Typical & Atypical Cognitive Development

Unit 3. Individual Differences in Cognitive Development from an Executive Function Perspective

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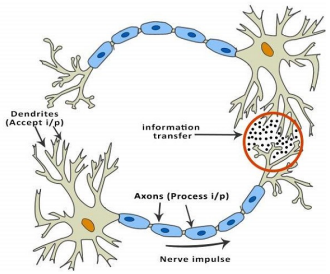
W H A T H A V E W E L E A R N E D S O F A R ?

… from a neuroconstructivist interpretation of cognitive development?

- On every level of observation (e.g., neurons, brain)
  - Idea of reciprocal relations between
    - different levels of observation (e.g., transactional model of gene-environment influences)
    - elements (e.g., cells) and their contexts (cell assemblies) on a given level (e.g., brain region)



- Idea of reciprocity captured by the “hardware-algorithm metaphor” of Westermann et al. (2007)
  - Notion of an algorithm changing the structure on which it is operating
  - Differences that start out small can over time grow larger and larger.

TOPIC OF TODAY'S SESSION

'Hardware-algorithm' metaphor exemplified by the development of reading comprehension

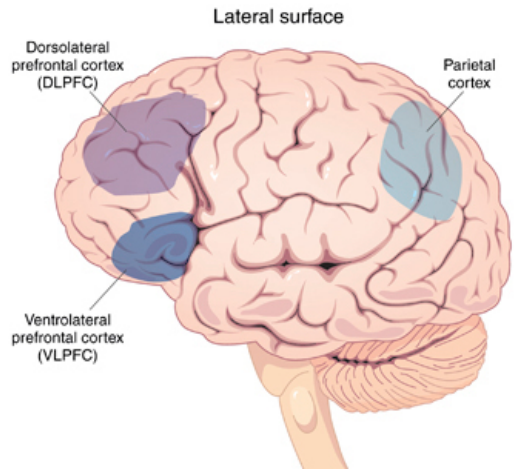
- Mutual influences between Executive Functions (EF) and Reading Comprehension (RC)
  - EF: Sub-served by already evolved biological structures and mechanisms ('wetware')
  - RC: Cognitive process (algorithm) relying on and affecting EF
- Educational implications that would follow from such an EF-RC interplay
  - Cognitive plasticity: Cognitive skills could be trained
  - Effective training techniques could be designed and become part of inclusive-educational practices

THE NOTION OF EXECUTIVE FUNCTIONS (EF)

- EF derived from the analysis of the consequences of damage in the Prefrontal Cortex (PFC; e.g., Zelazo & Müller, 2011)
  - Lesions of PFC are accompanied by certain difficulties
    - Planning, Concept formation, Abstract thinking
    - Decision making
    - Fluid Intelligence (e.g., Raven's matrices test; see Unit 0)
    - Monitoring one's own actions (self-regulation)

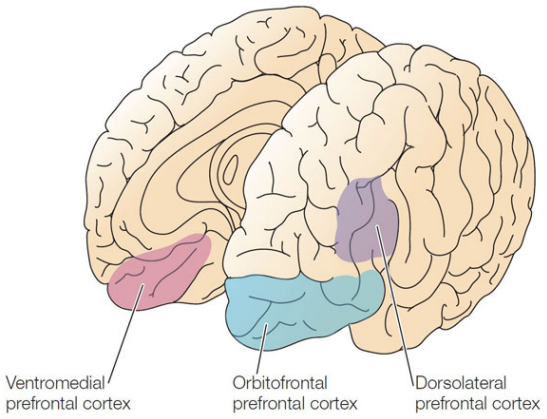
EXECUTIVE FUNCTIONS (EF): NEUROPHYSIOLOGICAL CORRELATES

Lateral PFC



Control of "cool" cognitive aspects of behavior

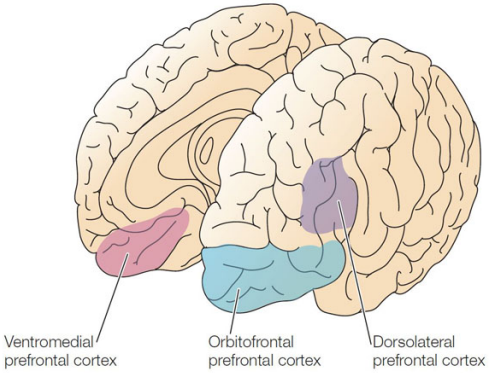
Ventro-medial PFC



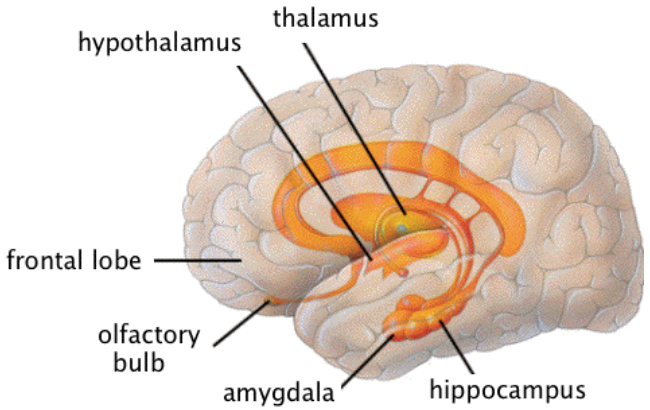
Control of "hot" affective behavioral aspects and 'theory of mind'

EXECUTIVE FUNCTIONS (EF): NEUROPHYSIOLOGICAL CORRELATES

- Ventro-medial PFC
  - Strong connections to the limbic system
    - in the midbrain, beneath the medial temporal lobe
    - involved in 4 Fs: feeding, fleeing, fighting, and sexual activity
  - → Integration of affective and non-affective information

