Typical & Atypical Cognitive Development: Theories of Cognitive Development

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TODAY'S ASSIGNMENTS

- No compulsory assignments until next session
  - Optional: preparation for next lecture on March 22
    - Reading new article available on https://seasense.github.io to answer three questions (see Unit 3)
- Reflection of today's lecture until March 29

TODAY'S SESSION

- Theory of Piaget
- Neo-Piagetian Theories
  - Speed of processing
  - Working memory capacity
  - Knowledge

  } Maturation vs. Learning } Empiricist-Nativist-Debate continues
- Neuroconstructivism
  - Links transactional accounts of gene-environment to neo-Piagetian models of development
  - Today's assignment

COGNITIVE DEVELOPMENT ACCORDING TO PIAGET

"*By watching babies at play it is possible to access their minds, because they think in actions, which later will go underground and become abstract thinking. Children are like scientists in that they try out little action and thought experiments and thus actively construct knowledge about the world; in fact the ideal endpoint of cognitive development is scientific thinking.*"

-- Miller (2011) on one of Piaget's most influential ideas

Jean Piaget (1896-1980)

- Swiss biologist, psychologist and philosopher
- How do we come to know something? How does intelligence develop? (see e.g. Empiricist-Nativist debate of previous session)
- Finding answers by studying developmental changes in the process of understanding concepts of *time*, *space* and *causality*

  … as well as the concepts of *quantity*, *speed*, *morality*, and *mind*

COGNITIVE DEVELOPMENT ACCORDING TO PIAGET

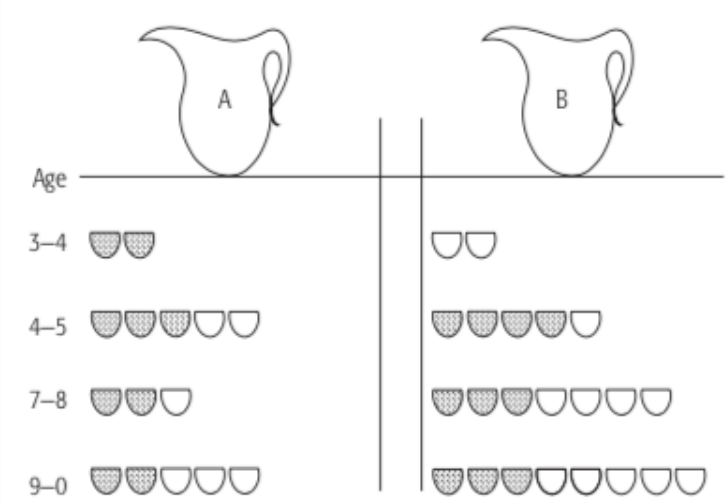
Stage	Characterization	Milestones
Sensorimotor (birth - 2 years)	• Organizing reflexes into **action-based concepts** (= Perception-action patterns) • Actions become more intentional	• **Object permanence**
Preoperational (2 – 7 years)	• Forming **mental categories** of objects and relations (i.e., of elements of action-based concepts) • Internal thought about the world	• **Thinking about causes**
Concrete operational (7 – 11 years)	• Performing mental operations on categories • Actions are still the main source of knowledge, but they are now mental (i.e., **internalized operations**)	• Logic dominates perception → **Conservation**
Formal operational (11 – 15 years)	• Performing mental operations not only on actions but also abstract (e.g., verbal, logical) statements	• **Generating and testing hypotheses**

WHAT DEVELOPS? THEORIES OF COGNITIVE DEVELOPMENT

- Piaget
  - Cognition as an active and self-organizing system
    - *Assimilation* attempt fails → Cognitive *conflict* → *Accommodation* of knowledge structure (e.g., mental category) → *Equilibrium* until assimilation fails again → …
- Neo-Piagetian Theories
  - Development through an increase of capacity vs. knowledge?
    - Do children 'think better' or do they 'know better' as they get older?
- Neuroconstructivism
  - Can be embedded into the transactional approach towards gene-environment interactions (see previous session)
    - A potential approach to solve the nativist-empiricist debate

WHAT DEVELOPS? NEO-PIAGETIAN THEORIES

- Position of Case (1985): Increasing Mental Capacity
  - E.g., growing working memory capacity ("short term storage space")
  - **Juice problem** of Noelting (1975)
    - Predicting which pitcher will taste most strongly of orange juice

