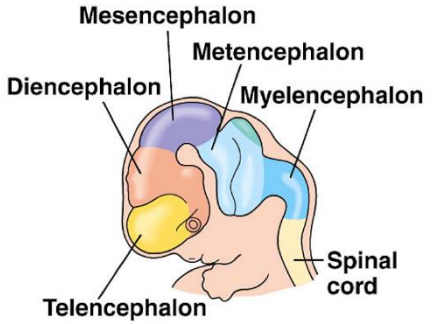
Biological basis of cognitive development

Physical development of embryo and fetus stages

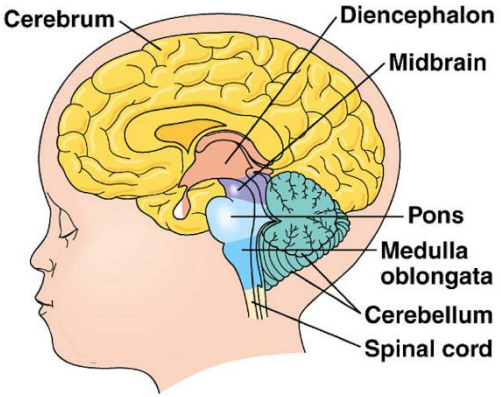
Physical development	Events
21-28 days	Neural tube formation / Heart
5 weeks	Arms/Legs
8 weeks	Internal organs / Eyes
8-12 weeks	Sexual organs / Hair/ Skin / Skeleton
13-16 weeks	Brain circumvolutions
30 weeks	Pre-term survival chances
38-40 weeks	Birth



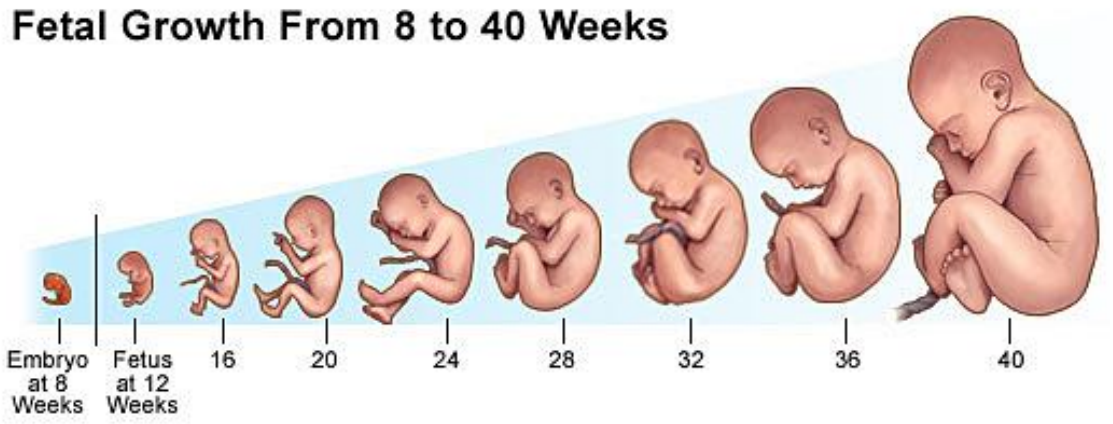
4 weeks



12 weeks



40 weeks



Biological basis of cognitive development

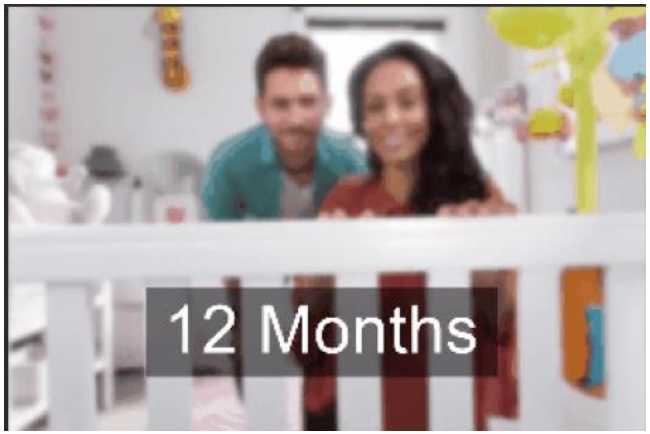
Spontaneous movements during embryo and fetus stages

