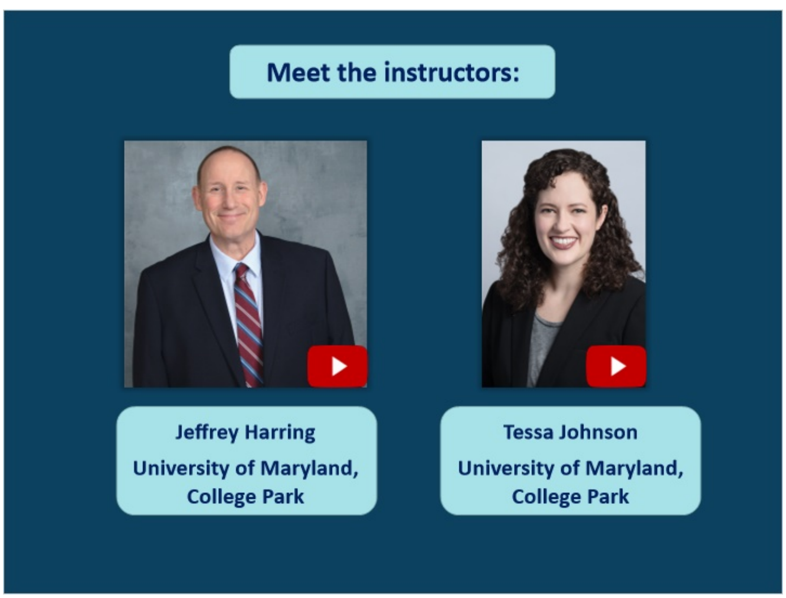
DM16 SLIDES (Version 1.0)

1. Module Overview

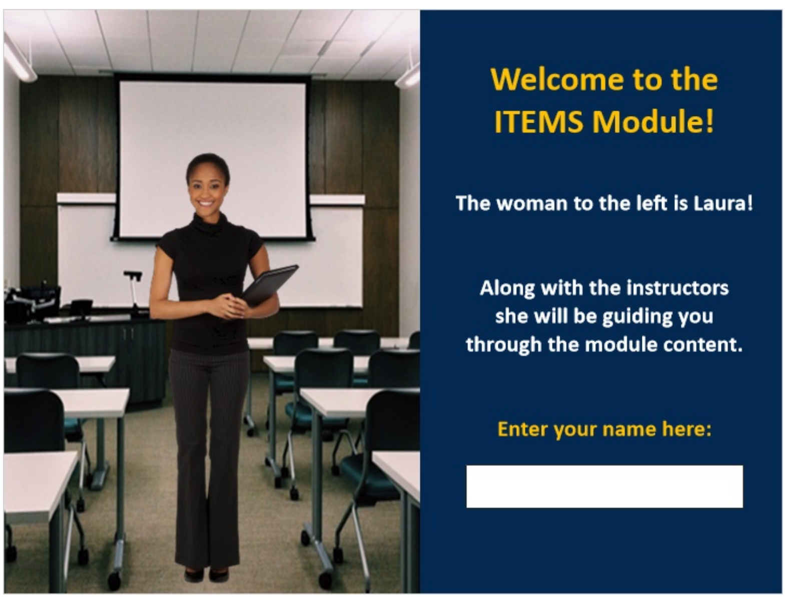
1.1 Module Cover (START)

1.2 Instructors



1.3 Designers

1.4 Welcome



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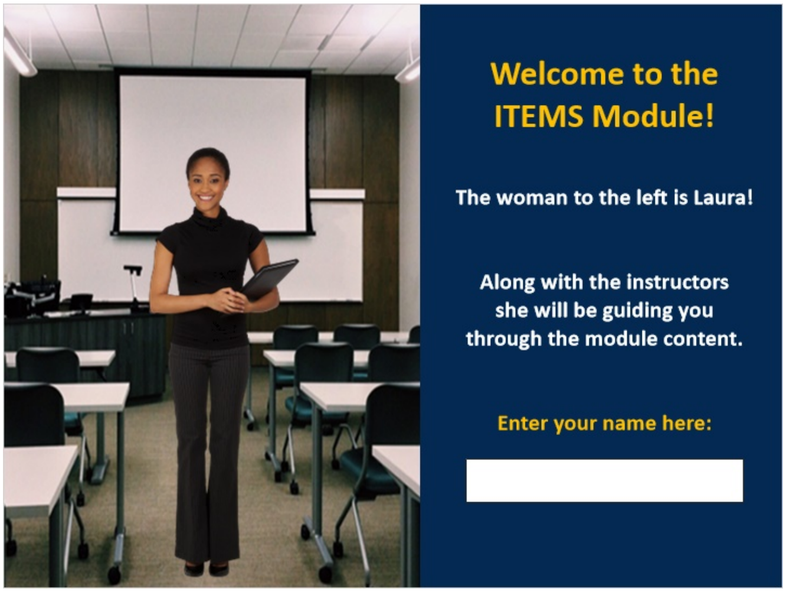
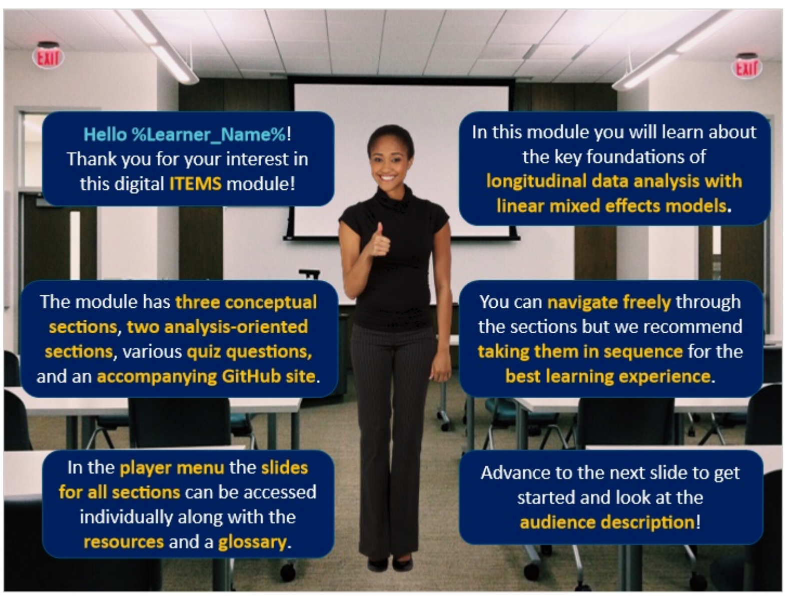
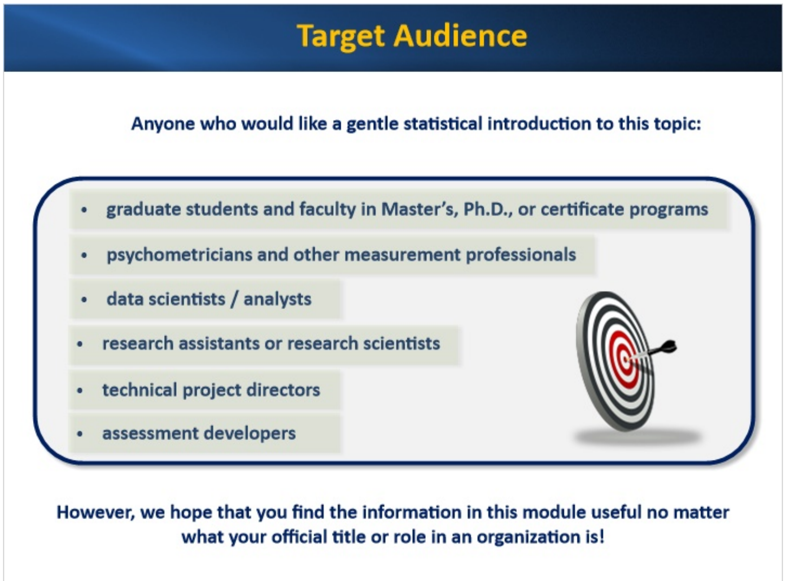


1.5 Overview



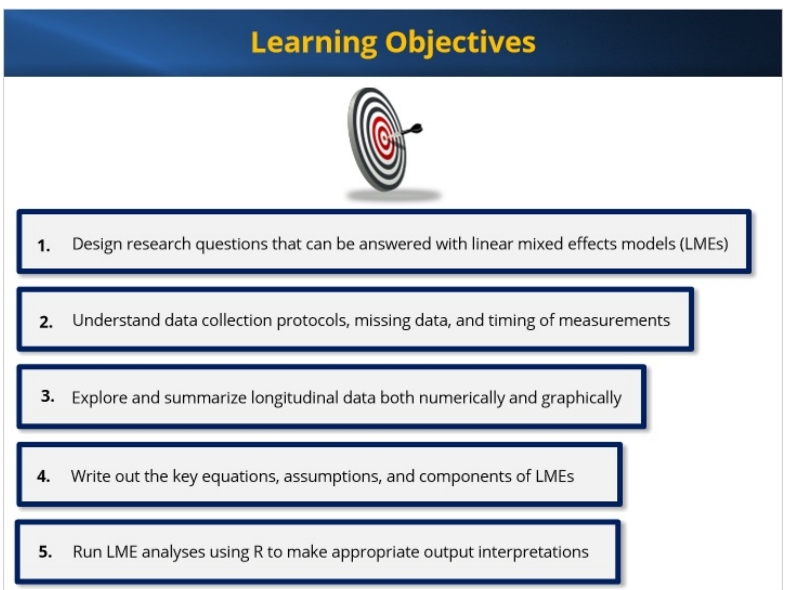
1.6 Target Audience



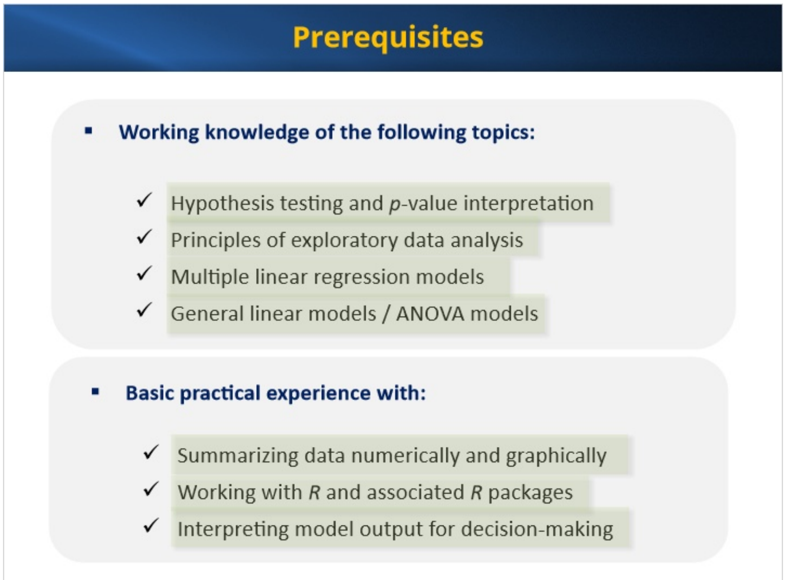
1.7 Expecations (I)

1.8 Expectations (II)

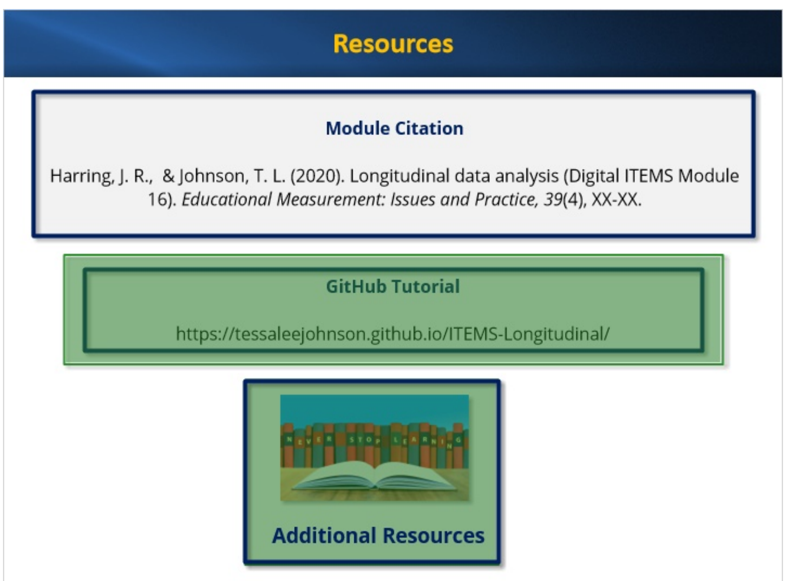
1.9 Learning Objectives



1.10 Prerequisites

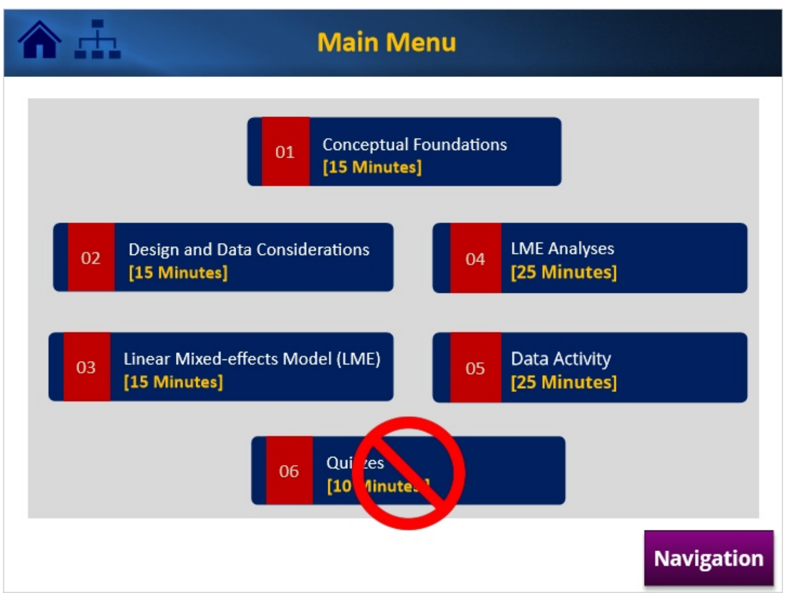


1.11 Resources



References (Slide Layer)

1.12 Main Menu

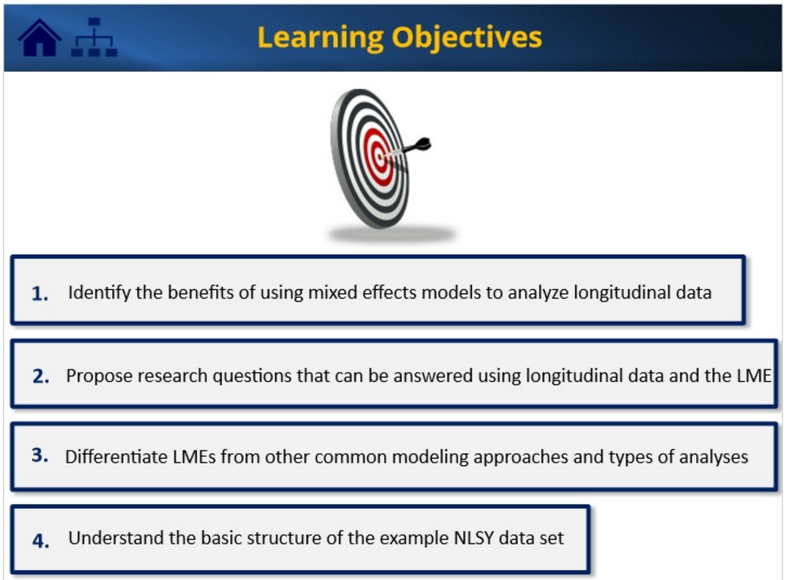


Navigation (Slide Layer)

