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Institut für Wissensmedien
Knowledge Media Research Center

Introduction to Multilevel Analysis

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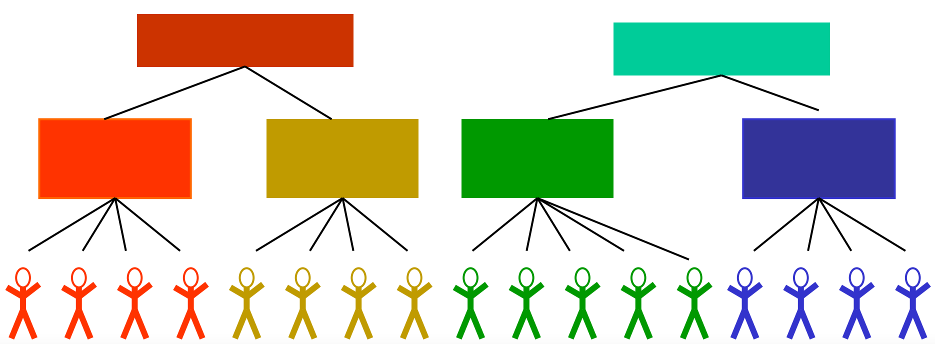


Aim of this session

- What‘s the problem about multilevel data?
- Options to handle multilevel data in CSCL

Caution: After this presentation you will not be able to do or fully understand a HLM model

– but you will be aware of all the mistakes you can do!

give you some take-home messages

Into to topic ....

„Extraverted children perform better in school"

What may be the reason for that?

What may be the processes behind?

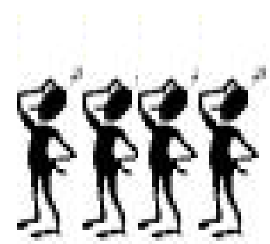
What does this mean statistically?

What is the problem about multi-level data?

Example: Effect of Extraversion on Learning Outcome

IV: Extraversion

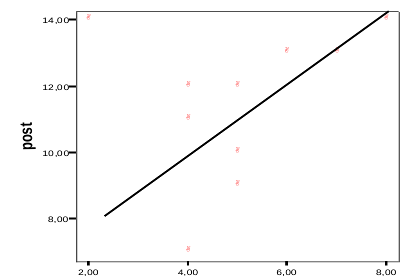
DV: performance



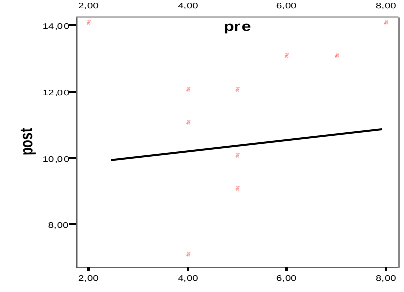
First view on the data

Extraversion	7	8	6	5	2	4	4	5	4	5
Performance	13	14	13	9	14	7	12	12	11	10

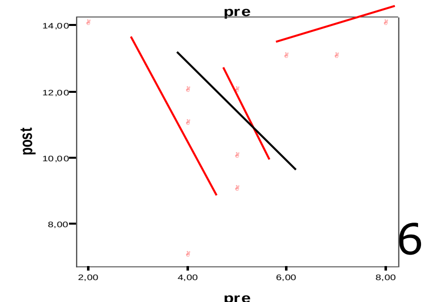
Pooled (n=10) **r = .26**



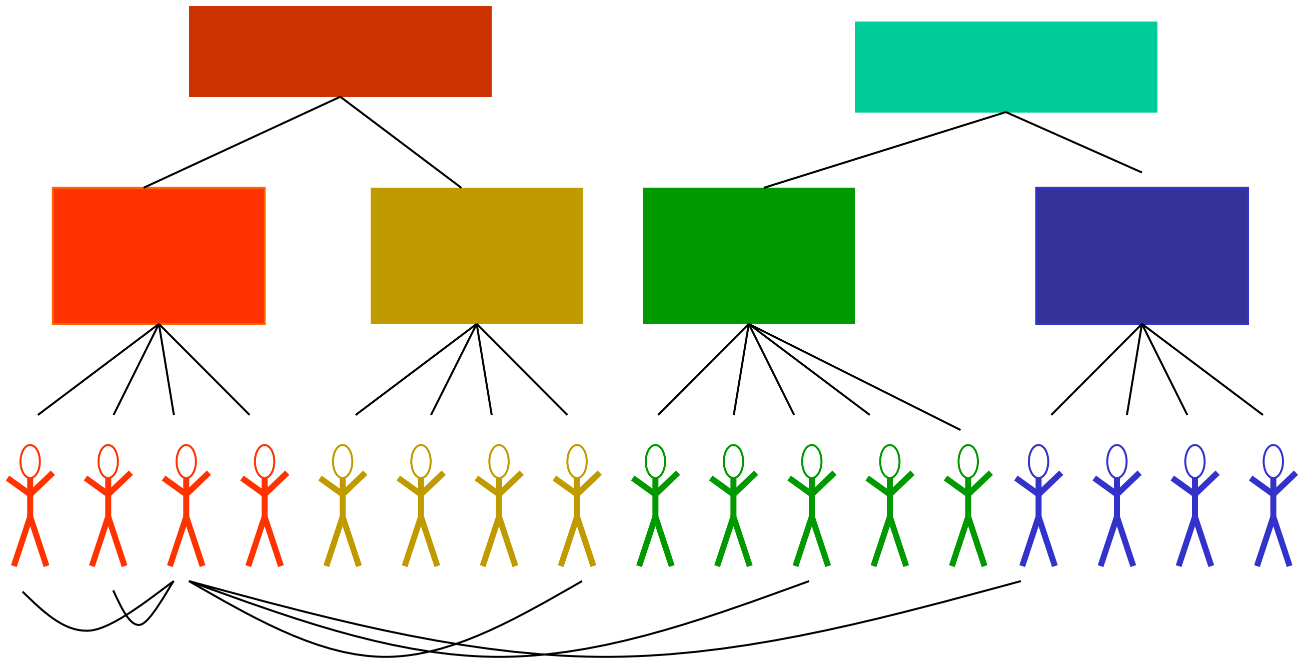
Aggregated (Mean of the groups; n=3) **r = .99**



Mean *correlation* (n=3)
r=.86 r=-.82 r=-.30 **r = -0.08**



Hierarchical data



Individual observations are *not* independent

Question

- What does it statistically mean, if the variance within the groups is small?

- with regard to standard-deviation?
- with regard to F?
- with regard to alpha?

Impact on statistics

- Analysis of Variance: heavily leans on the assumption of independence of observations

$$F = \frac{Var_{between}}{Var_{within}}$$

- Underestimation of the standard error
- Large number of spuriously “significant” results
- Inflation of Alpha

Alpha-Inflation

		INTRACLASS CORRELATION								
no. of groups	group size	.00	.01	.10	.30	.50	.70	.90	.95	.99
2	3	.05	.05	.07	.14	.24	.38	.63	.73	.88
	10	.05	.06	.17	.37	.53	.68	.83	.88	.95
	30	.05	.08	.34	.59	.72	.81	.90	.93	.97
	100	.05	.17	.57	.77	.84	.90	.95	.96	.98
3	3	.05	.05	.08	.19	.34	.56	.84	.92	
	10	.05	.06	.22	.54	.74	.87	.96	.98	.98
	30	.05	.10	.49	.80	.90	.96	.99	.99	1.00
	100	.05	.22	.78	.93	.97	.99	1.00	1.00	1.00
5	3	.05	.05	.10	.27	.51	.78	.97	.99	1.00
	10	.05	.07	.32	.74	.92	.98	1.00	1.00	1.00
	30	.05	.12	.69	.95	.99	1.00	1.00	1.00	1.00
	100	.05	.31	.94	.99	1.00	1.00	1.00	1.00	1.00
10	3	.05	.06	.13	.44	.78	.97	1.00	1.00	1.00
	10	.05	.08	.49	.94	1.00	1.00	1.00	1.00	1.00
	30	.05	.16	.91	1.00	1.00	1.00	1.00	1.00	1.00
	100	.05	.49	1.00	1.00	1.00	1.00	1.00	1.00	1.00

(Stevens, 1996, 240)

