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Multilevel Models in Meta-Analysis: A Systematic Review of Their Application and Suggestions

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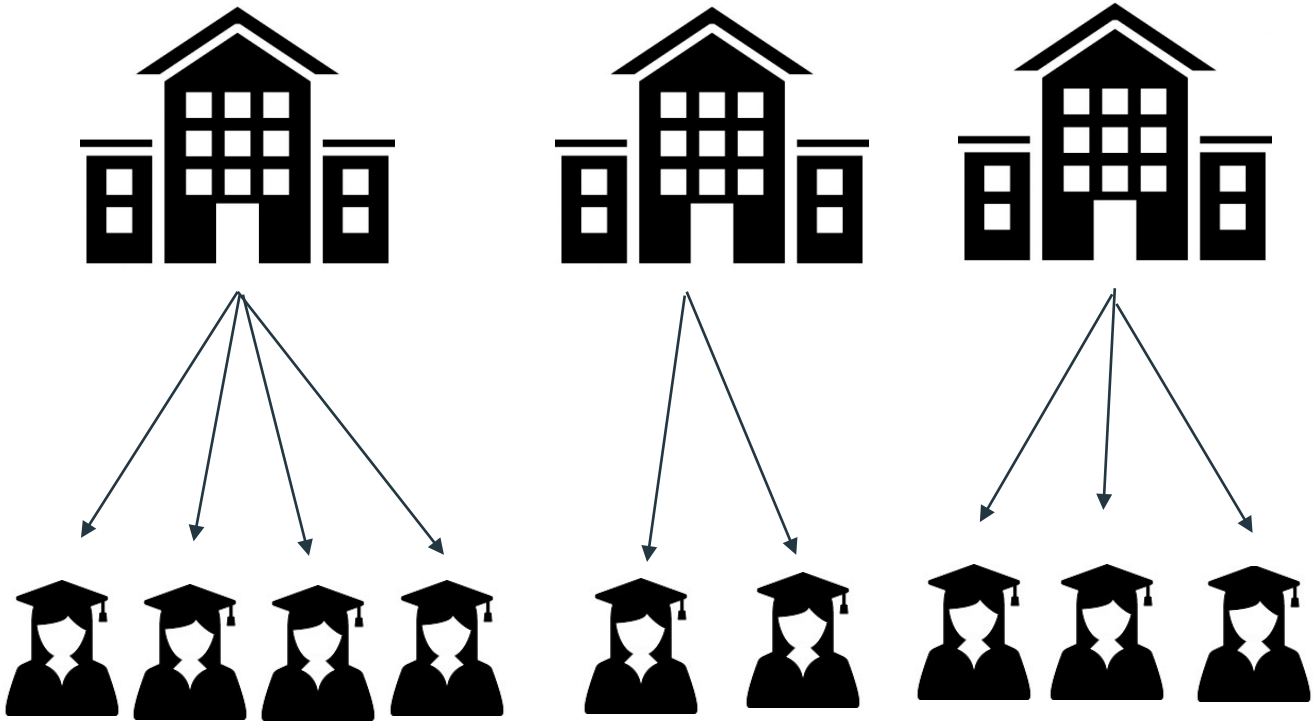
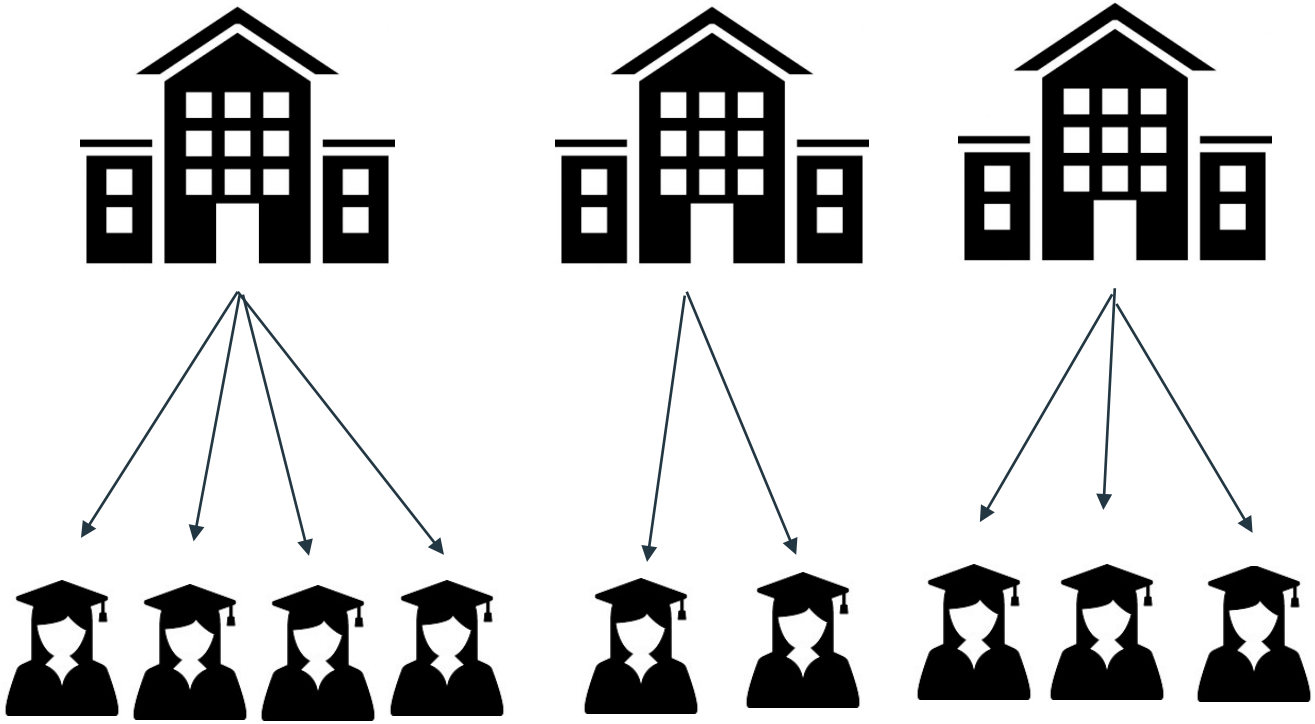
Multilevel models