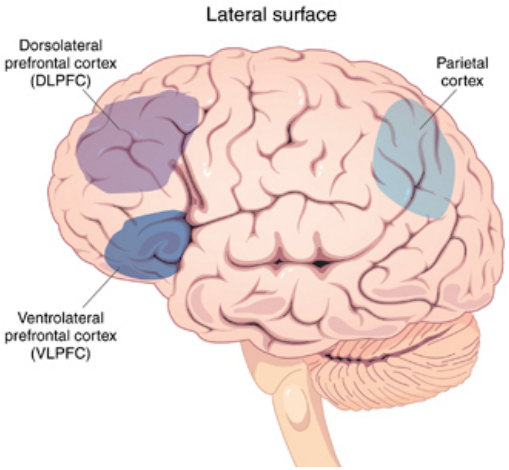


Limbic system

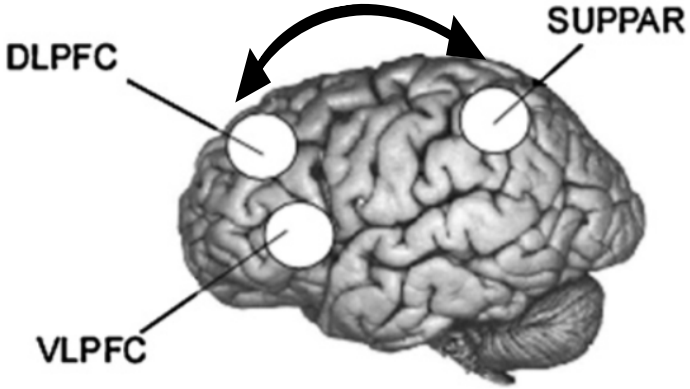


EXECUTIVE FUNCTIONS (EF): NEUROPHYSIOLOGICAL CORRELATES

- Lateral PFC
  - Integration of mnemonic and sensory information
- Example of WM Capacity (see previous unit)
  - A large-scale brain network
    - SUPPAR (visual organization), VLPFC & DLPFC (maintenance and manipulation)



Fronto-parietal connection increases in strength



Crone & Ridderinkhof, 2011

- Interactive specialization throughout childhood and continuing until adulthood
  - Due to maturation (e.g., increase of myelination and white matter of fronto-parietal communication)
  - Accompanied by increasing performance in WM tasks

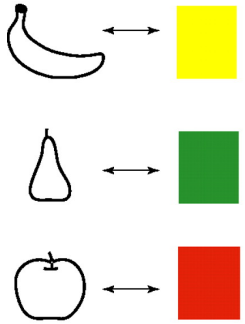
THE NOTION OF EXECUTIVE FUNCTIONS (EF)

- Different conceptions of how Working Memory (WM) and EF are interrelated
- Prominent examples,
  - Morasch et al. (2013)
    - **EF** as a dual-component process, comprised of **WM** and Inhibitory Control (IC)
  - Unsworth & Engle (2007)
    - **WM** consisting of different facets: Scope and Control of attention, Retrieval from memory
      - **EF** involved in each of the three facets
  - Miyake et al. (2000)
    - 3 distinct **EF**
      - Inhibition (of prepotent responses)
      - Updating (**WM** content: maintenance and manipulation)
      - Shifting (between mental sets)

THE NOTION OF EXECUTIVE FUNCTIONS (EF)

- Inhibition
  - E.g. measured by the Fruit Stroop test
    - A: Learning correct color for each fruit
    - B: Easy condition
    - C: Difficult condition
      - Suppress the dominant response (color you see)
      - Attend to the fruit and indicate the color it should have

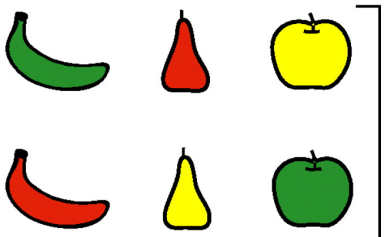
A



B

Level of difficulty - easy

C



Level of difficulty - difficult

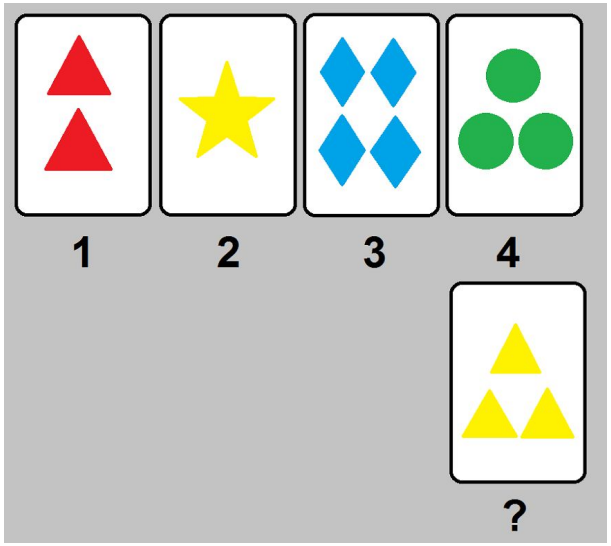
Performance measure:
RT(C) – RT(B)

THE NOTION OF EXECUTIVE FUNCTIONS (EF)

- Updating
  - E.g. measured by the Digit Span Backwards Task
    - Childs listens to sequences of digits
      - E.g., 4985
    - Asked to repeat each sequence in reverse order
      - Requires maintenance (to store the sequence) and manipulation (to reverse the order)
    - Performance measure: Number of correct repetitions

THE NOTION OF EXECUTIVE FUNCTIONS (EF)

- Shifting
  - Measured by Cognitive Flexibility Tasks
  - E.g. Wisconsin Card Sorting Task
    1. Find out the rule (target dimension) by which the card must be sorted
       - E.g., try out deck 2, if you think the target dimension is color (or deck 1, if you think the target dimension is shape)
       - Experimenter gives you feedback
    2. Certain number of consecutive correct trials
    3. Rule suddenly shifts (e.g., color → shape)
  - Performance measure: Number of perseverative errors