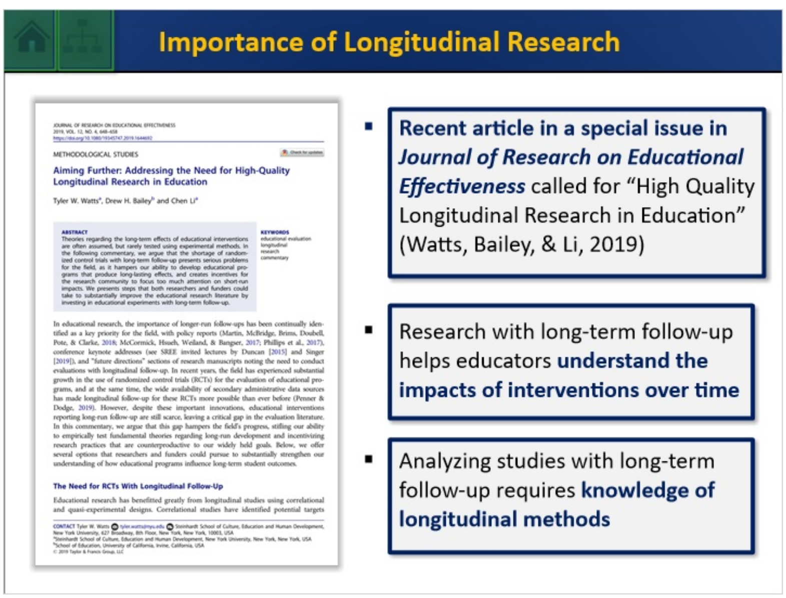
2. Section 1: Conceptual Foundations

2.1 Cover: Section 1

2.2 Learning Objectives: Section 1



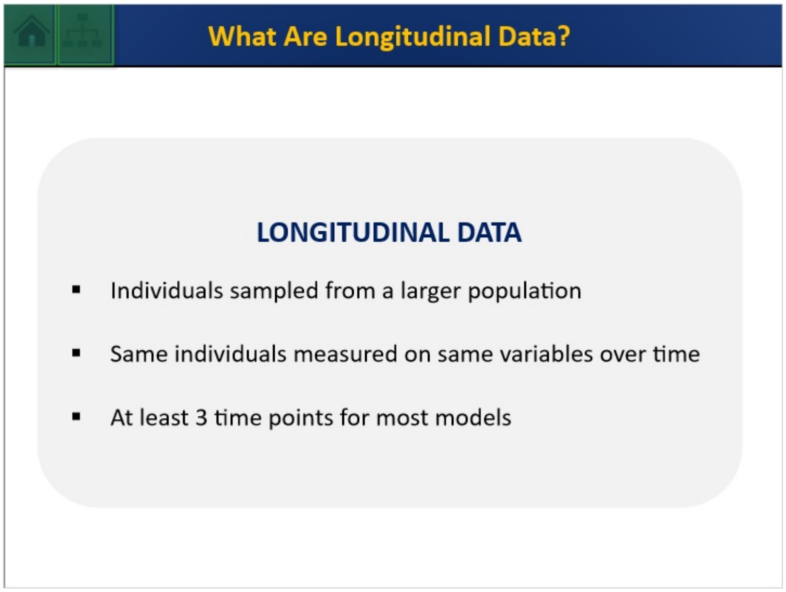
2.3 Importance of Longitudinal Research



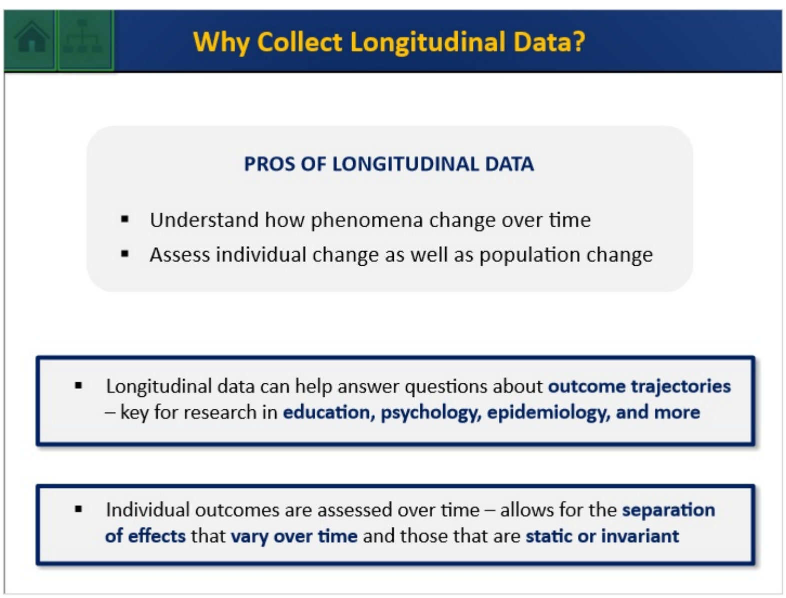
2.4 Topic Selection

2.5 Bookmark: Longitudinal Data

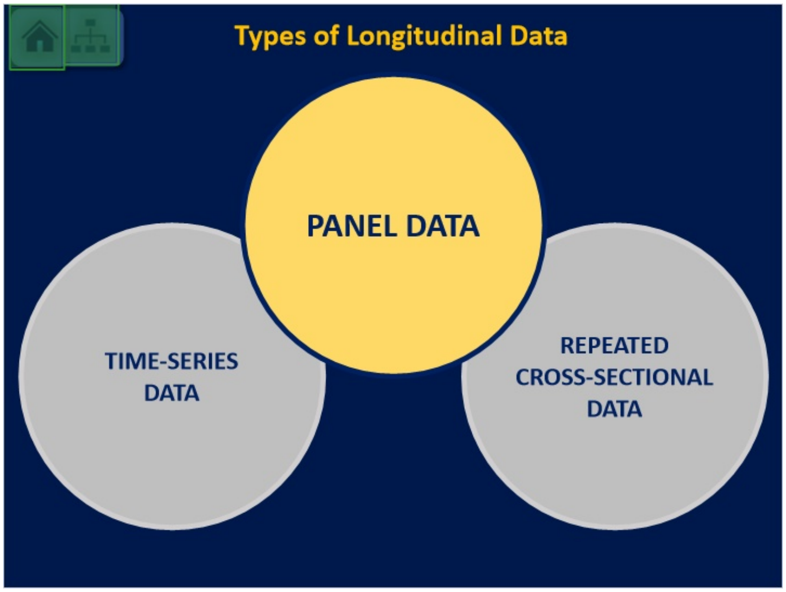
2.6 What Are Longitudinal Data



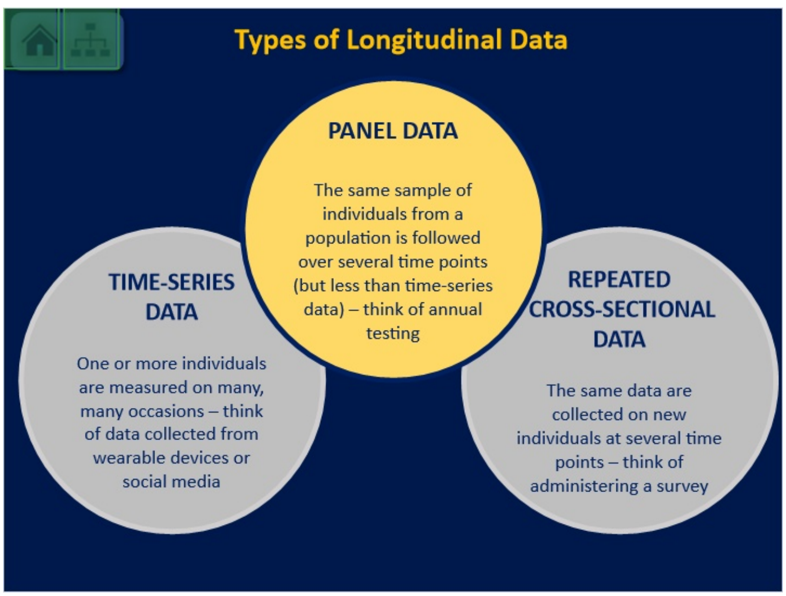
2.7 Why Collect Longitudinal Data



2.8 Types of Longitudinal Data I



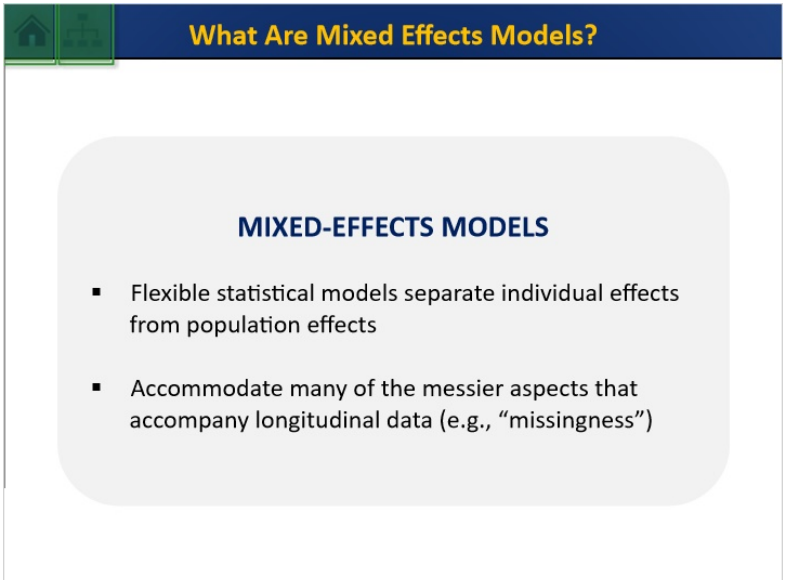
2.9 Types of Longitudinal Data II



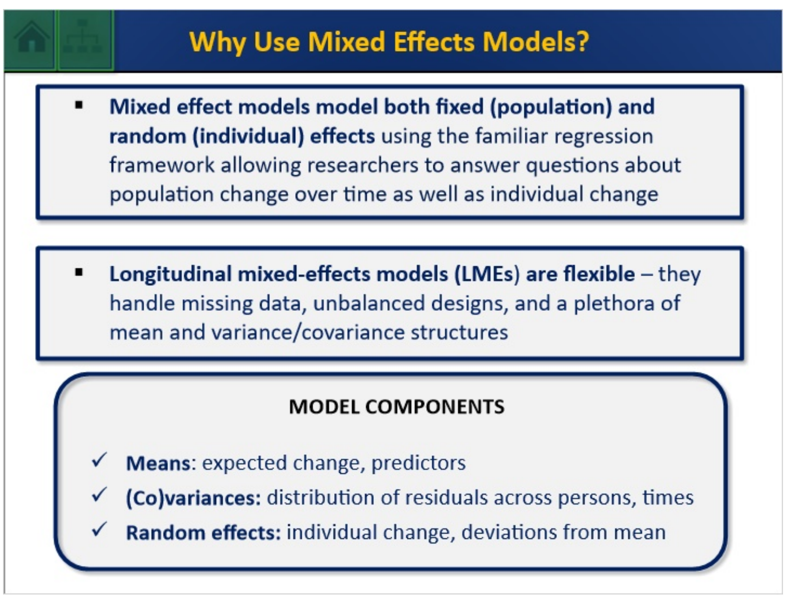
2.10 Bookend: Longitudinal Data

2.11 Bookmark: Mixed Effects Models

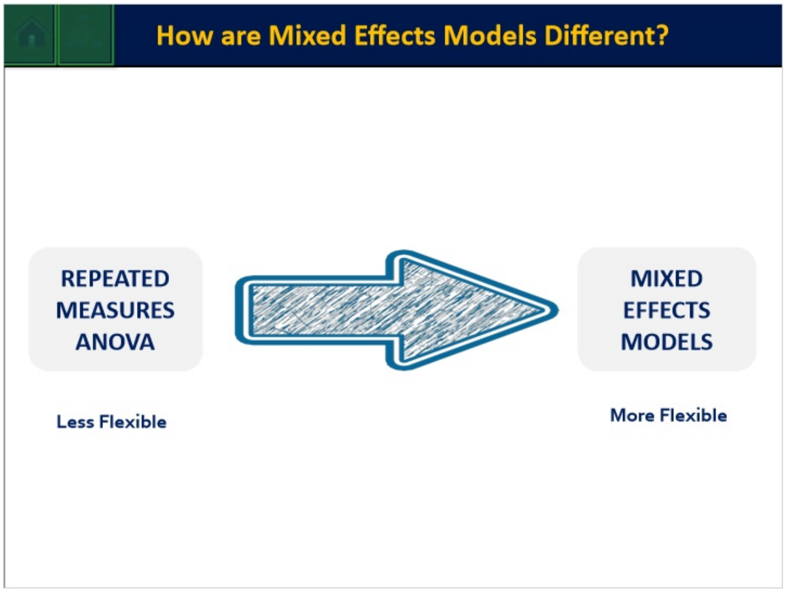
2.12 What Are Mixed Effects Models



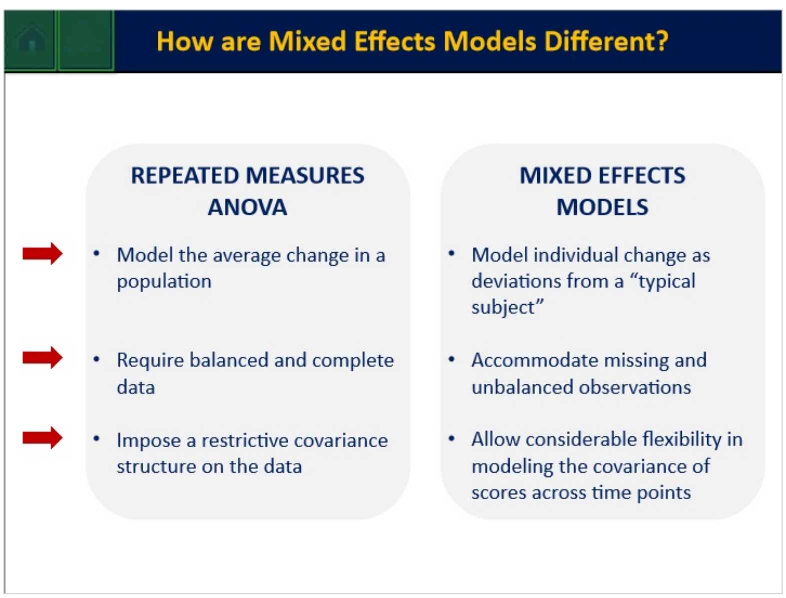
2.13 Why Use Mixed Effects Models



2.14 How Are Mixed Effects Models Different I



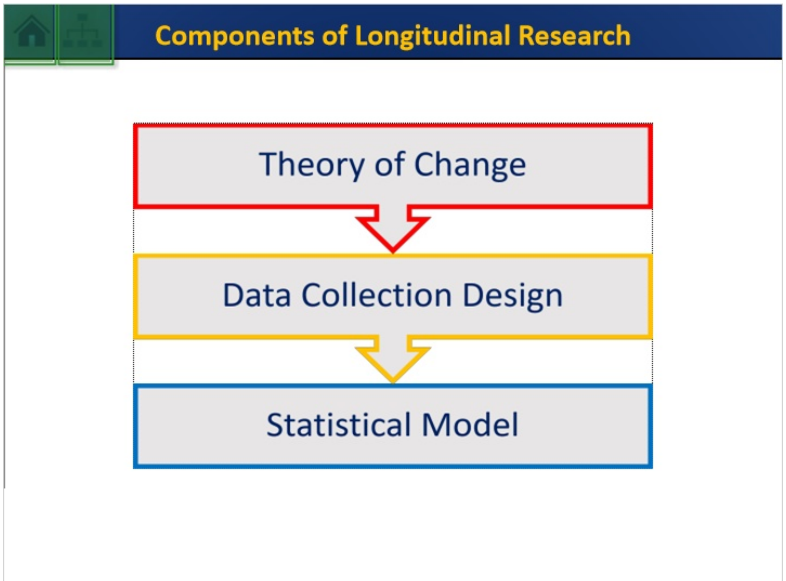
2.15 How Are Mixed Effects Models Different II