School

Students

Multilevel models



School

$$\beta_{0j} = \gamma_{00} + u_{0j}$$

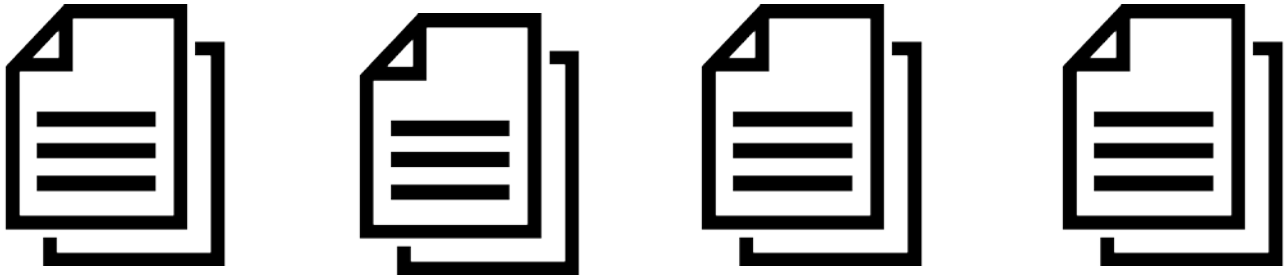
Students

$$y_{ij} = \beta_{0j} + e_{ij}$$

$$y_{ij} = \gamma_{00} + u_{0j} + e_{ij}$$

Multilevel models - meta-analysis

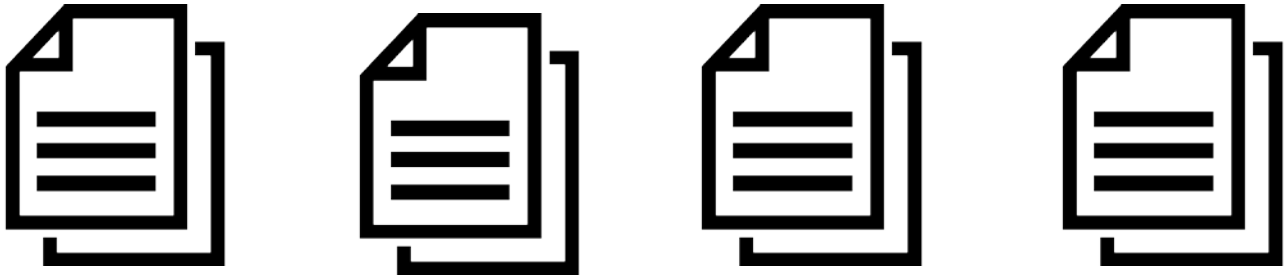
Level 2: Studies



Level 1: Participants

Multilevel models - meta-analysis

Level 2: Studies



Study 1 Study 2 Study 3 Study 4

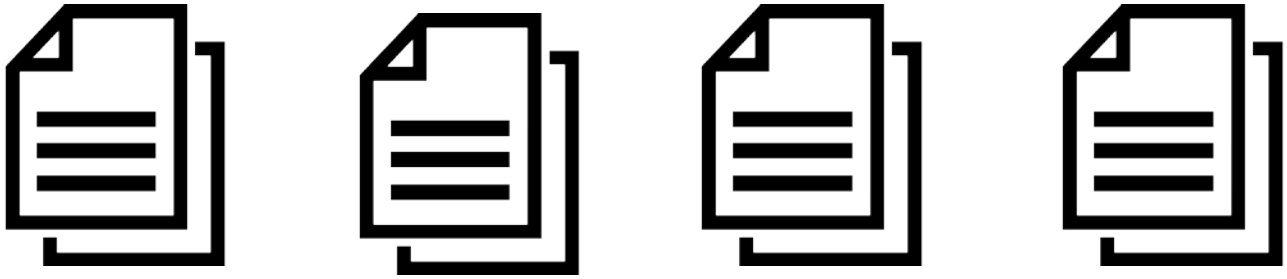
Level 1: Effect sizes

$\mathbf{ES_1}$ $\mathbf{ES_2}$ $\mathbf{ES_3}$ $\mathbf{ES_4}$

Multilevel models - meta-analysis

Level 2: Studies - *j*

$Level\ 2: \gamma_j = \theta_0 + u_j$



Study 1 | Study 2 | Study 3 | Study 4

Level 1: Effect sizes

$\mathbf{ES_1}$ $\mathbf{ES_2}$ $\mathbf{ES_3}$ $\mathbf{ES_4}$

$Level\ 1: y_j = \gamma_j + e_j$

$$y_j = \theta_0 + e_j + u_j$$

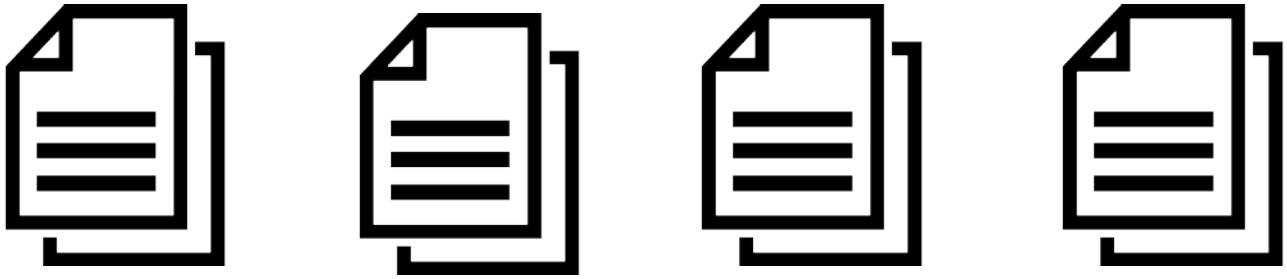
Multilevel models - meta-analysis

Level 2: Studies - j

$Level\ 2: \gamma_j = \theta_0 + u_j$

$u \sim N(0, \sigma_u^2)$

Between-studies variance



Study 1 | Study 2 | Study 3 | Study 4

Level 1: Effect sizes

$Level\ 1: y_j = \gamma_j + e_j$

$e \sim N(0, \sigma_{e_j}^2)$

Sampling-variance (assumed KNOWN)

$\mathbf{ES_1}$ $\mathbf{ES_2}$ $\mathbf{ES_3}$ $\mathbf{ES_4}$

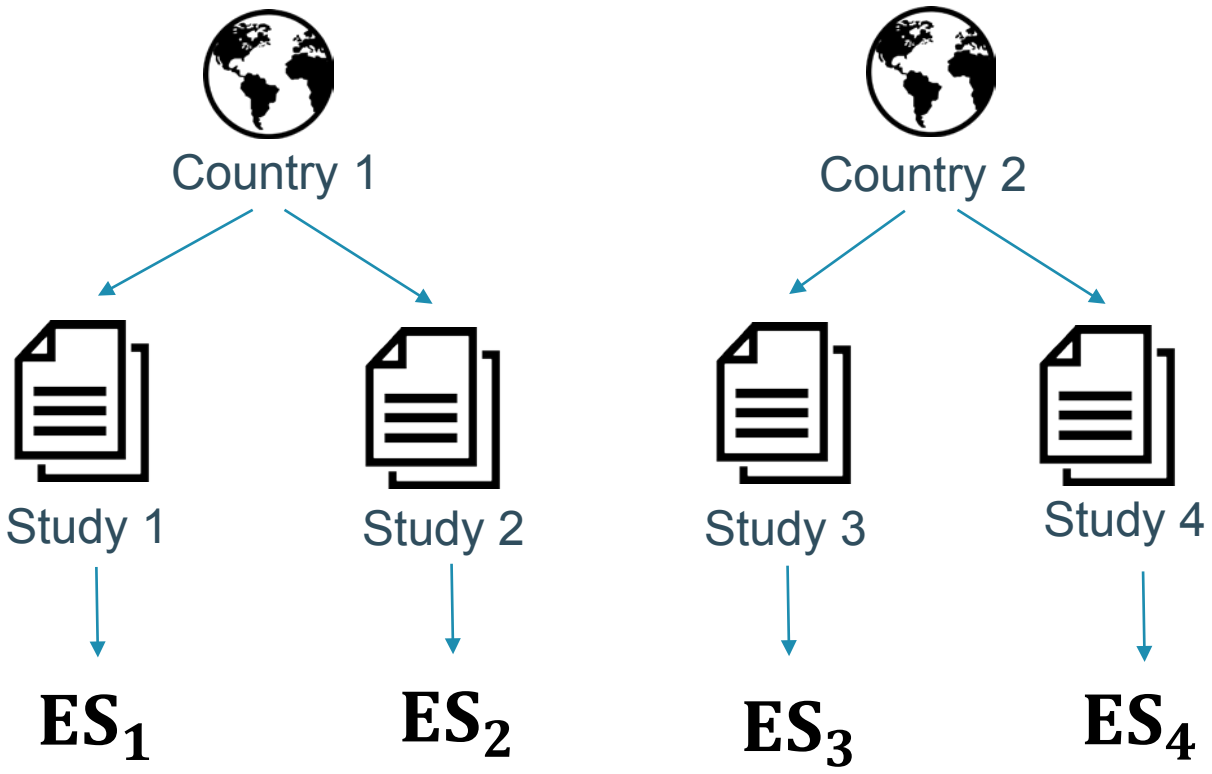
$$y_j = \theta_0 + e_j + u_j$$

Multilevel models - meta-analysis

Level 3: Countries

Level 2: Studies

Level 1: Effect sizes



Konstantopoulos (2011)

Multilevel models - meta-analysis

Level 3: Countries - *k*

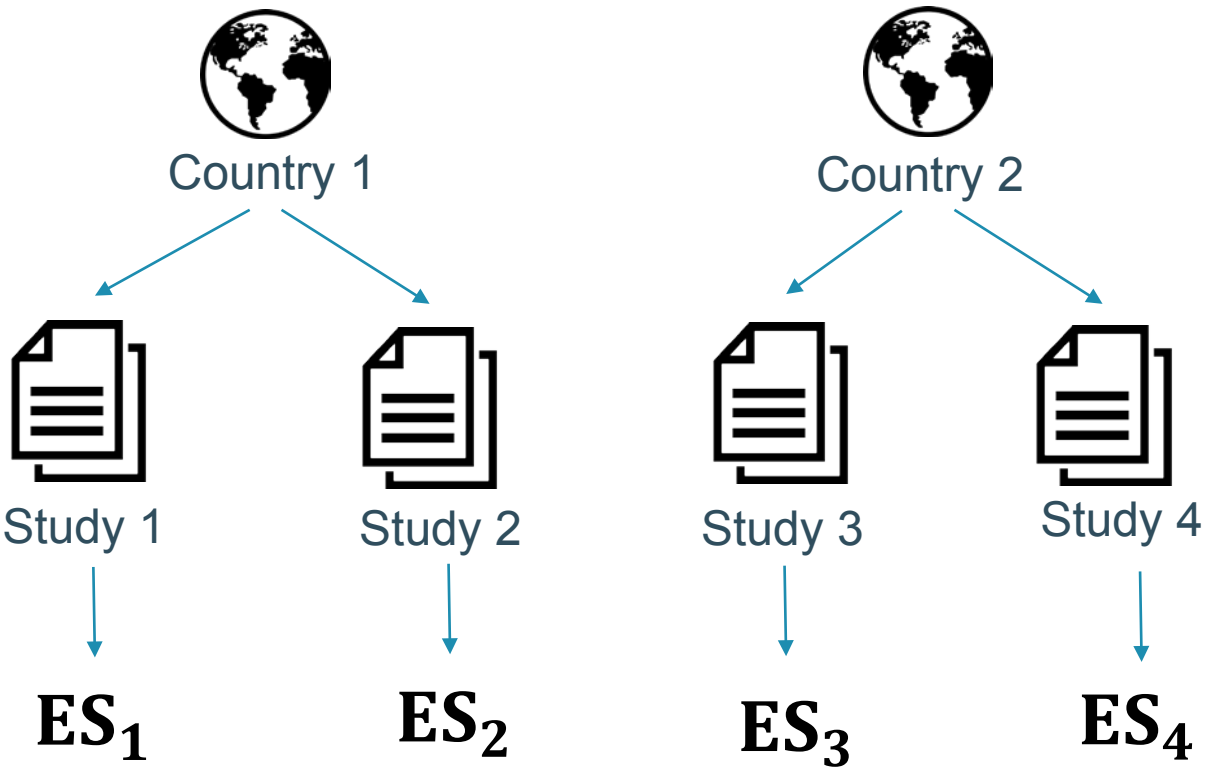
$Level\ 3: \theta_{0k} = \delta_{00} + w_{0k}$