Movements	Age of 1st observation (weeks)
Jolts	8
Hiccups	8-9
Global motion	9
Isolated motions of arm or leg	9
Isolated head motion	9-10
Stretch out, yawns	10
Mouth motions like vocalization	10
Tongue motions	11
Suction, swallowing	12
Ocular movements	16-23

Biological basis of cognitive development

Age of appearance of sensorial and motor capacities (weeks after conception)

Modality	Anatomical	Functional
Tact	7	11
Equilibrium	8	21
Olfaction / Taste	7-11	24
Hearing	8	32
Vision	10	Birth



Biological basis of cognitive development

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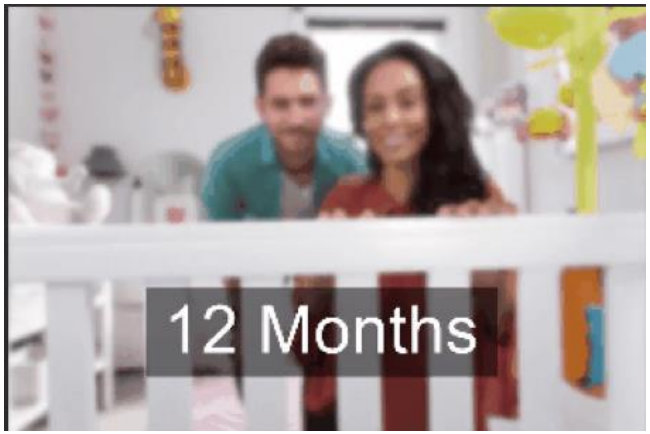
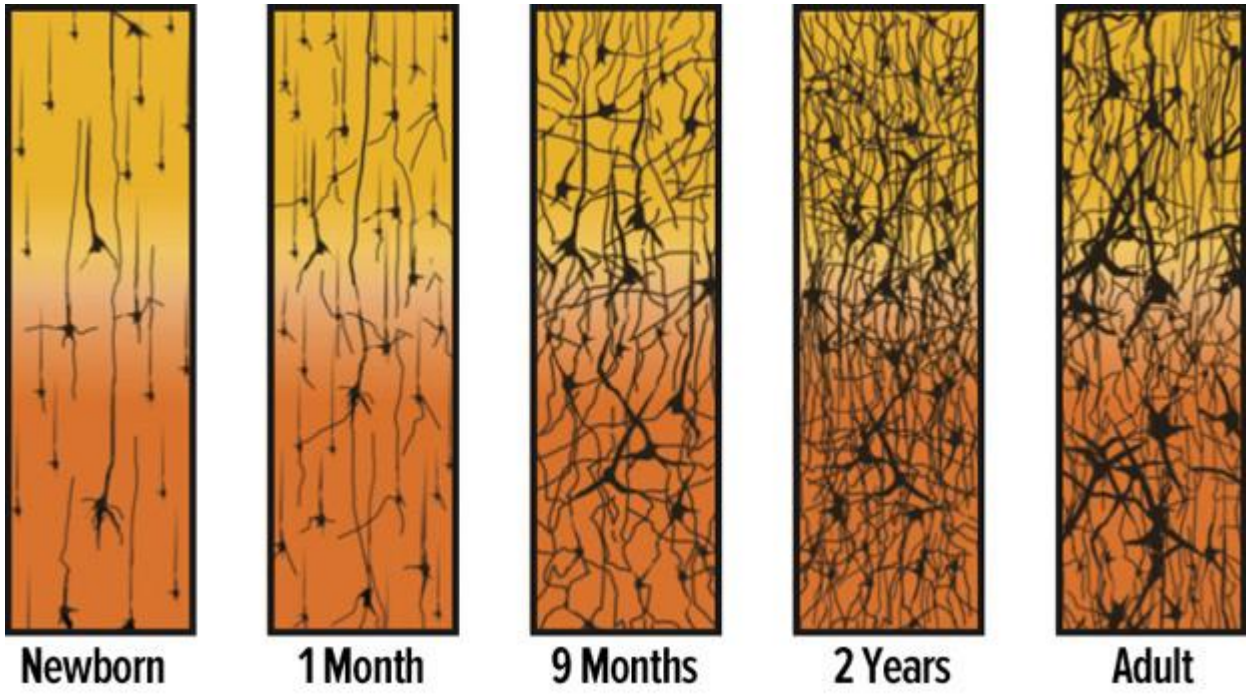