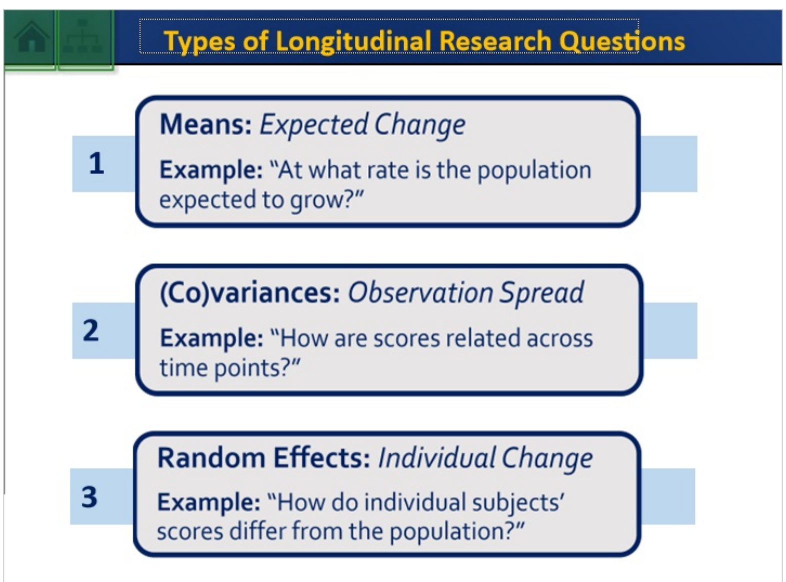
2.16 Bookend: Mixed Effects Models

2.17 Bookmark: Research Components

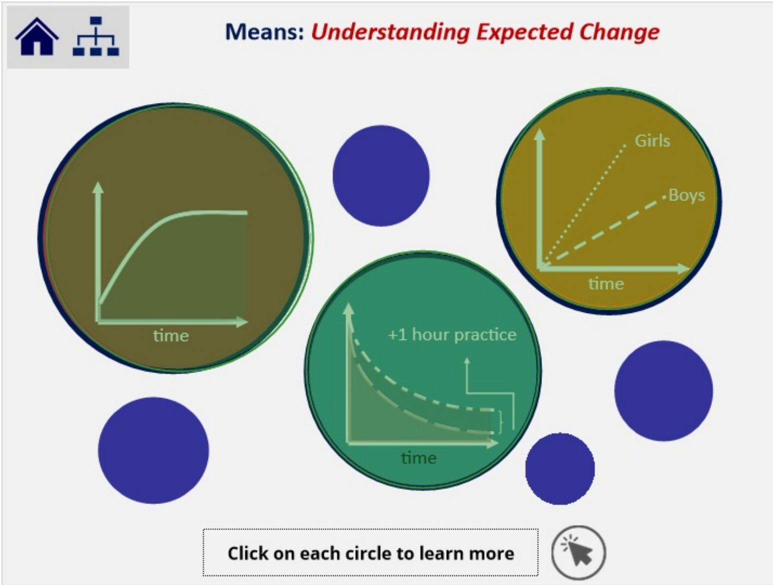
2.18 Components of Longitudinal Research



2.19 Types of Longitudinal Research Questions



2.20 Understanding Expected Change



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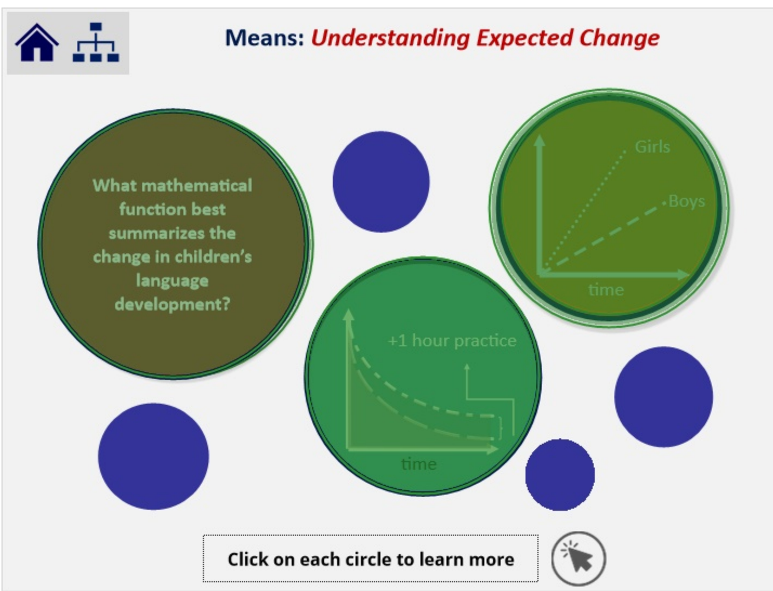

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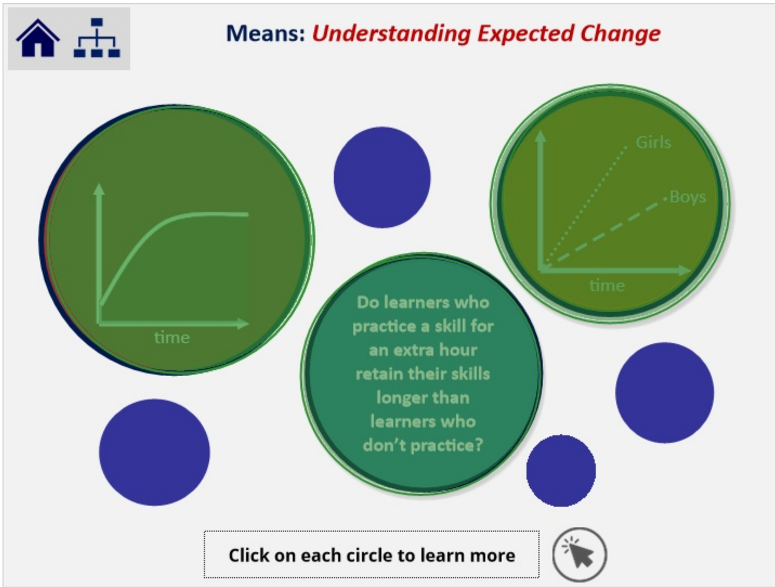

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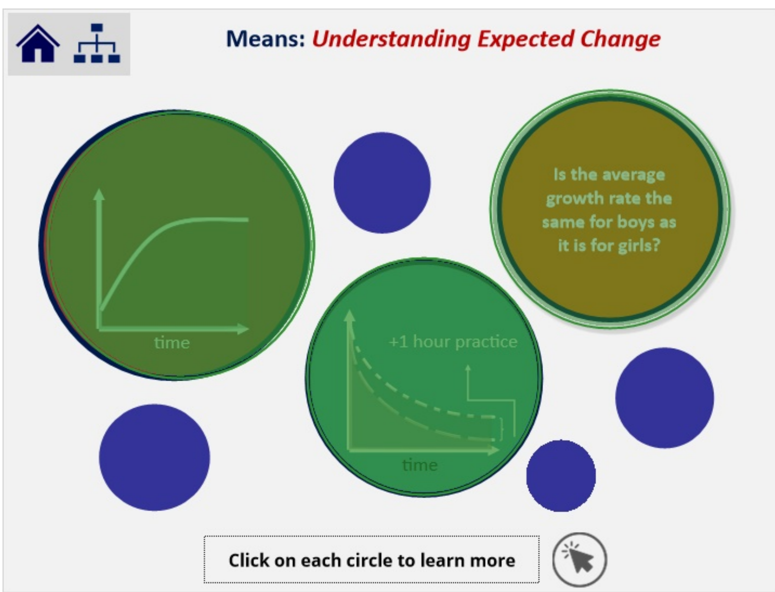
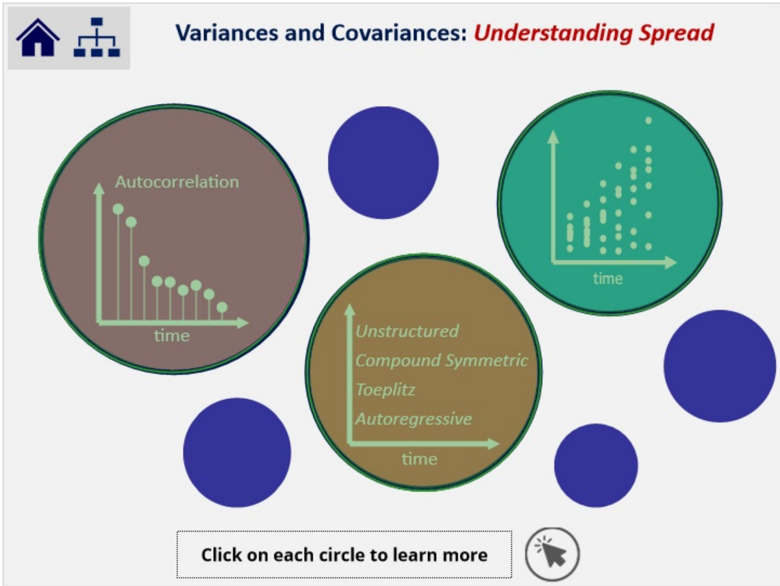


2.21 Understanding Spread



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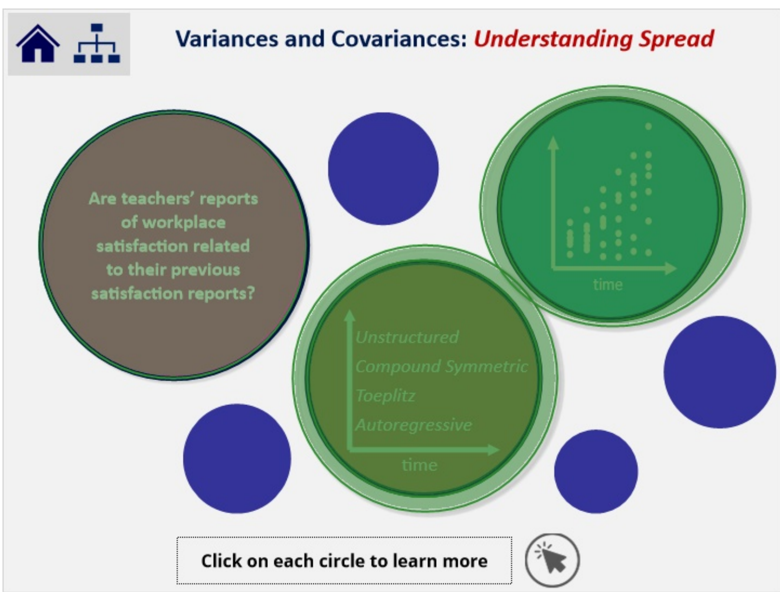

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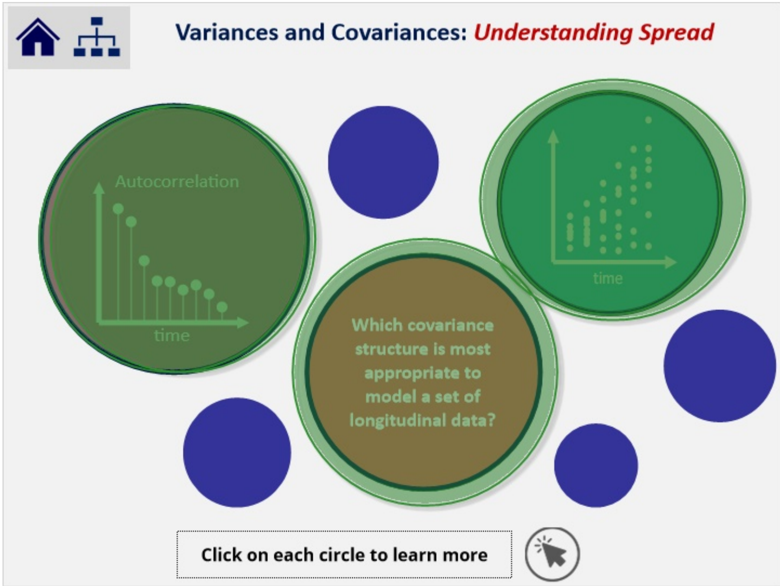

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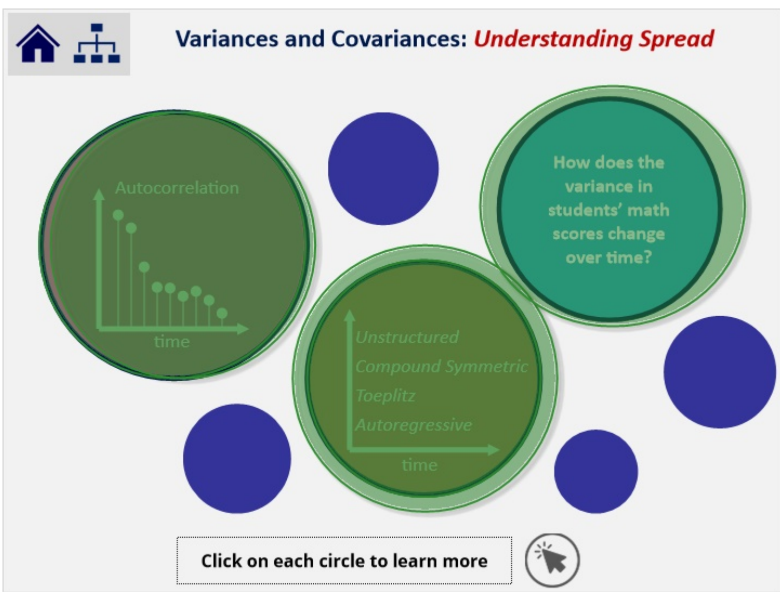
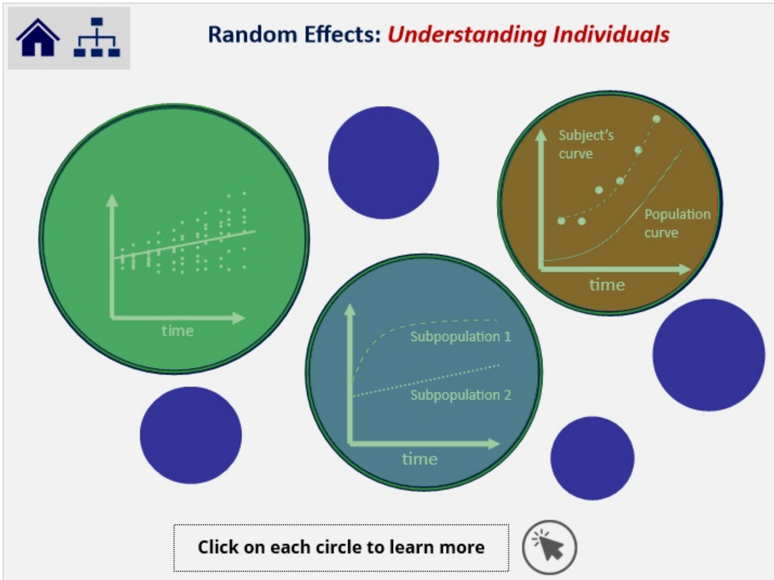