1st take-home message

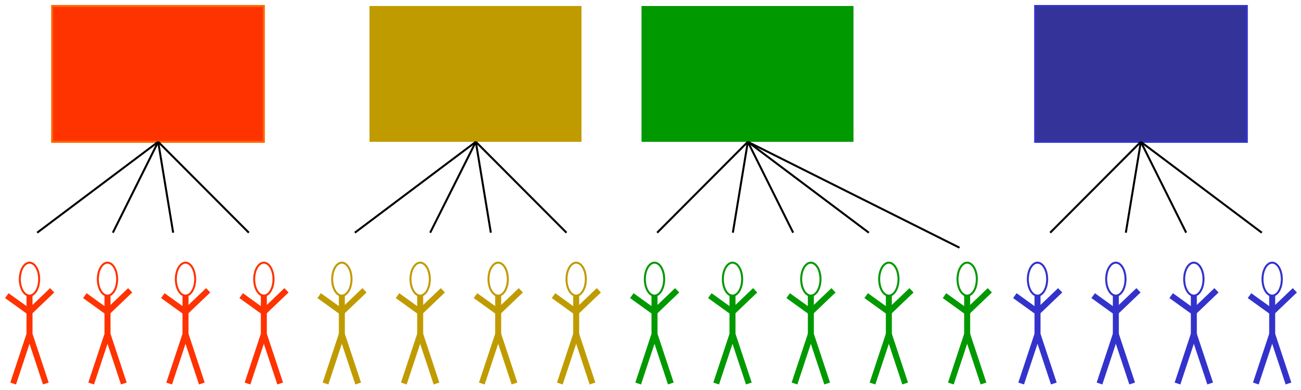
you are not allowed to use standard statistics with multi-level data

Stochastic Non-Independency

…. is *caused* by

1. **Composition**: people of the groups are already similar *before* the study even begins