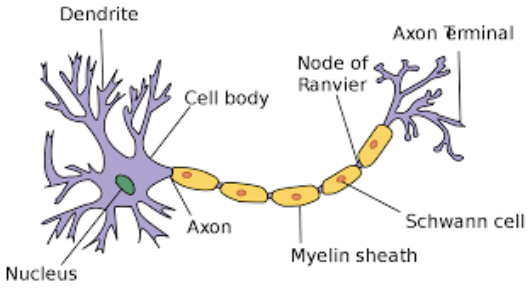


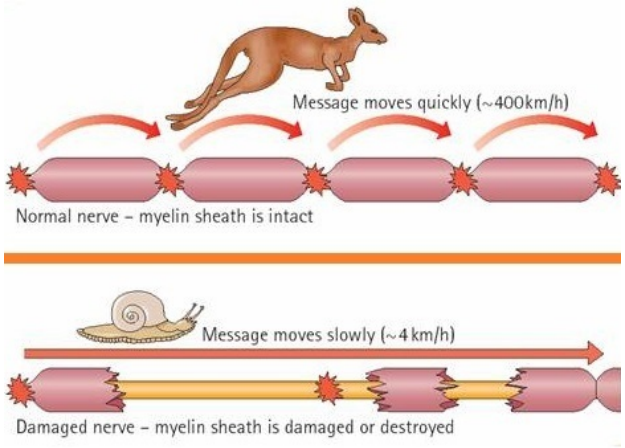
- Working memory requirements increase from problem type 1 to 4
- Systematic relationship between the chance of mastering the problem and age

→ Developmental sequences might be controlled by maturing working-memory capacity

WHAT DEVELOPS? NEO-PIAGETIAN THEORIES

- Position of Case (1985): Increasing Mental Capacity
  - If such position holds, then what are the underlying developmental mechanisms?
  - Potential explanation: Increased speed of neural function
    - **Increasing degree of white matter (brain connectivity) and myelination in frontal regions** (e.g., Crone & Ridderinkhof, 2011)
    - Myelin sheaths (for insulation) around axons to conduct signals more rapidly
      - 5ms and 20ms for a nerve impulse to cross the brain hemisphere in an adult and 4-year-old brain, respectively



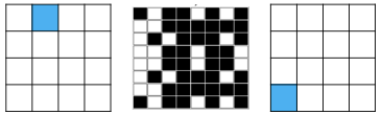


Link to Piagetian theory

Spurts in frontal brain growth preceding typical stages of development (e.g., Epstein, 1978; see also Crone & Ridderinkhof, 2011)

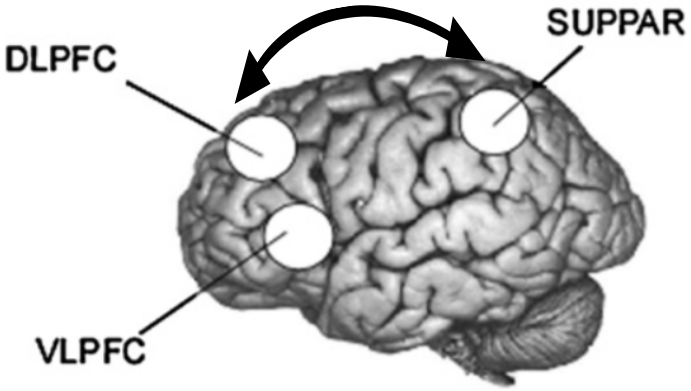
WHAT DEVELOPS? NEO-PIAGETIAN THEORIES

- Position of Case (1985): Increasing Mental Capacity
  - If such position holds, then what are the underlying developmental mechanisms?
  - Potential explanation: Formation of
    - **Increasing degree of white matter also in fronto-parietal regions** (Olesen et al., 2003)
    - Fronto-parietal network realizes visuo-spatial working memory (e.g., Symmetry Span task, tried out in previous session: https://seasense.github.io/index_SymSpan.html)



Crone & Ridderinkhof, 2011

Fronto-parietal connection increases in strength



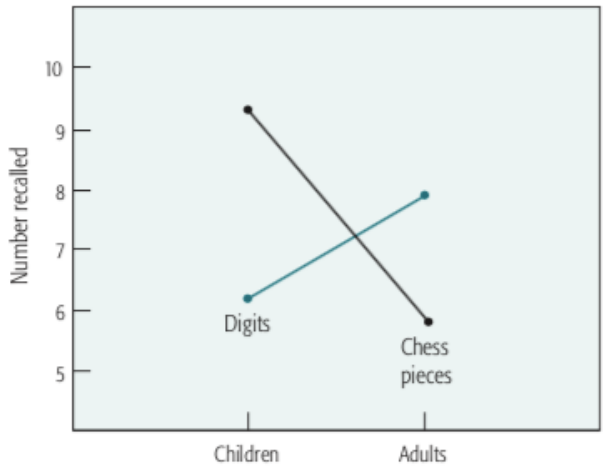
- SUPPAR: Superior parietal cortex (Visuo-spatial organization)
- VLPFC: Ventrolateral prefrontal cortex (Maintenance of information)
- DLPFC: Dorsolateral prefrontal cortex (Manipulation of maintained information)

