Analyzing Intervention Effects: Multilevel & Other Approaches

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Simplest Intervention Design

R → X Y_E

R → - Y_C

- Random assignment
- Experimental + Control group
- Analysis: *t* - test

Better Design: Have Pretest

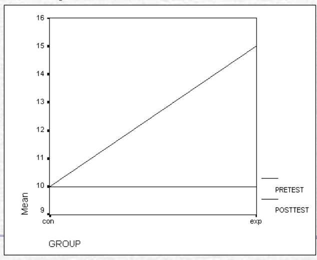
R → Y_{1E} X Y_{2E}

R → Y_{1C} - Y_{2C}

- Random assignment
- Experimental + Control group
- Pretest + Posttest
- Why Better?
- Analysis ?

Why is Pretest/Posttest Better?

- Much larger power
- But depends on analysis
- Imagine effect:



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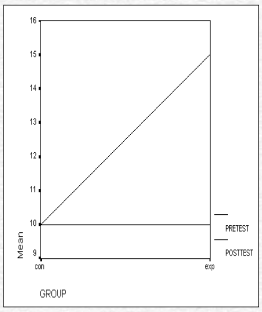
Analysis Possibilities

- Covariance analysis (ancova) *highest power*
- *t* - Test on difference scores *less power*
- Interaction in 2-way analysis of variance (manova) *less power*



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How Much Power?

- Example: assume posttest only
- Effect size is medium: Cohen's $d = 0.5$
- Sample size is 25 + 25 = 50
- Alpha = 0.05, test is two-sided
- Power of *t* - test is 0.41

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How Much Power?

- Example: assume pretest-posttest
- $d = 0.5$, N = 25 + 25 = 50, $\alpha = 0.05$
- Power depends on correlation pretest-posttest, *which is typically high*
- Assume $r = 0.3$ (Cohen: medium)
  - Power of ancova - test is 0.46
- Assume $r = 0.5$ (Cohen: high)
  - Power of ancova - test is 0.55

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How Much Power?

- Same example: pretest-posttest, $r = 0.6$
- Power of ancova - test is 0.57
- Power of *t* - test on difference scores (assume equal variances) is 0.49

(*t* - test on posttest was 0.41)

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How Much Power?

- Same example: pretest-posttest, $r = 0.6$
- Power of ancova - test is 0.57
- Power of interaction test in manova (interaction pre/posttest with exp/con) is 0.49

(*t* - test on posttest was 0.41)

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How Much Power?

- Power of ancova - test is 0.57
- Power *t* - test on difference scores 0.49
- Power of interaction test in manova 0.49
- Same hypothesis is tested, thus power is in general about equal
  - But difference scores *much* simpler

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Still Better Design: Have Pretest and Two Posttests

Y_{1E} X Y_{2E} Y_{3E}

R

Y_{1C} - Y_{2C} Y_{3C}

- First posttest immediately after intervention: effect
- Second posttest much later: retention
- Best analysis: covariance analysis on posttests, separately or simultaneous

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Why Multilevel Analysis?

- If your data have a grouping structure
  - Interventions in organizations
  - e.g. anti-smoking campaign in school classes, intervention done at class level
- If you have a panel design with substantial dropout
  - It is not unusual to loose 25% at each wave

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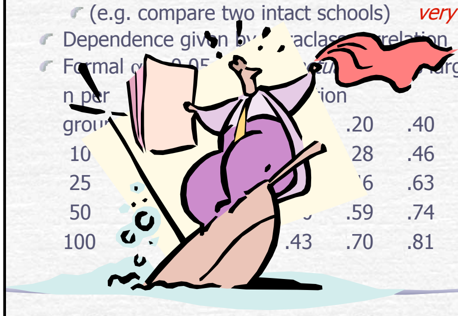
If Data Are Grouped

- Assume t-test, with natural groups
  - (e.g. compare two intact schools)
- Dependence given by [illegible]raclass [illegible]relation
- Formal [illegible] 0.05 [illegible] [illegible]rger!

