Analyzing Repeated Measures Data

Module 1: An Overview of Repeated Measures

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Workshop Outline: Overview

1. Repeated Measures Data:

   What it means and the basic approaches

2. The Roles of Subjects, Time, and Predictor Variables

   - Factors and Covariates

   - Crossed and Nested Factors

   - Fixed and Random Factors

   - Random Factors and Random Effects

What are Repeated Measures?

Teacher Expectation: Students' and teachers' ratings of rapport measured at 3 time points

Physical Training: Men measured on 13 physiological health measures before and after one of three training regimens
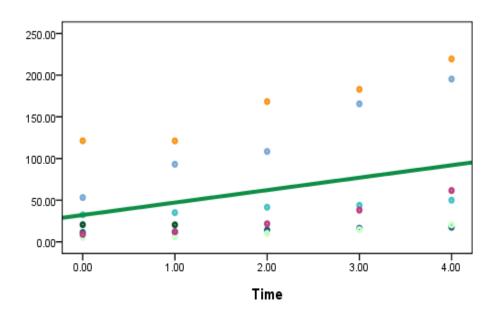
Swallowing: Participants's tongue pressure rise and release slopes during swallowing measured on 5 swallows for each of 11 tasks

County: Number of jobs in each county measured at each decile census

Infant: Six measures of breathing (eg. Inspriatory duration) measured for 15-50 breaths
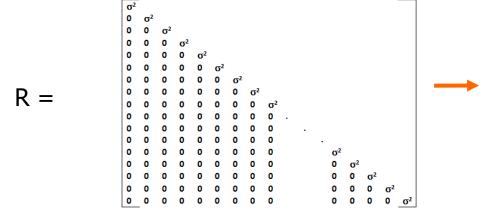
Why not a general linear model?

Approach: Alter the Residual Structure

Assume Independence

$$Y_j = \beta_0 + \beta_1 \text{Time} + \varepsilon_j$$

$\varepsilon_j \sim$ iid $N(0, \sigma^2)$
for outcome j

Account for Within-Subject Dependence

$$Y_{ij} = \beta_0 + \beta_1 \text{Time} + \varepsilon_{ij}$$

$\varepsilon_{ij} \sim$ iid $N(0, \Sigma)$
for subject i and outcome j

R =

THE ANALYSIS FACTOR

Approach: Control for Subject

$$Y_j = \beta_0 + \beta_1 Time + \beta_2 Sub_1 + \beta_3 Sub_2 + \beta_4 Sub_3 + \beta_5 Sub_4 + \beta_6 Sub_5 + \varepsilon_j$$

$$\varepsilon_j \sim \text{iid } N(0, \sigma^2) \text{ for outcome } j$$

$$Y_{ij} = \beta_0 + \beta_1 Time + u_i + \varepsilon_{ij}$$

$$\varepsilon_{ij} \sim \text{iid } N(0, \sigma^2)$$
for outcome j

$$u_i \sim \text{iid } N(0, \tau^2)$$
for subject i

Workshop Outline: Overview

1. Repeated Measures Data:

    What it means and the basic approaches

2. **The Roles of Subjects, Time, and Predictor Variables**
    — Factors and Covariates
    — Crossed and Nested Factors
    — Fixed and Random Factors
    — Random Factors and Random Effects

The Role of Subjects

Teacher Expectation: Student, Student(Teacher)

Physical Training: Person

Swallowing: Participant, Participant*Task

County: County

Infant: Infant

The Role of Time in the Repeat

Teacher Expectation: No predictors over time, time is inherent in the research question

Physical Training: Time indicates relation to training group

Swallowing: Repeats across tasks confounded with task; Repeats within tasks are indicated by trial
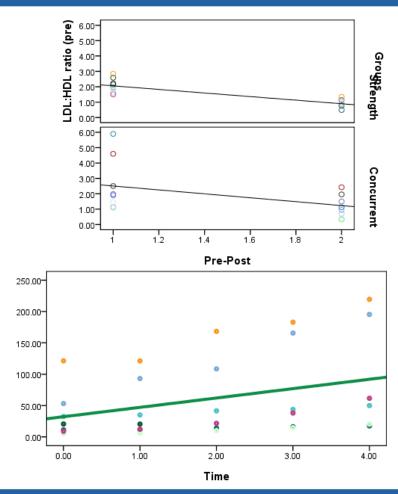
County: Inherent in research questions; covariates measured at each time point and at baseline