Biological basis of cognitive development

- Cortex development
  - Cell density grows up to 2-6 years and then decreases



Biological basis of cognitive development

- Cortex development
  - Synapse density grows up to 2-6 years and then decreases

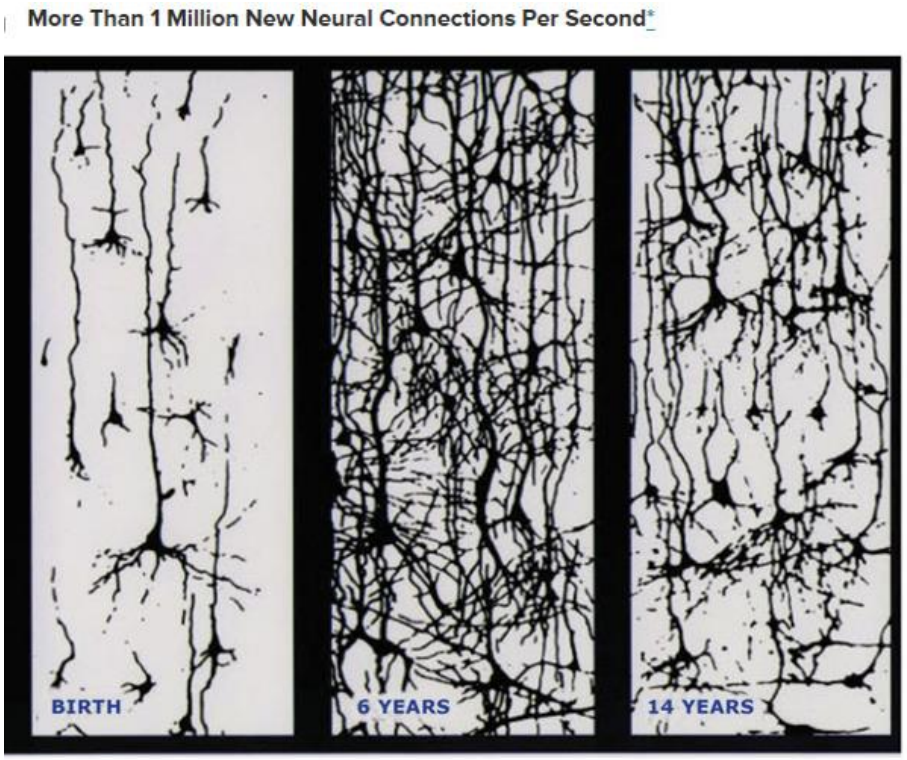


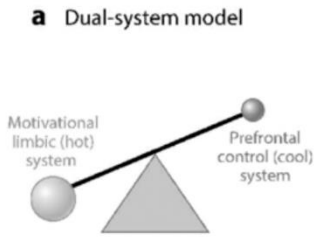
Image source: Conel, JL. The postnatal development of the human cerebral cortex. Cambridge, Mass: Harvard University Press, 1959.