Significance test *very* biased !

n per group					
	[illegible]	[illegible]	.20	.40	.80
10	[illegible]	[illegible]	28	.46	.75
25	[illegible]	[illegible]	[illegible]	.63	.84
50	[illegible]	[illegible]	.59	.74	.89
100	[illegible]	.43	.70	.81	.92



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If You Have Panel Dropout

- SPSS ancova & ma[illegible] by *casewise dele*[illegible]
  - Cases with missing[illegible]
- Minor disadvantage: wa[illegible]
- Major disadvantage: assume[illegible] dropout is completely at random

completely random:
do you *really*
believe that?

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Why Multilevel Analysis

- If your data do not have a grouping structure
- If your longitudinal study has negligible dropout
  - Say at most 5% (Little & Rubin, 1987)
- Multilevel analysis has *no* advantages

- Use (m)anova with pretest as covariate

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Example Intervention Data

- Experimental/Control group
  Pretest/Posttest: N = 2×25, $r = 0.6$
- Part of data file:

	id	group	expcon	pretest	posttest	diff
1	1	1	1	67	63	-4
2	2	1	1	66	69	3
3	3	1	0	66	55	-12
4	4	1	1	46	58	11
5	5	1	0	48	51	3
6	6	2	0	65	60	-5
7	7	2	1	37	42	5
8	8	2	1	38	39	0
9	9	2	1	57	53	-4
10	10	2	0	40	45	5
11	11	3	0	65	61	-4

file: example.sav

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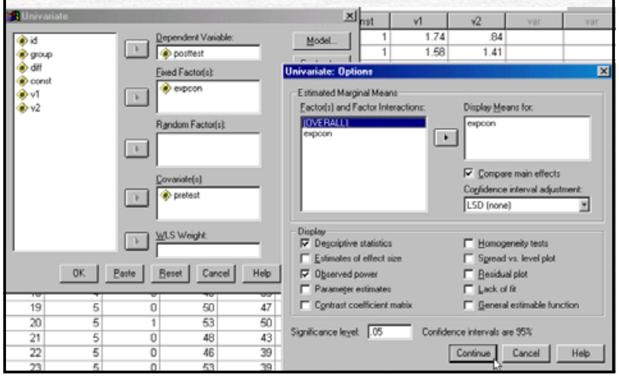
Anova on Intervention Data



Anova on Intervention Data

- SPSS - output:

Tests of Between-Subjects Effects

Dependent Variable: POSTTEST

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power[a]
Corrected Model	2040.500[b]	2	1020.250	15.609	.000	31.219	.999
Intercept	936.055	1	936.055	14.321	.000	14.321	.960
PRETEST	1728.000	1	1728.000	26.438	.000	26.438	.999
EXPCON	312.500	1	312.500	4.781	.034	4.781	.572
Error	3072.000	47	65.362				
Total	142925.000	50					
Corrected Total	5112.500	49					

a. Computed using alpha = .05

b. R Squared = .399 (Adjusted R Squared = .374)

However …

- If your data have a grouping structure

and / or

- If you have a panel design with substantial dropout

- You need multilevel analysis!

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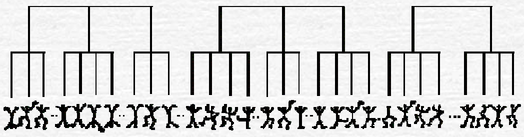
Multilevel Data



- Three level data structure
- Groups at may have different sizes
- Response variable at lowest level
- Explanatory variables at all levels
- Model assumes *sampling* at all levels

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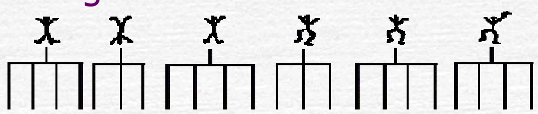
Longitudinal Data As Multilevel



- Six persons measured on up to four occasions
  - Levels are *occasion* level, and *person* level
- We can mix time variant (occasion level) and time invariant (person level) predictors
- Note that missing occasions are no problem

