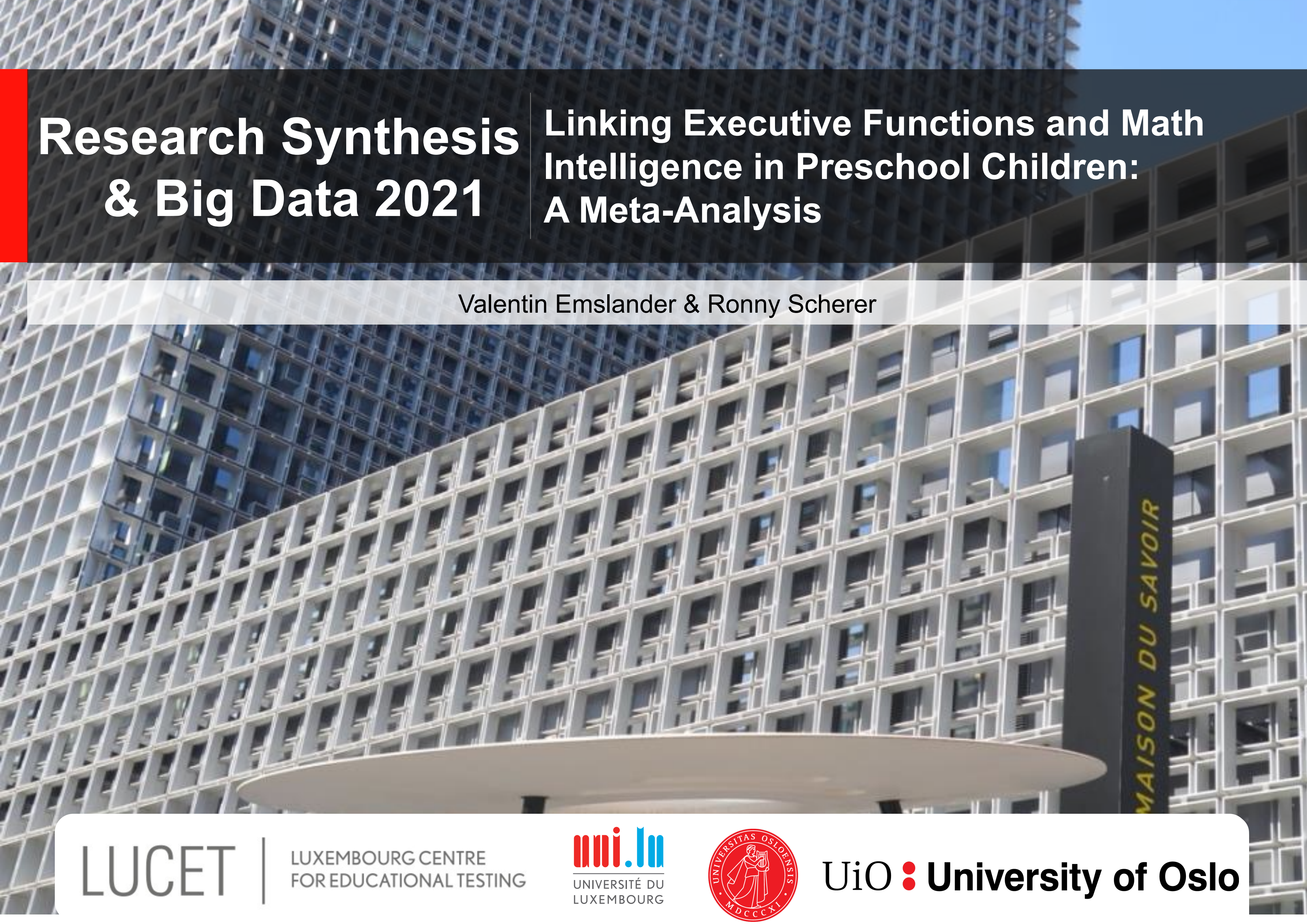
Research Synthesis & Big Data 2021

Linking Executive Functions and Math Intelligence in Preschool Children: A Meta-Analysis