2.22 Understanding Individuals



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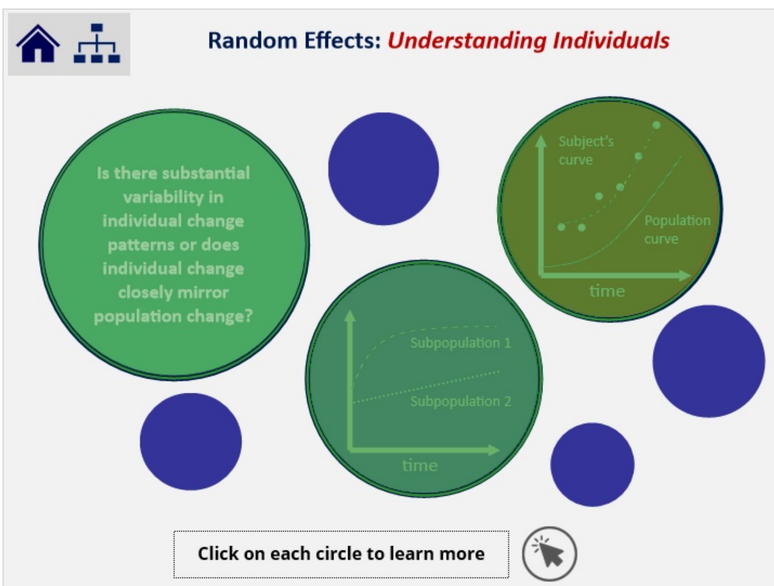
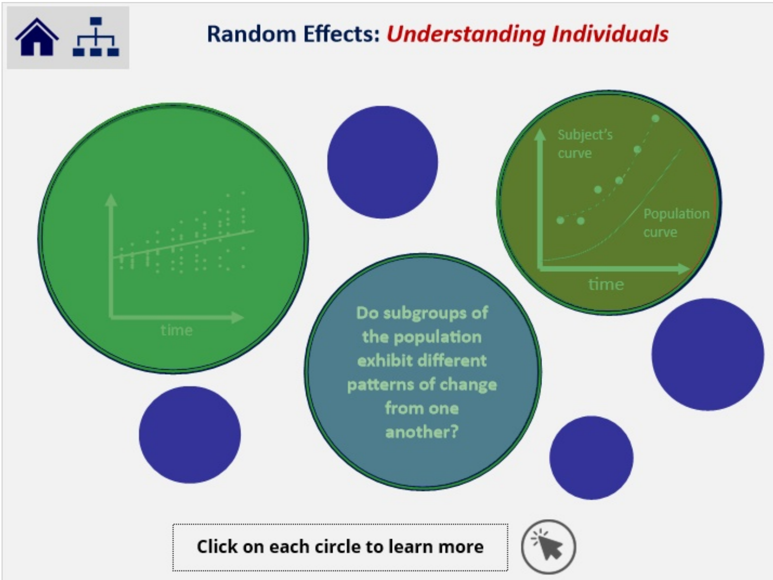


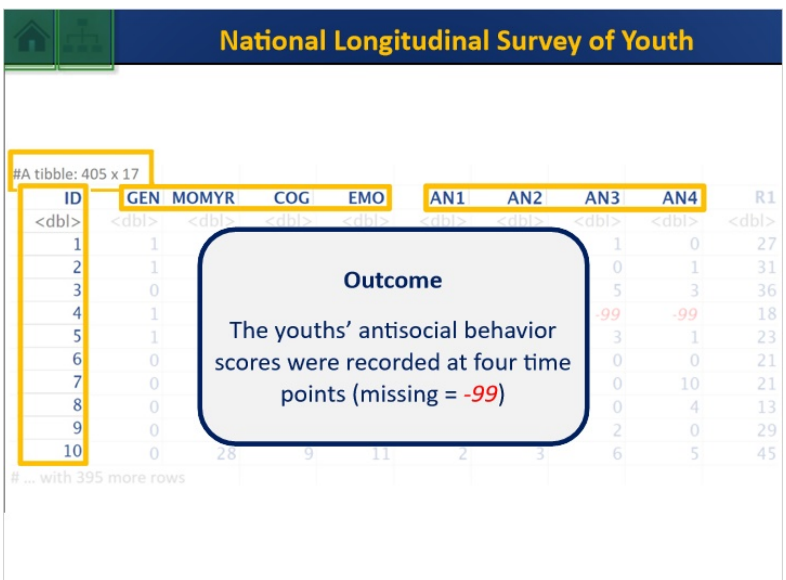
Q2 (Slide Layer)



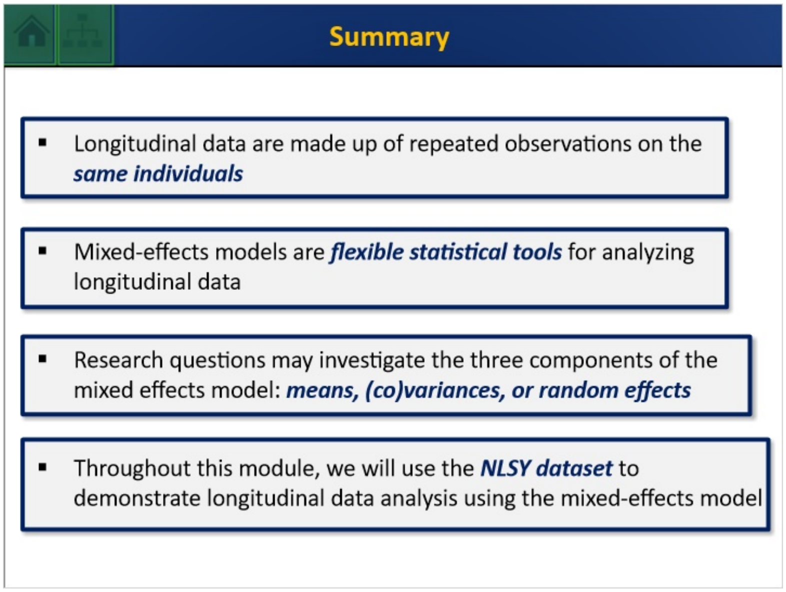
Q3 (Slide Layer)

2.23 Bookend: Research Components

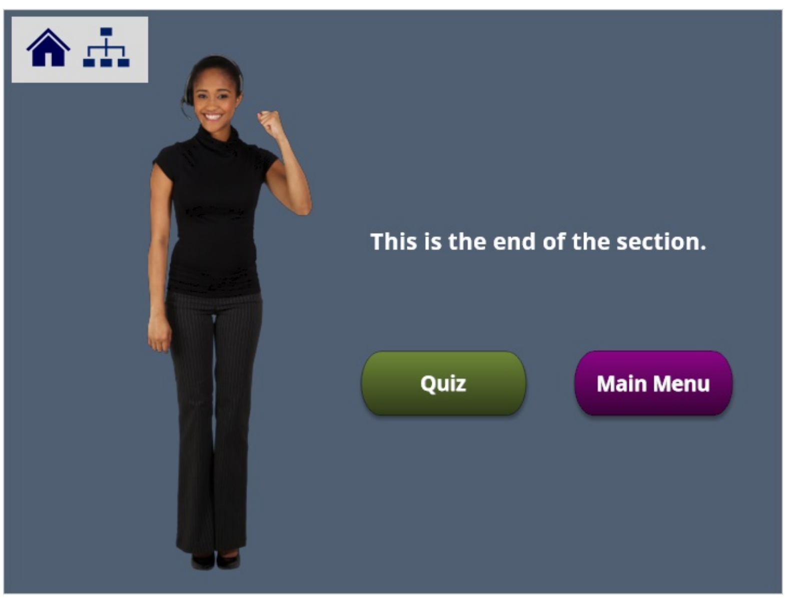
2.24 Example NLSY



2.25 Summary



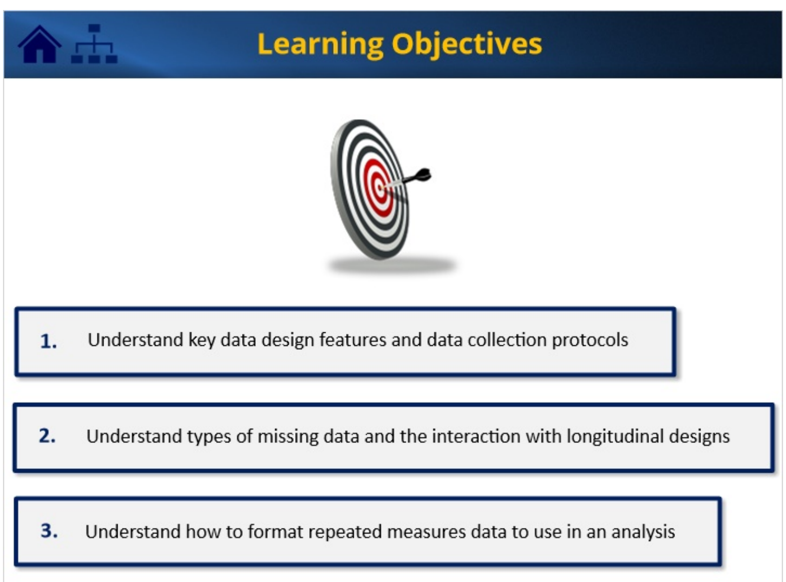
2.26 Bookend: Section 2



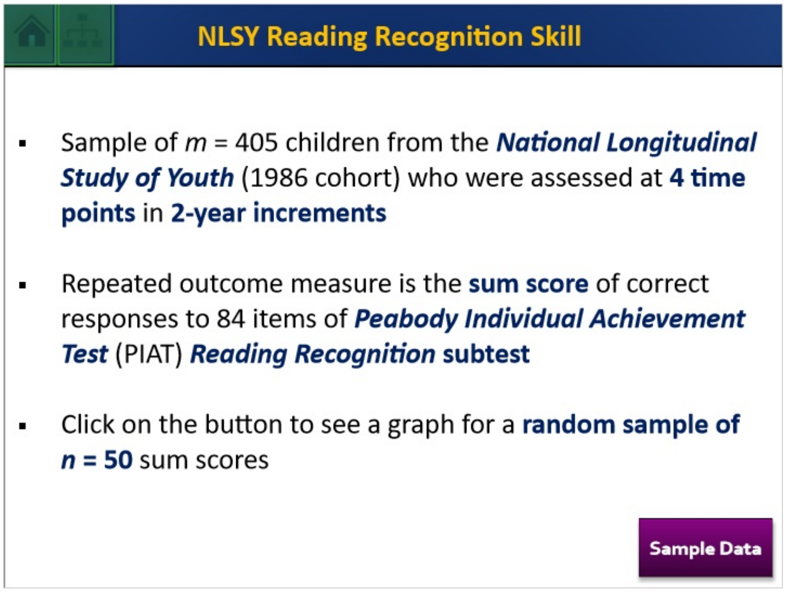
3. Section 2: Design and Data Considerations

3.1 Cover: Section 2

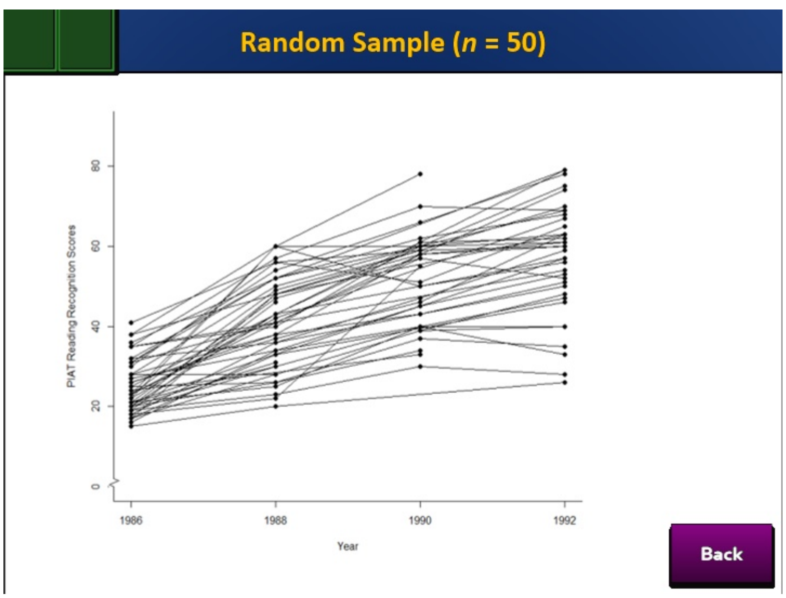
3.2 Learning Objectives: Section 2



3.3 NLSY Reading Recognition Skill

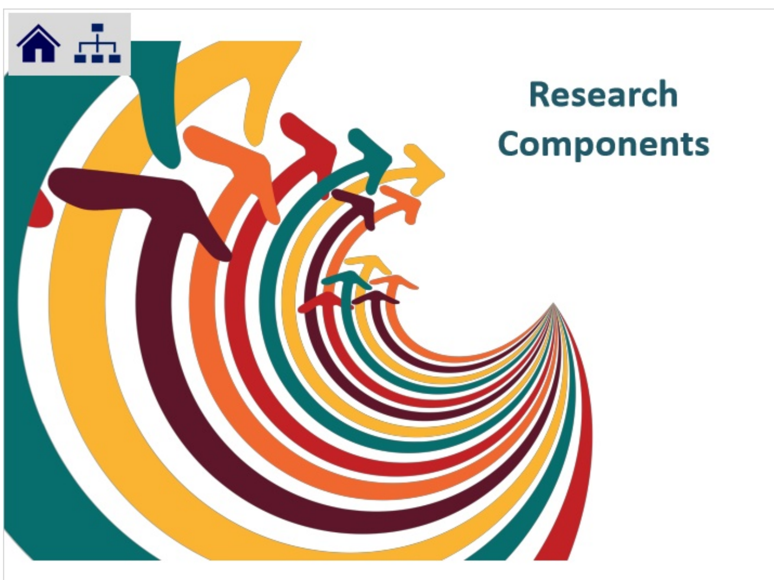


Sample Data (Slide Layer)