Level 2: Studies - *j*

$Level\ 2: \gamma_{jk} = \theta_{0k} + u_{jk}$

Level 1: Effect sizes

$Level\ 1: y_{jk} = \gamma_{jk} + e_{jk}$



$$y_{jk} = \delta_{00} + w_{0k} + u_{jk} + e_{jk}$$

Multilevel models - meta-analysis

Level 3: Countries - *k*

$Level\ 3: \theta_{0k} = \delta_{00} + w_{0k}$

σ_w^2 =Between-countries variance

Level 2: Studies - *j*

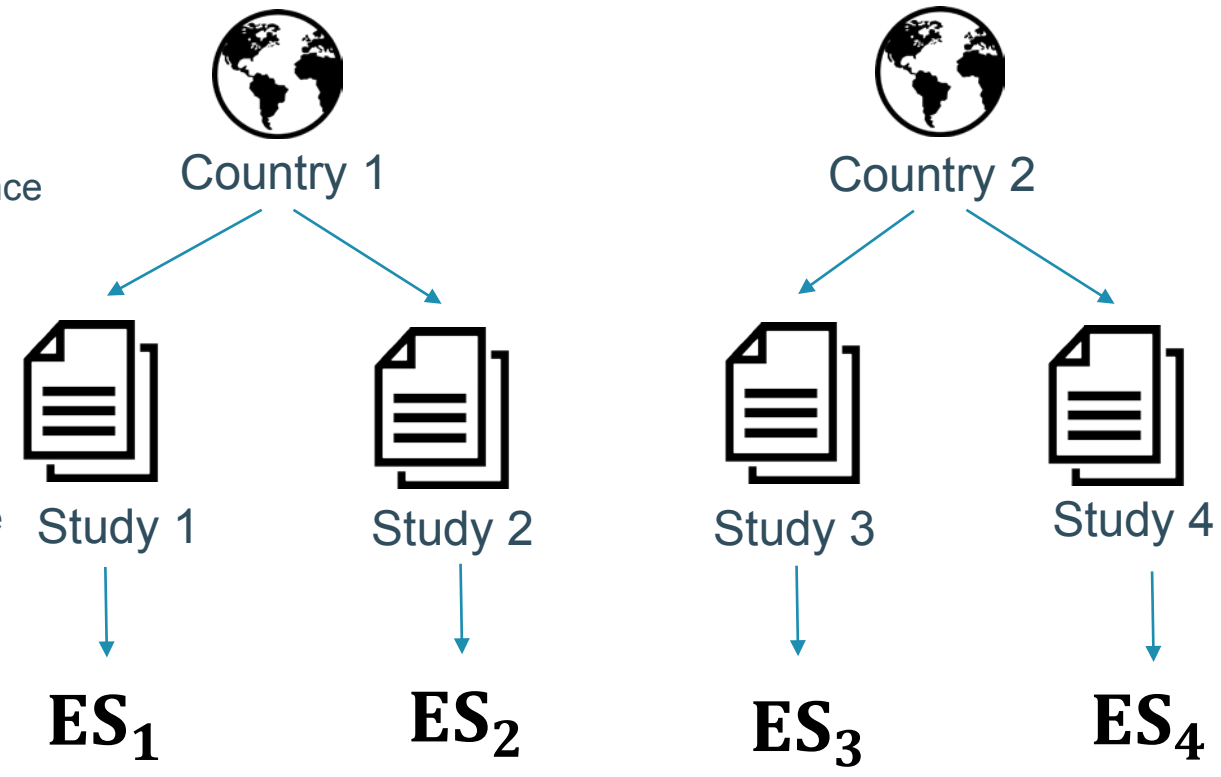
$Level\ 2: \gamma_{jk} = \theta_{0k} + u_{jk}$

σ_u^2 = Between-studies variance

Level 1: Effect sizes

$Level\ 1: y_{jk} = \gamma_{jk} + e_{jk}$

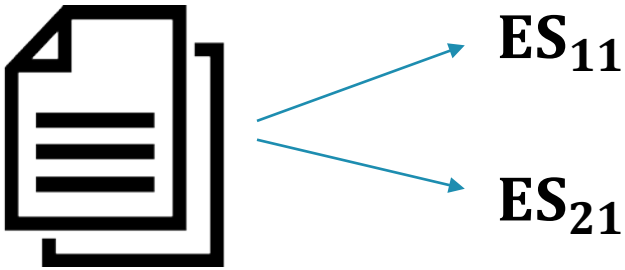
$\sigma_{e_j}^2$ =KNOWN sampling-variance



$$y_{jk} = \delta_{00} + w_{0k} + u_{jk} + e_{jk}$$

Multilevel models - meta-analysis

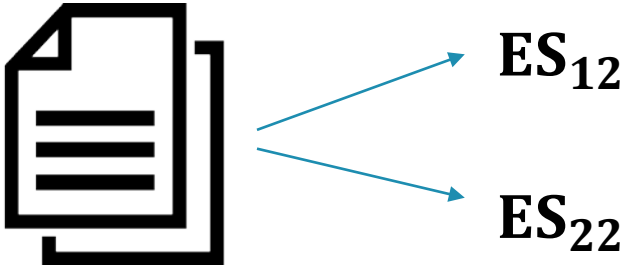
- Dependent effect sizes



Study 1

ES_{11}

ES_{21}



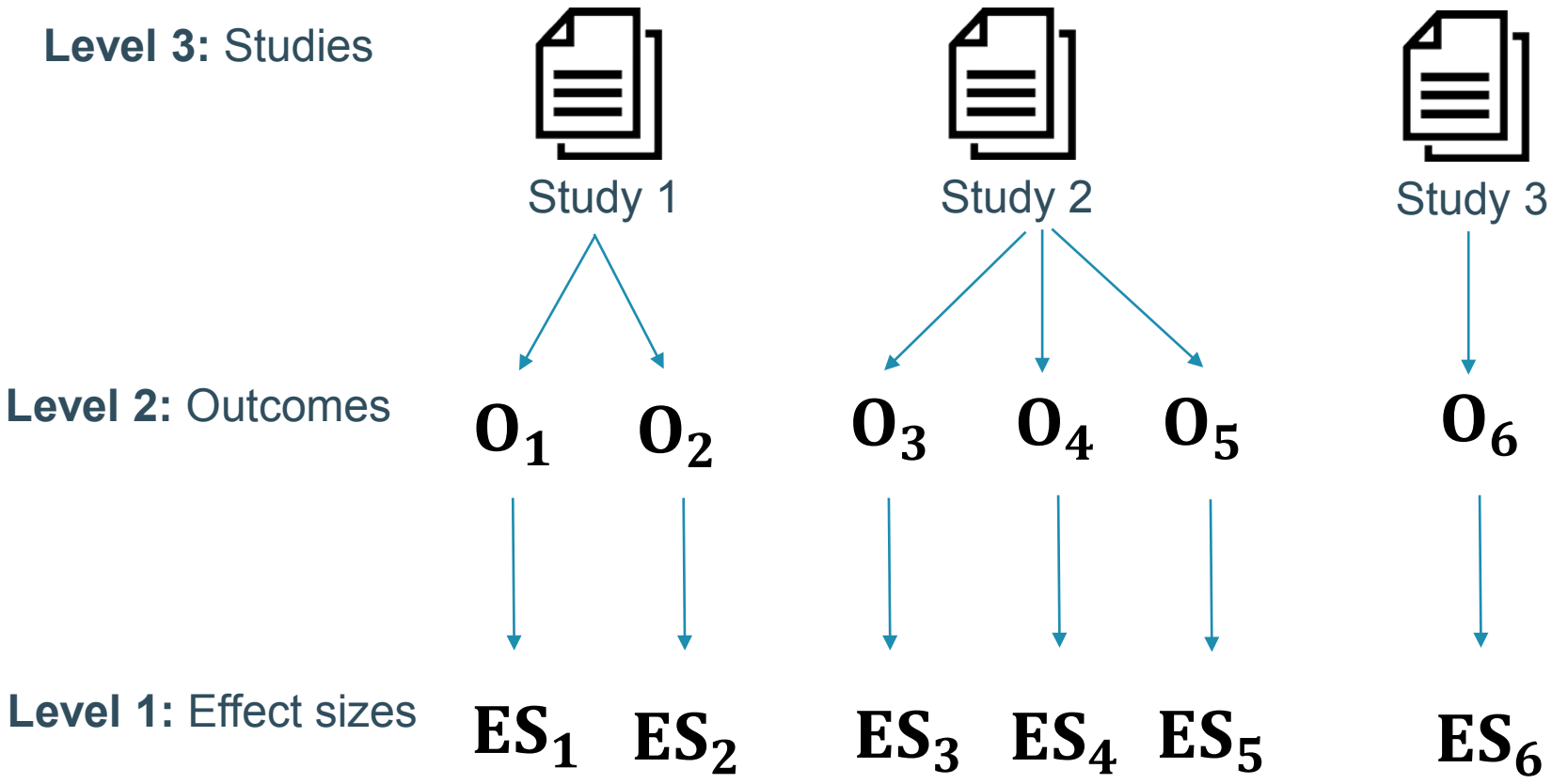
Study 2

ES_{12}

ES_{22}

- Several measures of the same construct
- Several comparison between several treatment group with a common control group
- Several subsamples

Multilevel models - meta-analysis



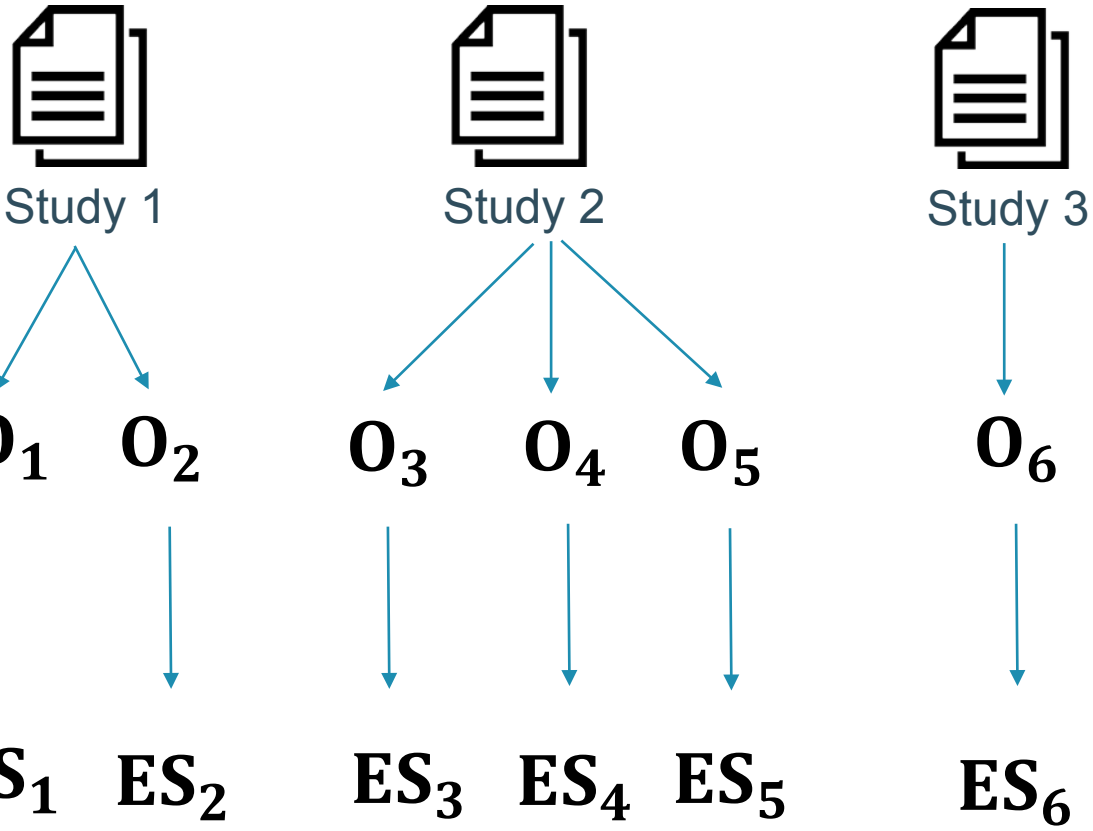
Van den Noortgate, López-López, Marín-Martínez, & Sánchez-Meca (2013; 2015)