Valentin Emslander & Ronny Scherer



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Executive Functions

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valentin.emslander@uni.lu
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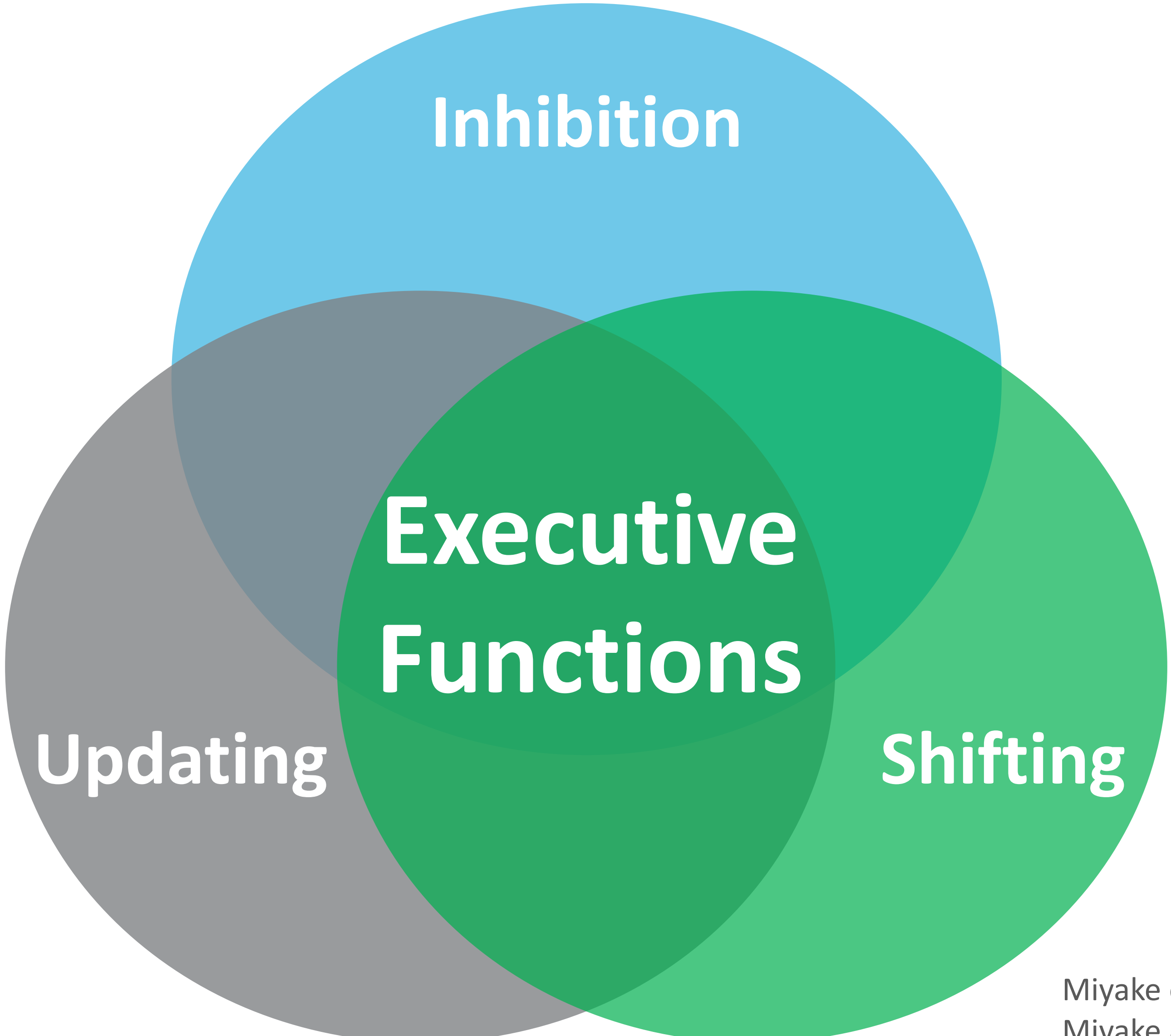

Miyake et al. (2000)
Miyake & Friedman (2012)

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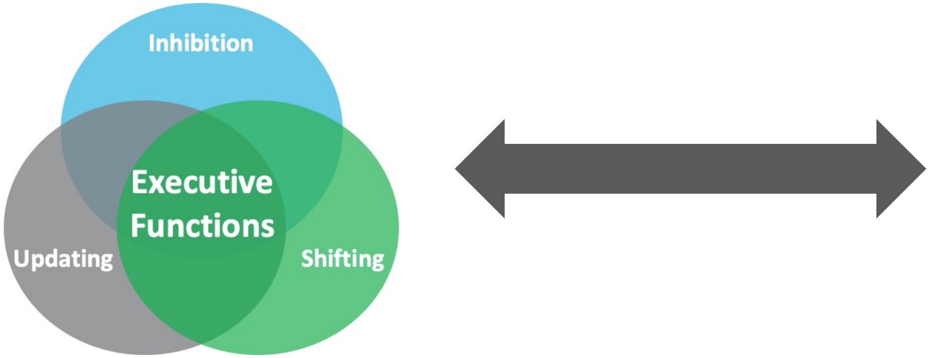
Background