   is a problem if you can not randomize

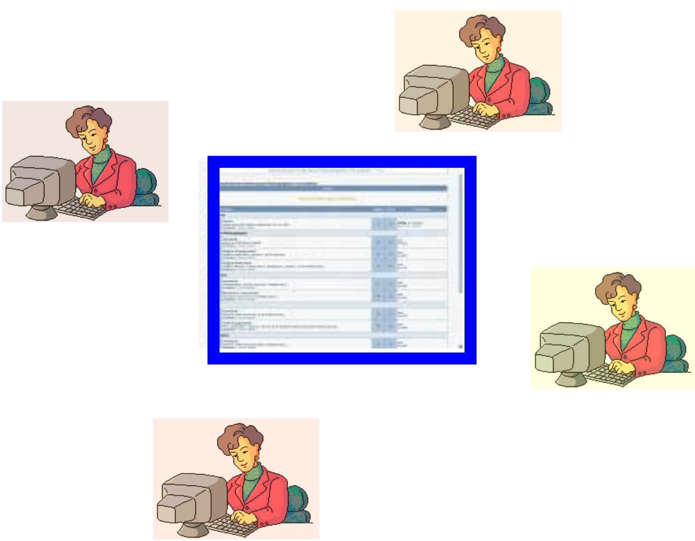


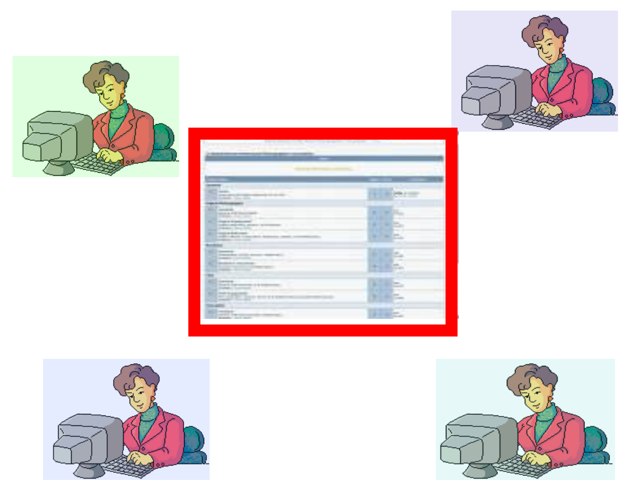
Stochastical Non-Independency

…. is *caused* by

2. **Common fate** caused through shared experiences *during* the experiment

   is always a problem in CL

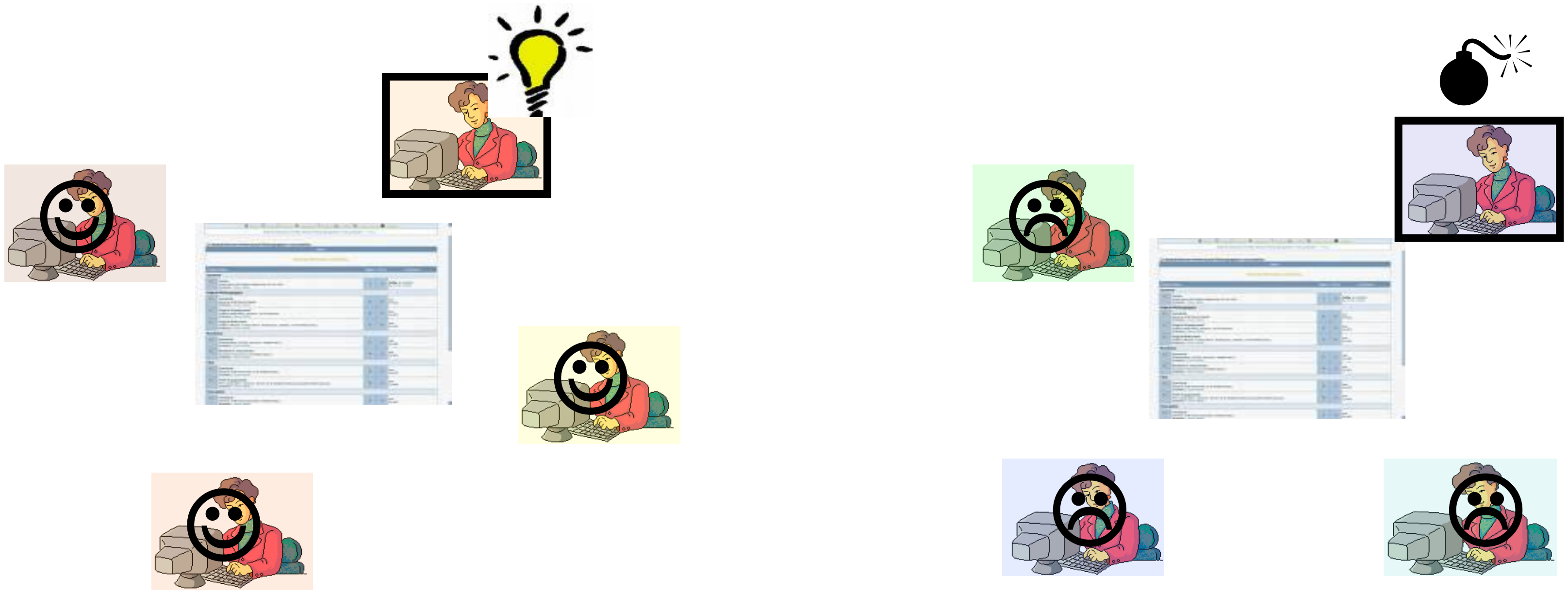




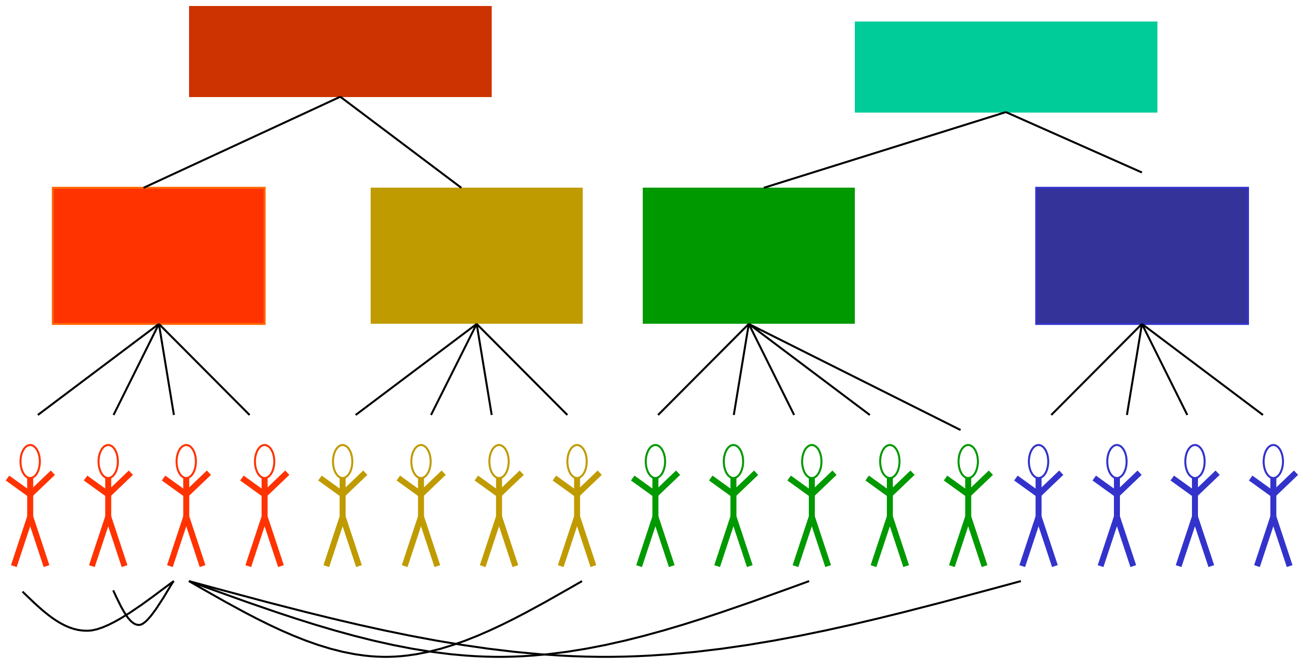
Stochastic Non-Independency

…. is *caused* by

3. **Interaction & reciprocal influence**



Hierarchical data



Intra-class correlation

2nd take-home message: Relevance for Learning Sciences

- CL explicitly bases on the idea of **creating** *non*-independency
- We want people to interact, to learn from each others, etc.
- CL should even aim at considering effects of non-independency
- if you work on CL-data, you have to consider the multi-level structure of the data not just as noice but as an intended effect

How to do this adequately?

Possible solutions

1. Working with fakes
2. Groups as unit of analysis
3. Slopes as outcomes
4. Hierarchical linear analysis (HLM)
5. Fragmentary (but useful) solutions

Solution 1: Working with fake

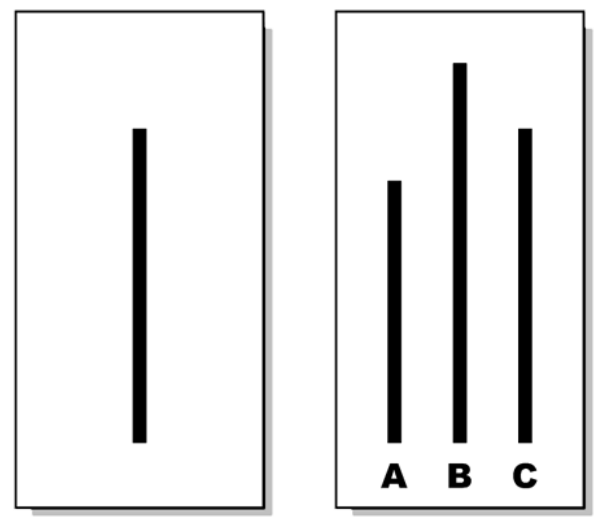
fake

fake

fake

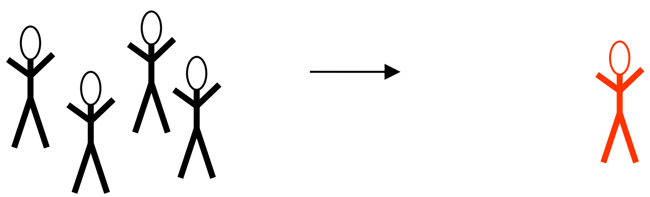
confederates
bogus feedback

classical experiment:
conformity study Asch (1950)



Solution 1: Working with fake

Pros:
- well established method in social psychology
- high standardization
- situation makes people behaving like being in a group, but it leads to statistically independent data
- causality

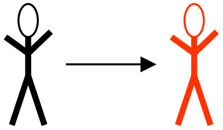


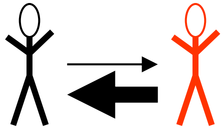
- sometimes easy to do in CSCL → anonymity

Solution 1: Working with fake

Cons:

- artificial situation
- no flexibility
- only simple action-reaction pairs can be faked. No real process of reciprocal interaction

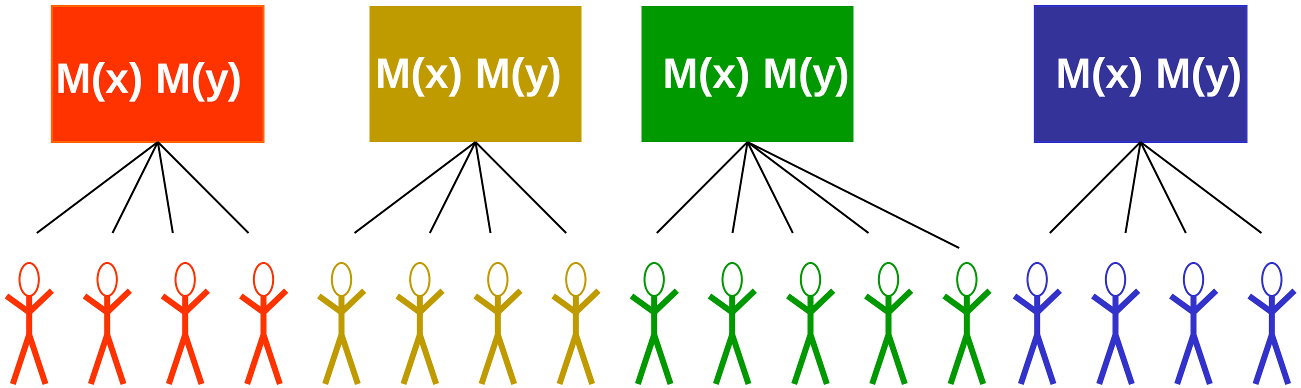




- non dynamics

Solution 2: Unit of Analysis

- *Group level*: Aggregated data



Pros:

- statistically independent measures

Cons:

- need of many groups
- waste of data
- results not valid for individual level → Robinson - Effect

Robinson-Effect (1950)

- illiteracy level in nine geographic regions (1930)
- percentage of blacks (1930)

regions	r = 0.95
individuals	r = 0.20

→ **Ecological Fallacy:** inferences about the nature of specific individuals are based solely upon aggregate statistics collected for the group to which those individuals belong.

Problem: Unit of analysis

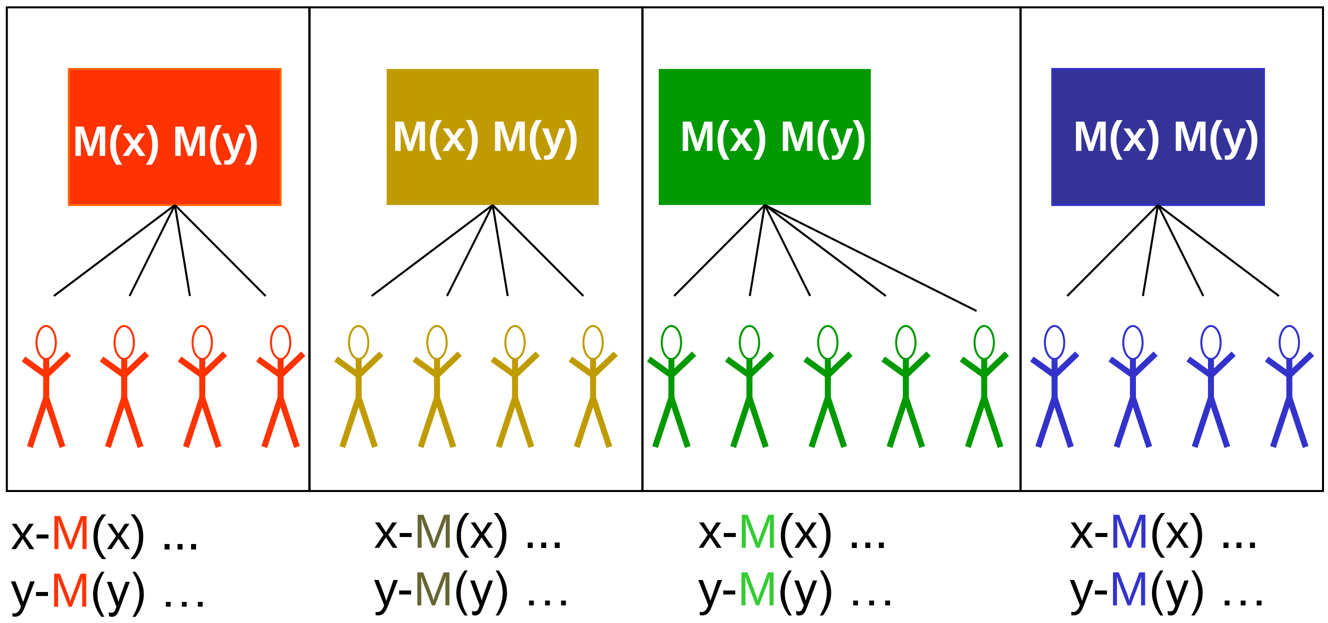
3rd take-home message

You can use group-level data

- but the results just describe the groups, not the individuals

Solution 2: Unit of Analysis

- ***Individual level***: centering around the group mean / standardization → elimination of group effects