Multilevel models - meta-analysis

Level 3: Studies - *j*

$Level\ 3: \theta_{0j} = \delta_{00} + u_{0j}$

σ_u^2 = Between-studies variance



Level 2: Outcomes - *i*

$Level\ 2: \gamma_{ij} = \theta_{0j} + v_{ij}$

σ_v^2 = Between-outcomes variance

Level 1: Effect sizes

$Level\ 1: y_{ij} = \gamma_{ij} + e_{ij}$

$\sigma_{e_j}^2$ = KNOWN sampling-variance

$$y_{ij} = \delta_{00} + u_{0j} + v_{ij} + e_{ij}$$

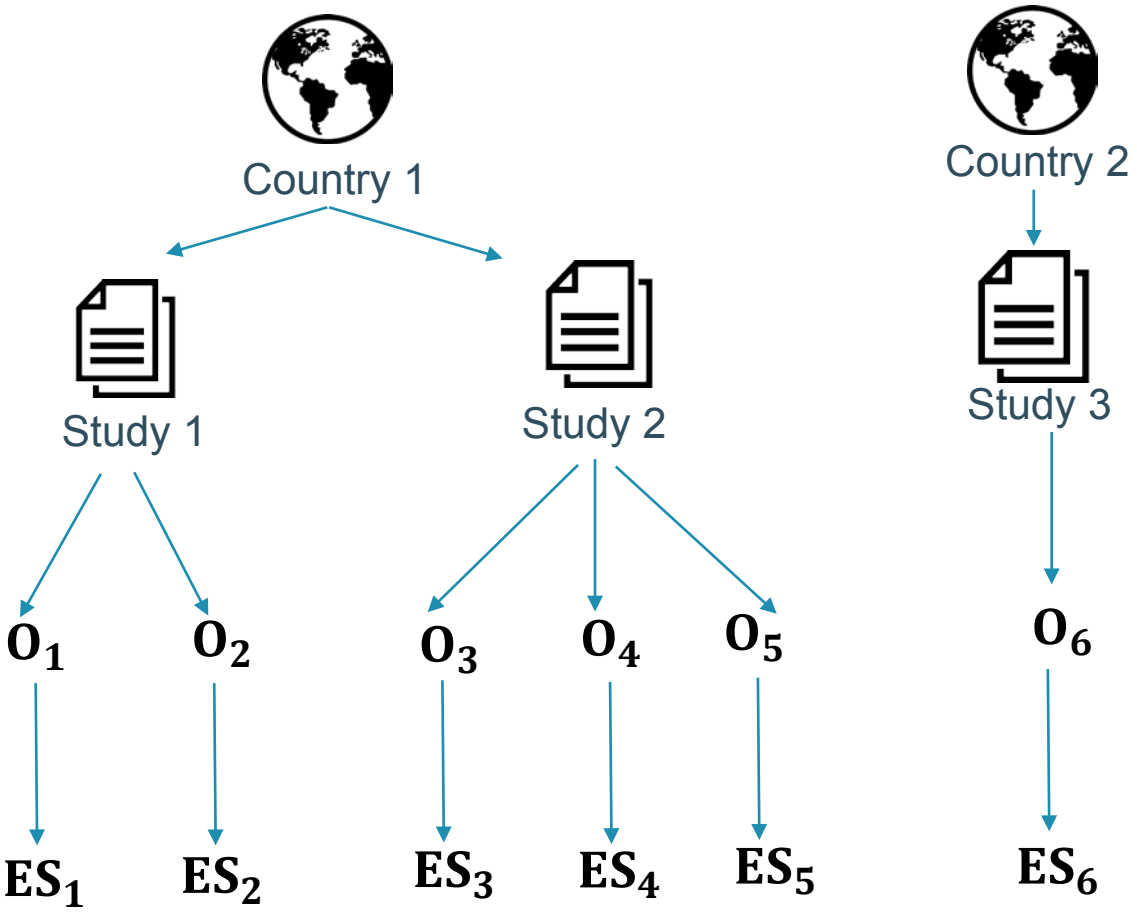
Multilevel models - meta-analysis

Level 4: Countries - *k*

Level 3: Studies - *j*

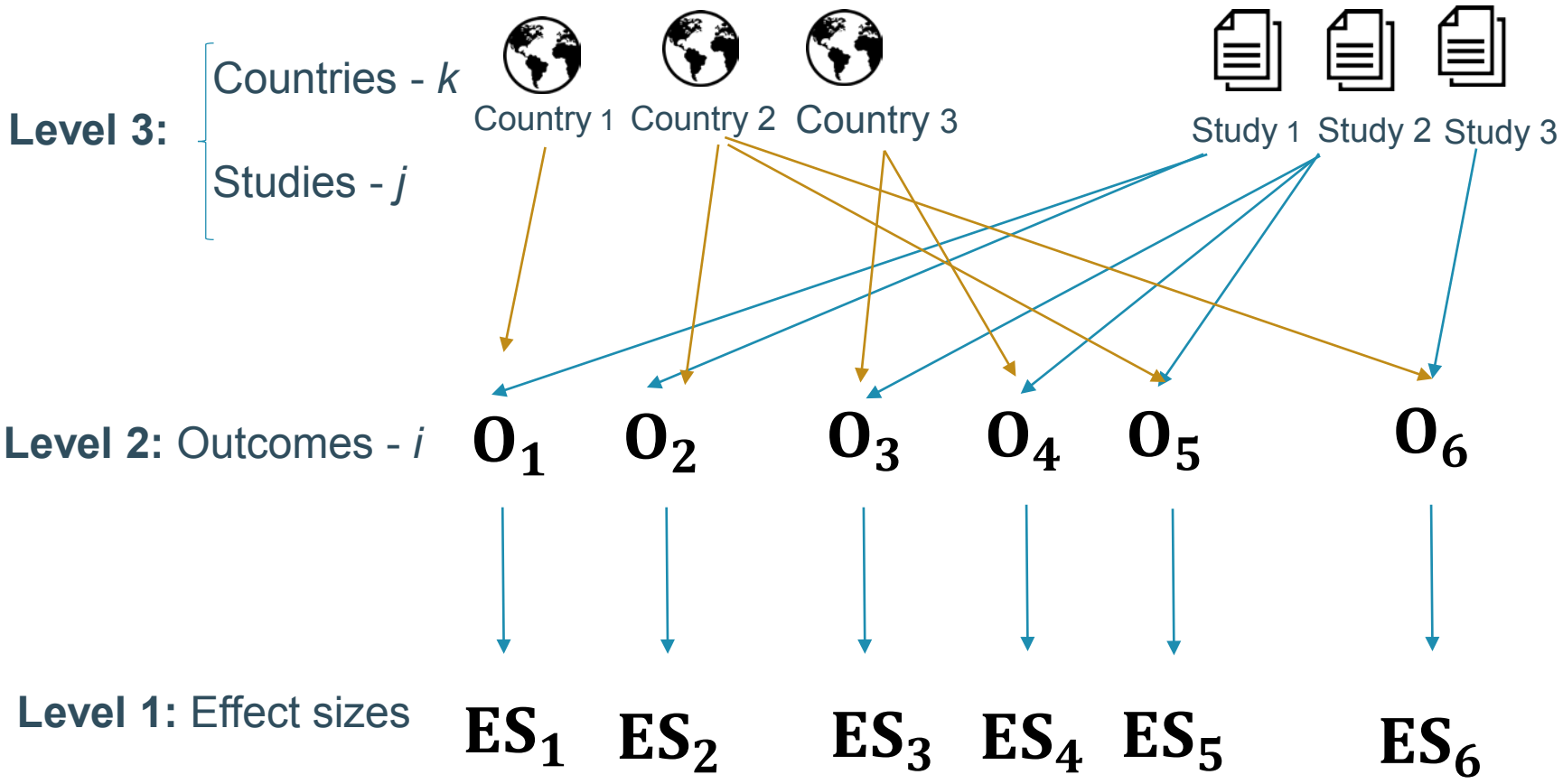
Level 2: Outcomes - *i*

Level 1: Effect sizes



$$y_{ijk} = \delta_{000} + w_{00k} + u_{0jk} + v_{ijk} + e_{ijk}$$

Other multilevel structures



$$y_{i(jk)} = \delta_{000} + w_{00k} + u_{00j} + v_{i(jk)} + e_{i(jk)}$$

Multilevel models - meta-analysis

Some advantages…

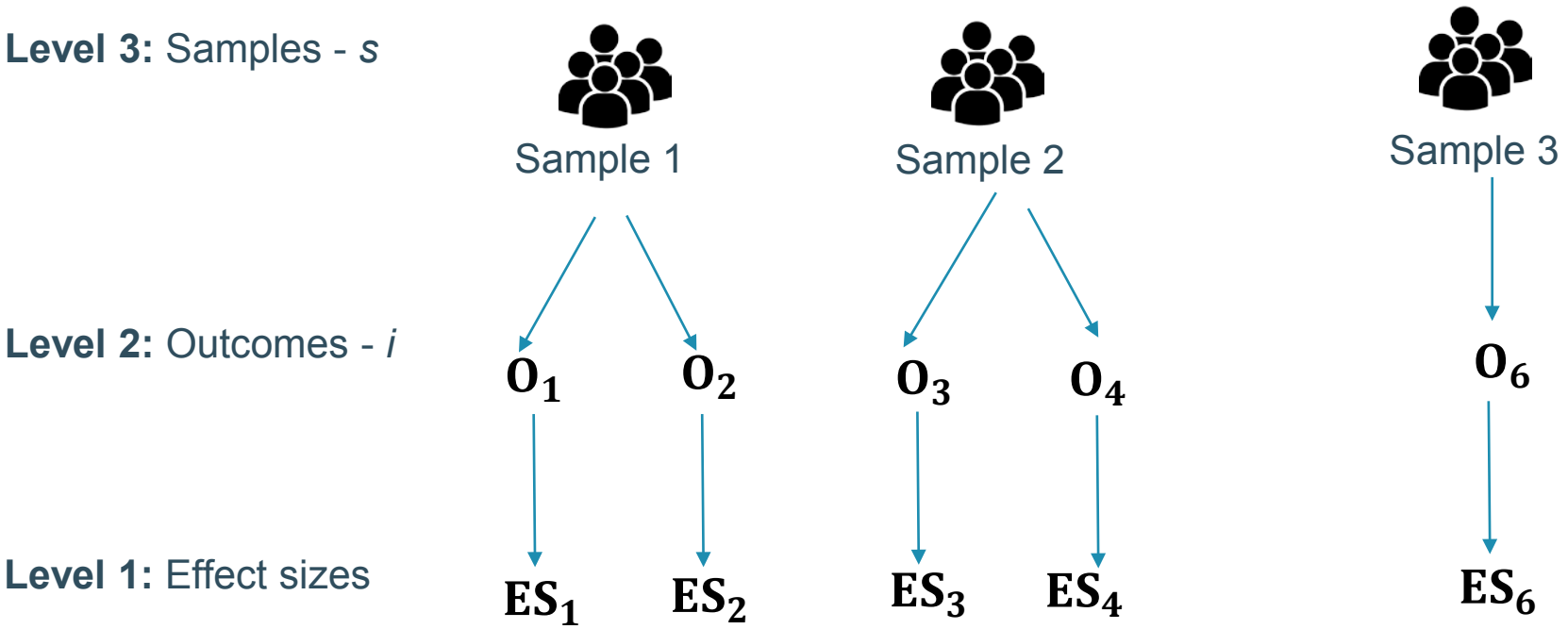
- It is possible to get the total variance disaggregated for each random effect

Some disadvantages…

- The model should include all relevant random effects

Example

Meta-analysis on the relationship between mindfulness and creativity



Example

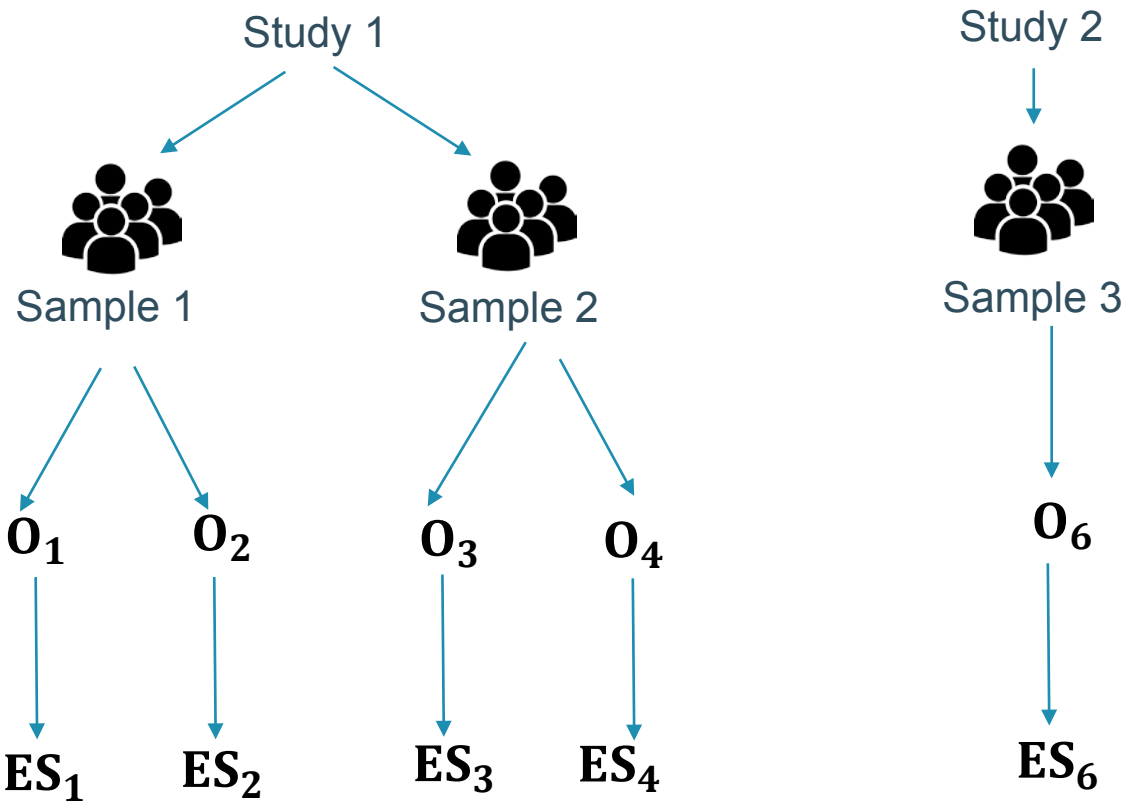
Meta-analysis on the relationship between mindfulness and creativity

Level 4: Studies - *j*