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The Multilevel Regression Model: the Lowest (Individual) Level

- Ordinary regression, one explanatory variable X:
  - $Y_i = \beta_0 + \beta_1 X_i + e_i$
  - β_0 intercept, β_1 regression slope, e_i residual error term
- In multilevel regression, at the lowest level:
  - $Y_{ij} = \beta_{0j} + \beta_{1j} X_{ij} + e_{ij}$
  - β_{0j} intercept, β_{1j} regression slope, e_{ij} residual error
  - subscript i for individuals, j for groups
  - each group has its own intercept coefficient β_{0j}
  - and its own slope coefficient β_{1j}
- Intercept and slope coefficients vary across the groups, hence the term *random coefficient* model

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The Multilevel Regression Model: the Second (Group) Level

- At the lowest level:
  - $Y_{ij} = \beta_{0j} + \beta_{1j} X_{ij} + e_{ij}$
  - Intercept and slope coefficients vary across the groups
- We predict intercept and slope with a second level regression model:
  - $\beta_{0j} = \gamma_{00} + \gamma_{01} Z_j + u_{0j}$
  - $\beta_{1j} = \gamma_{10} + \gamma_{11} Z_j + u_{1j}$
  - γ_{00} and γ_{01} are the intercept and slope to predict β_{0j} from $Z_{j,\ \text{with}}$ u_{0j} the residual error term
  - γ_{10} and γ_{11} are the intercept and slope to predict β_{1j} from $Z_{j,\ \text{with}}$ u_{1j} the residual error term
- Coefficients γ do not vary across groups

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The Multilevel Regression Model: Single Equation Version

- At the lowest (individual) level we have
  - $Y_{ij} = \beta_{0j} + \beta_{1j} X_{ij} + e_{ij}$
- and at the second (group) level
  - $\beta_{0j} = \gamma_{00} + \gamma_{01} Z_j + u_{0j}$
  - $\beta_{1j} = \gamma_{10} + \gamma_{11} Z_j + u_{1j}$
- Combining (substitution and rearranging terms) gives
  - $Y_{ij} = \gamma_{00} + \gamma_{10} X_{ij} + \gamma_{01} Z_j + \gamma_{11} Z_j X_{ij} + u_{1j} X_{ij} + u_{0j} + e_{ij}$
- Looks like an ordinary regression model with complicated error terms

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The Multilevel Regression Model: Single Equation Version

$Y_{ij} = [\gamma_{00} + \gamma_{10} X_{ij} + \gamma_{01} Z_j + \gamma_{11} Z_j X_{ij}] + [u_{1j} X_{ij} + u_{0j} + e_{ij}]$

- This equation has two distinct parts
  - $[\gamma_{00} + \gamma_{10} X_{ij} + \gamma_{01} Z_j + \gamma_{11} Z_j X_{ij}]$ contains all the fixed coefficients, it is the fixed part of the model
  - $[u_{1j} X_{ij} + u_{0j} + e_{ij}]$ contains all the random error terms, it is the random part of the model
- Plus:
  - The *cross-level* interaction $Z_j X_{ij}$ results from modeling the regression slope β_{1j} of individual level variable X_{ij} with the group level variable Z_j
  - the error term u_{1j} is connected to X_{ij}. Thus the residuals are larger for large values of X_{ij}, implying *heteroscedasticity*

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The Multilevel Regression Model: Interpretation

$Y_{ij} = [\gamma_{00} + \gamma_{10} X_{ij} + \gamma_{01} Z_j + \gamma_{11} Z_j X_{ij}] + [u_{1j} X_{ij} + u_{0j} + e_{ij}]$

- Fixed part is an ordinary regression model
- Complicated error term: $[u_{1j} X_{ij} + u_{0j} + e_{ij}]$
- Several error variances
  - σ_e^2 variance of the lowest level errors e_{ij}
  - σ_{00} variance of the highest level errors u_{0j}
  - σ_{11} variance of the highest level errors u_{1j}
    - σ_{01} covariance of u_{0j} and u_{1j}
- Note: σ_{00}, σ_{11}, and σ_{01} also interpreted as (co)variances of lowest level coefficients β_j