Solution 2: Unit of Analysis

Pros:

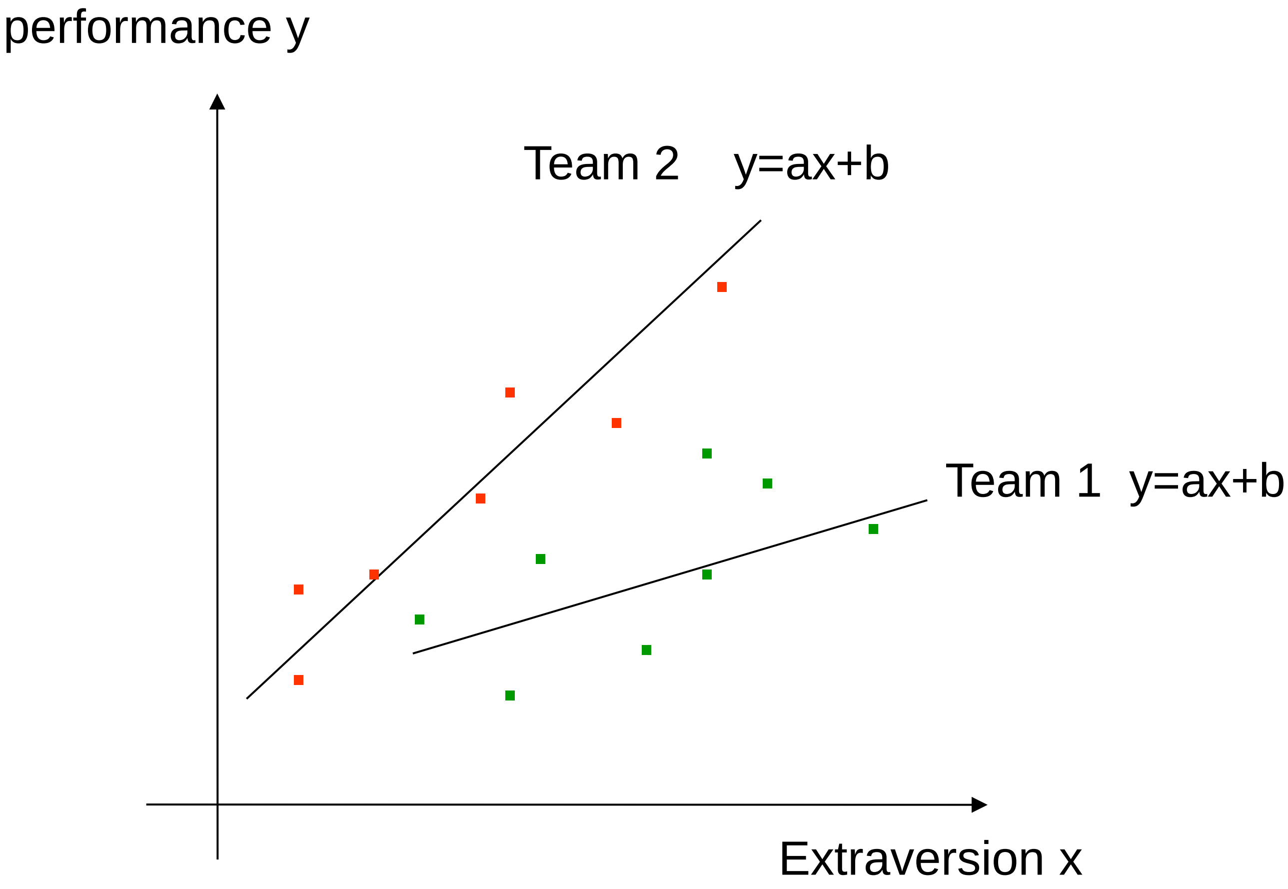
- easy to do
- makes use of all data of the individual level

Cons:

- works only, if variances are homogeneouos (centering)
- loss of information about heterogeneous variances (standardization)
- differences between groups are just seen as error-variance

Solution 3: Slopes as Outcomes

Burstein, 1982



Solution 3: Slopes as Outcomes

Pros:

- uses all information
- focus is on interaction effects between group-level (team) and individual-level variable

Cons:

- descriptive
- just comparing the groups which are given → no random-effects are considered

4th take-home message

Consider the slopes of the different groups.

They show group effects!

e.g. it is a feature of the group, if extraverted members are more effective

→ slopes describe groups

→ slopes are DVs

Solution 4: Hierarchical Linear Model

Bryk & Raudenbush, 1992

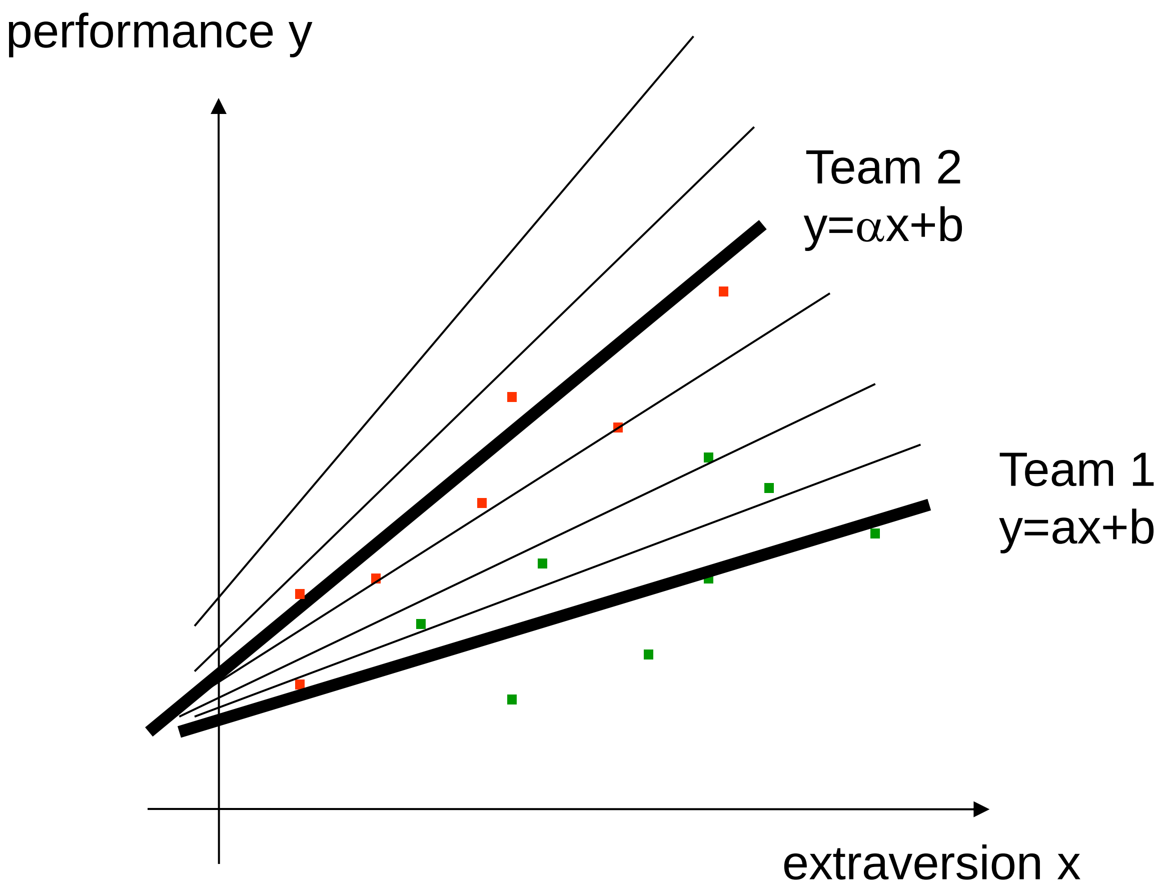
Two Main ideas

the groups (you have data from) represent a *randomly choosen sample* of a population of groups! (random effect model)

The slopes and intercepts are systematically varying variables.