Level 3: Samples - *s*

Level 2: Outcomes - *i*

Level 1: Effect sizes



Example

Meta-analysis on the relationship between mindfulness and creativity

	3-level model	4-level model
Overall effect (SE)	0.219 (0.065)	0.219 (0.072)
Level 2: between-outcomes	0.029	0.029
Level 3: between-samples	0.066	0.054
Level 4: between-studies		0.014

If model mispecified…

- Biased estimates of the…
  - Standard error of the fixed effects
    → Inflated Type I errors
  - Variance components (within-study and between-study variance)
    → Under- or over- estimated

Purpose

- How are multilevel models commonly specified in meta-analysis?

- Do researchers appropriately specify multilevel models in meta-analysis?

Systematic review

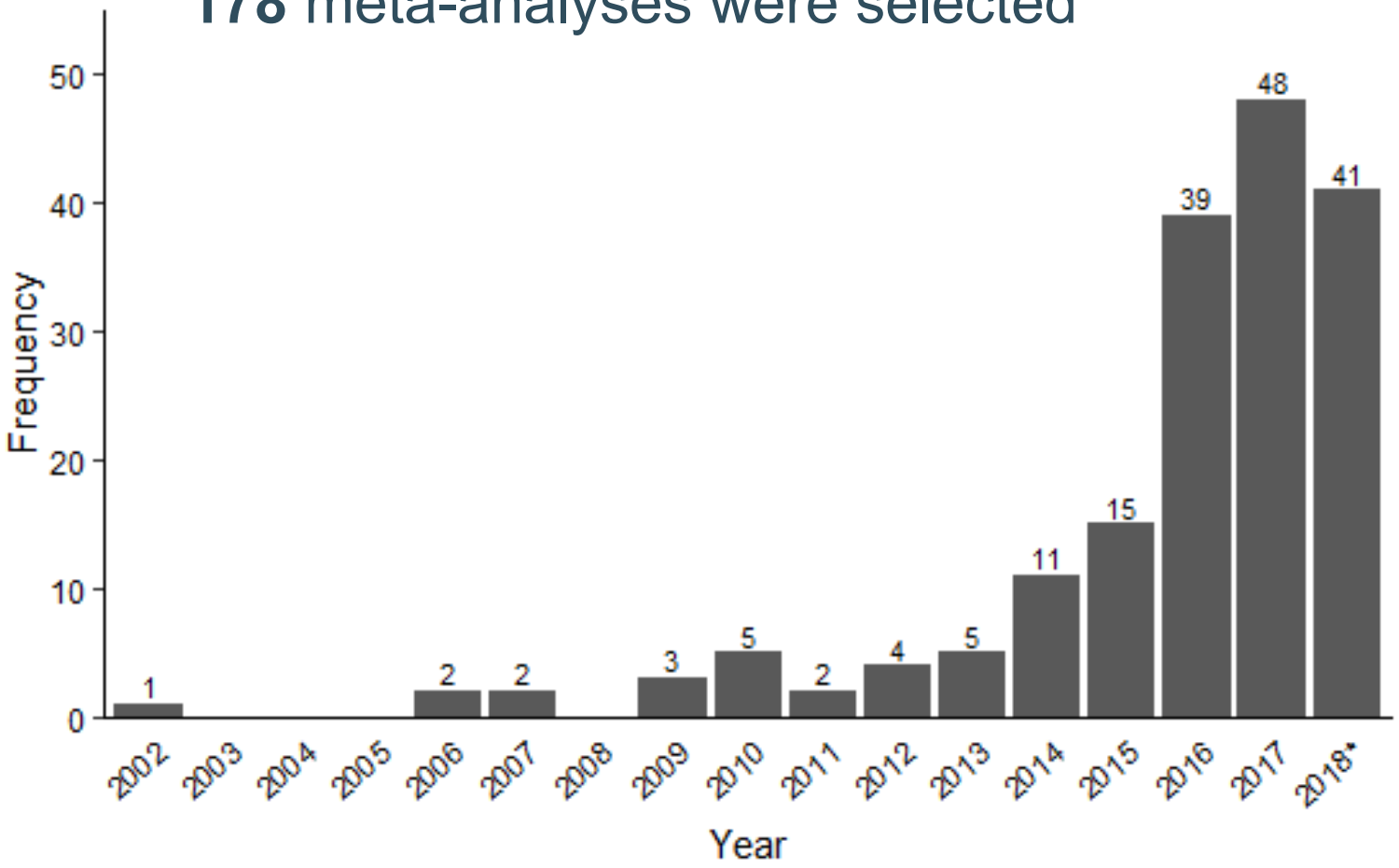
Method

Systematic search

- Meta-analysis that apply multilevel models with more than one random effect
  - Six electronic datasets: “three-level meta-analysis” OR “multilevel meta-analysis” OR “multilevel meta-analytic review’
  - Meta-analysis that cite methodological papers on the use of multilevel models in meta-analysis
    - Cheung (2014)
    - Van den Noortgate, López-López, Marín-Martínez, & Sánchez-Meca (2013; 2015)
    - Konstantopoulos (2011)
    - Raudenbush and Bryk (1985)
    - Hox and de Leeuw (2003)