Infant: No inherent time measure, order doesn't matter

The Role of Predictors

Factor: Categorical

Covariate: Continuous
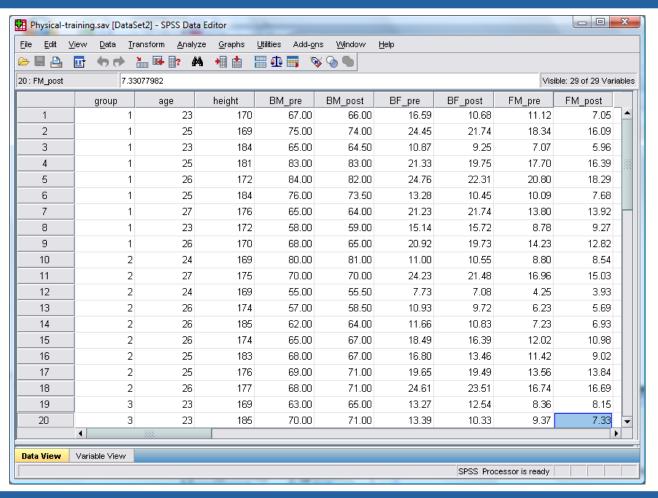
The Role of Predictors
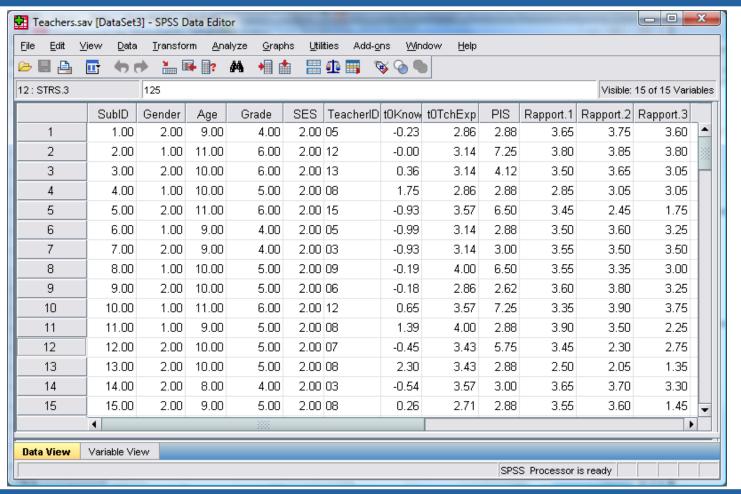
Within-Subject Factor vs. Between-Subject Factor
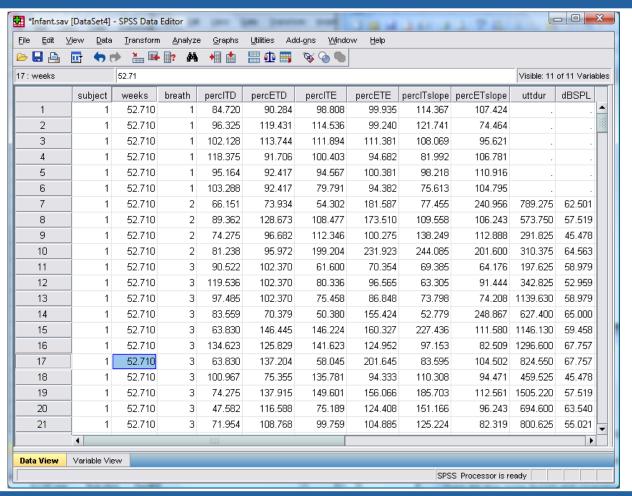
Time-Varying vs. Time-Invariant Covariate

Level 1(Time level) vs. Level 2 (Person level)

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Crossed vs. Nested Factors

Crossed: Every category of one factor co-occurs with every category of the other

Nested: Every category of one factor occurs with only one category of the other

group Groups * Time Pre-Post Crosstabulation

Count

		Time Pre-Post		
		1	2	Total
group Groups	1 Endurance	9	9	18
	2 Strength	9	9	18
	3 Concurrent	9	9	18
	Total	27	27	54

Crossed vs. Nested Factors

Physical Training Data

id * Time Pre-Post Crosstabulation

Count

		Time Pre-Post		
		1	2	Total
id	1	1	1	2
	2	1	1	2
	3	1	1	2
	4	1	1	2
	5	1	1	2
	6	1	1	2
	7	1	1	2
	8	1	1	2
	9	1	1	2
	10	1	1	2
	11	1	1	2
	12	1	1	2
	13	1	1	2
	14	1	1	2
	15	1	1	2
	16	1	1	2
	17	1	1	2
	18	1	1	2
	19	1	1	2
	20	1	1	2
	21	1	1	2
	22	1	1	2
	23	1	1	2
	24	1	1	2
	25	1	1	2
	26	1	1	2
	27	1	1	2
Total		27	27	54

Crossed vs. Nested Factors

Physical Training Data

id * group Groups Crosstabulation

Count

id		1 Endurance	2 Strength	3 Concurrent	Total
id	1	2	0	0	2
	2	2	0	0	2
	3	2	0	0	2
	4	2	0	0	2
	5	2	0	0	2
	6	2	0	0	2
	7	2	0	0	2
	8	2	0	0	2
	9	2	0	0	2
	10	0	2	0	2
	11	0	2	0	2
	12	0	2	0	2
	13	0	2	0	2
	14	0	2	0	2
	15	0	2	0	2
	16	0	2	0	2
	17	0	2	0	2
	18	0	2	0	2
	19	0	0	2	2
	20	0	0	2	2
	21	0	0	2	2
	22	0	0	2	2
	23	0	0	2	2
	24	0	0	2	2
	25	0	0	2	2
	26	0	0	2	2
	27	0	0	2	2
Total		18	18	18	54