Solution 4: Hierarchical Linear Model

Bryk & Raudenbush, 1992



variation of slopes
variation of intercepts

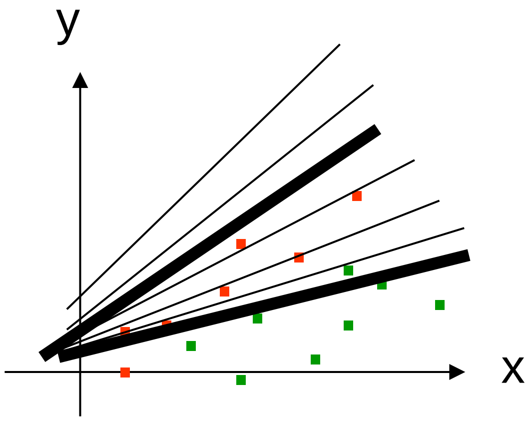
predicted with 2nd level variables

Solution 4: Hierarchical Linear Model

Bryk & Raudenbush, 1992

Equation system of systematically varying regressions

Level 1: $Y_{ij} = \beta_{0j} + \beta_{1j}X_{ij} + r_{ij}$



β_{0j} = intercept for group j

β_{1j} = regression slope group j

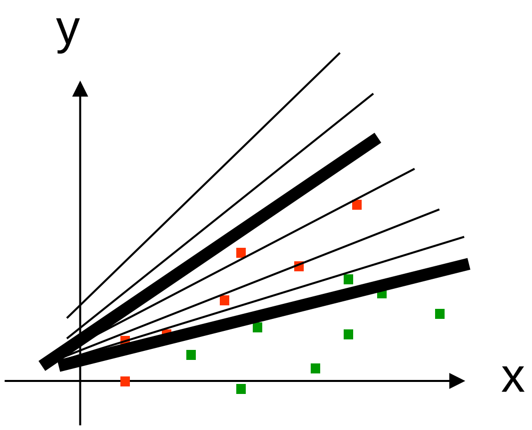
r_{ij} = residual error

HLM: Equation system

Level 1: $Y_{ij} = \beta_{0j} + \beta_{1j}X_{ij} + r_{ij}$

Level 2: $\beta_{0j} = \gamma_{00} + \gamma_{01}W_j + u_{0j}$

$\beta_{1j} = \gamma_{10} + \gamma_{11}W_j + u_{1j}$



W = explanatory variable on level 2
e.g. teacher experience

Total model

Level 1: $Y_{ij} = \beta_{0j} + \beta_{1j} X_{ij} + r_{ij}$ **(1)**

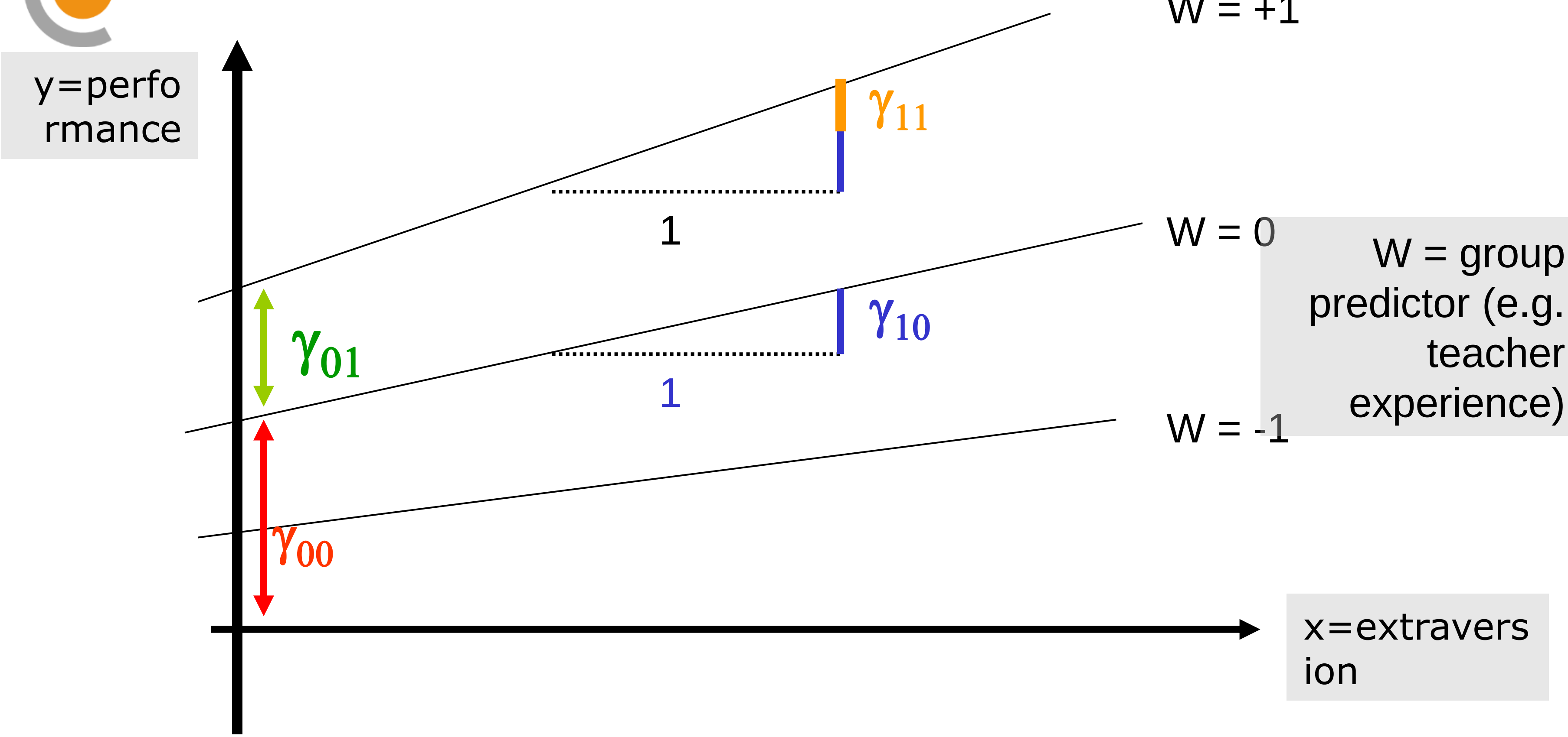
Level 2: $\beta_{0j} = \gamma_{00} + \gamma_{01} W_j + u_{0j}$ **(2)**

$\beta_{1j} = \gamma_{10} + \gamma_{11} W_j + u_{1j}$ **(3)**

Put (2) and (3) in (1)

$$Y_{ij} = (\gamma_{00} + \gamma_{01} W_j + u_{0j}) + (\gamma_{10} X_{ij} + \gamma_{11} W_j X_{ij} + u_{1j} X_{ij}) + r_{ij} \quad (4)$$

$$Y_{ij} = \underbrace{(\gamma_{00} + \gamma_{01} W_j + \gamma_{10} X_{ij} + \gamma_{11} W_j X_{ij})}_{\text{Fixed part}} + \underbrace{(u_{1j} X_{ij} + u_{0j} + r_{ij})}_{\text{Random (error) part}} \quad (5)$$



performance at x=0

influence extraversion

random part of slopes

individuum residuum

$$Y_{ij} = (\gamma_{00} + \gamma_{01}W_j + \gamma_{10}X_{ij} + \gamma_{11}W_jX_{ij}) + (u_{1j}X_{ij} + u_{0j} + r_{ij})$$

influence teacher exper.

cross-level interaction

random intercept

How to do?