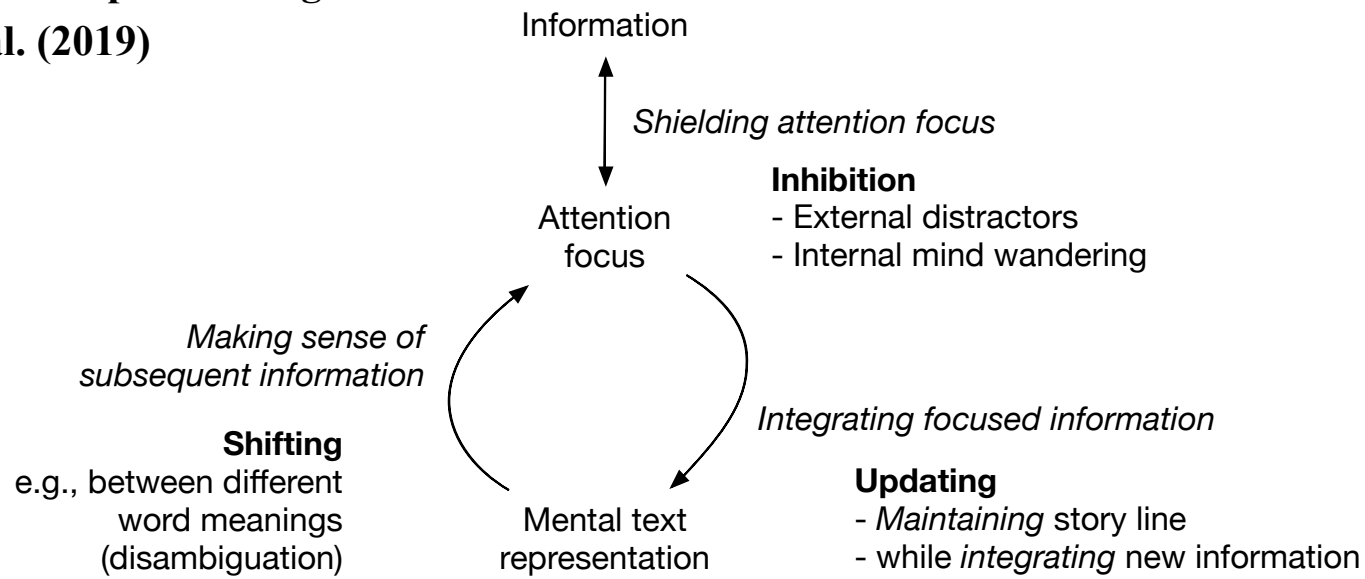


EXECUTIVE FUNCTIONS (EF) AND READING COMPREHENSION (RC)

RC according to Kintsch (2018)

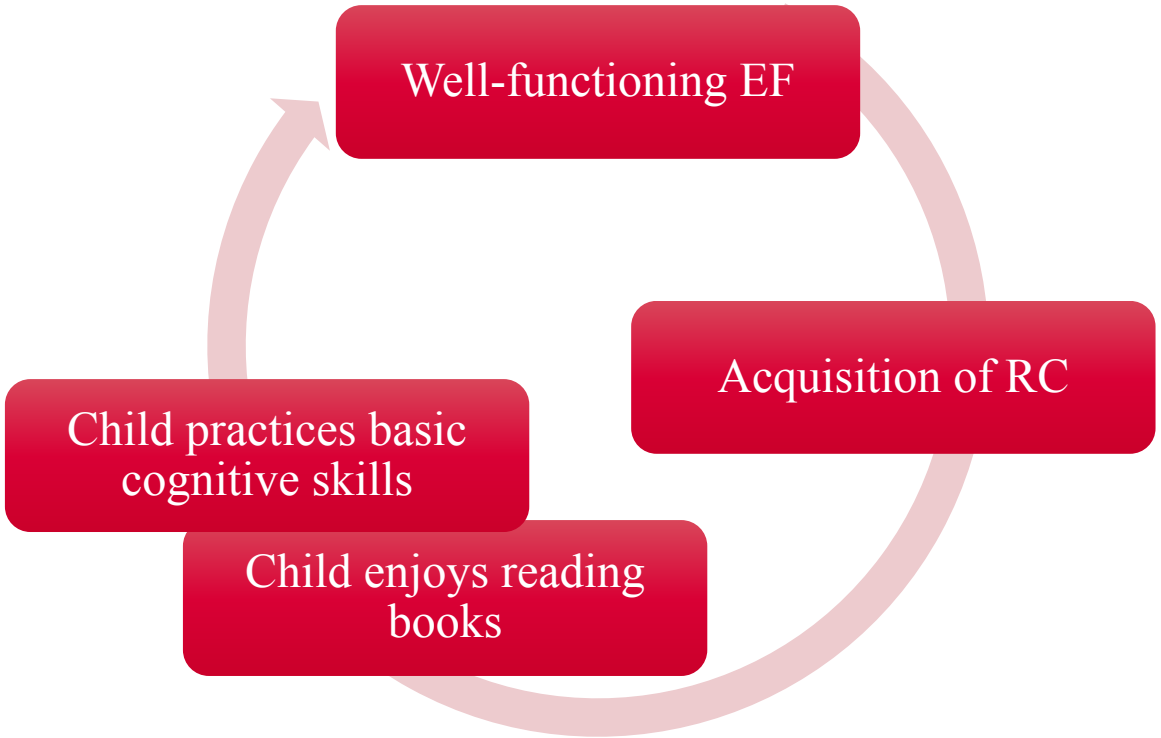
- Extracting the meaning from written information and integrating the latter into an evolving text representation (Kintsch, 1998)

RC-EF relationship according to Meixner et al. (2019)



EXECUTIVE FUNCTIONS (EF) AND READING COMPREHENSION (RC)

- Starting point of study of Meixner et al. (2019): **Hypothesis of reciprocal relations between RC and EF**



EXECUTIVE FUNCTIONS (EF) AND READING COMPREHENSION (RC)

Reciprocal relations between RC and EF

- Results of prior work
  - Children with poor performance in WM tasks show also poor reading comprehension (e.g., Carretti et al., 2005)
  - Dyslexic children have been found to exhibit multiple deficits in updating, shifting, and inhibition (e.g., Reiter et al., 2005)
- Gap in research addressed by Meixner et al. (2019)
  - Prior work shows that EF and RC are related
  - Does not show the developmental consequences of this relationship

→ Research questions

- Are there bidirectional relations between EF and RC over a 1-year period during primary school?
- Which of the 3 EF (inhibition, updating, shifting) has the strongest impact?