Link to Piagetian theory

Qualitative network changes especially at the transition from childhood to adolescence (see slide 15)

WHAT DEVELOPS? NEO-PIAGETIAN THEORIES

- Study of Chi (1978): What's the impact of knowledge?
  - Why do children perform worse than adults in different memory tasks?
  - Study design
    - Age: Memory performance of 10 year-olds (skilled chess players) vs. adults on two types of tasks
    - Memory task: Digit span task (recalling number sequences) vs. Chess memory task (recalling chessboard presented for 10s and then withdrawn)



Main result: Interaction

- Adults outperform children in the digit span task, but the children are better in the chess task

Interpretation?

WHAT DEVELOPS? NEO-PIAGETIAN THEORIES

- Study of Schneider et al. (1988): What's the impact of knowledge?
  - Study design
    - Schoolchildren at grade levels 3, 5, and 7 recall a story about soccer
    - Each child categorized as soccer expert or novice

Mean percentages of idea units recalled		
Grade	Soccer experts	Soccer Novices
3	54	32
5	52	33
7	61	42

How would you interpret this result pattern in terms of the impact of age vs. knowledge?

WHAT DEVELOPS? NEUROCONSTRUCTIVIST THEORY

- Neuroconstructivism (e.g., Westermann et al., 2007)
  - A direct link between results of behavior genetics and developmental psychology
  - Theoretically a way to reconcile
    - Nativism: Development due to capacity increases (Maturation)
    - Empiricism: Development due to knowledge increases (Learning)
  - Building on Piaget's view of development
    - Development as a trajectory shaped by multiple interacting biological and environmental constraints
    - Processes of maturation and learning interact and contribute to cognitive development

COGNITIVE DEVELOPMENT FROM THE PERSPECTIVE OF THE NEUROCONSTRUCTIVISM

- Neuroconstructivism
  - Sources of constraints
    - Genes (see Unit 1: ‘transactional model’ and ‘gene expressivity’)
    - Encellment (see Units 0 & 1: ‘synaptic plasticity’, ‘learning rule of Hebb’)
    - Embrainment
    - Embodiment
    - Ensocialment

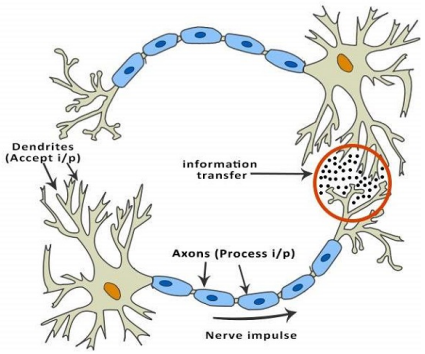
Principle of context dependence on every level

COGNITIVE DEVELOPMENT FROM THE PERSPECTIVE OF THE NEUROCONSTRUCTIVISM

- Neuroconstructivism
  - Sources of constraints
    - **Genes**
      - Traditional view
        - One-directional chain: Gene (DNA) → RNA transcription → Protein
        - Progressive unfolding of the information in the genome
      - Contemporary transactional process view (see Unit 1)
        - Gene environment interactions, according to which gene expression is subject to environmental and behavioral influences
          - Gene expression not strictly preprogrammed
          - Study of Gottlieb (1992; Op. cit. Westermann et al., 2007)
            - In Zebra finches, the activity of signing induces the expression of the gene ZENK (regulating synaptic plasticity) in motor brain areas

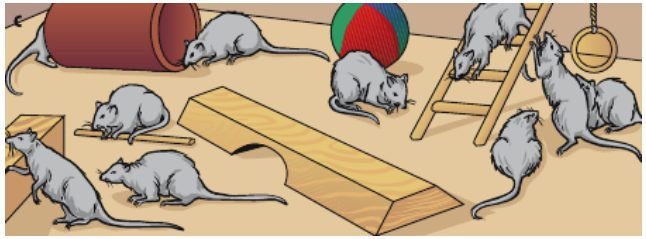
COGNITIVE DEVELOPMENT FROM THE PERSPECTIVE OF THE NEUROCONSTRUCTIVISM

- Neuroconstructivism
  - Sources of constraints
    - Genes
    - **Encellment** (neural constructivism)
      - Development of a cell constrained by its cellular environment
      - Assemblies of frequently stimulated cells co-activate each other and form stabilized circuits
        - See learning rule of Hebb (see Unit 1): "What fires together, wires together"