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The Multilevel Regression Model: Estimation

- At the lowest (individual) level we have
  - $Y_{ij} = \beta_{0j} + \beta_{1j} X_{ij} + e_{ij}$
- and at the second (group) level
  - $\beta_{0j} = \gamma_{00} + \gamma_{01} Z_j + u_{0j}$
  - $\beta_{1j} = \gamma_{10} + \gamma_{11} Z_j + u_{1j}$
- Maximum Likelihood (ML) estimation
  - Gamma coefficients, standard errors, p-values
  - Variance components σ_e^2 and σ_{00}, σ_{01}, σ_{11}
  - (significance of (co)variances in Σ)
  - Model *deviance*

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Data Structure
Multilevel Regression Model

- MLwiN & most other software
  - All data in one single file
  - Levels identified by identification numbers
    - school number, class number, pupil number
- HLM
  - Separate file for each level
  - Reads SPSS, SAS, EXCEL & other files
- Note: SPSS 11.0 mixed model module is seriously flawed, do not use

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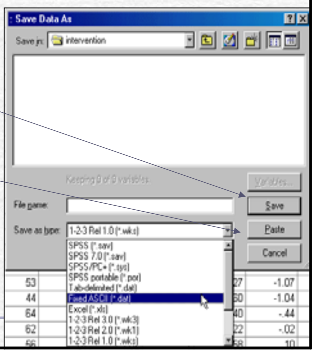
Preparing Data for MLwiN

- Group and individual identification numbers
- Regression constant computed in SPSS
  - const = 1
  - (not visible here)
- Write data out as *fixed ascii* -file

	id	group	expcon	pretest	posttest
1	1	1	1	67	63
2	2	1	1	66	69
3	3	1	0	66	55
4	4	1	1	46	58
5	5	1	0	48	51
6	6	2	0	65	60
7	7	2	1	37	42
8	8	2	1	38	39
9	9	2	1	57	53
10	10	2	0	40	45
11	11	3	0	65	61
12	12	3	0	45	53
13	13	3	1	46	51
14	14	3	1	44	59
15	15	3	0	49	48
16	16	4	1	48	66
17	17	4	1	42	67
18	18	4	0	48	65
19	19	5	0	50	47
20	20	5	1	53	50

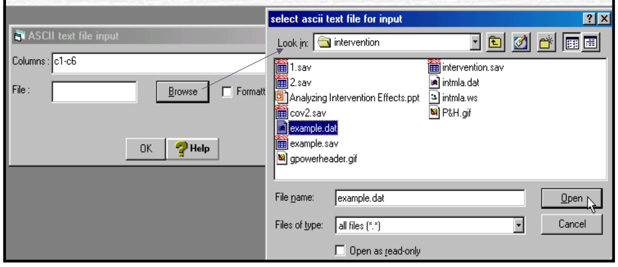
Porting Data to MLwiN

- Write data out as *fixed ascii* -file
  - Using *Save As*
  - *Save* gives *all* variables
- Or *Paste* into syntax window and replace *all* with list of variables
  - WRITE OUTFILE = 'd:\Joop\intervention\example.dat'
  - TABLE / id group expcon pretest posttest const .
  - EXECUTE .



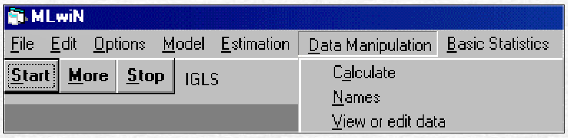
Start MLwiN & Input Data

- Under *File* open fixed ascii file
  - Specify columns = # of variables
  - Specify location & file



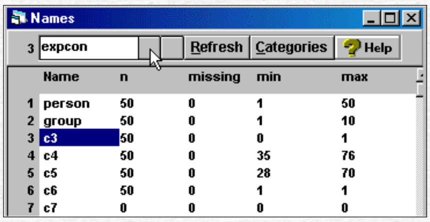
MLwiN: Next

- Nothing seems to happen
  - Click on Data Manipulation to assign names



- Assigning names to columns is important
  - c1=person, c2=group, c3=expcon, c4=pretest, c5=posttest, c6=const