Iterative testing of different models

Baseline model: null model, intercept-only model

$$Y_{ij} = (\gamma_{00} + \gamma_{01}W_j + \gamma_{10}X_{ij} + \gamma_{11}W_jX_{ij}) + (u_{1j}X_{ij} + u_{0j} + r_{ij})$$

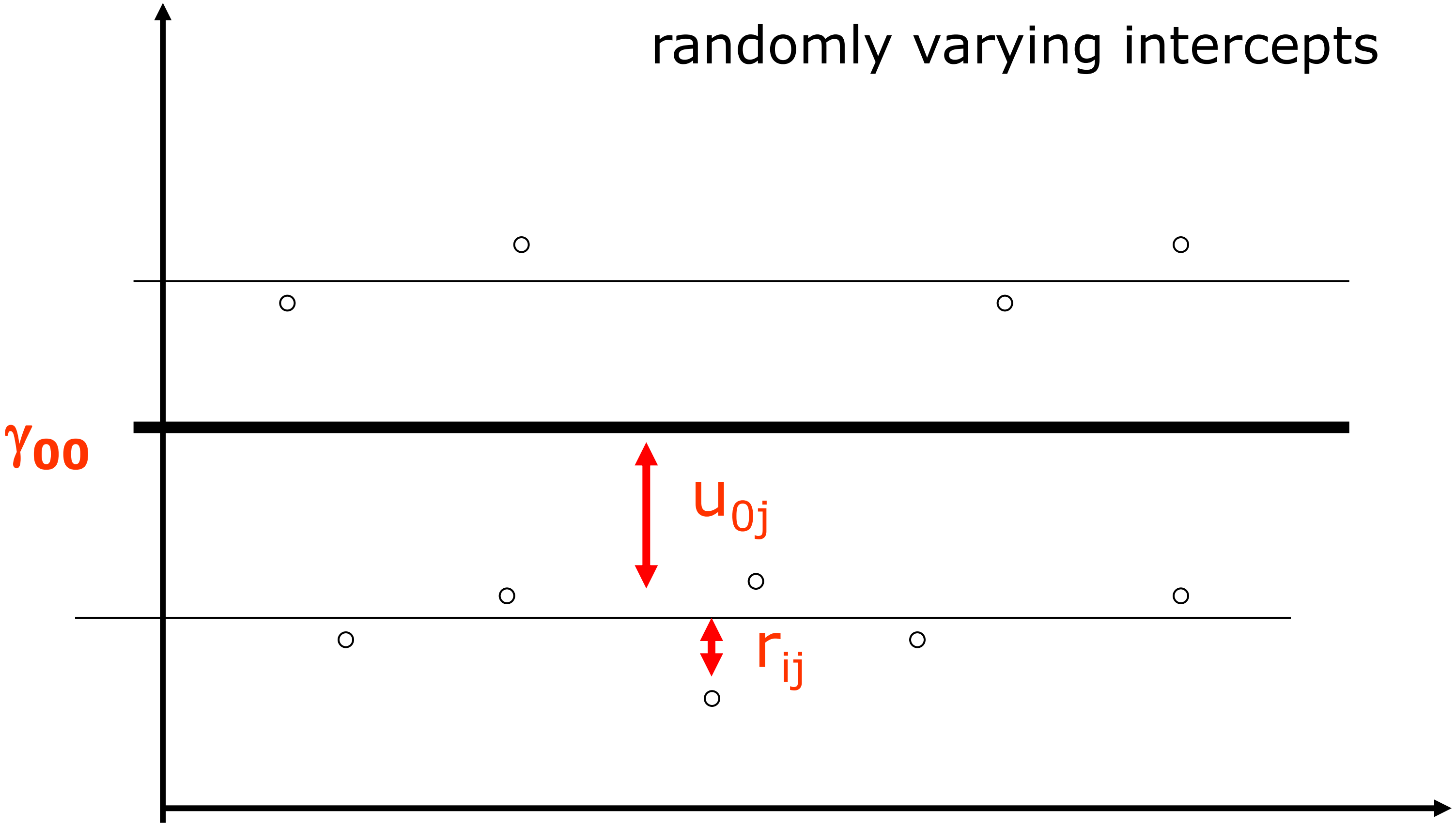
$$Y_{ij} = \gamma_{00} + \qquad + u_{0j} + r_{ij}$$

Grand Mean

Variance between groups

residuum

Baseline model: null model or intercept-only model



$$Y_{ij} = \gamma_{00} + u_{0j} + r_{1ij}$$

Baseline model: null model, intercept-only model

$$Y_{ij} = (\gamma_{00} + \gamma_{01}W_j + \gamma_{10}X_{ij} + \gamma_{11}W_jX_{ij}) + (u_{1j}X_{ij} + u_{0j} + r_{ij})$$

$$Y_{ij} = (\gamma_{00} + \qquad\qquad + u_{0j} + r_{ij}$$

Grand Mean

Variance between groups

residuum

which amount of variance is explained through the groups?

→ Intraclasscorrelation ICC = $\dfrac{Var\ (u_o)}{Var\ (u_o) + Var\ (r_{ij})}$

2nd model: Random intercept model with first level predictor

We predict the individual measures with a first-level predictor

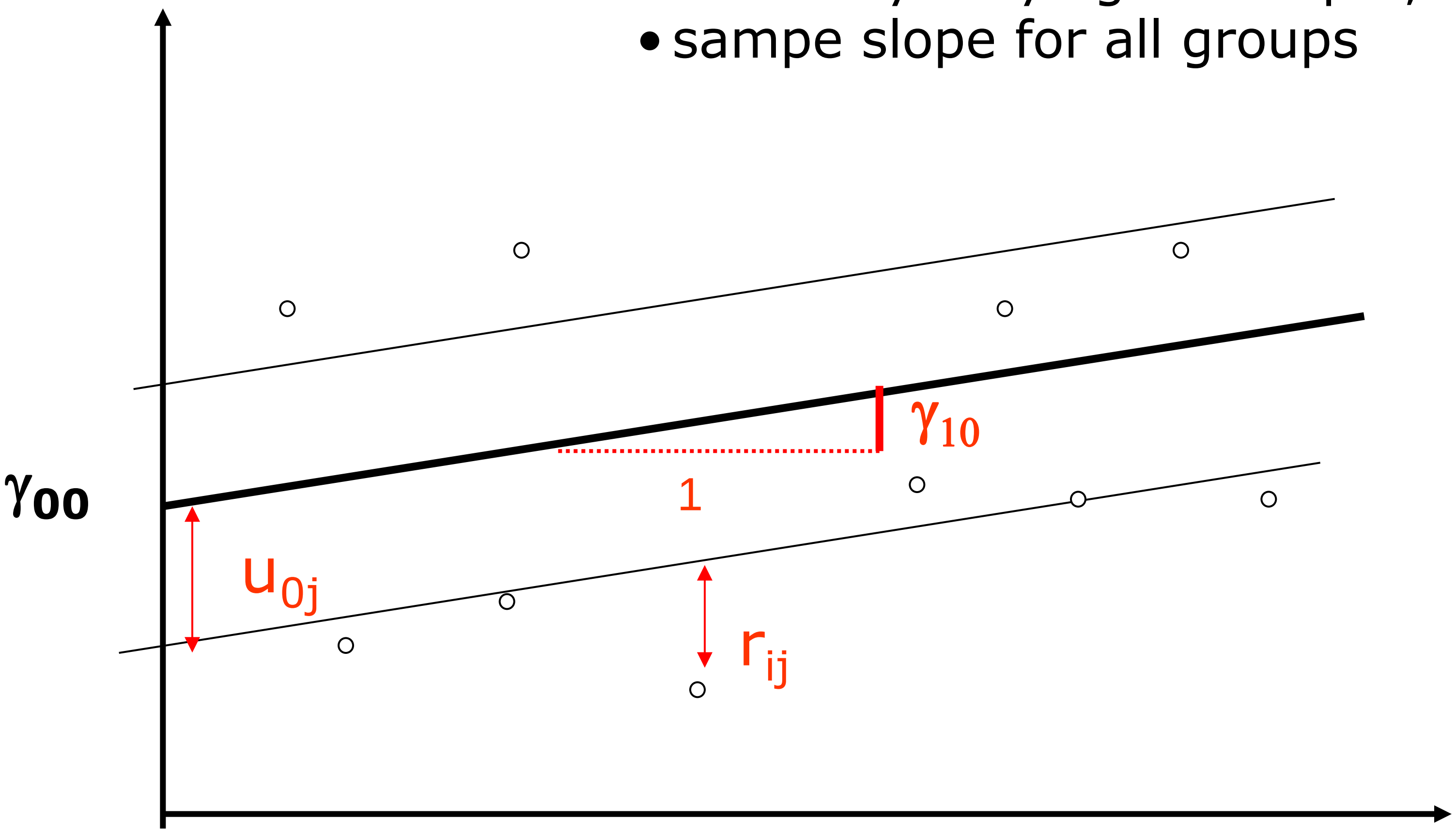
$$Y_{ij} = (\gamma_{00} + \gamma_{01}W_j + \gamma_{10}X_{ij} + \gamma_{11}W_jX_{ij}\ ) + (u_{1j}X_{ij} + u_{0j} + r_{ij})$$