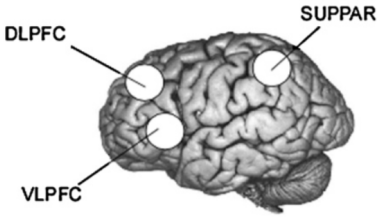
- Study of Sale et al. (2009)
  - Brains of rats raised under cognitively stimulating environments (toys, other rats, opportunities for physical exercise) had
    - an increased dendric arborization and a higher number of synapses (=stabilized circuits),

    → less age-related cell-death



COGNITIVE DEVELOPMENT FROM THE PERSPECTIVE OF THE NEUROCONSTRUCTIVISM

- Neuroconstructivism
  - Sources of constraints
    - Genes
    - Encellment (neural constructivism)
    - **Embrainment**
      - Interactive specialization: As individual neurons are interlinked and affect each other, so entire brain regions develop in a network of regions (Johnson, 2010)
      - Example of Visuo-Spatial Working Memory Capacity (see slide 8)



Qualitative developmental differences (Scherf et al., 2006; Crone & Ridderinkhof, 2011)

Age	SUPPAR	VLPFC	DLPFC
Children	↑		
Adolescents	↑	⇧	⇧
Adults	↑	↑	↑

Maturation

Learning*

* Interactive specialization can be improved through extensive working memory training

COGNITIVE DEVELOPMENT FROM THE PERSPECTIVE OF THE NEUROCONSTRUCTIVISM

- Neuroconstructivism
  - Sources of constraints
    - Genes
    - Encellment (neural constructivism)
    - Embrainment
    - **Embodiment**

      - Body develops in parallel with cognitive abilities, which serves to change the information available to the child
      - E.g., low visual acuity during first months

      → Only coarse environmental aspects can be processed → broad & simple mental representations

      - As visual acuity improves, more visual details are added

      → Progressively more complex mental representations

      → Protecting the immature mind from being overloaded

      Proactive exploration and manipulation of the environment as an essential part of cognitive development

COGNITIVE DEVELOPMENT FROM THE PERSPECTIVE OF THE NEUROCONSTRUCTIVISM

- Neuroconstructivism
  - Sources of constraints
    - Genes
    - Encellment (neural constructivism)
    - Embrainment
    - Embodiment
    - **Ensocialment**
      - Social environment in which a child develops
        - E.g., Contingent timing of interactions between a caregiver and a child to develop
          - Secure attachment
          - Expression of emotions
          - As well as concepts (e.g. of the physical world)
        - Early traumatic experiences (e.g., neglect) can have severe effects on the neural and thus behavioral development (e.g., Cirulli et al., 2003)

SUMMARY: SESSIONS 0, 1&2

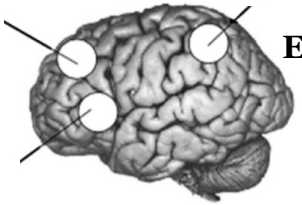
Social and physical environment

Ensocialment

Body & Behavior

Embodiment

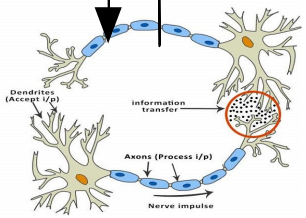
Brain



Embrainment

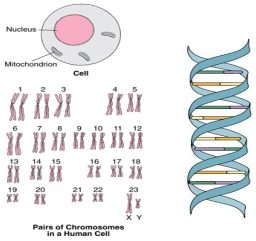
Encellment

Neurons



Gene expressivity

Genes



Cognitive Development

LITERATURE OF TODAY'S SESSION

- Anderson, J. (2015). Cognitive psychology and its implications (8th edition). New York, NY: Worth Publishers.
  - Parts of chapter 14 ("Individual Differences in Cognition")
- Crone, E., & Ridderinkhof, R. (2011). The developing brain: from theory to neuroimaging and back. *Developmental Cognitive Neuroscience, 1,* 101-109. DOI: https://doi.org/10.1016/j.dcn.2010.12.001
- Goswami, U. (2011). The Wiley-Blackwell Handbook of Childhood Cognitive Development. West-Sussex, UK: Wiley-Blackwell.
  - *Part IV: Theories of Cognitive Development*
- Westermann, G., Thomas, M., & Karmiloff-Smith, A. (2011). *Neuroconstructivism*. In U. Goswami (Ed.), The Wiley-Blackwell Handbook of Childhood Cognitive Development (pp. xx-xx). West-Sussex, UK: Wiley-Blackwell.

Break