STUDY ON RELATIONS BETWEEN EF AND RC (MEIXNER ET AL., 2019)

Method

- Participants: N = **1.657** children (52.1% girls) from 35 primary schools in Brandenburg, Germany.
- Design: Tested at 2 time points (T1 and T2) at the end of 2 consecutive school years
  - T1
    - 441 first graders (M=7.21 years, SD=0.40)
    - 548 second graders (M=8.28, SD=0.49)
    - 526 third graders (M=9.13, SD=0.49)
  - T2
    - 421 now 2nd graders (M=7.99 years, SD=0.39)
    - 533 now 3rd graders (M=8.98 years, SD=0.52)
    - 517 now 4th graders (M=9.88 years, SD=0.52)

STUDY ON RELATIONS BETWEEN EF AND RC (MEIXNER ET AL., 2019)

Method

- Measures
  - **Executive Functions** (EF; see slides 9-11)
    - Inhibition: Fruit Stroop Task
    - Updating: Digit Span Backwards Task
    - Attention shifting: Cognitive Flexibility Task

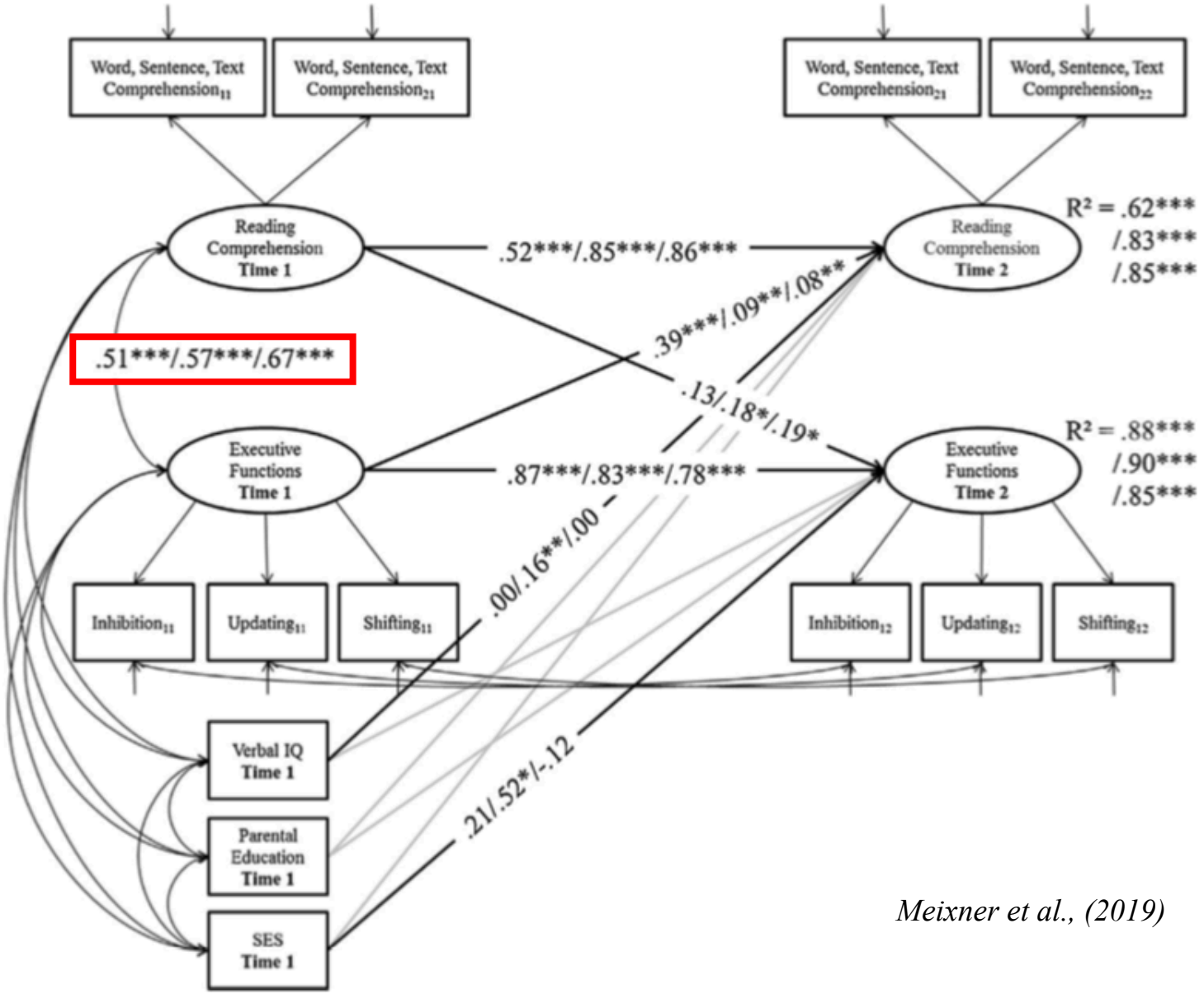
STUDY ON RELATIONS BETWEEN EF AND RC (MEIXNER ET AL., 2019)