What we know

- EFs are linked to broader math skills (any math test)
- EF subdimensions differ in their relation to broad math skills
- in both school students and adults
  - E.g., Friso-van den Bos et al., 2013; Peng et al., 2016

What is still debated

- What is the relation between EFs and (narrow) math intelligence?
- How strong is this relation in preschool children?
- Do EFs subdimensions differ?
- Preschool children can't read → how does assessment influence this link?



Research Questions 1 & 2

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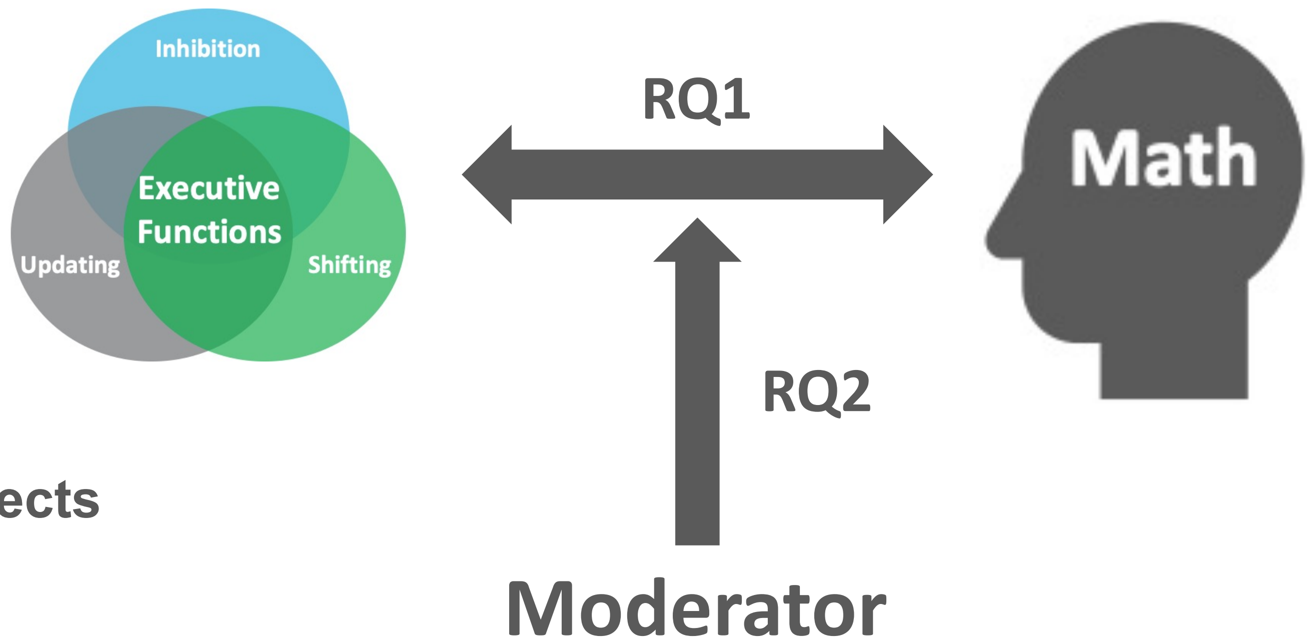
RQ 1: Overall correlations

- All EFs
- Inhibition
- Shifting
- Updating



RQ 2: Moderator effects

- Study
- Sample
- EF measurement
- Math intelligence measurement

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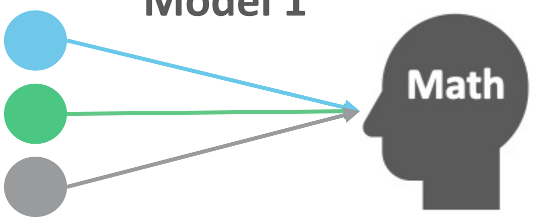
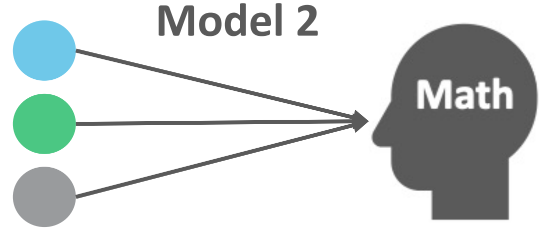
RQ 3: Model Testing

- To what extent do the three subdimensions of EFs (i.e., inhibition, shifting, updating) differ in their ability to explain variation in math intelligence
- How much variation do they explain jointly?