Crossed vs. Nested Factors

Teacher Data

SubID Subject ID * Time Measurement time Crosstabulation

Count

		Time Measurement time			
		1	2	3	Total
SubID Subject ID	1	1	1	1	3
	2	1	1	1	3
	3	1	1	1	3
	4	1	1	1	3
	5	1	1	1	3
	6	1	1	1	3
	7	1	1	1	3
	8	1	1	1	3
	9	1	1	1	3
	10	1	1	1	3
	11	1	1	1	3
	12	1	1	1	3
	13	1	1	1	3
	14	1	1	1	3
	15	1	1	1	3
	16	1	1	1	3
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	18	1	1	1	3
	19	1	1	1	3
	20	1	1	1	3
	21	1	1	1	3
	22	1	1	1	3
	23	1	1	1	3
	24	1	1	1	3
	25	1	1	1	3
	26	1	1	1	3
	27	1	1	1	3
	28	1	1	1	3
	29	1	1	1	3
	30	1	1	1	3

Crossed vs. Nested Factors

Teacher Data

Grade Grade in school * Time Measurement time Crosstabulation

Count

		Time Measurement time			
		1	2	3	Total
Grade Grade in school	4	20	20	20	60
	5	41	41	41	123
	6	21	21	21	63
	Total	82	82	82	246

Gender Sex * Time Measurement time Crosstabulation

Count

		Time Measurement time			
		1	2	3	Total
Gender Sex	1.00 Girl	46	46	46	138
	2.00 Boy	36	36	36	108
	Total	82	82	82	246

SES Free lunch status * Gender Sex Crosstabulation

Count

		Gender Sex		
		1.00 Girl	2.00 Boy	Total
SES Free lunch status	1.00 Free Lunch	1	3	4
	2.00 Neither Free Nor Reduced Lunch	45	33	78
	Total	46	36	82

Crossed vs. Nested Factors

Teacher Data

SubID Subject ID * Gender Sex Crosstabulation

Count

		Gender Sex		
		1.00 Girl	2.00 Boy	Total
SubID Subject ID	1	0	3	3
	2	3	0	3
	3	0	3	3
	4	3	0	3
	5	0	3	3
	6	3	0	3
	7	0	3	3
	8	3	0	3
	9	0	3	3
	10	3	0	3

SubID Subject ID * Grade Grade in school Crosstabulation

Count

		Grade Grade in school			
		4	5	6	Total
SubID Subject ID	1	3	0	0	3
	2	0	0	3	3
	3	0	0	3	3
	4	0	3	0	3
	5	0	0	3	3
	6	3	0	0	3
	7	3	0	0	3
	8	0	3	0	3
	9	0	3	0	3
	10	0	0	3	3

SubID Subject ID * TeacherID Teacher Crosstabulation

Count

		TeacherID Teacher																Total
		01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	
SubID Subject ID	1	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	3
	2	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	3
	3	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	3
	4	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	3
	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	3
	6	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	3
	7	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	3
	8	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	3
	9	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	3
	10	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	3

Fixed vs. Random Factors

	Fixed Factors	Random Factors
Effect measured by:	differences in means	variation among means
Results test:	the mean differences	the variance of the distribution of means
Results:	limited to the values you chose	generalize to the distribution
Number of Parameters:	k-1	1

Fixed vs. Random Factors

Physical Training

Factor	Fixed	Random
Group Time Subject		
Group*Time Group*Subject Time*Subject		
Group*Time*Subject		

Fixed vs. Random Factors

Teacher

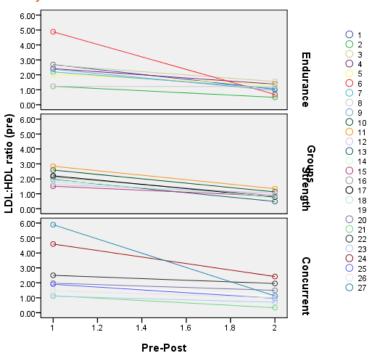| Factor	Fixed	Random
Time Subject Grade SES Teacher		
Time*Subject Time*Grade Subject*Grade		
Time*Teacher Grade*Teacher		

Random Factor vs. Random Effects

$$Y_{ij} = \beta_0 + \beta_1 Time + \beta_2 Group + u_{0i} + u_{1i} Time + \varepsilon_{ij}$$

for subject i at time j

Module 1 Review

1. Repeated Measures Data is defined by multiple measurements of the outcome variable for each subject

2. Model association among repeated measurements through estimating their correlation or controlling for subject

3. Factors are categorical; Covariates are numerical

4. The repeat may be over time or a condition

5. Time may be continuous or categorical

6. Nesting of subjects is common

7. Subject is always a Random Factor, among others

8. Random Effects are defined by the height or change in Y for the random factor