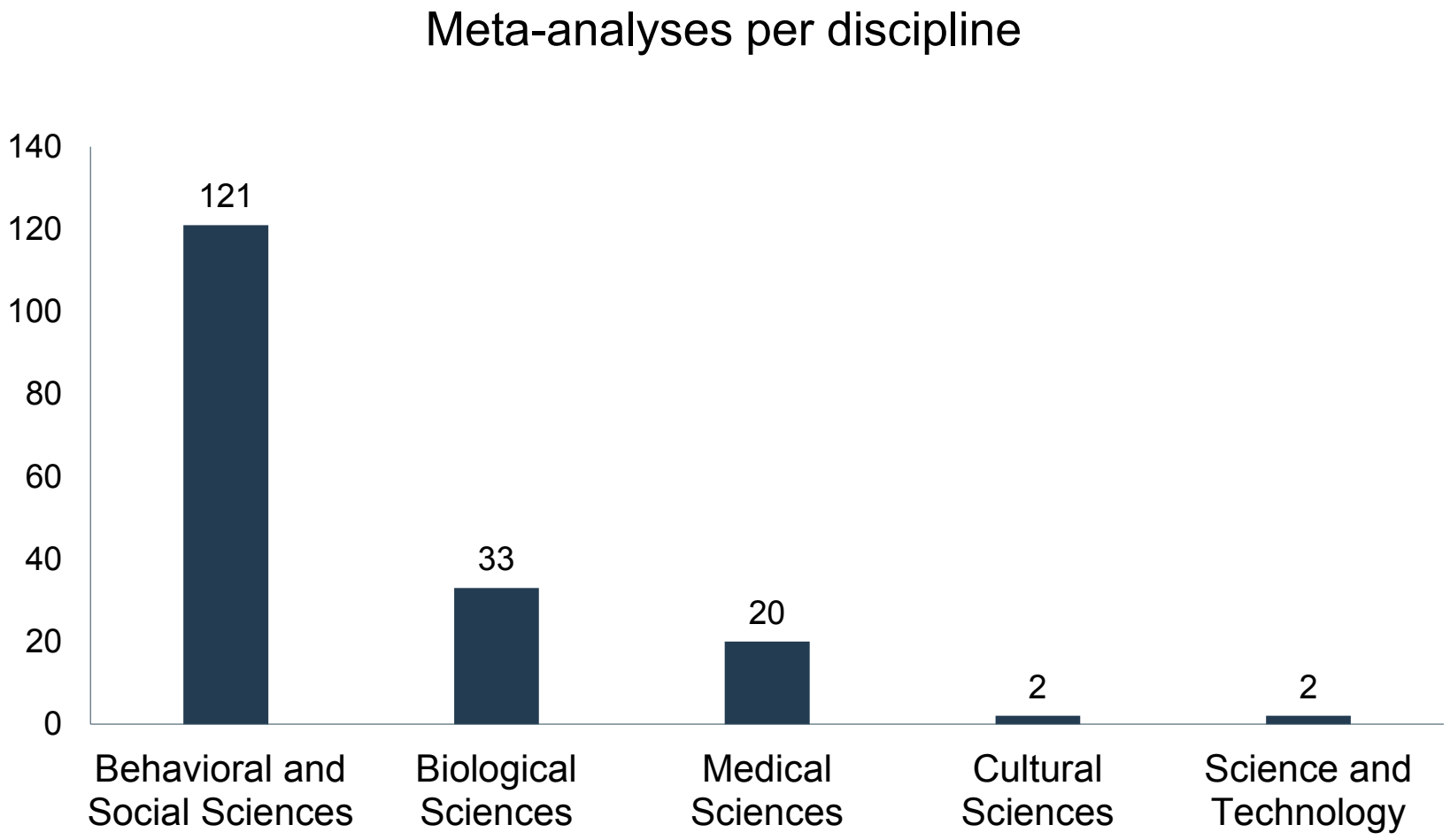
Results

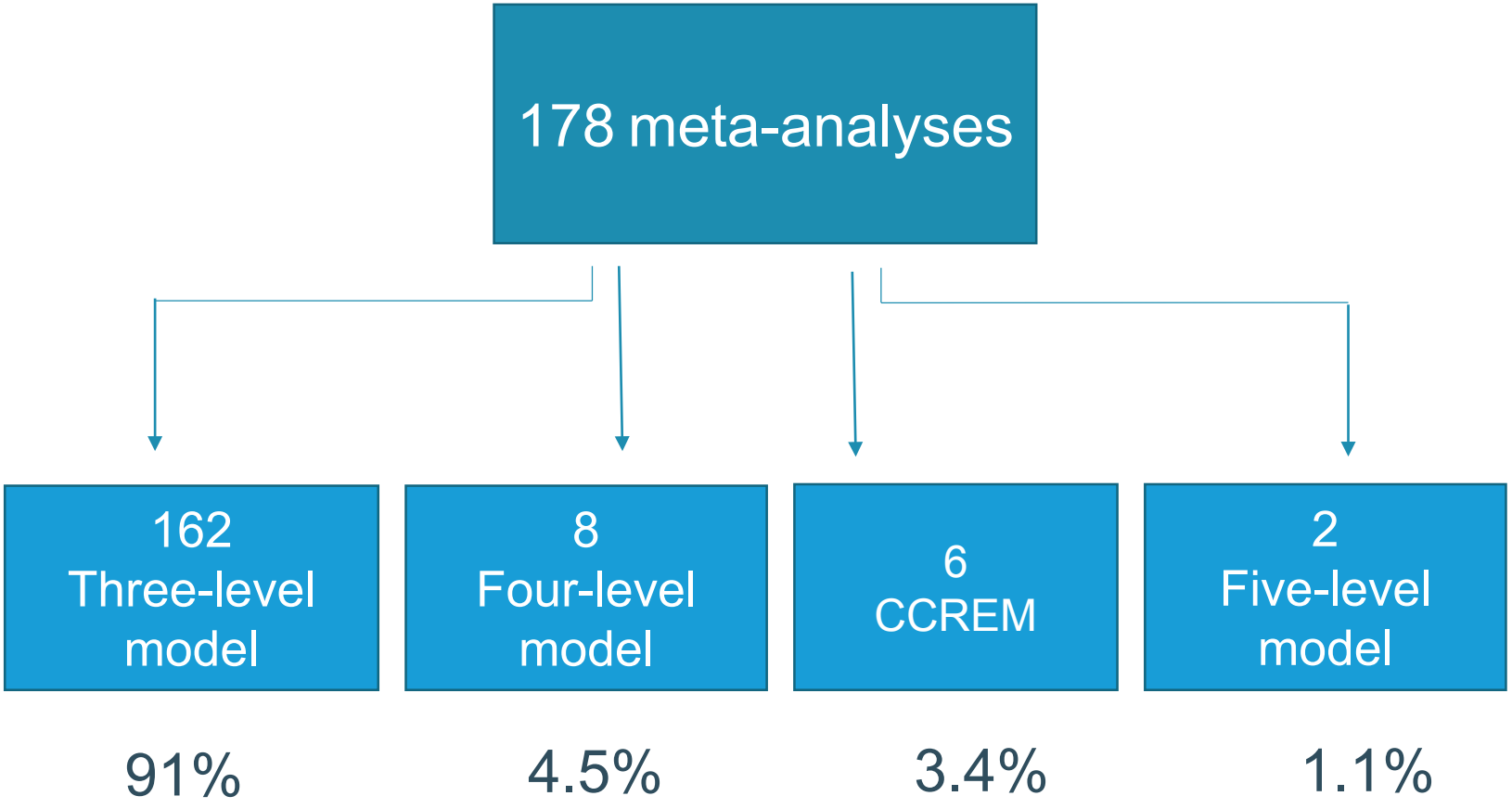
178 meta-analyses were selected



Results

178 meta-analyses were selected




178 meta-analyses
162 Three-level model
8 Four-level model
6 CCREM
2 Five-level model
91%
4.5%
3.4%
1.1%