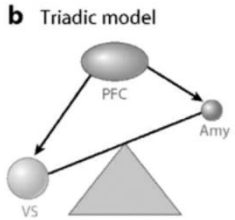
Adolescent brain

- Development and plain life periods
  - Prenatal – conception to birth (9 months)
  - Infancy – birth to 18 months
  - Early childhood – 18 months to 5-6 years of age
  - Middle and late childhood – 5-6 to 10-11 y.o.a.
  - Adolescence – 11-13 to 18-19 years of age
    - Early adolescence – puberty
    - Late adolescence
  - Adulthood – 18-19 to end of life
    - Early adulthood – 18-19 to mid-30s
    - Middle adulthood – 35-40 to 55-65
    - Late adulthood – after 65 years of age

Adolescent brain

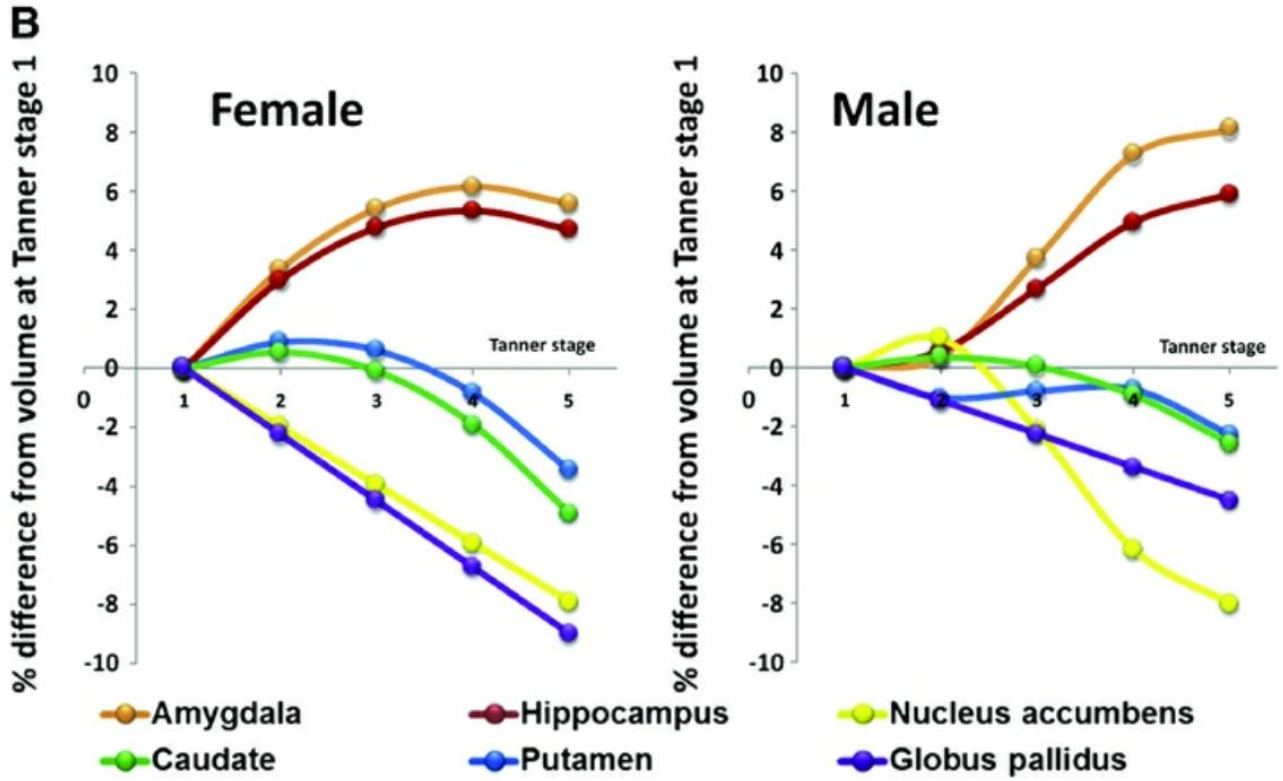
- What is the function of adolescence ? (Schlegel,2001)
  - Establish capacity of behavioral autonomy
  - Establish social independence
- How does the brain facilitates independence
  - Increased capacity of making decisions
  - Increased capacity of risk prediction
- Challenges to these capacities
  - Dual factors (puberty) – Steinberg et al, 2008
    - Sensation-seeking versus risky decision-making
    - Surge in dopaminergic activity – Pre-frontal vs Limbic system
  - Triadic model (late adolescence) – Ernst, Pine & Hardin, 2006
    - Components: cognitive impulsivity, risk-seeking, emotional intensity and social orientation
    - Pre-frontal, striatum, amygdala
      - » Pre-frontal – regulation of the motivational factor
      - » Striatum – motivational aspects
      - » Amygdala – emotional components