Method

- Measures
  - **Reading comprehension** (RC)
    - Reading comprehension at word, sentence and text level
      - Word level
        - 36 picture-word matching items
        - Selecting correct word from a set of orthographically similar words
      - Sentence level
        - Completing 14 fragmental sentences
          - E.g., With a ___ you can drive. (choices: hammer, bike, ...)
      - Text level
        - 10 short text passages
        - Answering corresponding multiple choice questions (e.g., potential headings of the passage)

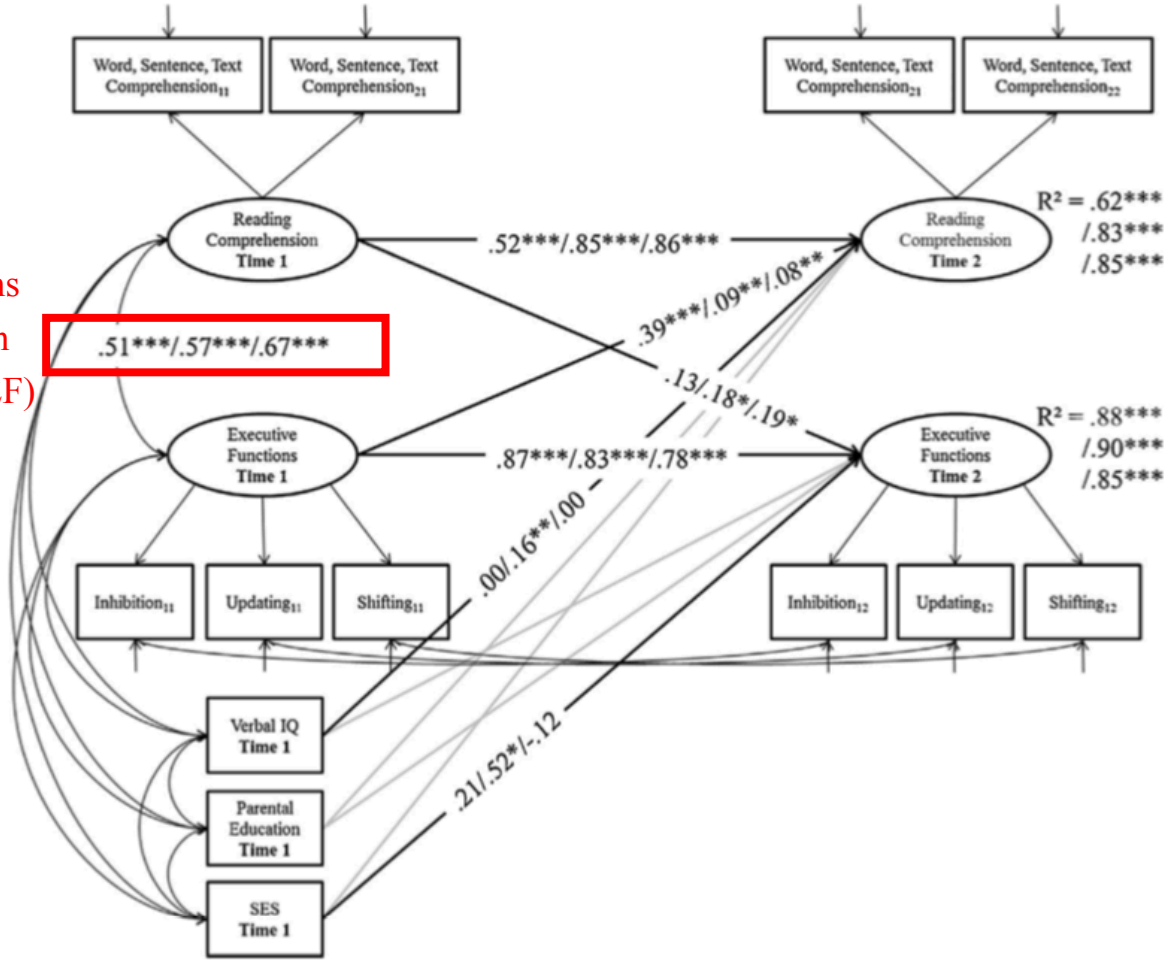
Example item for word level

bug
mug
hug
jug

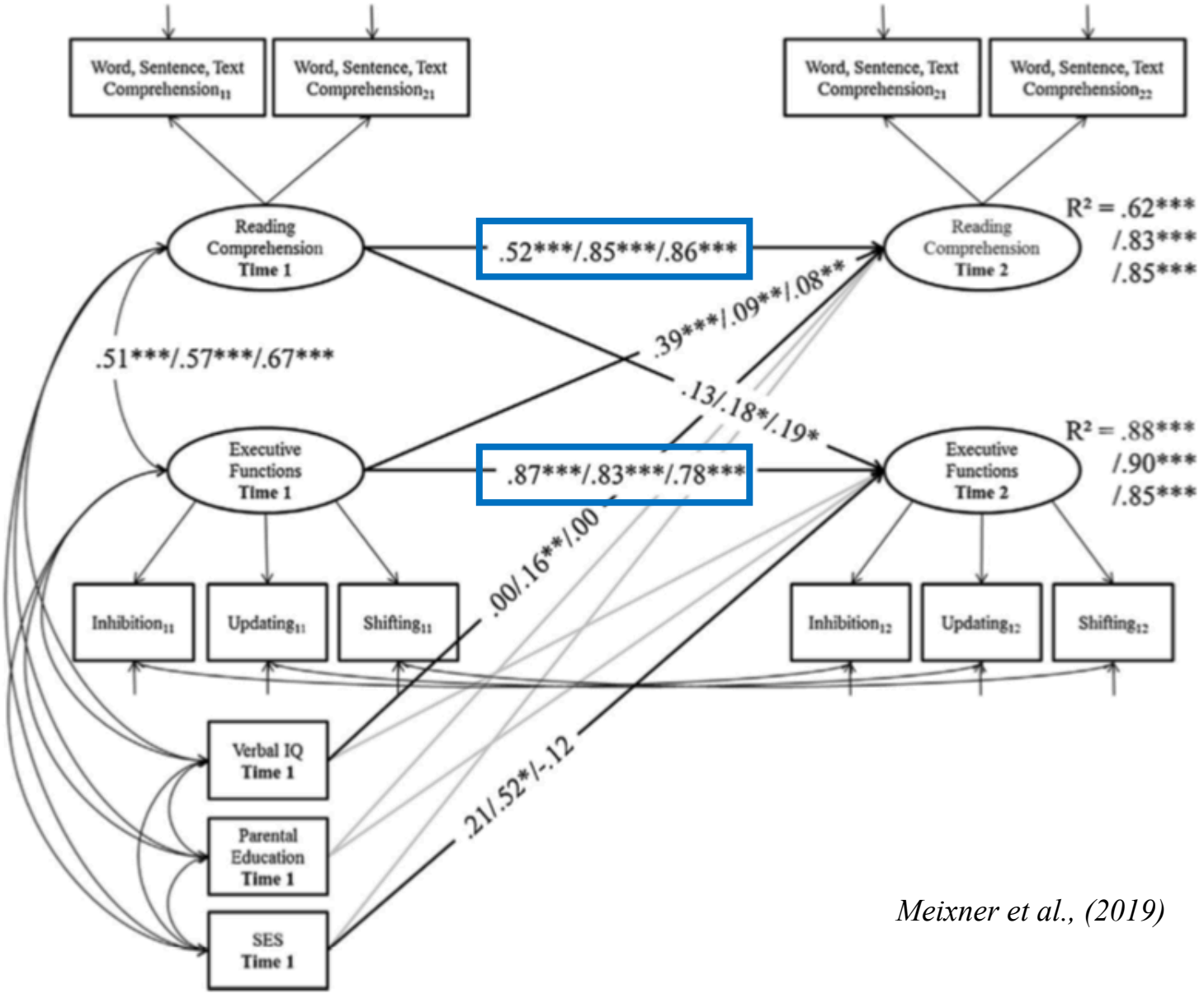


Meixner et al., (2019)

Strong and significant correlations between Reading Comprehension (RC) and Executive Functions (EF)



Meixner et al., (2019)



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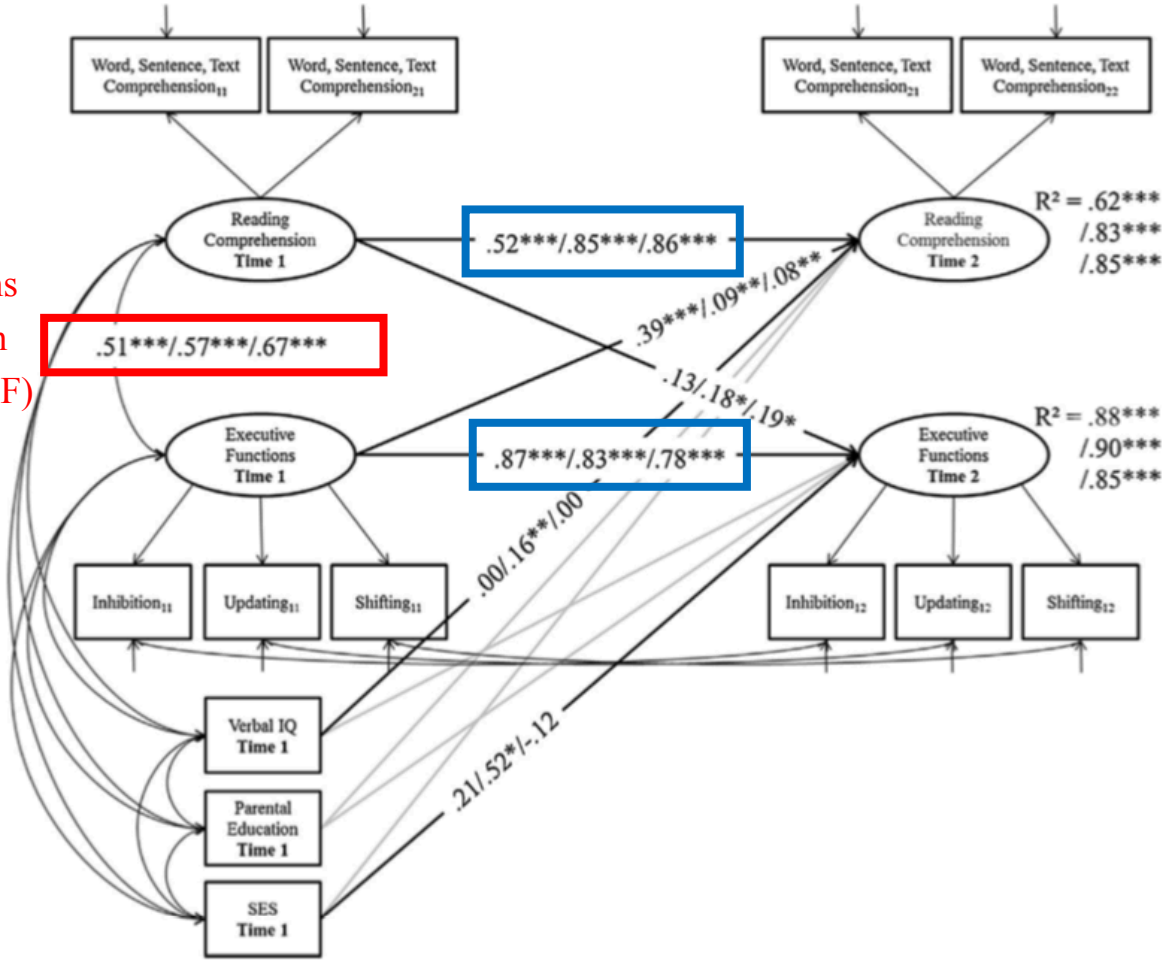
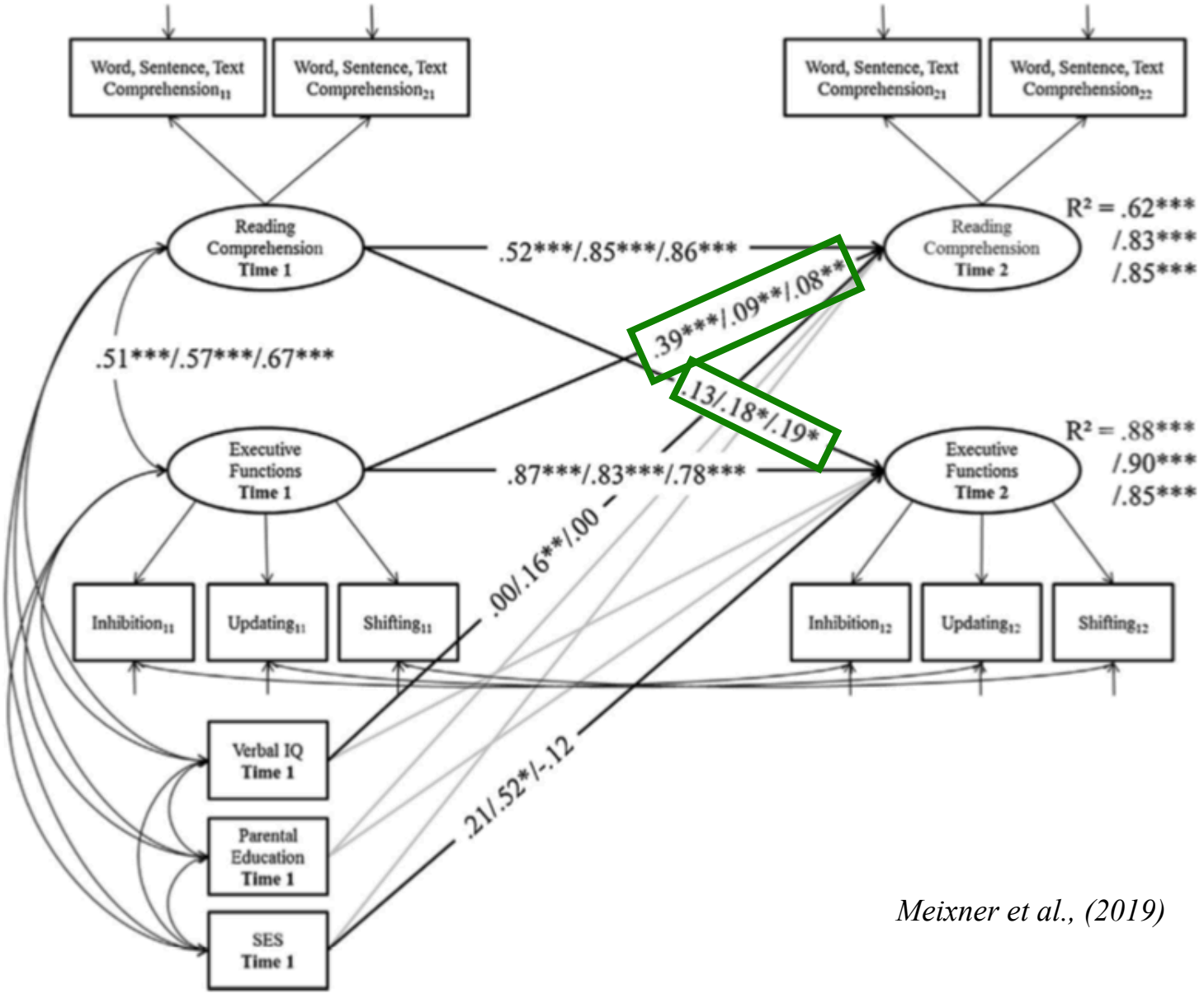