MLwiN: Next

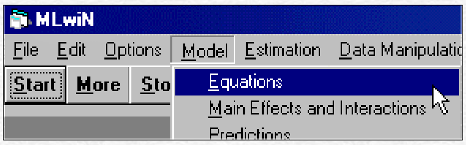


	Name	n	missing	min	max
1	person	50	0	1	50
2	group	50	0	1	10
3	c3	50	0	0	1
4	c4	50	0	35	76
5	c5	50	0	28	70
6	c6	50	0	1	1
7	c7	0	0	0	0

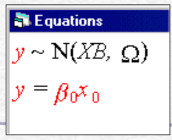
- Select column to assign name
  - Type name in textbox, next hit *Enter* or click on unmarked button

MLwiN: Next

- Go to Model, open Equations window



- Which produces this:
  - The Equations window is where we specify the model



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The Equations Window: Heart of MLwiN

- Specify the outcome variable
- Specify the variables that identify levels
- Add predictors
  - Including the regression constant
- Specify which 1st level predictors have random (=varying) regression coefficients across level 2 units
  - Including the regression constant
    - Almost always random at all levels

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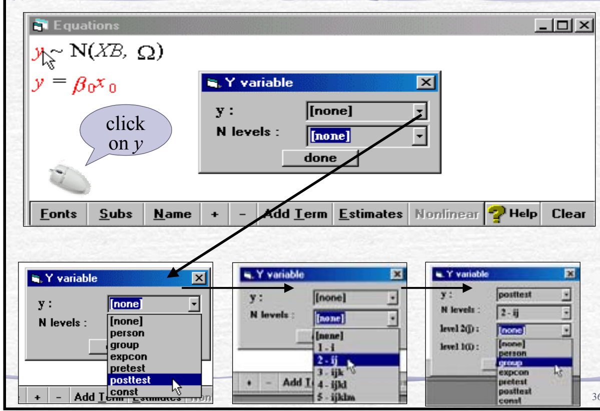
Specify Outcome & Levels