$$Y_{ij} = (\gamma_{00} + \quad \gamma_{10}X_{ij} \quad + u_{0j} + r_{ij})$$

first level predictor

2nd model: Random intercept model with first level predictor

- randomly varying intercepts;
- sampe slope for all groups



$Y_{ij} = \gamma_{00} + \gamma_{10}X_{jj} + u_{0j} + r_{ij}$

3rd model: Random intercept model with second-level predictor

We predict the the intercepts with a second-level predictor

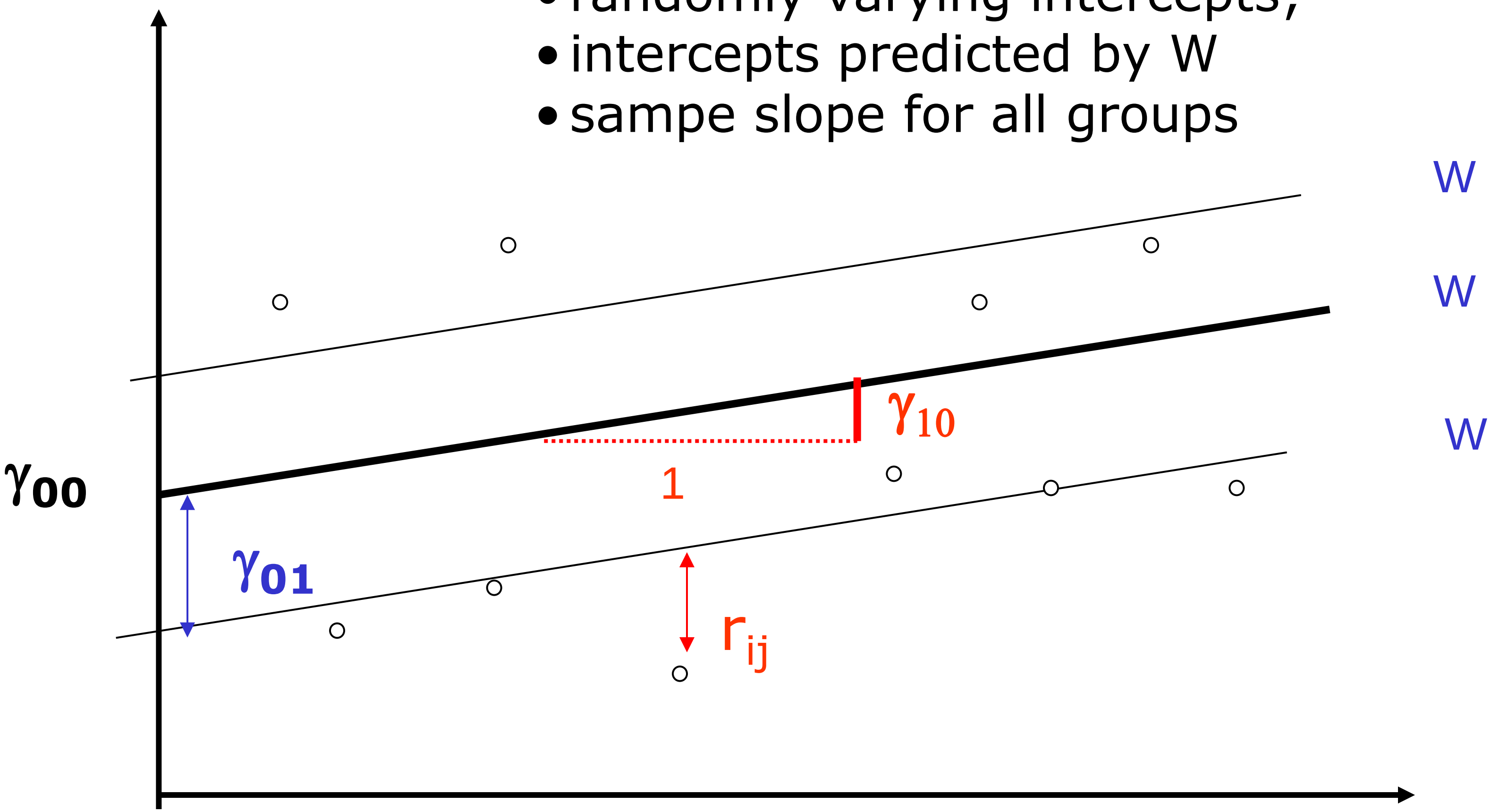
$$\mathbf{Y_{ij} = (\gamma_{00} + \gamma_{01}W_j + \gamma_{10}X_{ij} + \gamma_{11}W_jX_{ij}) + (u_{1j}X_{ij} + u_{0j} + r_{ij})}$$

$$\mathbf{Y_{ij} = (\gamma_{00} + {\color{red}\gamma_{01}W_j} + \gamma_{10}X_{ij} + \qquad + u_{0j} + r_{ij})}$$

2nd level predictor

3rd model: Random intercept model with second-level predictor

- randomly varying intercepts;
- intercepts predicted by W
- sampe slope for all groups



$$Y_{ij} = \gamma_{00} + \gamma_{01}W_j + \gamma_{10}X_{ij} + u_{0j} + r_{ij}$$

4. Random coefficient-model

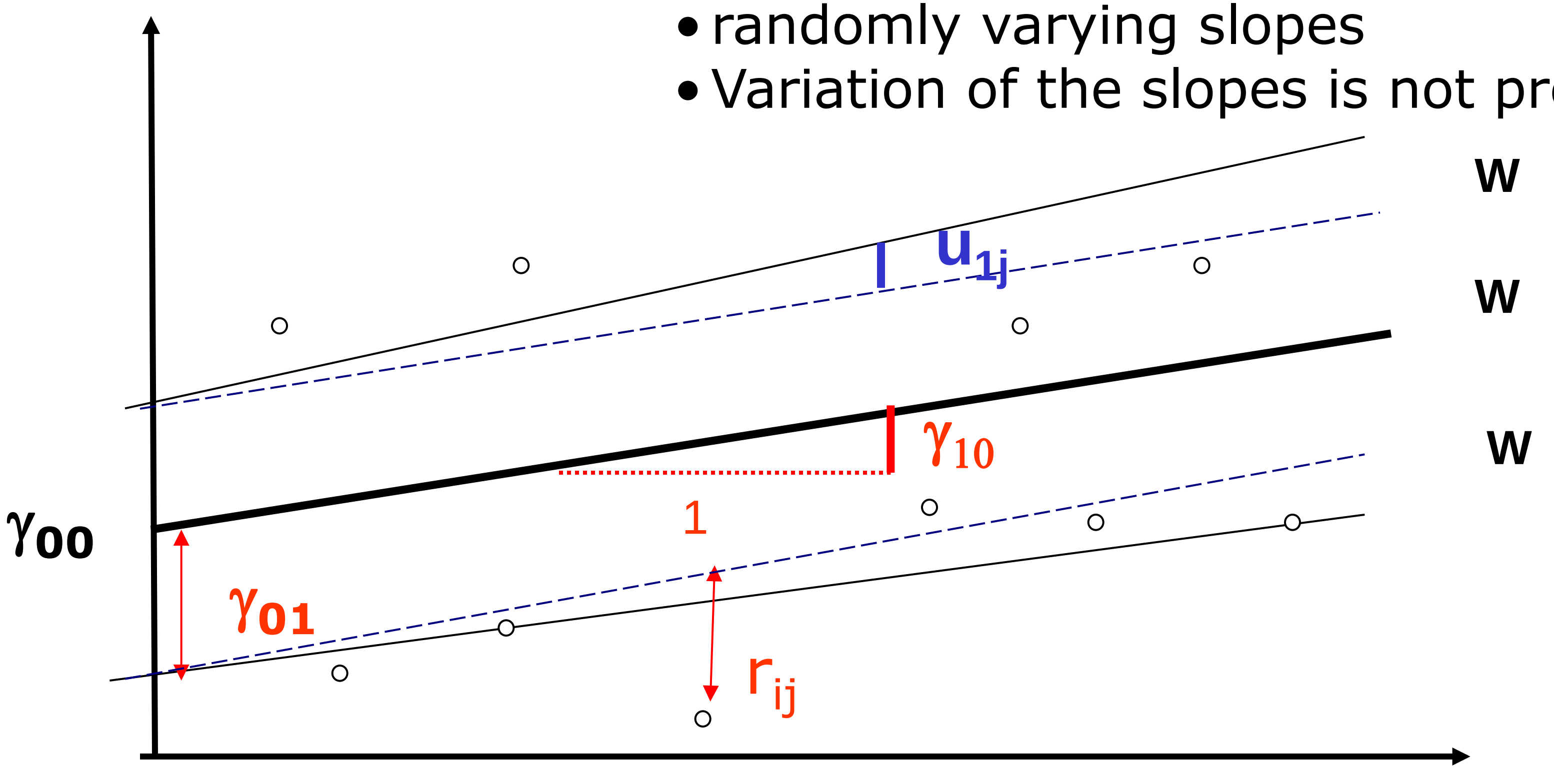
$$Y_{ij} = (\gamma_{00} + \gamma_{01}W_j + \gamma_{10}X_{ij} + \gamma_{11}W_jX_{ij}) + (u_{1j}X_{ij} + u_{0j} + r_{ij})$$