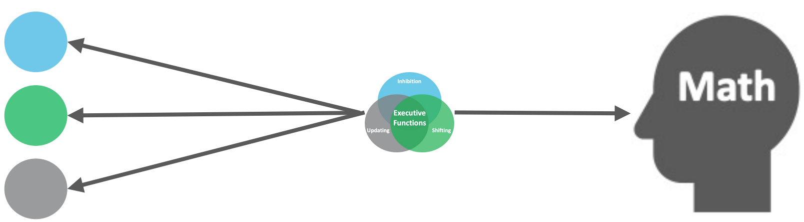
Model 1



Model 2



Model 3



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RQ 3: Model Testing

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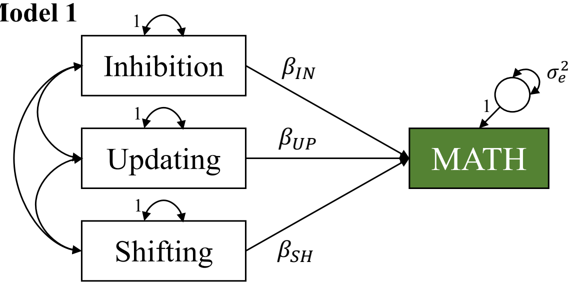
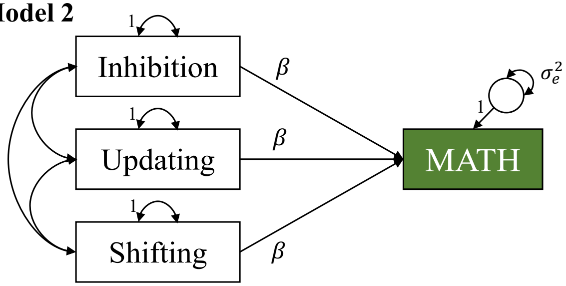
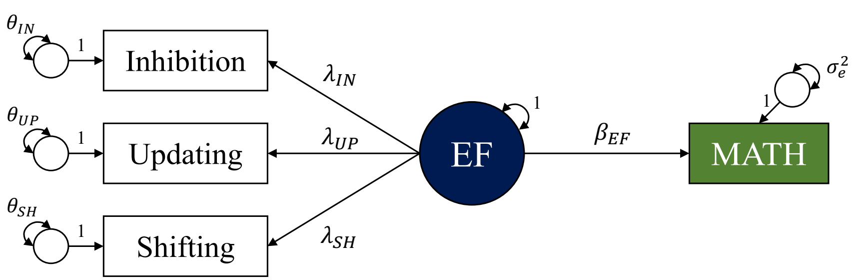
Model 1