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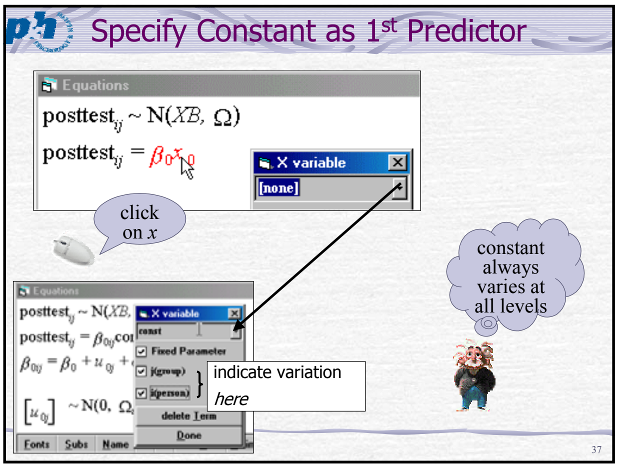
Specify Constant as 1st Predictor
Equations
posttest ~ N(XB, Ω)
X variable
[none]
click on x
constant always varies at all levels
indicate variation here
Fixed Parameter
delete Term
Done
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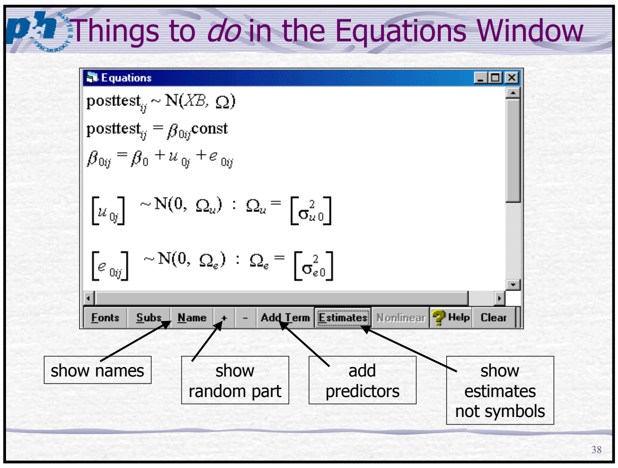
Things to do in the Equations Window
Equations
Fonts Subs Name + - Add Term Estimates Nonlinear Help Clear
show names
show random part
add predictors
show estimates not symbols
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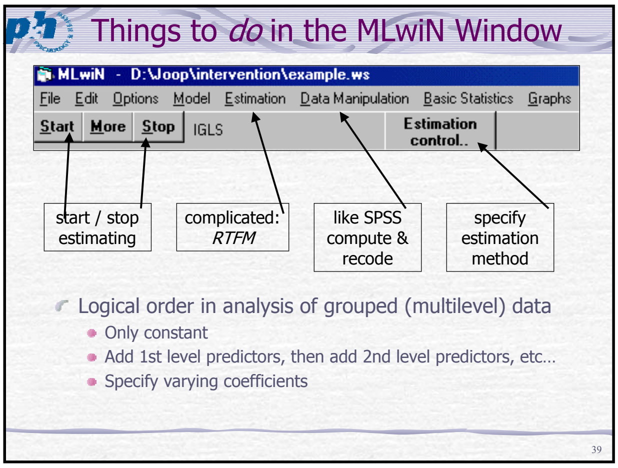
Things to do in the MLwiN Window
MLwiN - D:\Joop\intervention\example.ws
File Edit Options Model Estimation Data Manipulation Basic Statistics Graphs
Start More Stop IGLS Estimation control..
start / stop estimating
complicated: RTFM
like SPSS compute & recode
specify estimation method
Logical order in analysis of grouped (multilevel) data
Only constant
Add 1st level predictors, then add 2nd level predictors, etc...
Specify varying coefficients
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Start Computations …

- As by magic …, estimates appear
  - Constant plus the two variance components
  - The intraclass correlation is $(\sigma_{11}/(\sigma_{11}+\sigma_e^2))$
  - Here (25.79/(25.79 + 78.04) = 0.25
  - 25% of variance at group level

Equations

$$\text{posttest}_{ij} \sim \mathrm{N}(XB, \Omega)$$

$$\text{posttest}_{ij} = \beta_{0ij}\text{const}$$

$$\beta_{0ij} = 52.870(2.043) + u_{0j} + e_{0ij}$$

$$\begin{bmatrix} u_{0j} \end{bmatrix} \sim \mathrm{N}(0,\ \Omega_u) \ : \ \Omega_u = \begin{bmatrix} 25.787(18.919) \end{bmatrix}$$

$$\begin{bmatrix} e_{0ij} \end{bmatrix} \sim \mathrm{N}(0,\ \Omega_e) \ : \ \Omega_e = \begin{bmatrix} 78.044(17.444) \end{bmatrix}$$

Fonts | Subs | Name | + | - | Add Term | Estimates | Nonlinear | Help | Clear

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Multilevel Analysis

- Add predictor variables
  - Assess significance
  - Like usual multiple regression

BUT

- 1st level predictors may have regression coefficients varying across groups
- Interesting hypothesis: is intervention effect constant across groups?
  - If not: which group variables explain differences in intervention effect?