Adolescent brain

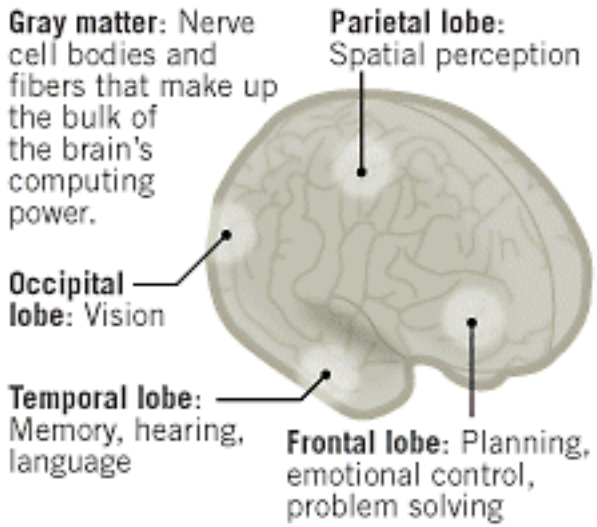
- Structural changes (Goddings et al, 2014)



Adolescent brain

- **Growing a Grown-up Brain**

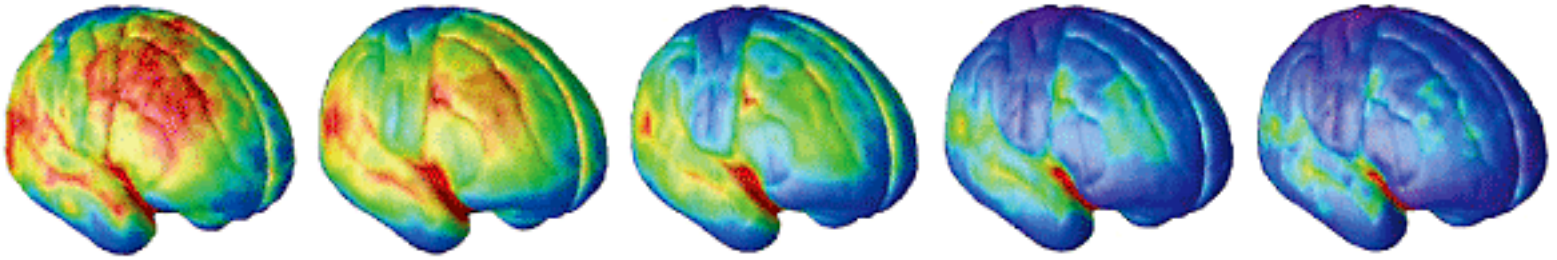
Scientists have long thought that the human brain was formed in early childhood. But by scanning children's brains with an MRI year after year, they discovered that the brain undergoes radical changes in adolescence. Excess gray matter is pruned out, making brain connections more specialized and efficient. The parts of the brain that control physical movement, vision, and the senses mature first, while the regions in the front that control higher thinking don't finish the pruning process until the early 20s.



Gray matter density

Gray matter becomes less dense as the brain matures.

More dense — Less dense



Source: "Dynamic mapping of human cortical development during childhood through early adulthood," Nitin Gogtay et al., *Proceedings of the National Academy of Sciences*, May 25, 2004; California Institute of Technology

This is all for today.

See you next week !