Model 2



Model 3



Literature Search

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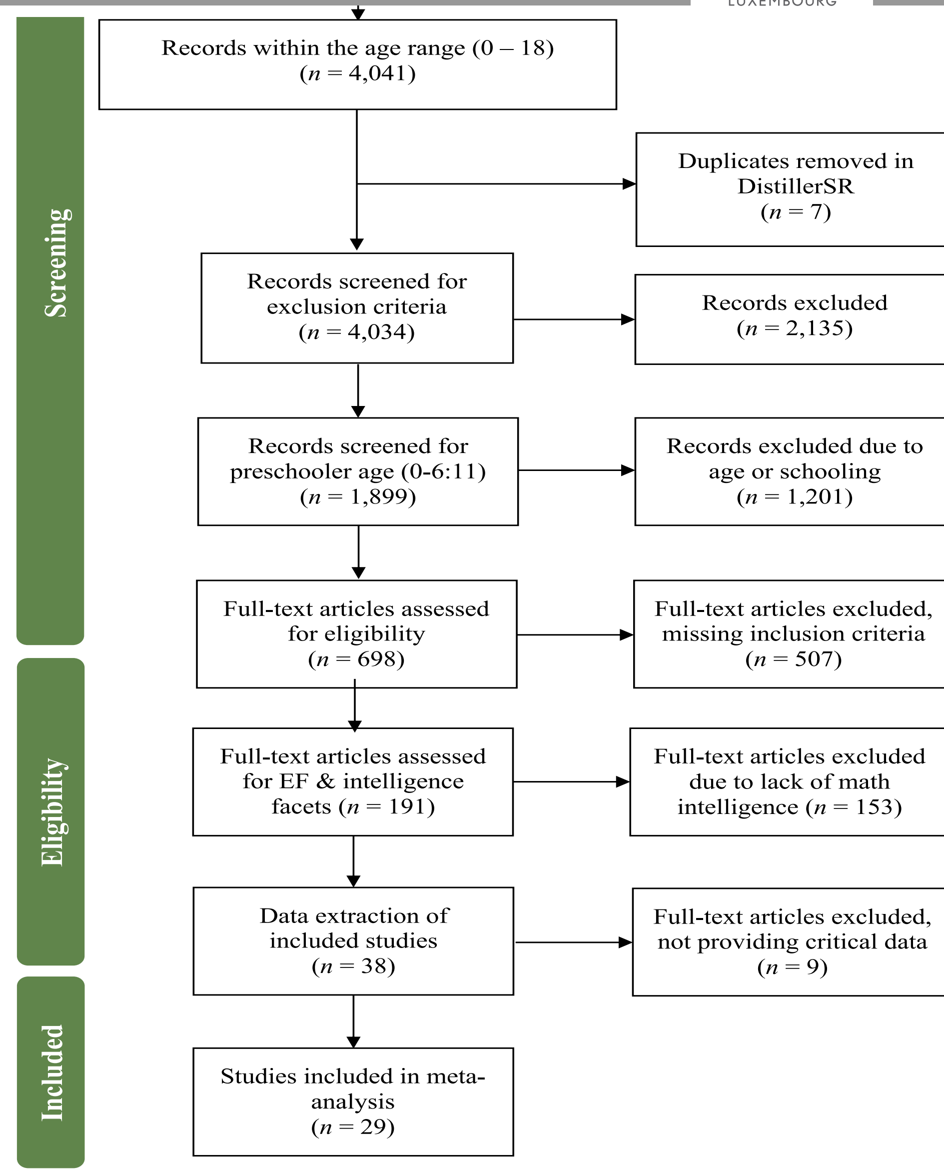
- English, published 2000 or later
- Preschool children (0 - 6:11)
- No medical condition
- Report an effect size of at least one EF and one kind of math intelligence

- Screened: 4034 titles/abstracts
- Screened: 191 full texts
- Included: 29 studies

- Agreement: κ = 93 % to κ = 98 %



Included Data

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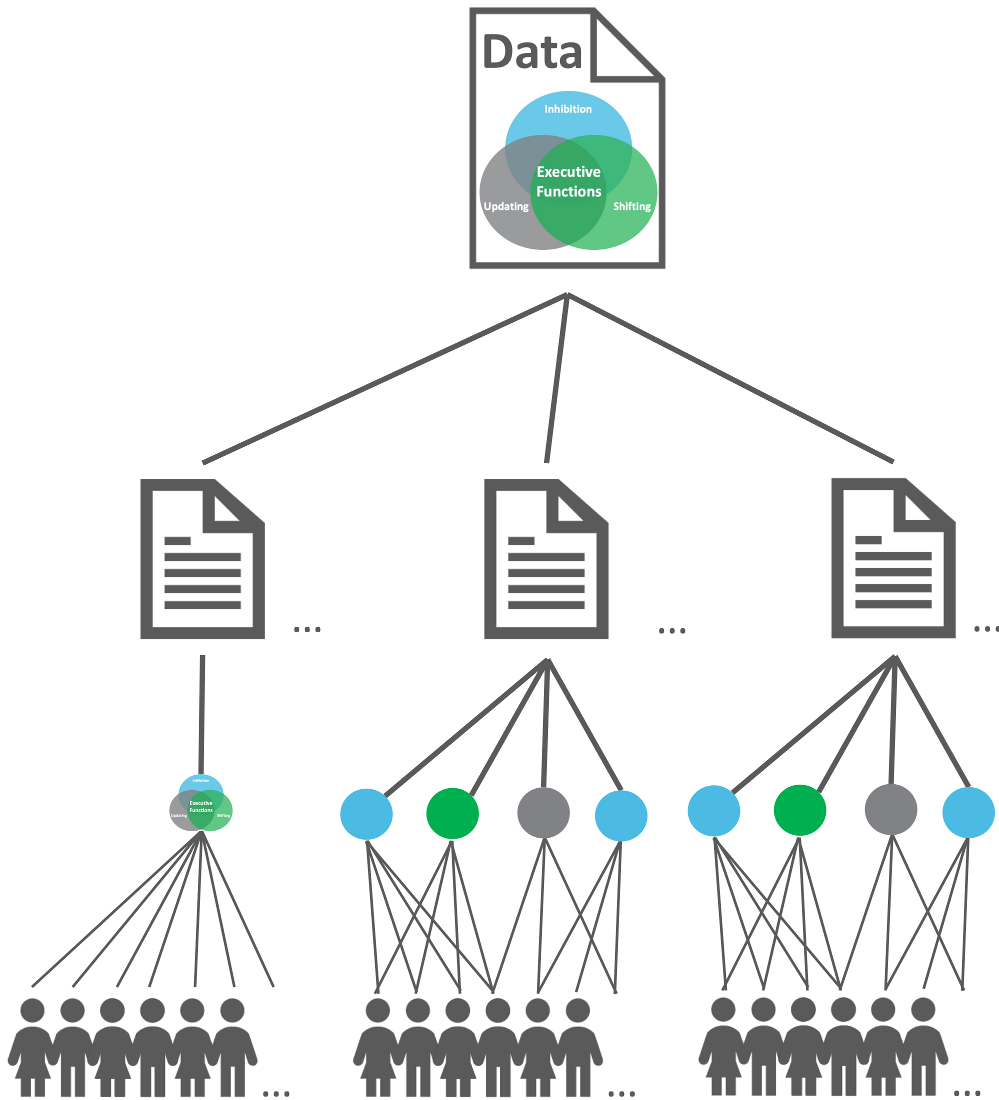
- **Three-level meta-analysis**
- 29 **studies**
- 268 **effect sizes**
  - 120 *inhibition*
  - 60 *shifting*
  - 78 *updating*
- 25,510 **preschool children**