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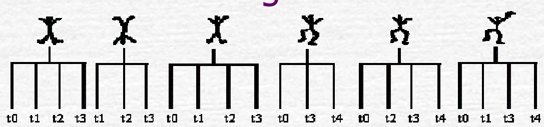
Back to Longitudinal Data



- Six persons measured on up to four occasions
  - Levels are *occasion* level, and *person* level
- We can mix time variant (occasion level) and time invariant (person level) predictors
- Note that missing occasions are no problem

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Typical Longitudinal Data File

1:student | 1

	student	sex	highgpa	gpa1	gpa2	gpa3	gpa4	gpa5	gpa6	job1	job2	job3	job4	job5	job6
1	1	2	2.8	2.3	2.1	3.0	3.0	3.0	3.3	2	2	2	2	2	2
2	2	1	2.5	2.2	2.5	2.6	2.6	3.0	2.8	2	3	2	2	2	2
3	3	2	2.5	2.4	2.9	3.0	2.8	3.3	3.4	2	2	2	3	2	2
4	4	1	3.8	2.5	2.7	2.4	2.7	2.9	2.7	3	2	2	2	2	2
5	5	1	3.1	2.8	2.8	2.8	3.0	2.9	3.1	2	2	2	2	2	2
6	6	2	2.9	2.5	2.4	2.4	2.3	2.7	2.8	2	3	3	2	3	3
7	7	1	2.3	2.4	2.4	2.8	2.6	3.0	3.0	3	2	3	2	2	2
8	8	2	3.9	2.8	2.8	3.1	3.3	3.3	3.4	2	2	2	2	2	2
9	9	1	2.0	2.8	2.7	2.7	3.1	3.1	3.5	2	2	3	2	2	2
10	10	1	2.8	2.8	2.8	3.0	2.7	3.0	3.0	2	2	2	3	2	2
11	11	2	3.9	2.6	2.9	3.2	3.6	3.6	3.8	2	3	2	2	2	2
12	12	2	2.9	2.6	3.0	2.3	2.9	3.1	3.3	3	2	2	2	2	2
13	13	1	3.7	2.8	3.1	3.5	3.6	3.9	3.9	2	2	2	2	2	2
14	14	2	3.5	2.4	3.0	2.9	3.0	3.3	3.4	2	2	2	2	2	2

Typical Longitudinal Data File, Prepared for Multilevel Analysis

gpaflat.dat - Notepad

File Edit Search Help

```
1    0   2.3   2 2 2.8
1    1   2.1   2 2 2.8
1    2   3.0   2 2 2.8
1    3   3.0   2 2 2.8
1    4   3.0   2 2 2.8
1    5   3.3   2 2 2.8
2    0   2.2   2 1 2.5
2    1   2.5   3 1 2.5
2    2   2.6   2 1 2.5
2    3   2.6   2 1 2.5
2    4   3.0   2 1 2.5
2    5   2.8   2 1 2.5
3    0   2.4   2 2 2.5
3    1   2.9   2 2 2.5
3    2   3.0   2 2 2.5
3    3   2.8   3 2 2.5
3    4   3.3   2 2 2.5
```

1:student | 1

	student	occasion	gpa
1	1	1	2.3
2	1	2	2.1
3	1	3	3.0
4	1	4	3.0
5	1	5	3.0
6	1	6	3.3
7	2	1	2.2
8	2	2	2.5

Multilevel longitudinal data file as raw data and as SPSS file

SPSS file useful for preliminaries: inspect distributions, outliers, exploratory analyses

Intervention Data File

ident	expcon	pretest	post1	post2
1	0	35	37	38
2	0	58	47	44
3	0	41	37	42
4	1	43	48	39
5	1	43	40	32
6	0	39	37	26
7	0	62	45	40

Person Identification, Exp/Con group, 1 pretest, immediate posttest, follow-up posttest

Creating the Multilevel Longitudinal Data File

- SPSS-file intervention.sav
- In SPSS: make sure each variable has enough columns
- No system missing values but explicit missing data code
- Write raw data to interventionflat.dat

	organ	ident	expcon	pretest	post1	post2
1	1	1	0	35	37	38
2	1	2	0	58	47	44
3	1	3	0	41	37	42

Syntax2 - SPSS Syntax Editor

```
WRITE OUTFILE='D:\Joop\intervention\interventionflat.dat' TABLE /
        organ ident '0 ' pretest '1 ' '0 ' '0 ' expcon /
        organ ident '1 ' post1  '0 ' '1 ' '0 ' expcon /
        organ ident '2 ' post2  '0 ' '0 ' '1 ' expcon .
EXECUTE.
```