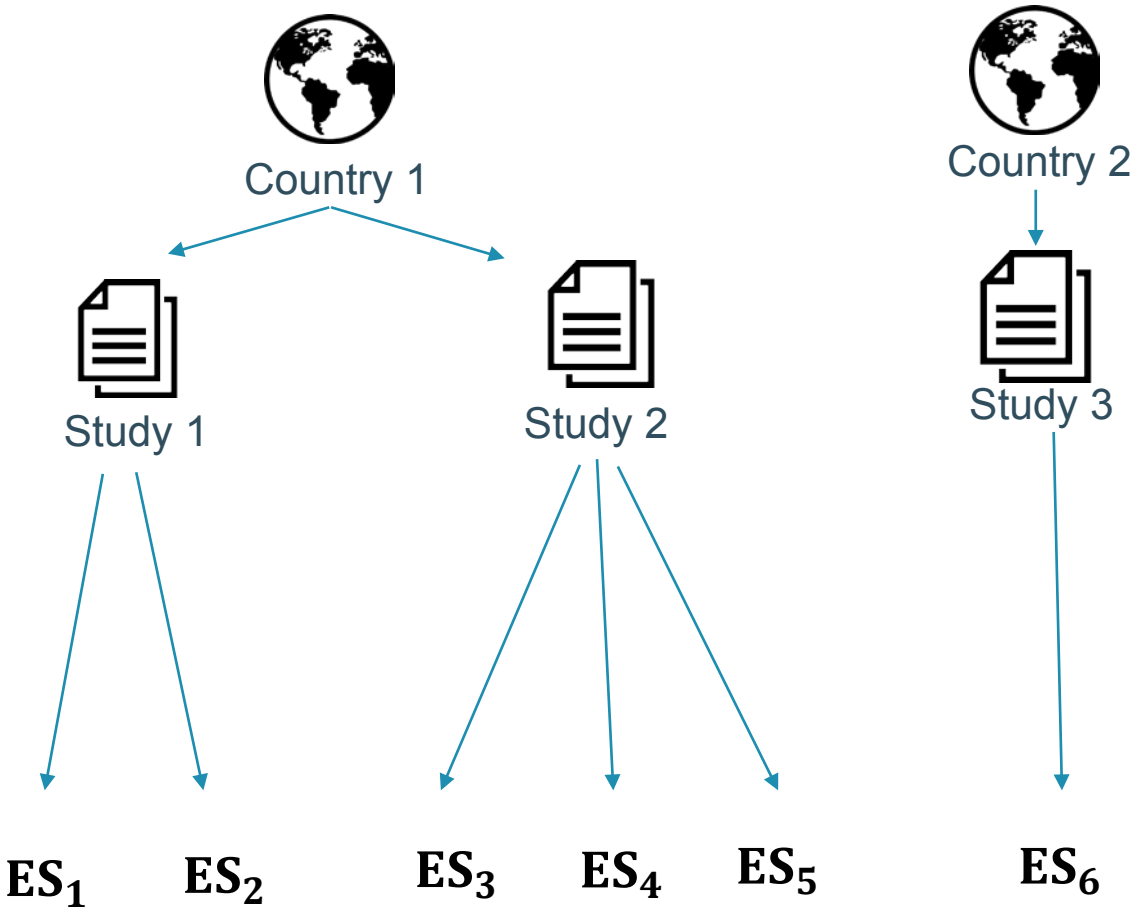
Potential alternative specifications

1. 3-level model ⟶ 4-level model to account for multiple outcomes within studies

Level 3: Countries - *k*

Level 2: Studies - *j*

Level 1: Effect sizes



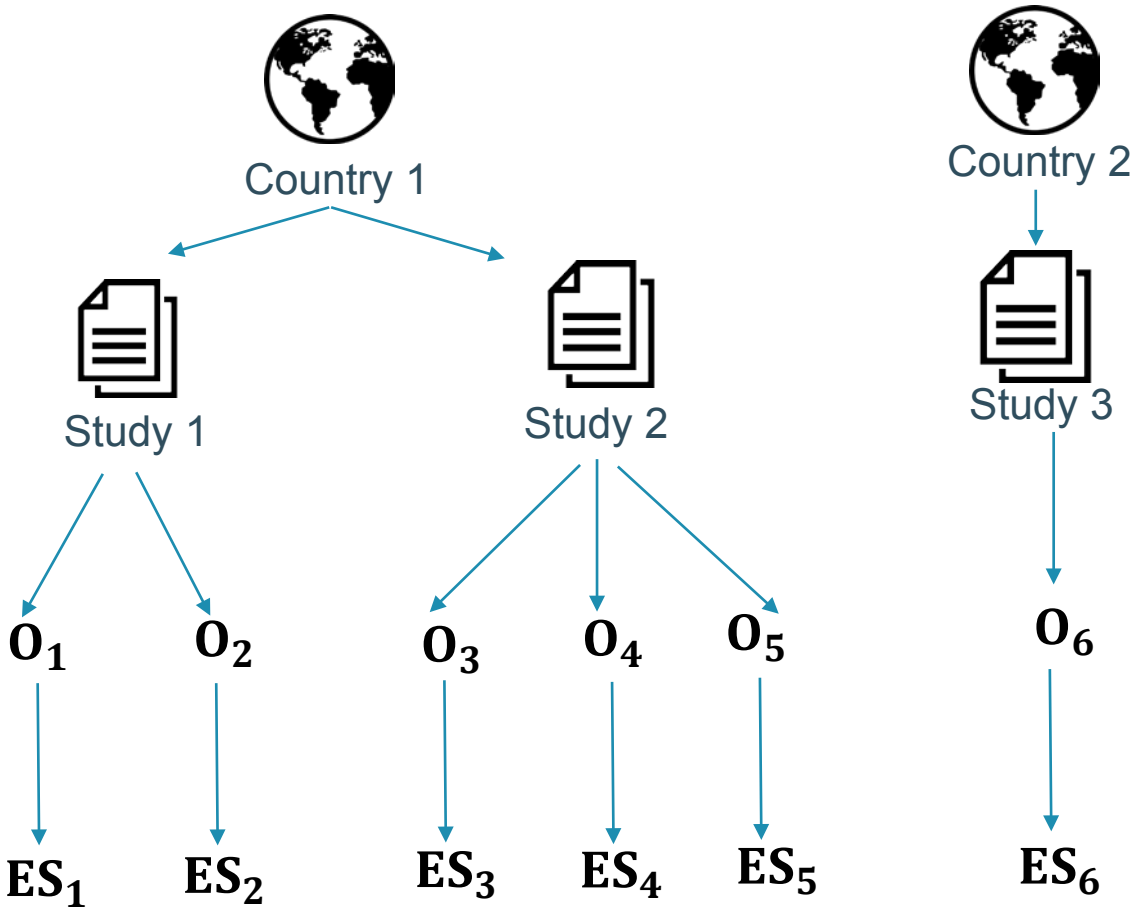
$$y_{jk} = \delta_{00} + w_{0k} + u_{jk} + e_{jk}$$

Level 4: Countries – *k*

Level 3: Studies – *j*

Level 2: Outcomes - *i*

Level 1: Effect sizes



$$y_{ijk} = \delta_{000} + w_{00k} + u_{0jk} + v_{ijk} + e_{ijk}$$

Potential alternative specifications

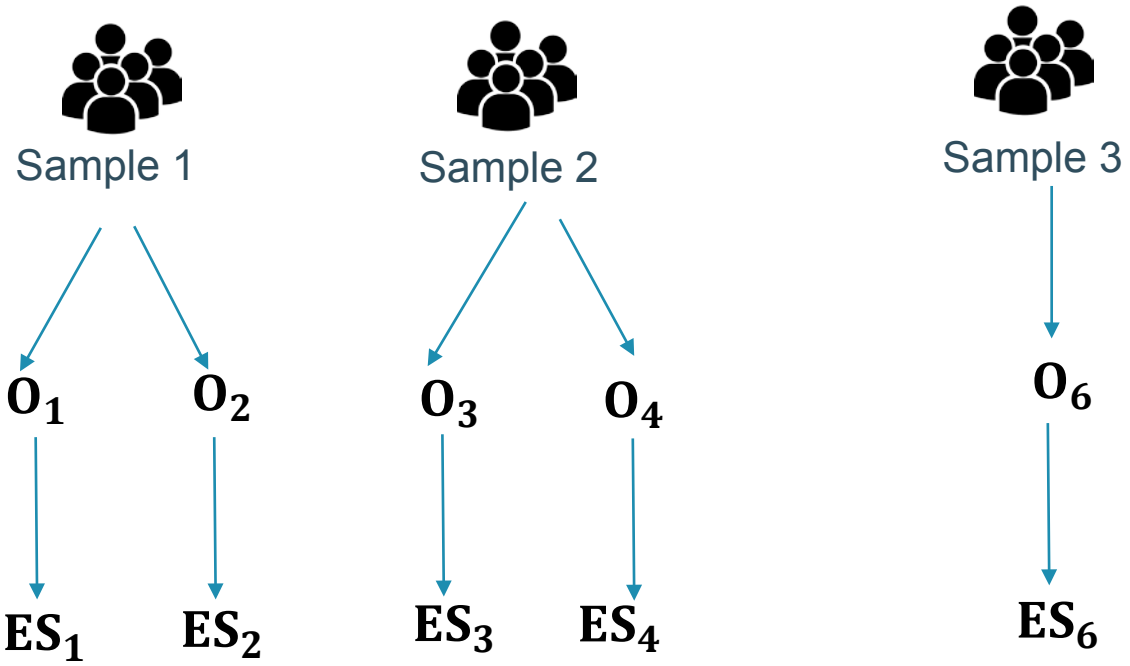
1. 3-level model ⟶ 4-level model to account for multiple outcomes within studies

2. 3-level model ⟶ 4-level model to account for dependency across studies.

Level 3: Samples - *s*

Level 2: Outcomes - *i*

Level 1: Effect sizes



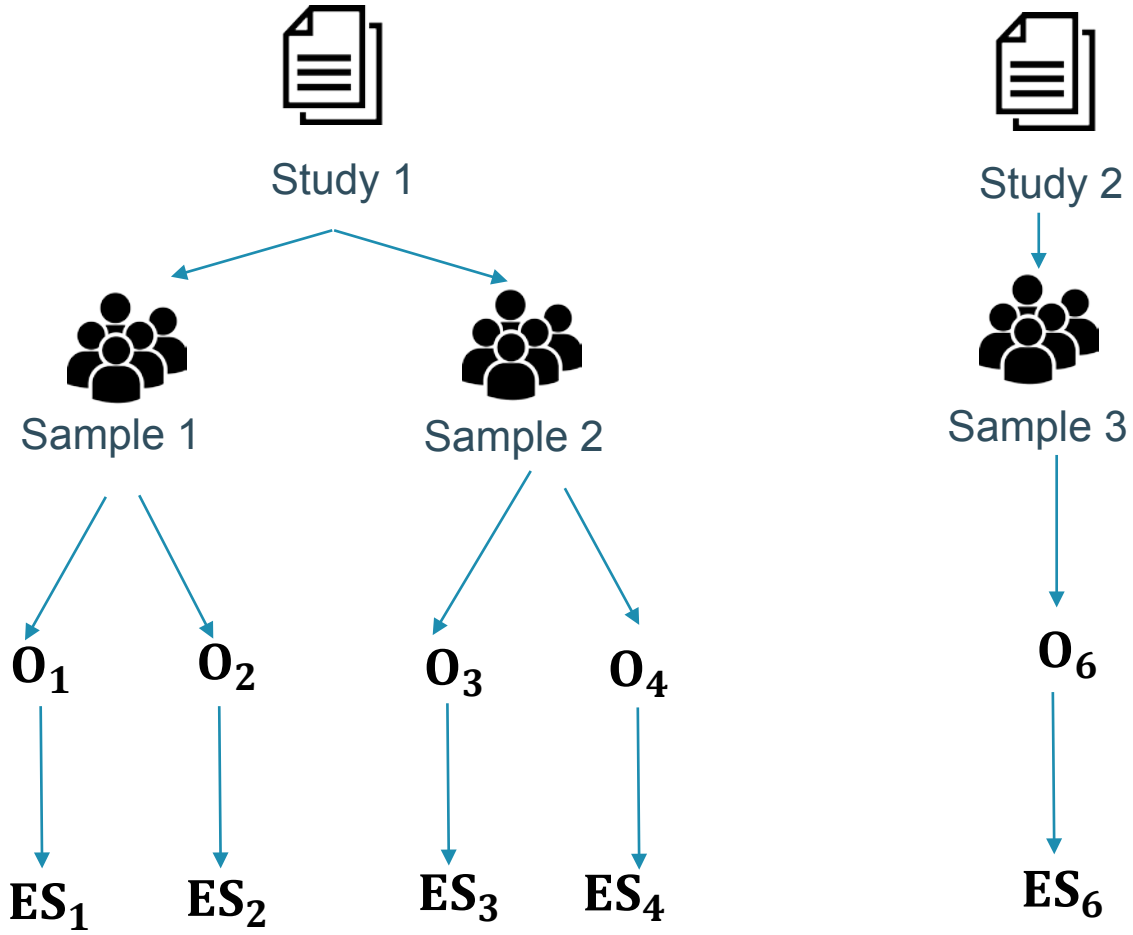
$$y_{is} = \delta_{000} + n_{0s} + v_{is} + e_{is}$$