Methods

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- Inter-coder agreement between κ = 93 % to κ = 98 %
- RQ 1: Overall correlation
  - Random-effects three-level meta-analysis
  - 4 meta-analyses: 1) overall, 2) inhibition, 3) shifting, 4) updating
  - metafor (Viechtbauer, 2010) & metaSEM (Cheung, 2015)
- RQ 2: Moderator effects
  1. Study (e.g., publication year)
  2. Sample (e.g., age)
  3. Measurement (e.g., tasks used to test EFs)
- RQ 3: Model Testing
  - Correlation-based meta-analytic structural equation modelling (MASEM)
  - One-stage (Cheung & Cheung, 2016) and two-stage MASEM (Jak & Cheung, 2020)

RQ 1: Overall Correlation

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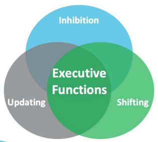
- Mean correlation with math intelligence in preschool children:



	Correlation	95% CI	Effect sizes
1. All EFs	$\bar{r} = .35$	[.31, .39]	$k = 268$
2. Inhibition	$\bar{r} = .30$	[.34, .42]	$k = 120$
3. Shifting	$\bar{r} = .38$	[.24, .36]	$k = 60$
4. Updating	$\bar{r} = .36$	[.31, .44]	$k = 78$

- Nonsignificant differences between EFs

Descriptive Results – Measurement moderators

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- Most frequently used tasks:
  - **Stroop-like tasks** (*k* = 66 of 120) to measure **inhibition**
  - **Dimensional change tasks** (*k* = 46 of 60) to measure **shifting**
  - **Difficult span tasks** (*k* = 28 of 78) to measure **updating**
- Administration of EF measures (total *k* = 268)
  - **verbally** (*k* = 96)
  - **apparatus-based** (*k* = 75)
  - **computer-based** (*k* = 48)
  - **paper-and-pencil** (*k* = 5)
- Math intelligence measures
  - predominantly administered **verbally** (*k* = 222; 83%)

RQ 2: Moderator Effects

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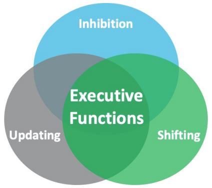
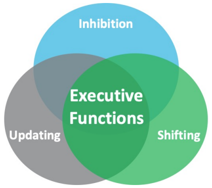
1. *Continent*: Larger effect for American samples

2. *EF Subdimension*: Order of effects,
   - Inhibition < Shifting = Updating



3. *EF task type*:
   - Largest effects for Composite, Tap (inhibition), Simon (inhibition), Random generation (updating), and Difficult span (updating) tasks