- Data are read back in SPSS in free format (variables separated by spaces) in 'new' data layout
- Saved in SPSS file interventionflat.say

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Creating the Multilevel Longitudinal Data File

- Data are read back in SPSS in free format (variables separated by spaces) in 'new' data layout
- Saved in SPSS file interventionflat.sav

	ident	occ	test	pre	post1	post2	expcon
1	1.00	1.00	35.00	1.00	.00	.00	.00
2	1.00	2.00	37.00	.00	1.00	.00	.00
3	1.00	3.00	38.00	.00	.00	1.00	.00
4	2.00						
5	2.00						
6	2.00						
7	3.00						
8	3.00						
9	3.00						
10	4.00						

Syntax2 - SPSS Syntax Editor

```
data list file 'D:\Joop\intervention\interventionflat.dat' free/
 ident occ test pre post1 post2 expcon .
execute.
```

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Creating the Multilevel Longitudinal Data File

- Remove in this file all 'cases' (= occasions) that have a missing value on 'test' (= missed occasion)
- Write remainder to raw data file, transport to MLwiN
- Male levels: 1st = occasion, 2nd = person (ident)
- Dummies for pretest & 2 posttests
- Effect of 'expcon' modeled as interaction with post1 or post2 dummy

	ident	occ	test	pre	post1	post2	expcon
1	1.00	1.00	35.00	1.00	.00	.00	.00
2	1.00	2.00	37.00	.00	1.00	.00	.00
3	1.00	3.00	38.00	.00	.00	1.00	.00
4	2.00	1.00	58.00	1.00	.00	.00	.00
5	2.00	2.00	47.00	.00	1.00	.00	.00
6	2.00	3.00	44.00	.00	.00	1.00	.00
7	3.00	1.00	41.00	1.00	.00	.00	.00

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Creating the Multilevel Longitudinal Data File

- Note: effect of ‘expcon’ modeled as interaction with post1 or post2 dummy means less power
  - Just as in manova
  - But testscore may be missing at any occasion
- Alternative (pretest as covariate) only fesible if both pretest and posttest1 virtually no missings
  - Which does happen …

	ident	occ	test	pre	post1	post2	expcon
1	1.00	1.00	35.00	1.00	.00	.00	.00
2	1.00	2.00	37.00	.00	1.00	.00	.00
3	1.00	3.00	38.00	.00	.00	1.00	.00
4	2.00	1.00	58.00	1.00	.00	.00	.00
5	2.00	2.00	47.00	.00	1.00	.00	.00
6	2.00	3.00	44.00	.00	.00	1.00	.00
7	3.00	1.00	41.00	1.00	.00	.00	.00

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Usual Longitudinal Multilevel Analysis

- Baseline model always includes occasions as linear predictor or series of dummies
  - Check for autonomous shift over time
- Add covariate ‘expcon’ as interaction with ‘post1’ and / or ‘post2’ dummy
  - We may add covariate ‘expcon’ as interaction with ‘pretest’ to check initial equality of groups

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Remember …

- If your data have a grouping structure

and / or

- If you have a panel design with substantial dropout

- You need multilevel analysis!

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Because …

- SPSS ancova & ma… by *casewise dele*…
  - Cases with missing…
- Minor disadvantage: wa…
- Major disadvantage: assume… dropout is completely at random

completely random: do you *really* believe that?

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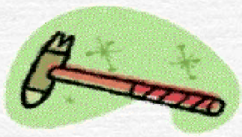
Just to Hammer it in …

- *The* advantage of multilevel models in pretest - posttest designs
- Is the softer assumption of missing at random (MAR)
- Instead *completely* at random (MCAR)
- MAR is plausible if dropout can be predicted from available variables
  - Including the pretest!



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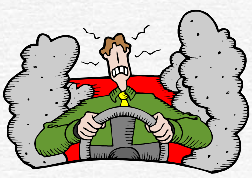
OK …

- Let's get moving!



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