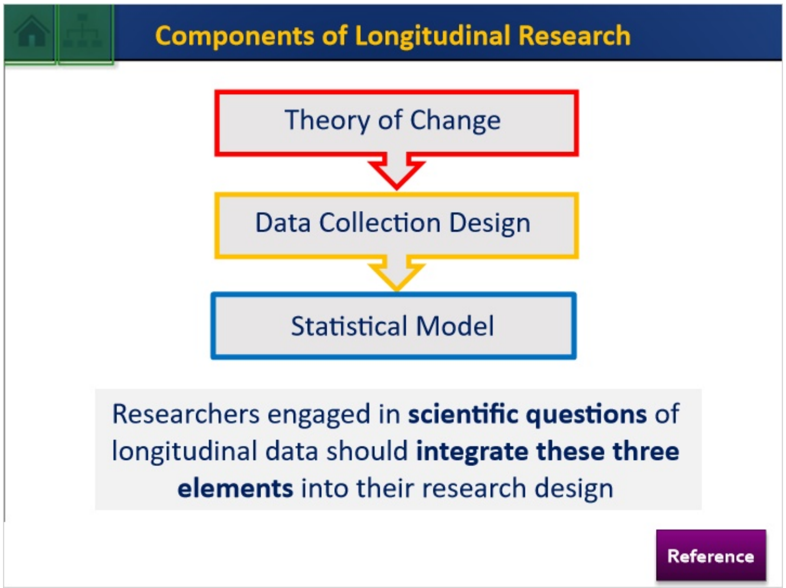


3.4 Topic Selection

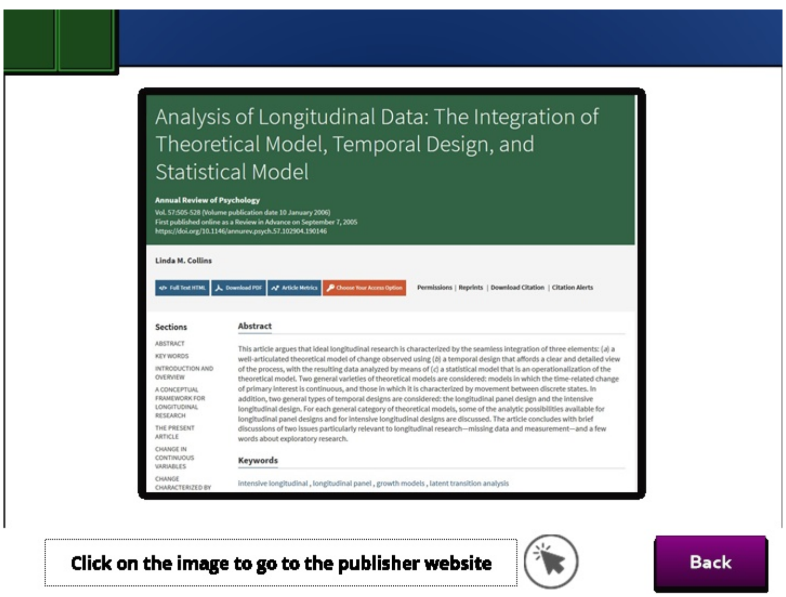
3.5 Bookmark: Research Components



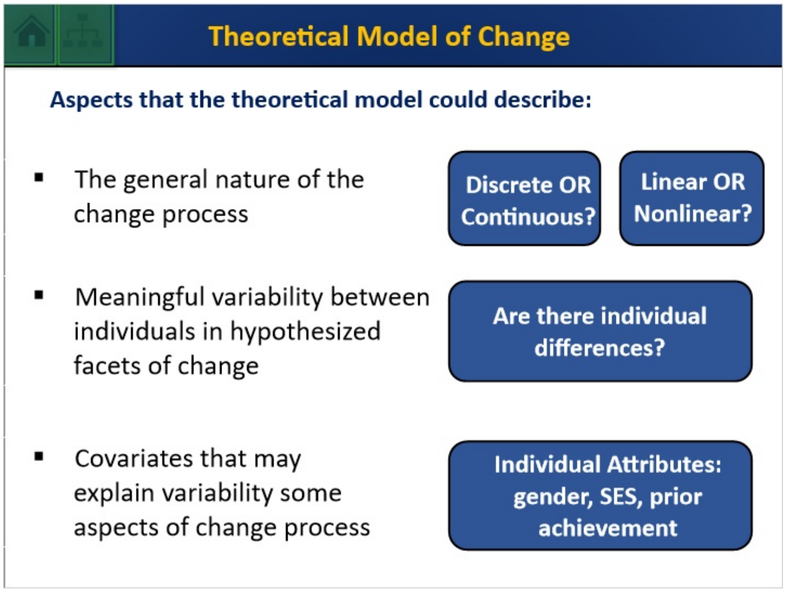
3.6 Components of Longitudinal Research



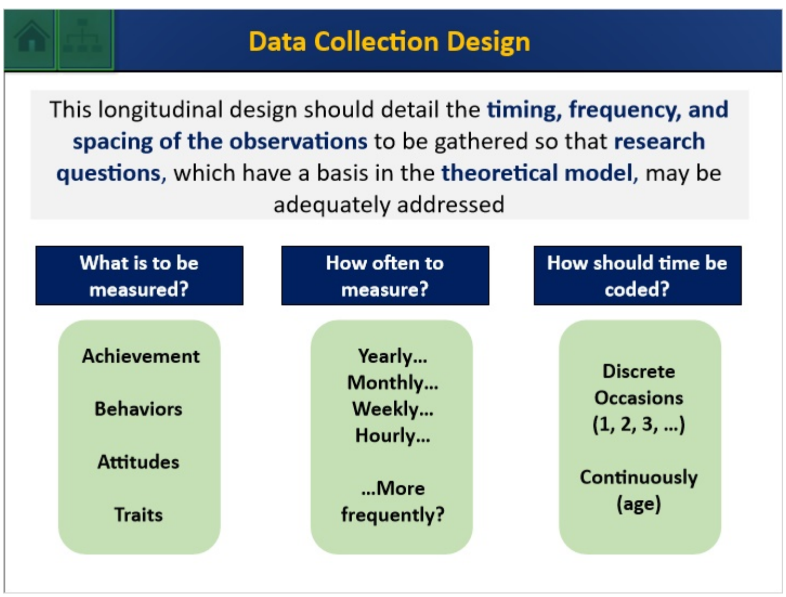
Reference (Slide Layer)