$$Y_{ij} = (\gamma_{00} + \gamma_{01}W_j + \gamma_{10}X_{ij} + \quad u_{1j}X_{ij} + u_{0j} + r_{ij})$$

Heteroscedasticity

4. Random coefficient-model

- randomly varying intercepts;
- intercepts predicted by W
- slope
- randomly varying slopes
- Variation of the slopes is not predicted



$$Y_{ij} = \gamma_{00} + \gamma_{01}W_j + \gamma_{10}X_{jj} + u_{1j}X_{jj} + u_{0j} + r_{ij}$$

5. Context model: cross-level interaction

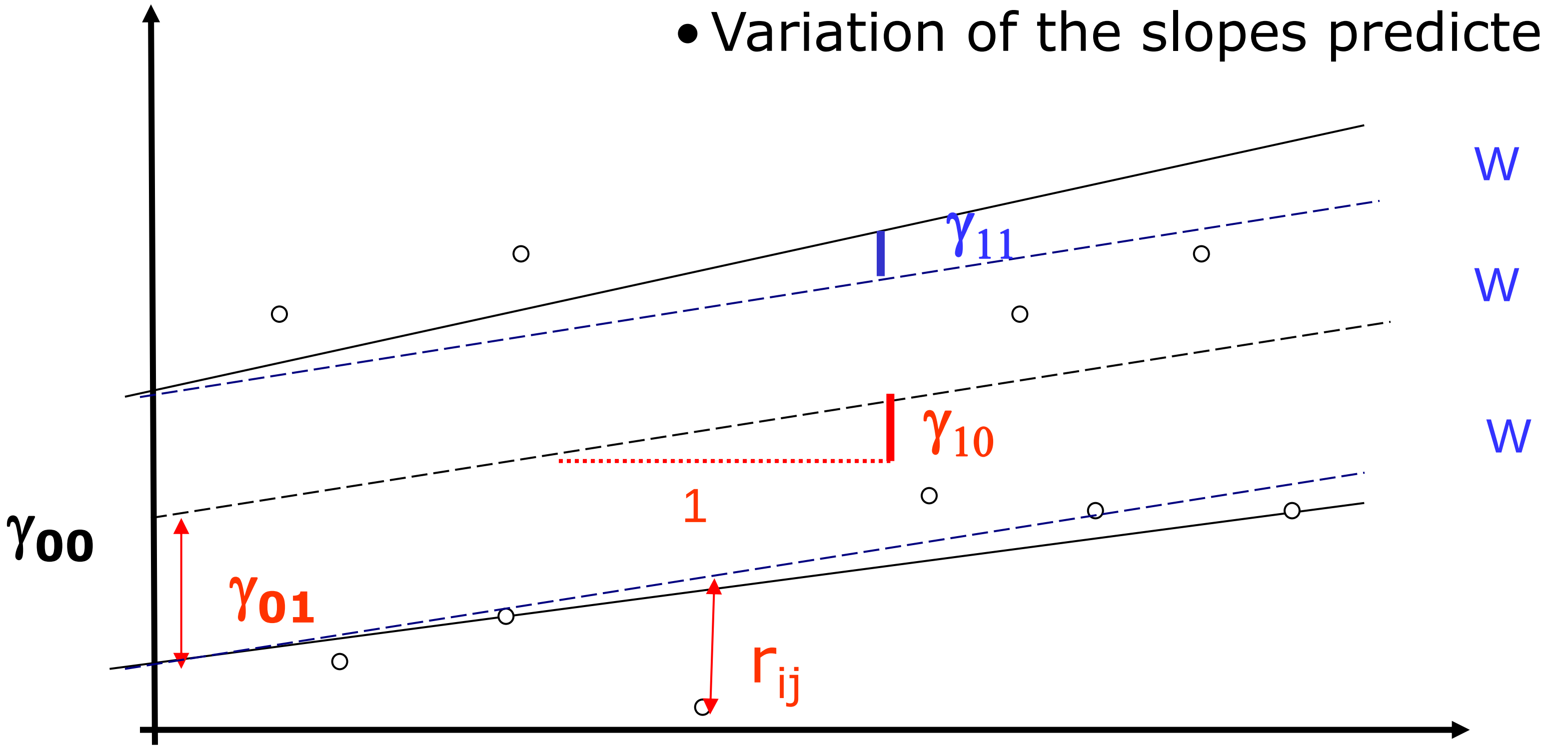
$$Y_{ij} = (\gamma_{00} + \gamma_{01}W_j + \gamma_{10}X_{ij} + \gamma_{11}W_jX_{ij}) + (u_{1j}X_{ij} + u_{0j} + r_{ij})$$

$$Y_{ij} = (\gamma_{00} + \gamma_{01}W_j + \gamma_{10}X_{ij} + \gamma_{11}W_jX_{ij}) + (u_{1j}X_{ij} + u_{0j} + r_{ij})$$

Cross-level interaction

5. Context model: cross-level interaction

- randomly varying intercepts;
- intercepts predicted by W
- slopes predicted by W
- randomly varying slopes
- Variation of the slopes predicted by W



$$Y_{ij} = \gamma_{00} + \gamma_{01}W_j + \gamma_{10}X_{ij} + \gamma_{11}W_jX_{ij} + u_{1j}X_{ij} + u_{1j} + r_{ij}$$

Pros and Cons of multilevel model

Pros

- deals with ML data
- allows to test group-level influences
- allows to test cross-level interactions
- method would optimally fit to many questions of CL

Instruction group level	**c**ollaboration interaction between group members → ICC as goal	**l**earning learning as individual variable
IV →	Process →	DV

Pros and Cons of multilevel model

Cons

- sometimes difficult to specify
- needs many data

→ bottleneck for CL

5th take-home message

Do not test the whole model, but do it iteratively

(1) test, if the groups significantly differ
(2) explain the difference of the intercepts with group-level predictors
(3) test if the slope significanly differ
(4) explain the difference of the slopes with group-level predictors
(5) test if there is a cross-level interaction

Required sample size

see Hox, J. (2002), p. 175

- 30/30 rule (Kreft, 1996): ok for interest in fixed parameters
- accurate group level variance estimates: 6-12 groups (Brown & Draper, 2000)
- 10 groups: variance estimates are much too small (Maas & Hox, 2001)
- if interest is in cross-level interactions: 50/20
- if interest is in the random part: 100/20

Multilevel Articles in CSCL

- **Strijbos, Martens, Jochems, & Broers**, *Small Group Research 2004*

  → *33 students (10 groups); usefulness of roles on group efficiency*

- **Schellens, Van Keer & Martin Valcke**, *Small Group Research, 2005*

  → *286 students (23 groups); measurement occasions within students; roles in groups*

- **Piontkowski, Keil & Hartmann**, Analyseebenen und Dateninter-dependenz in der Kleingruppenforschung am Beispiel netzbasierter Wissensintegration; *Zeitschrift für Sozialpsychologie, 2006*

  → *120 students (40 groups); sequenzing tool; amount of discussion in a group*

Take home messages

- be aware of group effects
- think about working with fakes
- think about groups as unit of analysis
- look for the variances! → heterogeneous variances can be a sign for group effects
- look for different slopes!
- try to explain slopes
- look for the ICC

Questions?