High stability of both factors

Students who achieve high reading comprehension and executive function scores at T1, will again achieve high scores at T2

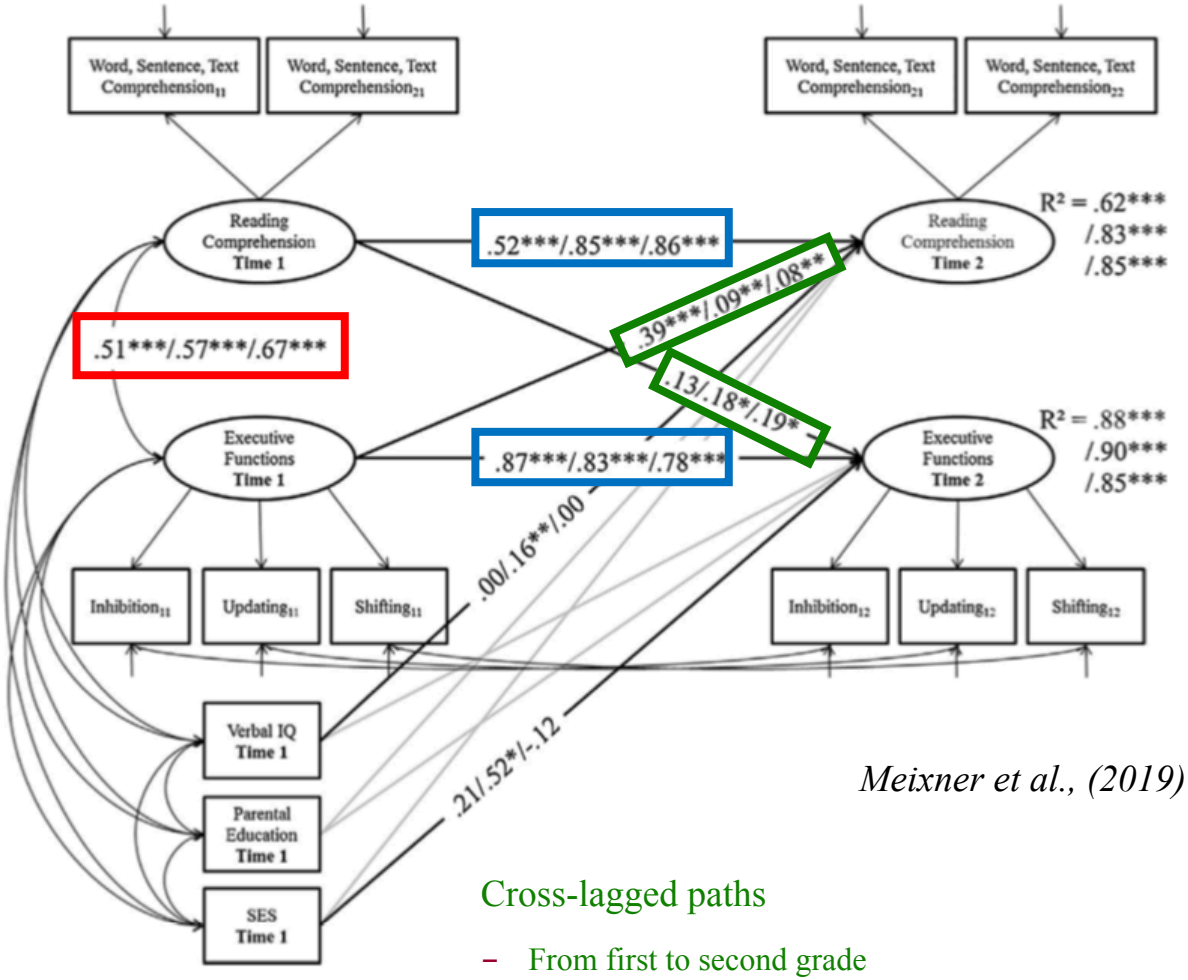
Meixner et al., (2019)