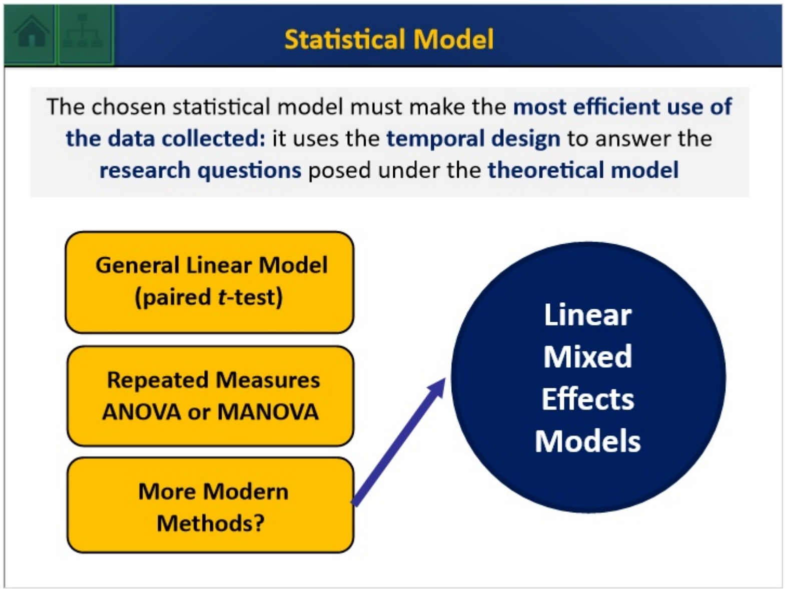
3.7 Theoretical Model of Change



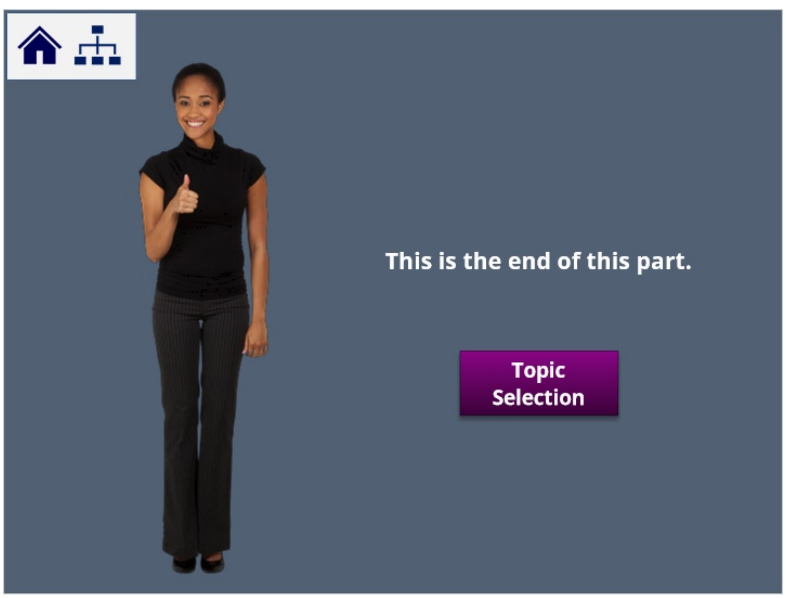
3.8 Data Collection Design



3.9 Statistical Model

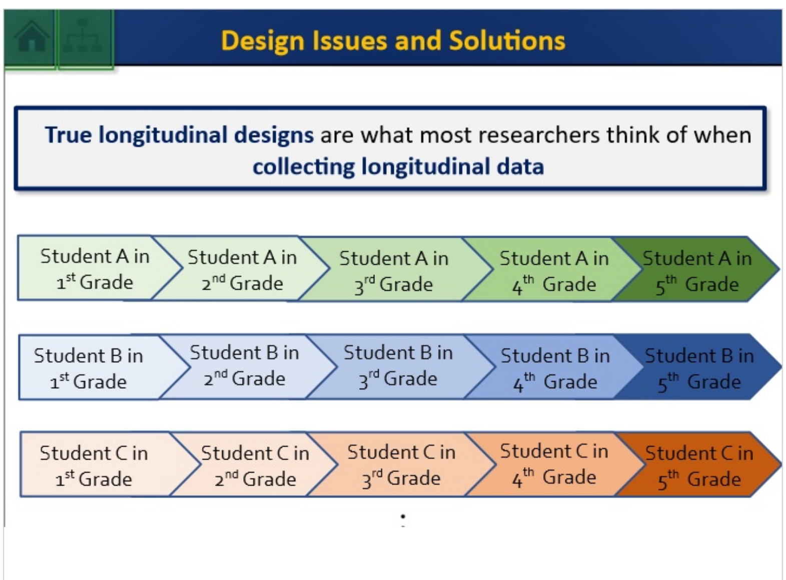


3.10 Bookend: Research Components

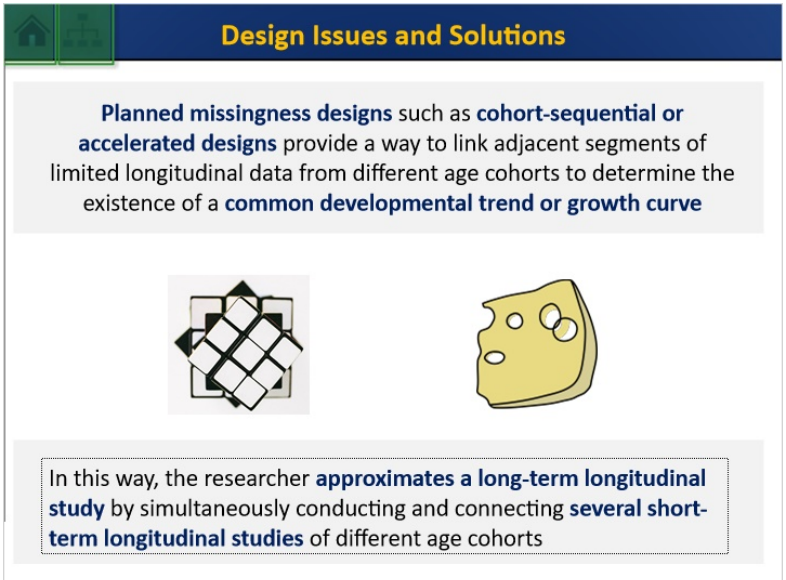


3.11 Bookmark: Data Designs

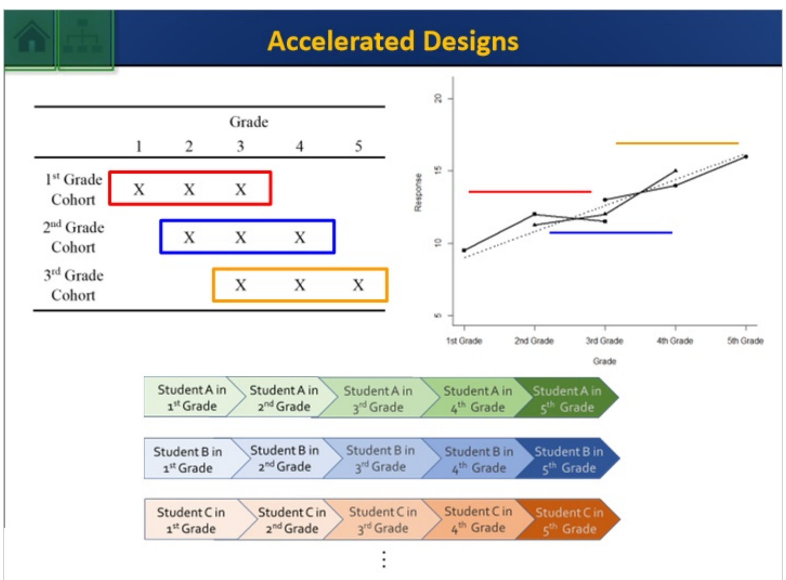
3.12 Design Issues and Solutions I



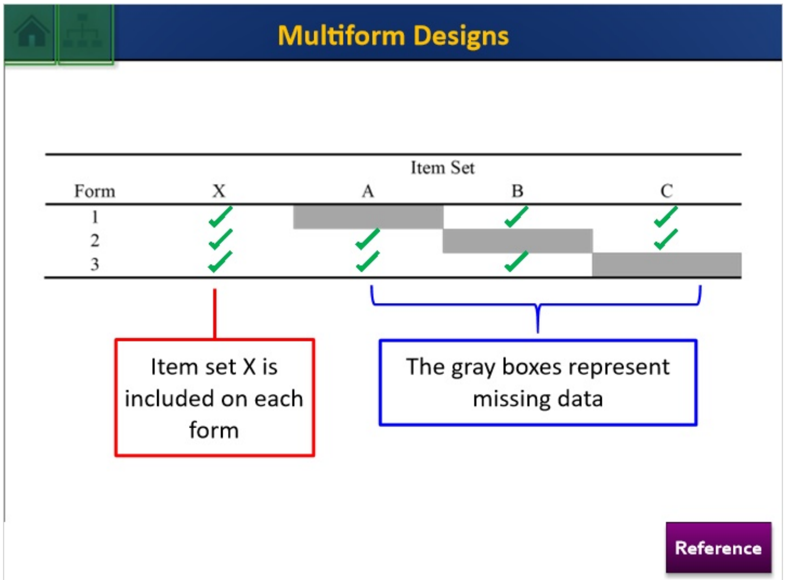
3.13 Design Issues and Solutions II



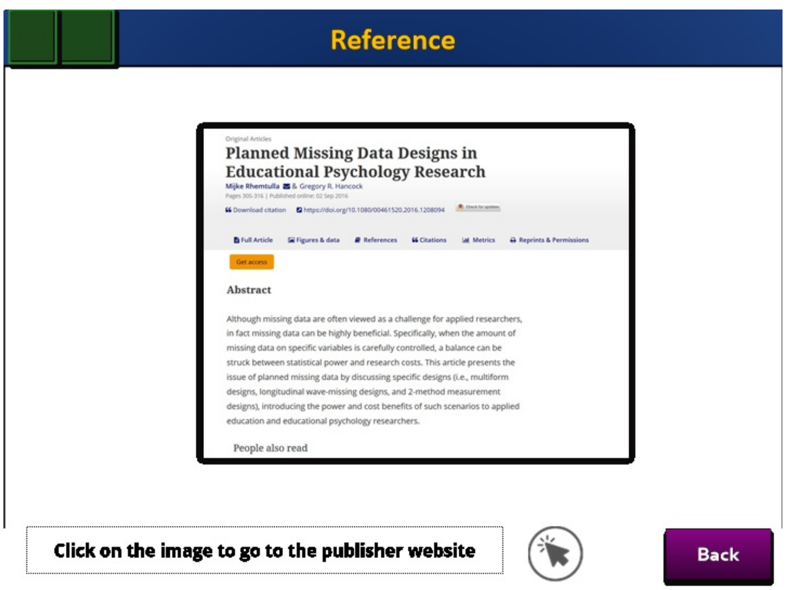
3.14 Accelerated Designs



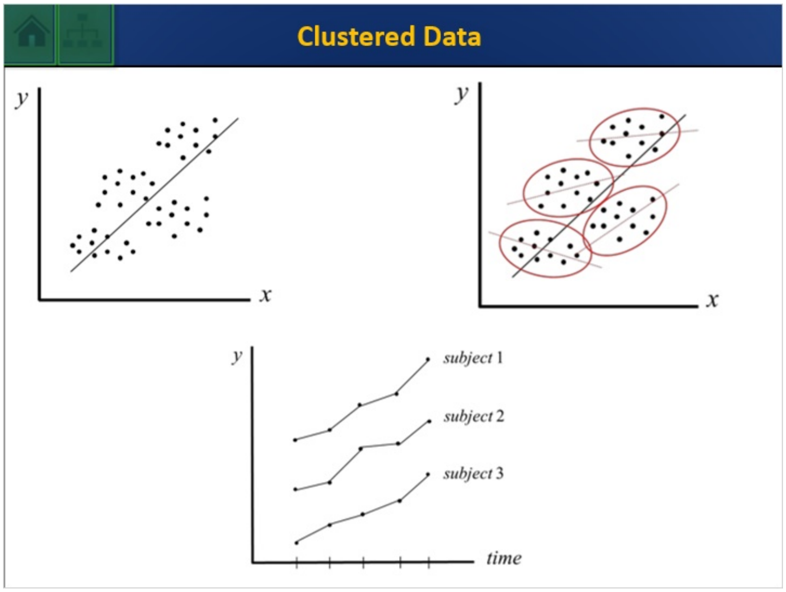
3.15 Multiform Designs



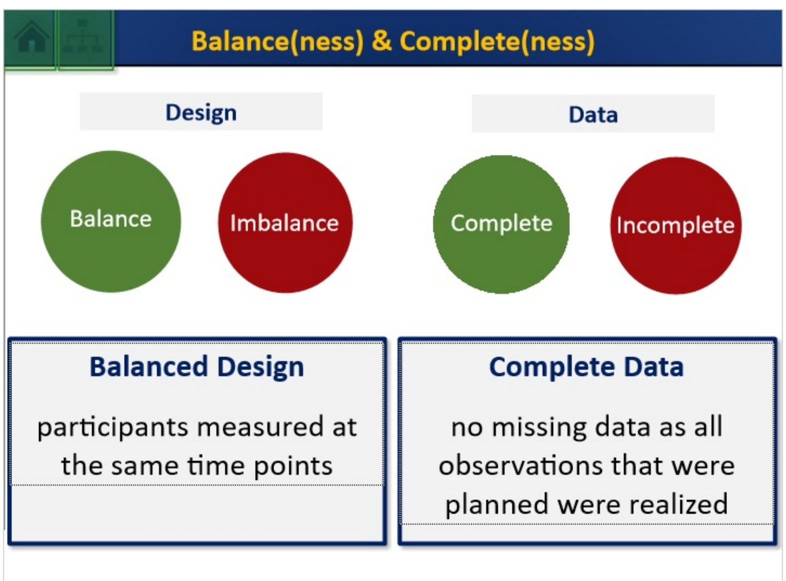
Reference (Slide Layer)



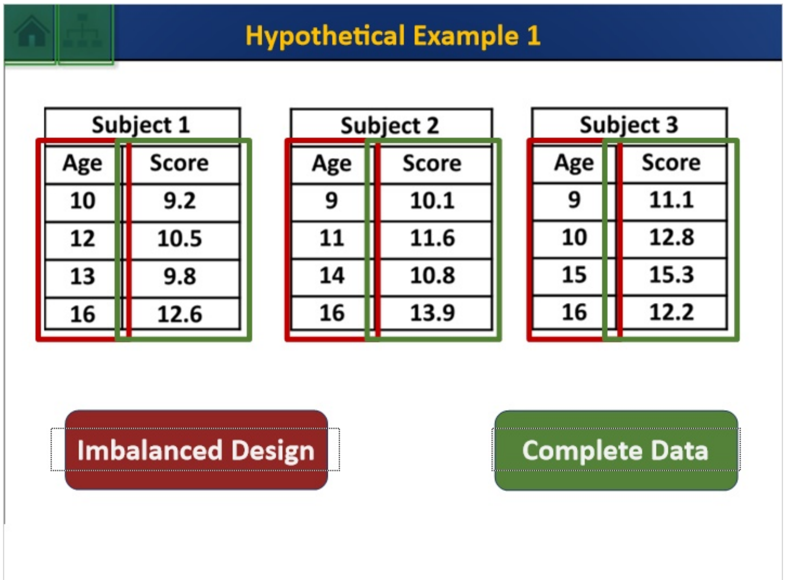
3.16 Clustered Data



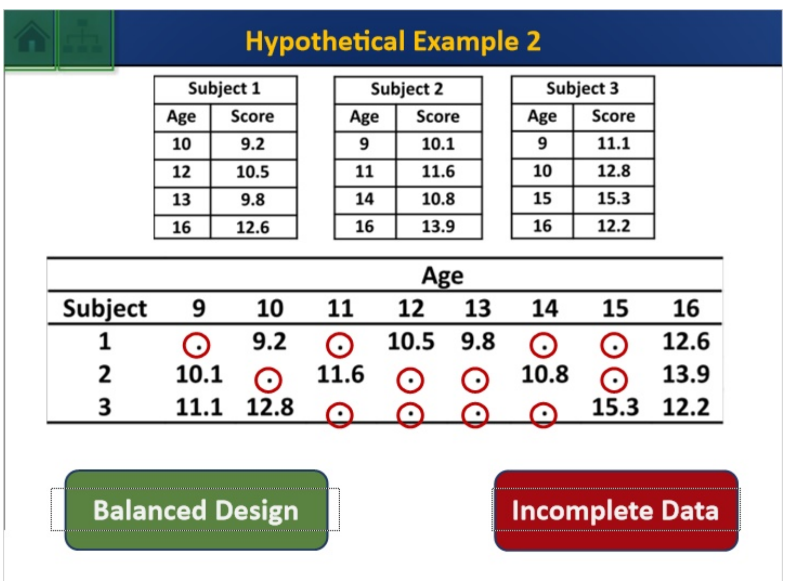
3.17 Balanceness & Completeness



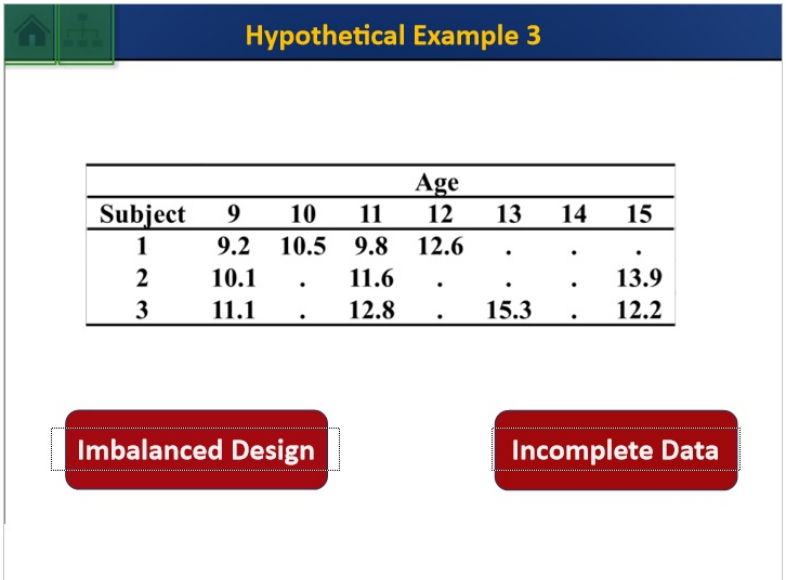
3.18 Hypothetical Example I



3.19 Hypothetical Example II

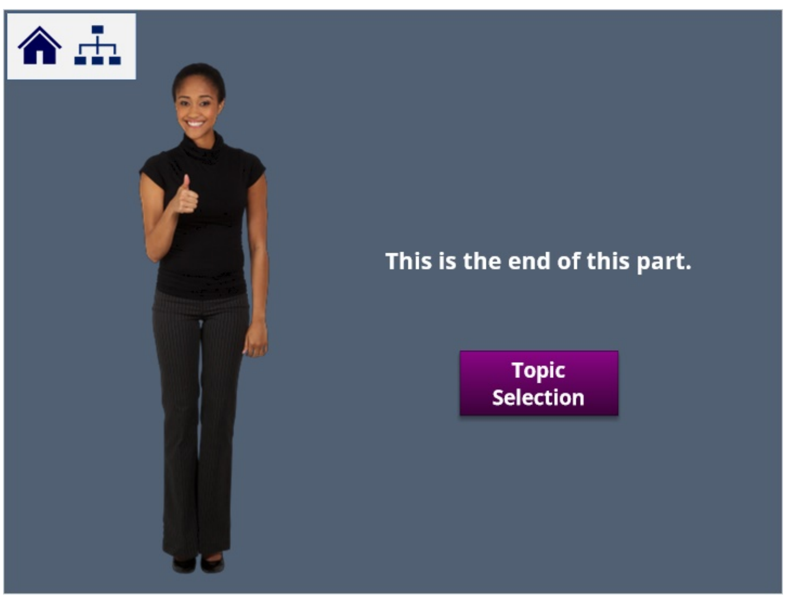


3.20 Hypothetical Example III



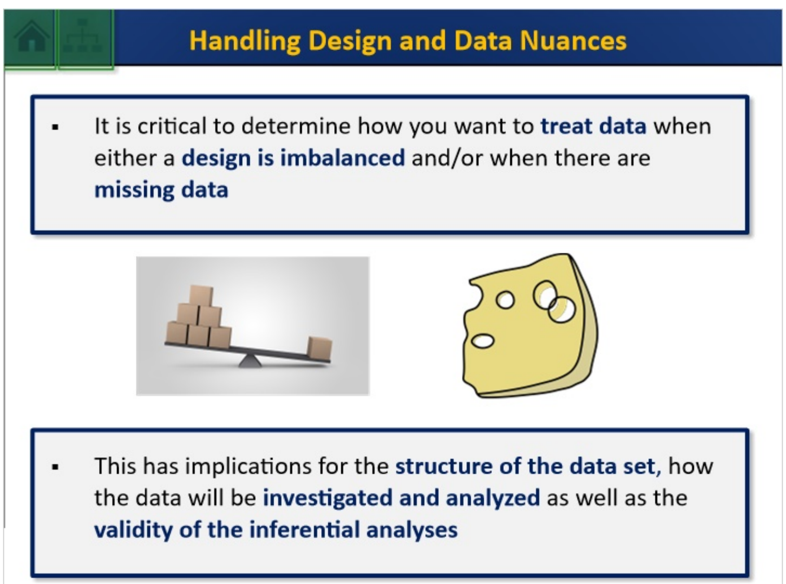
	Age						
Subject	9	10	11	12	13	14	15
1	9.2	10.5	9.8	12.6	.	.	.
2	10.1	.	11.6	.	.	.	13.9
3	11.1	.	12.8	.	15.3	.	12.2

3.21 Bookend: Data Designs



3.22 Bookmark: Handling Data Issues

3.23 Handling Design and Data Nuances



3.24 Not Recommended

Not Recommended

	Age							
Subject	9	10	11	12	13	14	15	16
1	.	9.2	.	10.5	9.8	.	.	12.6
2	10.1	.	11.6	.	.	10.8	.	13.9
3	11.1	12.8	.	.	.	.	15.3	12.2

	Wave			
Subject	1	2	3	4
1	9.2	10.5	9.8	12.6
2	10.1	11.6	10.8	13.9
3	11.1	12.8	15.3	12.2

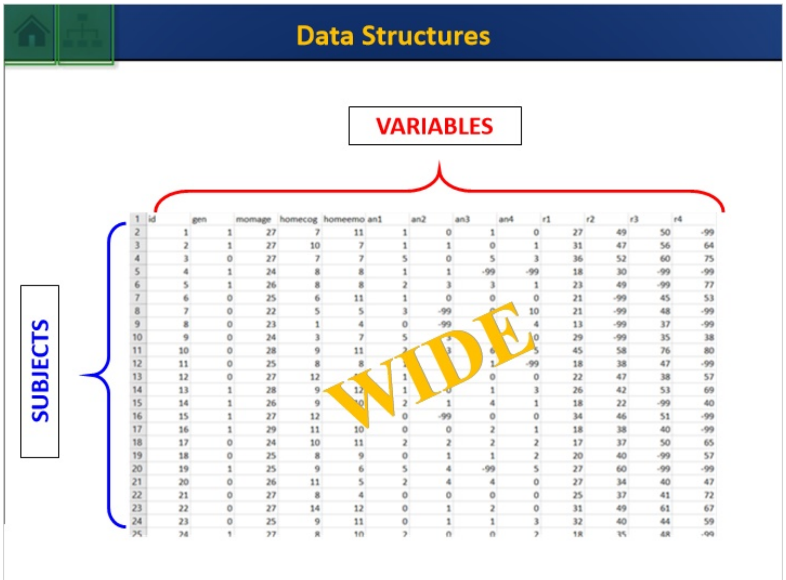
In this example, **ignoring age may be indefensible** especially if the scores reflect some type of **developmental phenomenon** that is naturally tied to age

3.25 Recommended

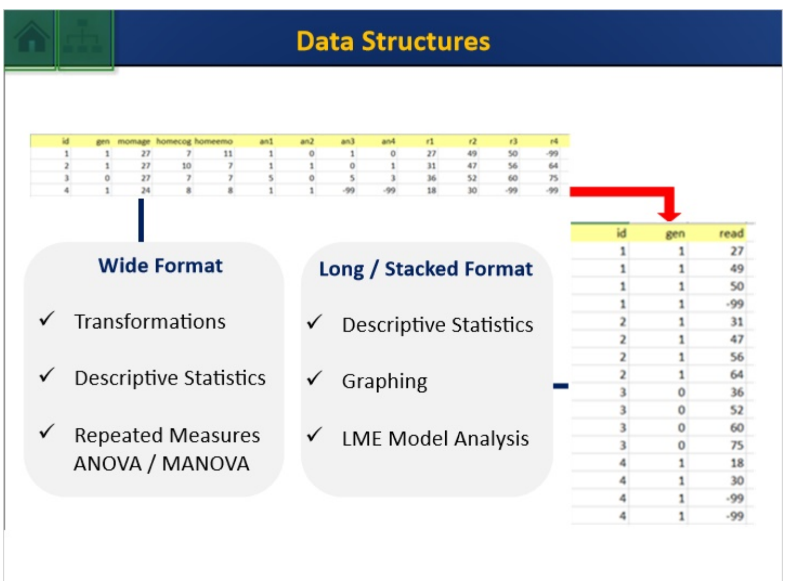
Recommended

- It is common, and often preferred, in longitudinal studies not to **force data to be complete and balanced**
- This allows the observations to be **anchored to the chronological metric** rather than the order in which the observations were obtained
- In the previous example, if the **age distinction** is an important substantive feature, then the data should be treated as **incomplete within a balanced design**
- Plan ahead for a **sensible data collection procedure** and **anticipate issues** that will arise