4. *Mode of math intelligence testing*:
   - Largest effects for verbal and behavioral testing

5. *Reliability of math intelligence measures*:
   - Measures with greater reliability showed closer link to EFs

RQ 3: Model Testing

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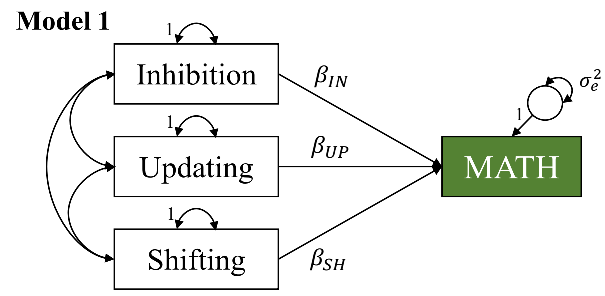
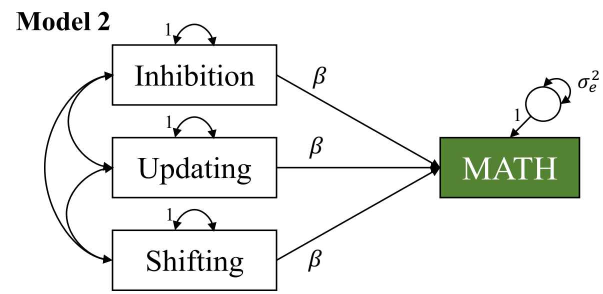
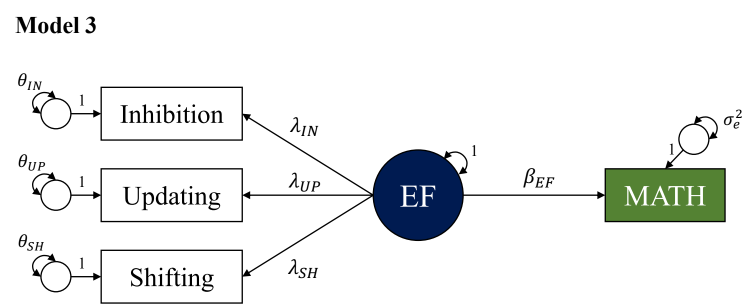
- *Model 1*
  - inhibition ($\beta_{inhibition}$ = 0.16, 95 % CI [0.07, 0.24])
  - shifting ($\beta_{shifting}$ = 0.27, 95 % CI [0.19, 0.35])
  - updating ($\beta_{updating}$ = 0.27, 95 % CI [0.20, 0.34])
  - residual variance σ_e^2 = 0.75 (95 % CI [0.69, 0.80])
  - Explained math intelligence variance: **25 %**



- *Model 2* (equal regression coefficients for EFs)
  - overall regression coefficient β = 0.23 (95 % CI [0.21, 0.26])
  - residual variance σ_e^2 = 0.75 (95 % CI [0.69, 0.80])
  - Explained math intelligence variance: **25 %**



- ***Model 3* (EFs as one latent variable)**
  - inhibition ($\lambda_{inhibition}$ = 0.49, 95 % CI [0.41, 0.57])
  - shifting ($\lambda_{shifting}$ = 0.53, 95 % CI [0.45, 0.61])
  - updating ($\lambda_{updating}$ = 0.53, 95 % CI [0.45, 0.60])
  - overall regression coefficient β = 0.70 (95 % CI [0.62, 0.79])
  - residual variance was σ_e^2 = 0.51 (95 % CI [0.37, 0.62])
  - Explained math intelligence variance: **49 %** **→ One latent variable better than distinct variables**



Limitations

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- **Limited to preschool children** (without medical condition or disorder)
  - **Why**: Generalizability to the general public (e.g., Kingdon et al., 2016)
  - Not generalizable over other age groups or with medical conditions
- **WEIRD sample**
  - **Why:** ~74% of all effect sizes from US samples
  - Further evidence from other countries is needed
- **Small study pool**
  - **Why**: Strict exclusion criteria & lack of reporting
  - Not all moderators of interest could be investigated
- **Pragmatic categorization of EF task types**
  - **Why**: Large variety of possible categorizations (e.g., Garon et al., 2008).
  - Might lead to divergent findings to other meta-analyses

Discussion & Conclusion

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- Overall correlations are similar to previous meta-analyses
  - Indicate relation, but not redundance of EFs and math intelligence
- Age was not a significant moderator. However:
  - Trend over the previous meta-analyses,
  - Decreasing relations between math intelligence and inhibition and shifting with age.
- Moderators showed importance of task choice and psychometric quality when measuring EFs and math intelligence
- MASEM could not confirm the three core EFs to be differentially related to math intelligence