Level 4: Studies - *j*

Level 3: Samples - *s*

Level 2: Outcomes - *i*

Level 1: Effect sizes



$$y_{isj} = \delta_{000} + u_{00j} + n_{0sj} + v_{isj} + e_{isj}$$

Potential alternative specifications

1. 3-level model → 4-level model to account for multiple outcomes within studies

2. 3-level model → 4-level model to account for dependency across studies.

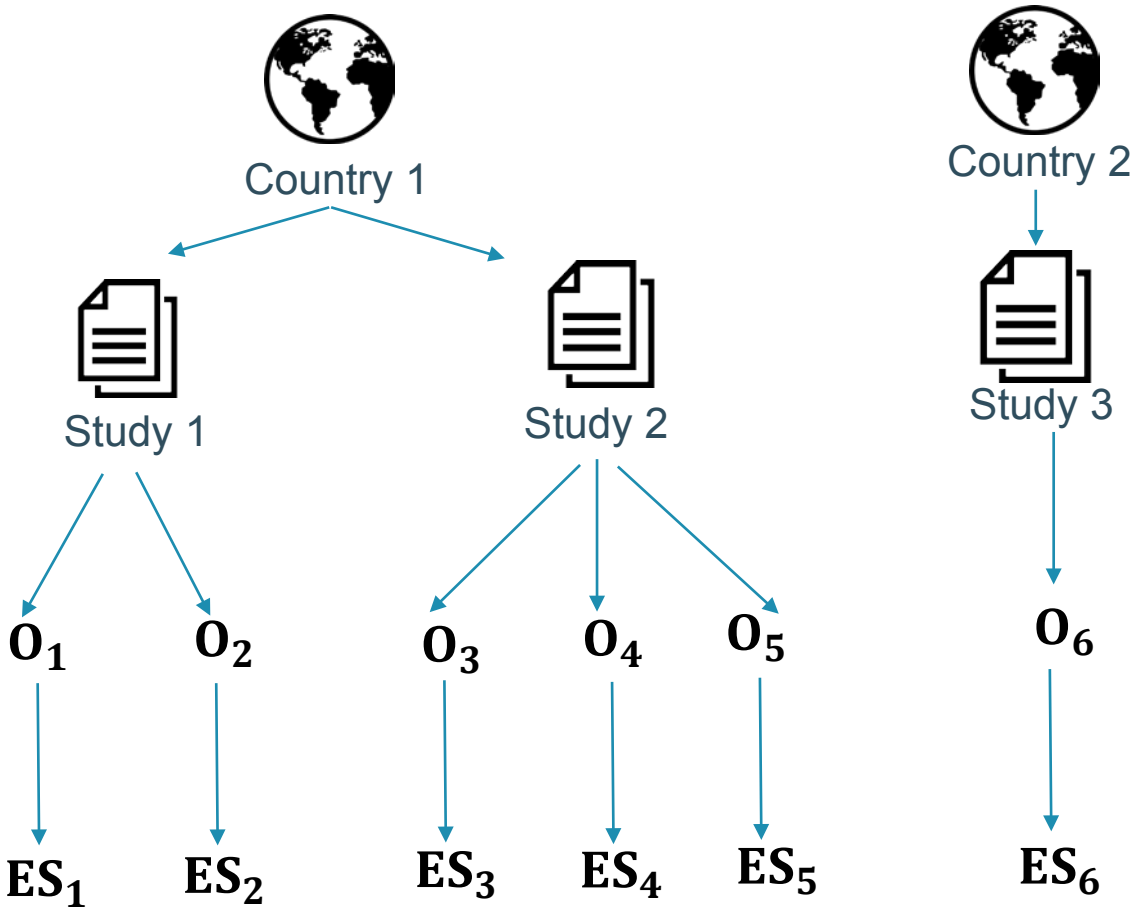
3. (hierarchical) 3-level model → 3-level CCREM to account for crossed random factors

Level 4: Countries - *k*

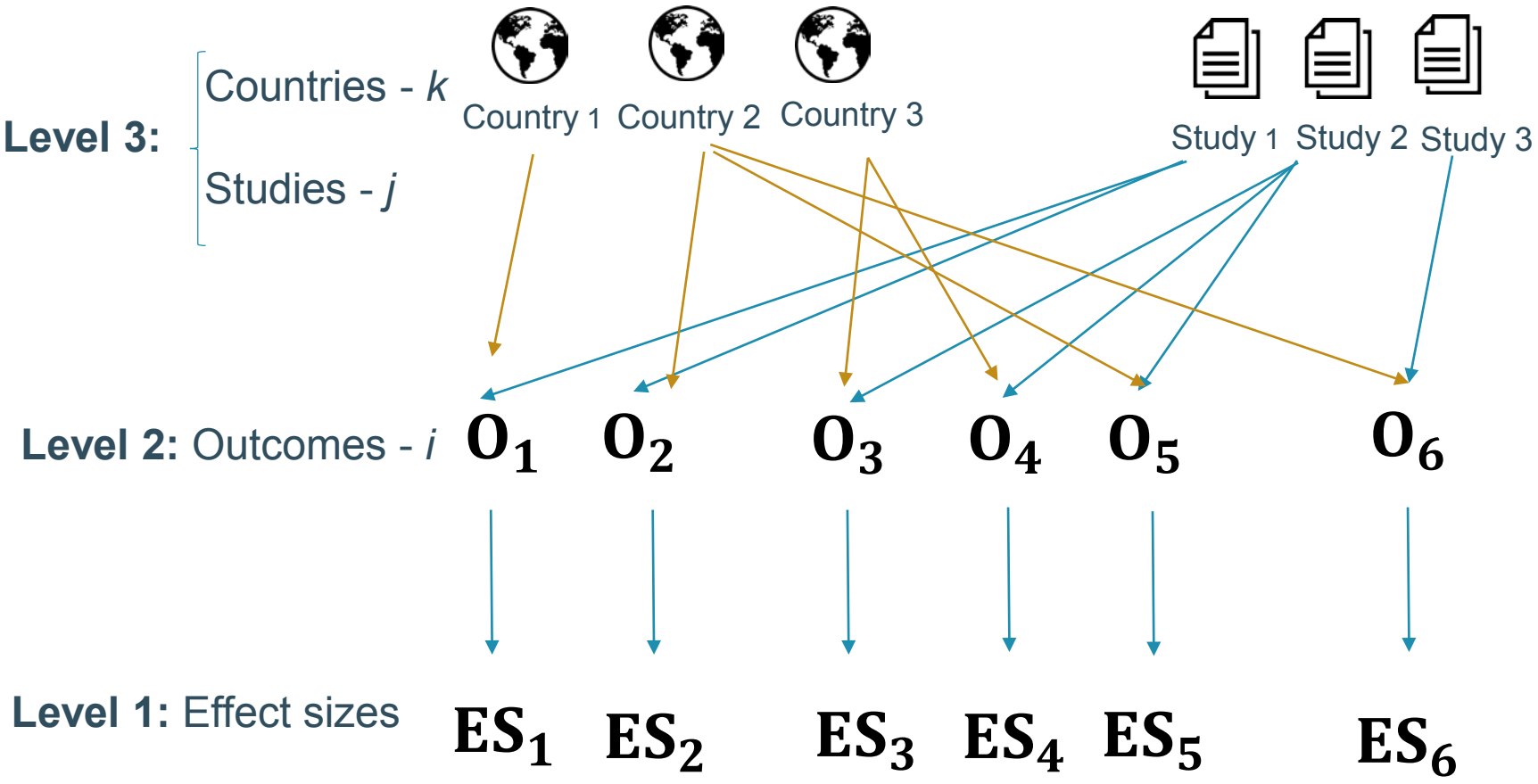
Level 3: Studies - *j*

Level 2: Outcomes - *i*

Level 1: Effect sizes



$$y_{ijk} = \delta_{000} + e_{ijk} + v_{ijk} + u_{0jk} + w_{00k}$$



$$y_{i(jk)} = \delta_{000} + e_{i(jk)} + v_{i(jk)} + u_{00j} + w_{00k}$$

Important notes

- Not everything can be treated as a random effect

- For instance: COUNTRY

FIXED (Moderator)	RANDOM EFFECT
Few countries	Many countries
Interest in specific differences between some countries	Interested in variance of effect sizes due to differences between countries

Conclusion

- Careful consideration of the data structure before performing multilevel meta-analysis
- Careful consideration of whether a variable is fixed or random
- Specify correctly the multilevel model to avoid biased parameter estimates

Thank you very much for your attention!

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