3.26 Data Structures I

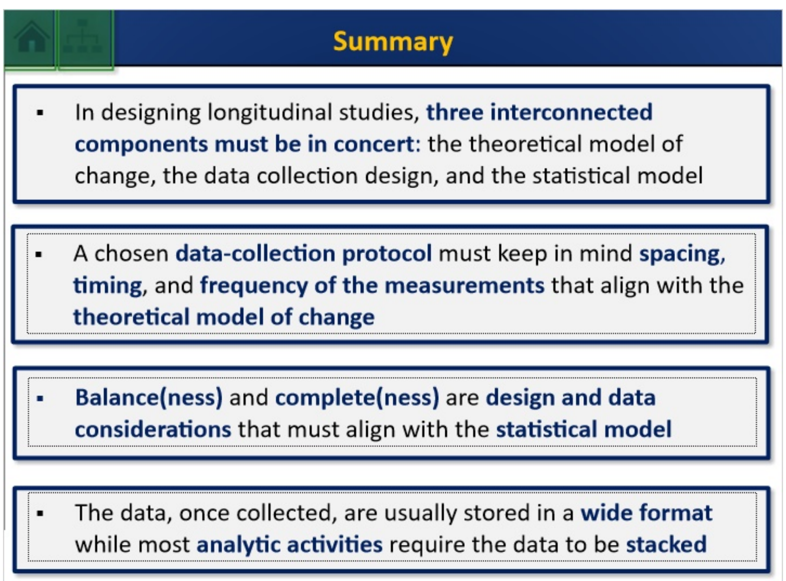


3.27 Data Structures II

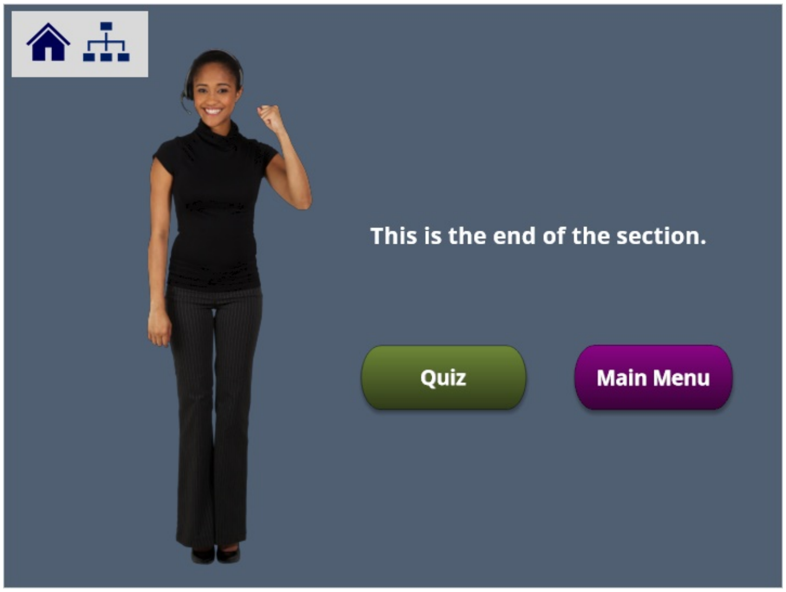


3.28 Bookend: Handling Data Issues

3.29 Summary



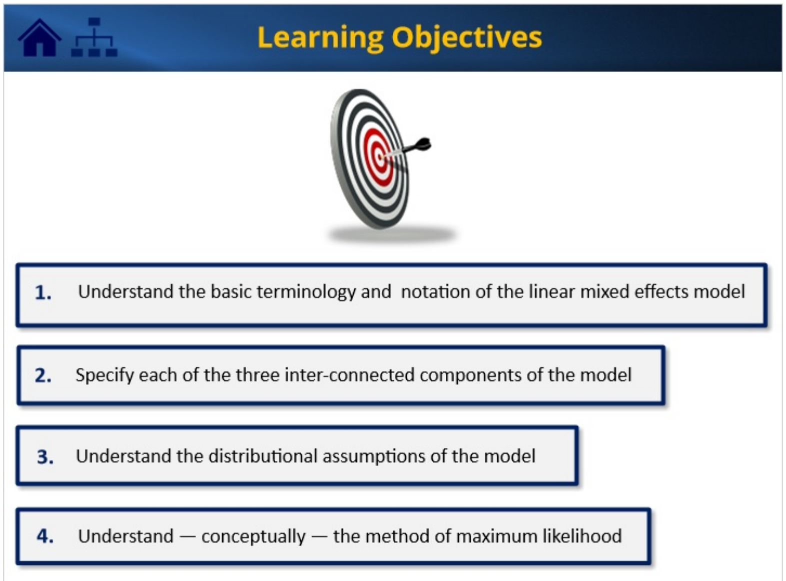
3.30 Bookend: Section 2



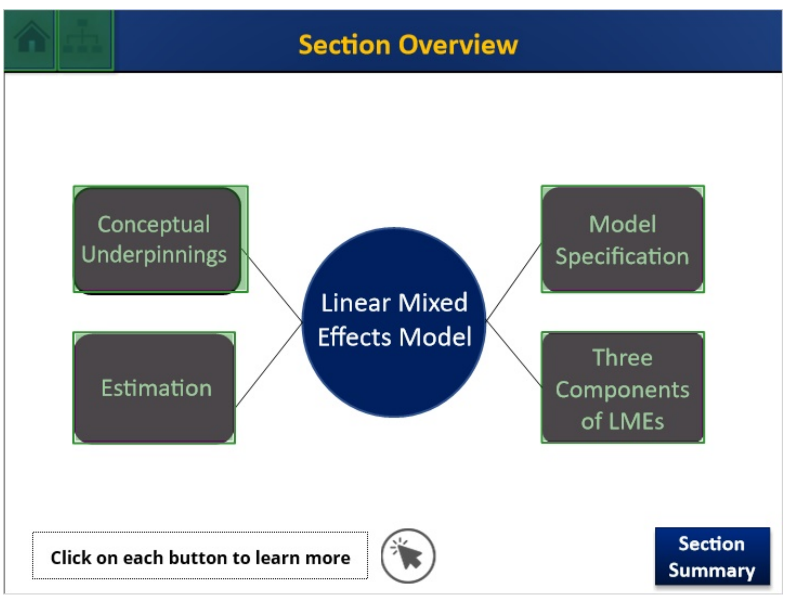
4. Section 3: Linear Mixed Effects Models

4.1 Cover: Section 3

4.2 Learning Objectives: Section 3

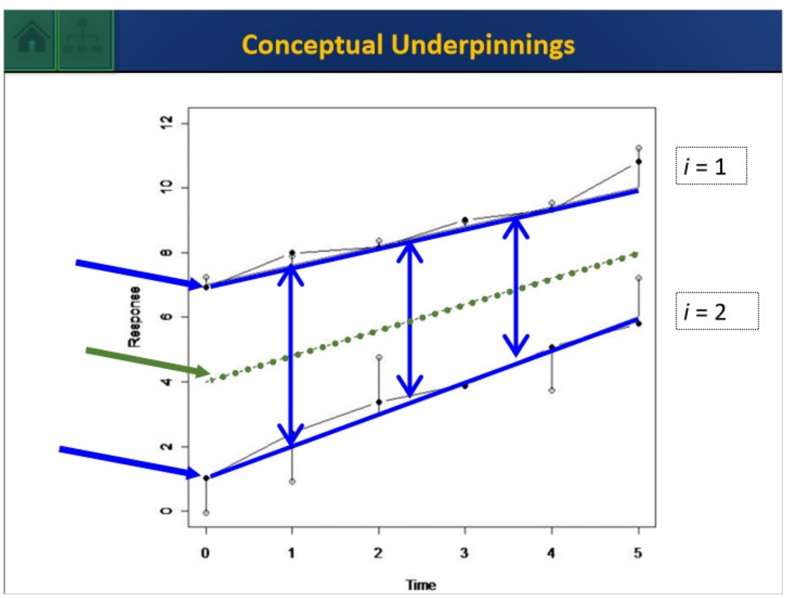


4.3 Topic Selection

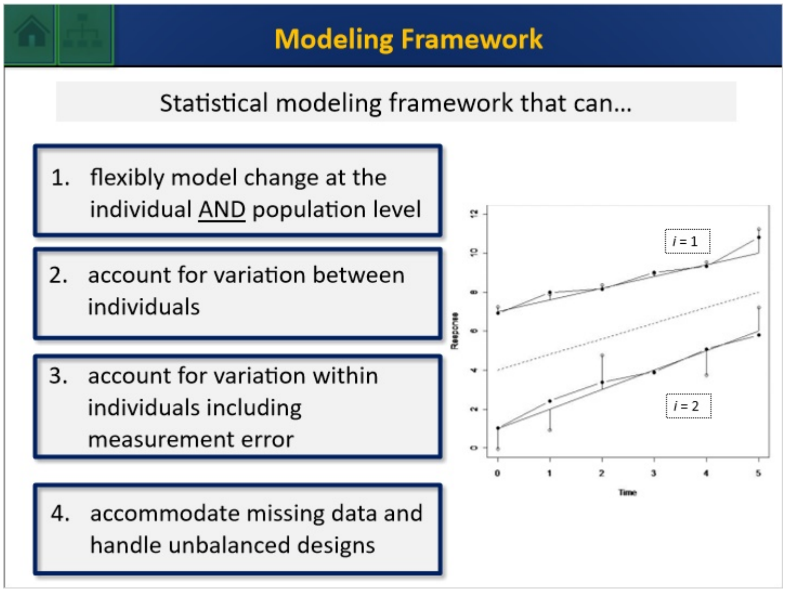


4.4 Bookmark: Conceptual Underpinnings

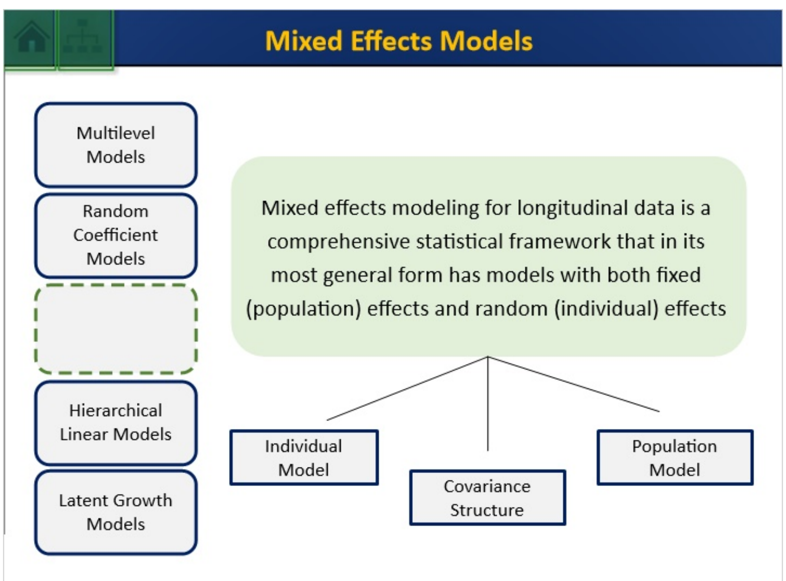
4.5 Conceptual Underpinnings



4.6 Modeling Framework



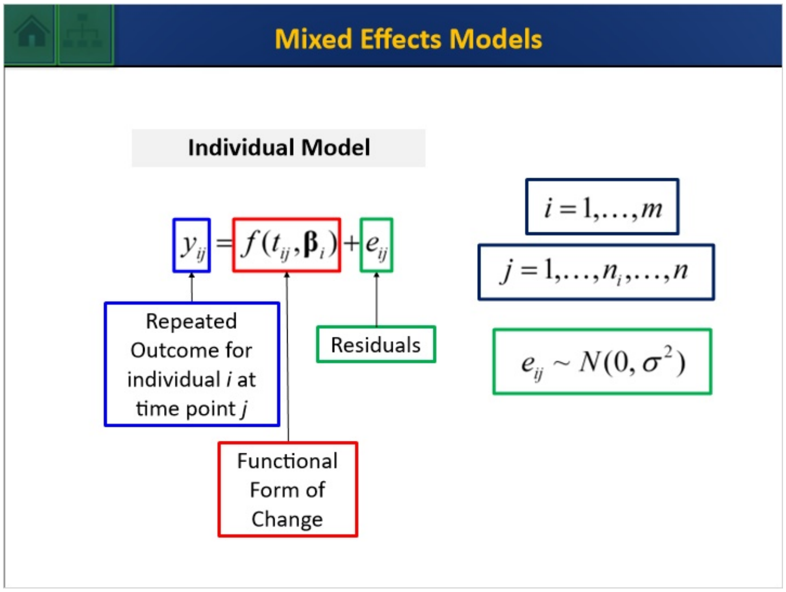
4.7 Mixed Effects Models I



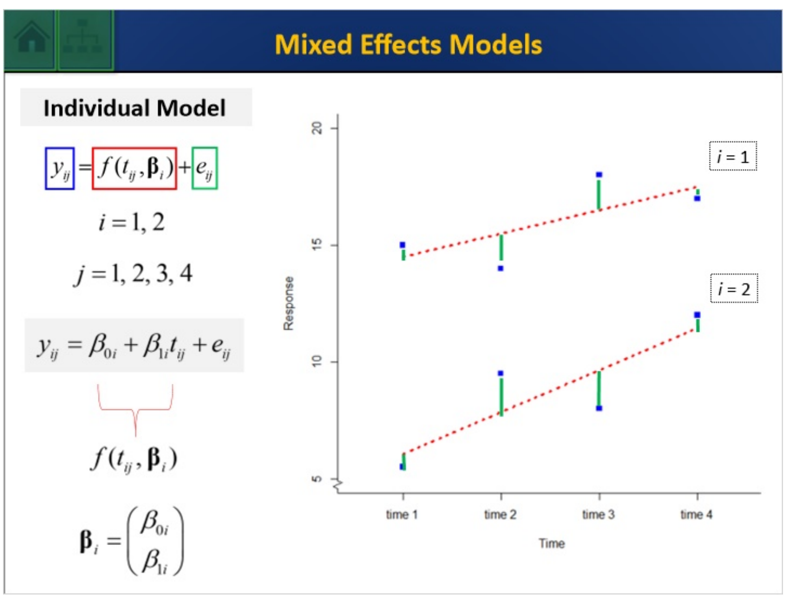
4.8 Bookend: Conceptual Underpinnings

4.9 Bookmark: Model Specification

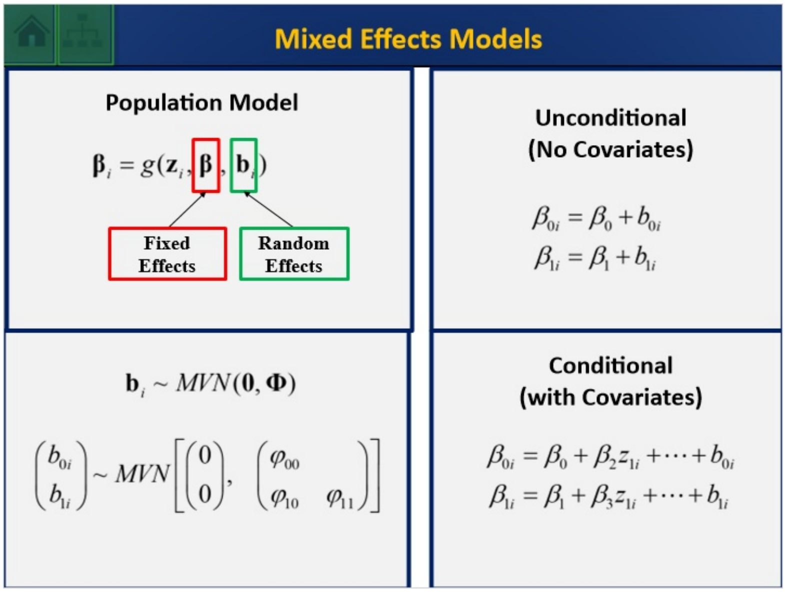
4.10 Mixed Effects Models II



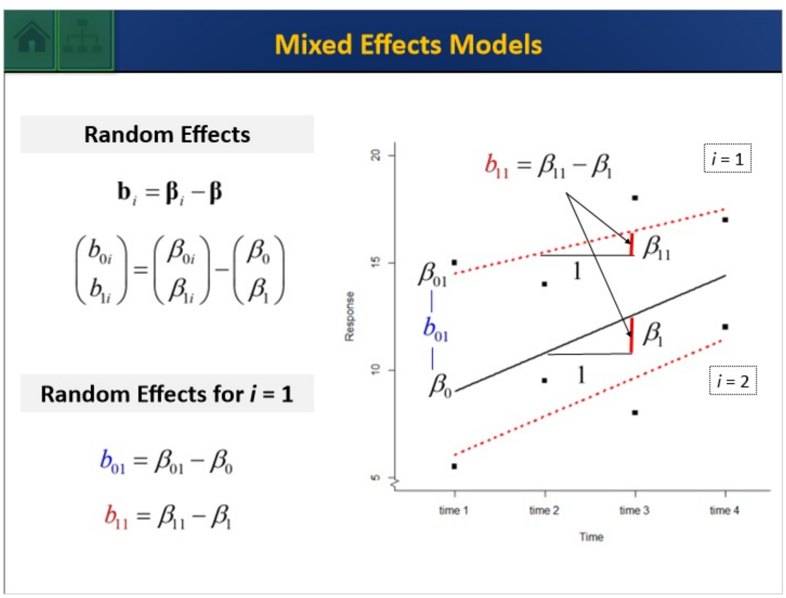
4.11 Mixed Effects Models III



4.12 Mixed Effects Models IV



4.13 Mixed Effects Models V



4.14 Mixed Effects Models VI

Mixed Effects Models

Individual Model	Unconditional Population Model
$y_{ij} = \beta_{0i} + \beta_{1i} t_{ij} + e_{ij}$	$\beta_{0i} = \beta_0 + b_{0i}$ $\beta_{1i} = \beta_1 + b_{1i}$