Meixner et al., (2019)

Results

Strong and significant correlations (see session 1) between Reading Comprehension (RC) and Executive Functions (EF)



Meixner et al., (2019)

High stability of both factors

Students who achieve high reading comprehension and executive function scores at T1, will again achieve high scores at T2

Cross-lagged paths

- From first to second grade
  - EF predict RC but not vice versa

  → **Unidirectional positive influence of EF on RC**
- From 2nd/3rd to 3rd/4th
  - EF predict RC, and RC predicts EF

  → **Reciprocal relationship**

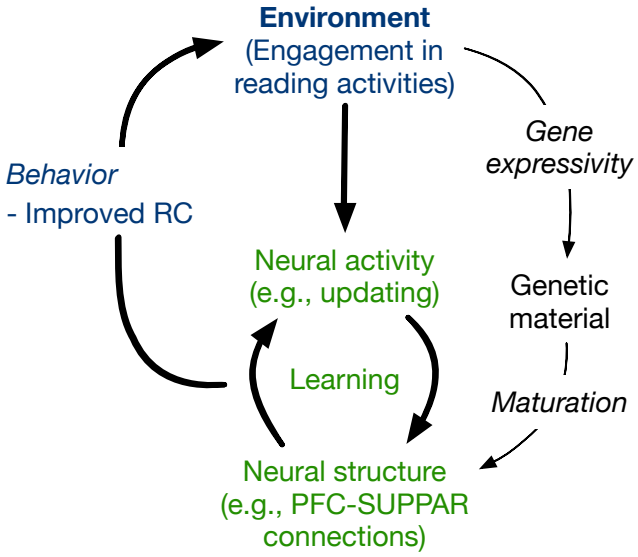
STUDY ON BIDIRECTIONAL RELATIONS BETWEEN EF AND RC (MEIXNER ET AL., 2019)

- Further results
  - 1st grade
    - All three aspects of EF (updating, inhibition, shifting) contribute to 2nd grade RC
  - 2nd and 3rd grade and beyond
    - Only updating significantly predicts RC (at T2)
    - Only text comprehension (highest level of RC) predicts EF (at T2)
    - → **The bidirectional EF-RC relations are based mainly on the more complex components of these constructs (i.e., updating and text comprehension)**

STUDY ON BIDIRECTIONAL RELATIONS BETWEEN EF AND RC (MEIXNER ET AL., 2019)

Discussion

- At early stages of competence development, EF play a more dominant role and facilitate the acquisition of RC (not vice versa)
- Later (2nd grade and beyond), mutual developmental support between EF and RC
- After basic word-decoding processes have been acquired in first and second grade, reading for comprehension starts to emerge



Results fit well the transactional model of cognitive development (see session 1)

- "Extensive practice of reading comprehension might work like 'muscle training' for EF"
- Children with improved RC might engage more frequently in reading activities, which in turn increases EF

CONCLUSION OF TODAY'S SESSION

- Evidence of reciprocal relations between EF and RC

→ Cognitive Plasticity: The executive function of updating seems to be trainable.

→ Design and Evaluation of EF-training programs to facilitate inclusive education

  - Topic of next session

LITERATURE OF TODAY'S SESSION

Cowan, N. (2014). Working memory underpins cognitive development, learning, and education. *Educational Psychology Review, 26*, 197-223. https://dx.doi.org/10.1007%2Fs10648-013-9246-y

Goswami, U. (2011). The Wiley-Blackwell Handbook of Childhood Cognitive Development. West-Sussex, UK: Wiley-Blackwell.

Chapter 22: Executive function in typical and atypical development

Meixner, J., Warner, G., Lensing, N., Schiefele, U., & Elsner, B. (2019). The relation between executive functions and reading comprehension in primary-school students: a cross-lagged-panel analysis. *Early Childhood Research Quarterly, 46*, 62-74. DOI: https://doi.org/10.1016/j.ecresq.2018.04.010

Morasch, K., Raj, V., & Bell, M. (2013). The development of cognitive control from infancy through childhood. In D. Reisberg (Ed.), *Oxford handbook of cognitive psychology* (pp. 989-999). New York: Oxford University Press. https://doi.org/10.1093/oxfordhb/9780195376746.013.0062

- Break