Conclusion

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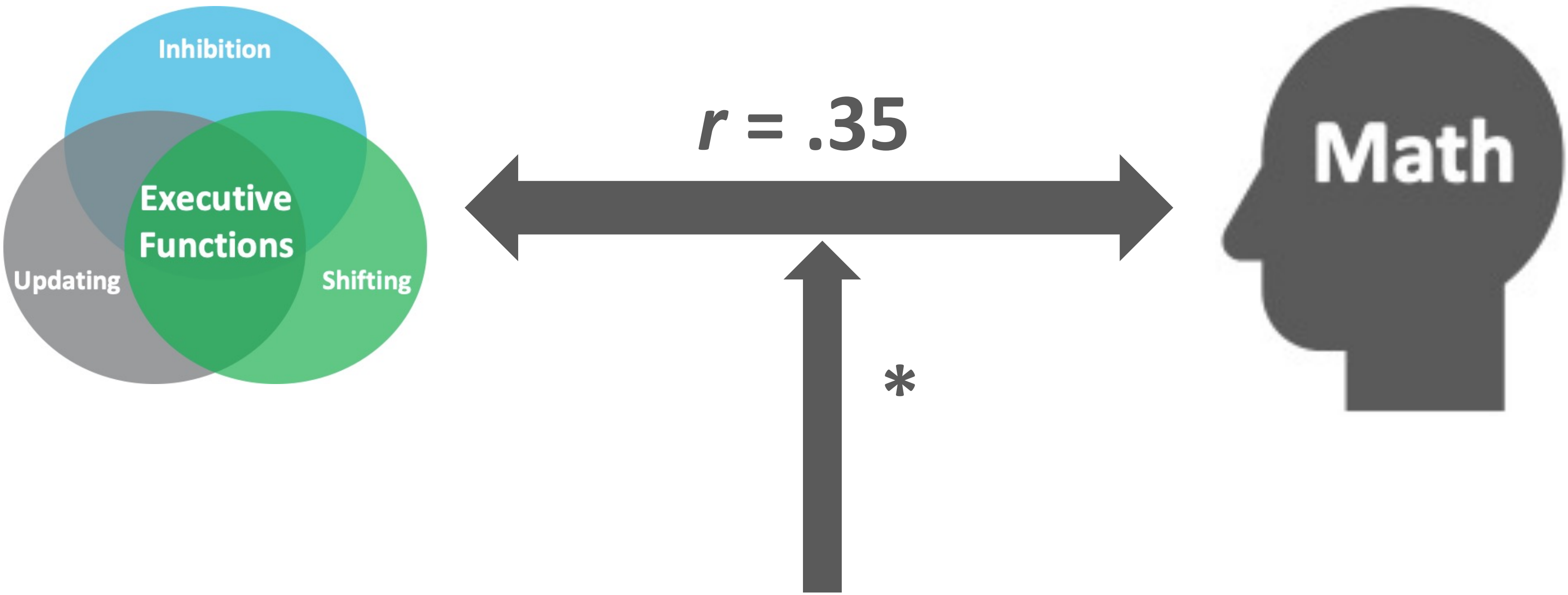

EF moderators:

- Task type
- Subdimension

Math moderators:

- Reliability
- Verbal / behavioral mode of testing

Take Home Messages

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1) Are EFs and math intelligence related?

- Yes, EFs, as a composite as well as three subdimensions, are positively and significantly related to math intelligence in preschool children.

2) What does this imply?

- It implies an overlap in some skills and measures and, ultimately, the involvement of EFs in solving math intelligence tasks and vice versa.

3) Does this mean, we should only measure one of the two skills?

- No, the evidence presented does not suggest that assessing one of the two constructs may make assessment of the other redundant.

4) Does the measurement of EFs and math intelligence influence their relation?

- Yes, measurement characteristics explained more variance than sample or study characteristics, showing the importance of considering the psychometric quality of both EFs and math intelligence assessments (e.g., reliability & appropriateness).

5) Are EFs best represented by three distinct EFs or with one latent variable?

- Representing EFs with a latent variable (capturing their covariance) explained substantially more variance in math intelligence in preschool children.

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valentin.emslander@uni.lu

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Thank you!

What are your questions and remarks?

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Valentin Emslander
valentin.emslander@uni.lu