Mixed Effects Model

$$y_{ij} = (\beta_0 + b_{0i}) + (\beta_1 + b_{1i}) t_{ij} + e_{ij}$$

- β_0: population intercept
- b_{0i}: random effect for intercept
- β_1: population slope
- b_{1i}: random effect for slope
- e_{ij}: residual

4.15 Linear Mixed Effects Models I

Linear Mixed Effects Models

$$y_{ij} = \beta_0 + \beta_1 t_{ij} + b_{0i} + b_{1i} t_{ij} + e_{ij} \quad t_{i1} = 0,\ t_{i2} = 1,\ t_{i3} = 2,\ t_{i4} = 3 \quad n = 4$$

Written Out

$$\begin{aligned} y_{i1} &= \beta_0 + \beta_1 t_{i1} + b_{0i} + b_{1i} t_{i1} + e_{i1} \\ y_{i2} &= \beta_0 + \beta_1 t_{i2} + b_{0i} + b_{1i} t_{i2} + e_{i2} \\ y_{i3} &= \beta_0 + \beta_1 t_{i3} + b_{0i} + b_{1i} t_{i3} + e_{i3} \\ y_{i4} &= \beta_0 + \beta_1 t_{i4} + b_{0i} + b_{1i} t_{i4} + e_{i4} \end{aligned}$$

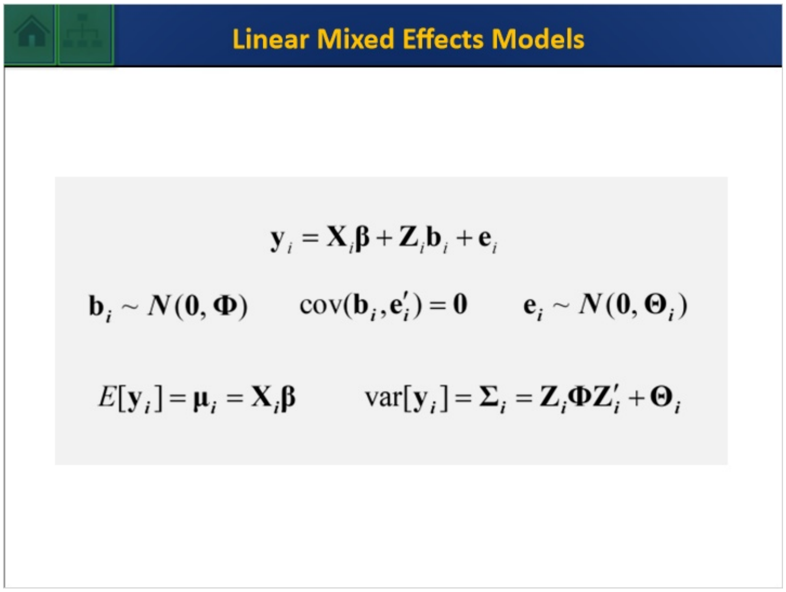
Matrix Form

$$\begin{pmatrix} y_{i1} \\ y_{i2} \\ y_{i3} \\ y_{i4} \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ 1 & 1 \\ 1 & 2 \\ 1 & 3 \end{pmatrix} \begin{pmatrix} \beta_0 \\ \beta_1 \end{pmatrix} + \begin{pmatrix} 1 & 0 \\ 1 & 1 \\ 1 & 2 \\ 1 & 3 \end{pmatrix} \begin{pmatrix} b_{0i} \\ b_{1i} \end{pmatrix} + \begin{pmatrix} e_{i1} \\ e_{i2} \\ e_{i3} \\ e_{i4} \end{pmatrix}$$

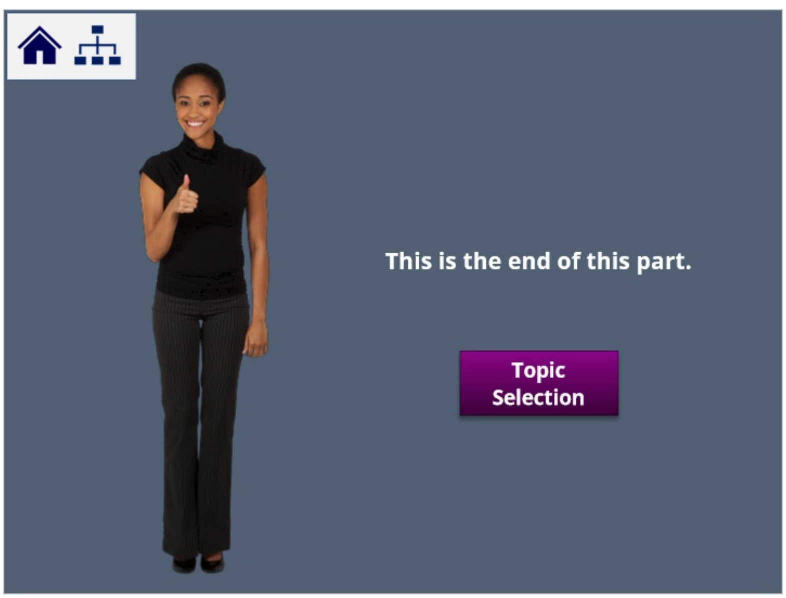
Compact Matrix Form

$$\mathbf{y}_i = \mathbf{X}_i \boldsymbol{\beta} + \mathbf{Z}_i \mathbf{b}_i + \mathbf{e}_i$$

4.16 Linear Mixed Effects Models II

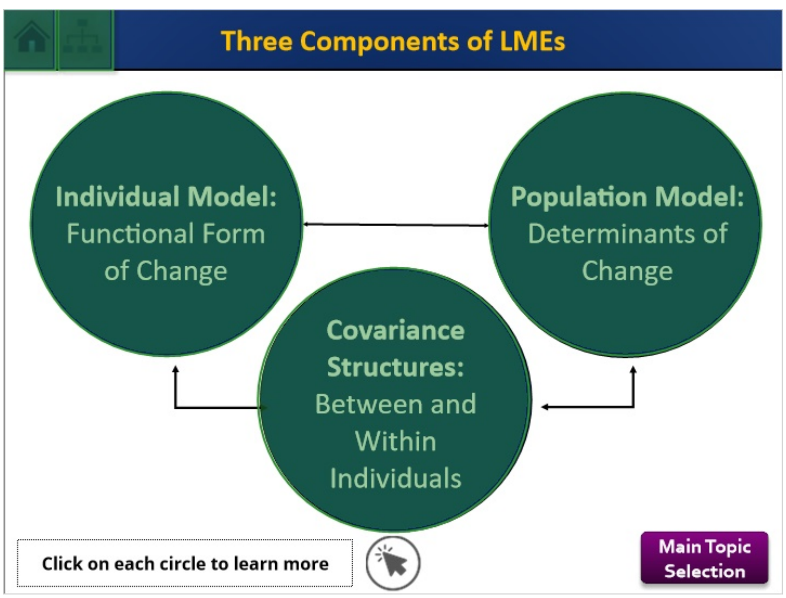


4.17 Bookend: Model Specification



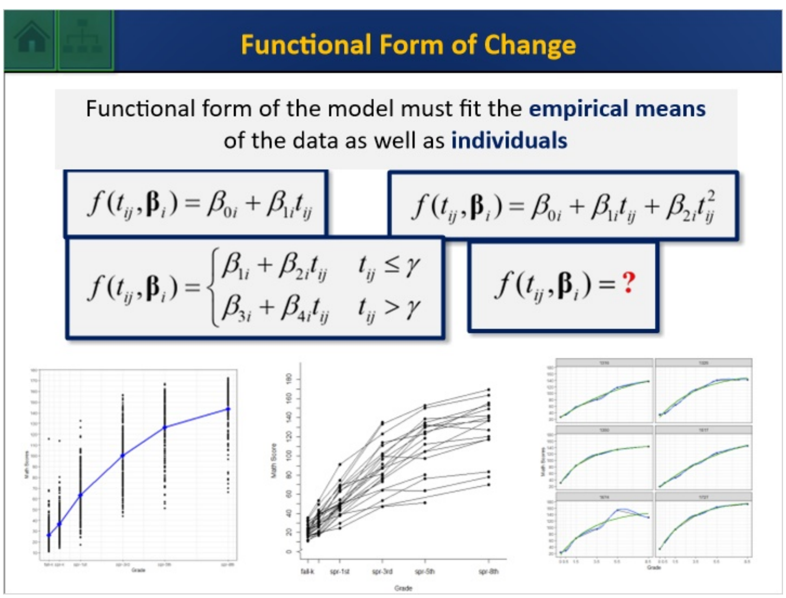
4.18 Bookmark: Three Components of LMEs

4.19 Component Selection

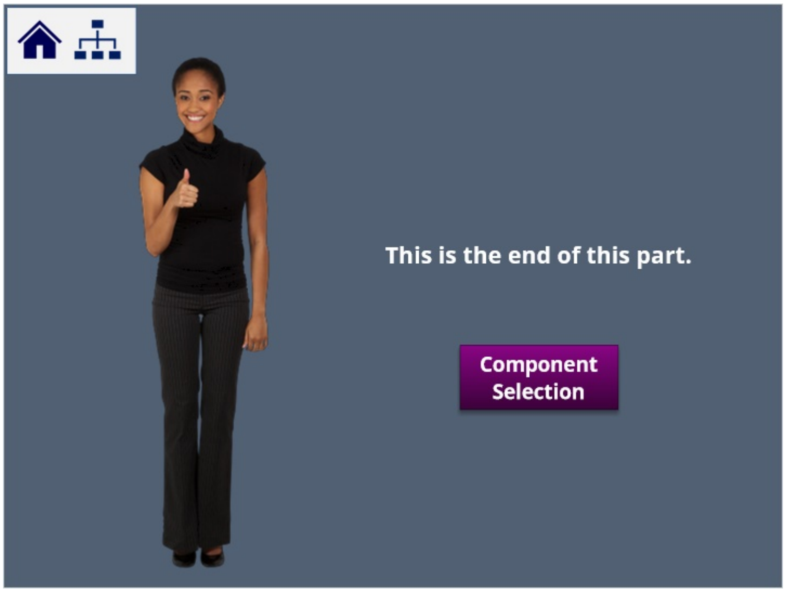


4.20 Bookmark: Functional Form

4.21 Functional Form of Change

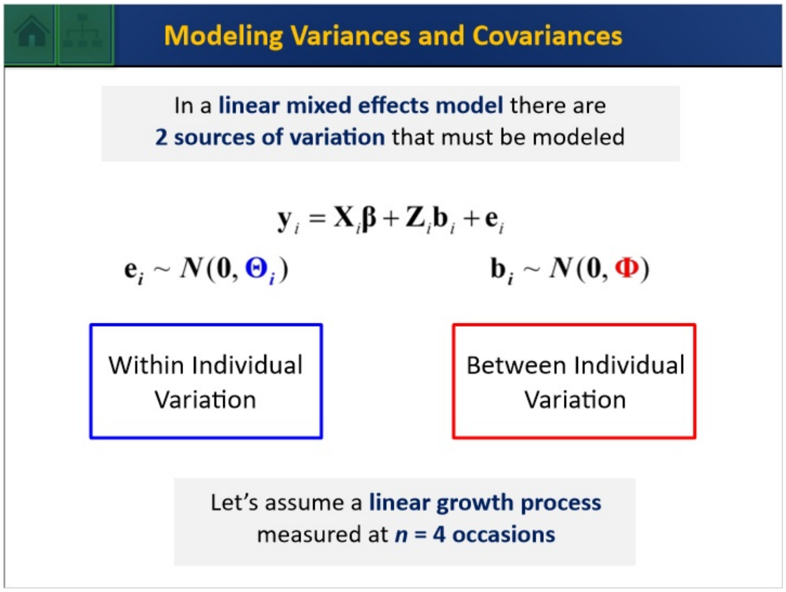


4.22 Bookend: Functional Form

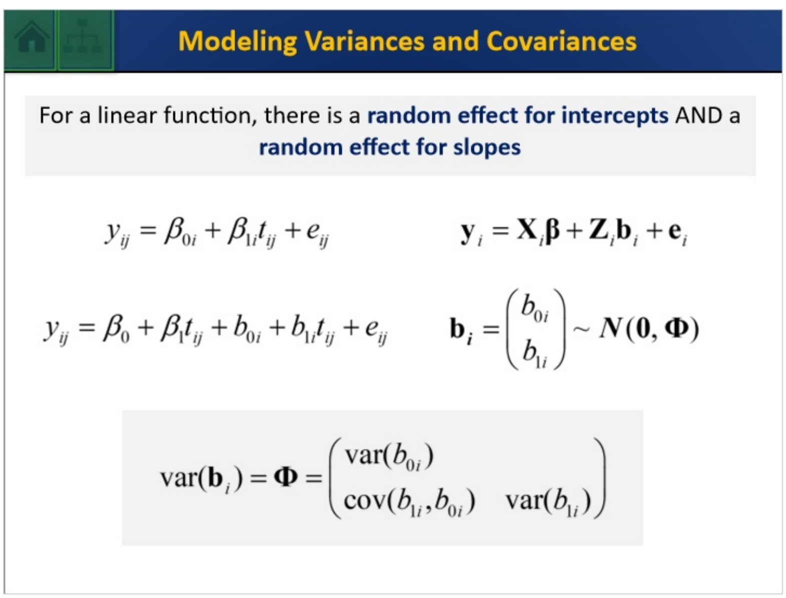


4.23 Bookmark: Variances and Covariances

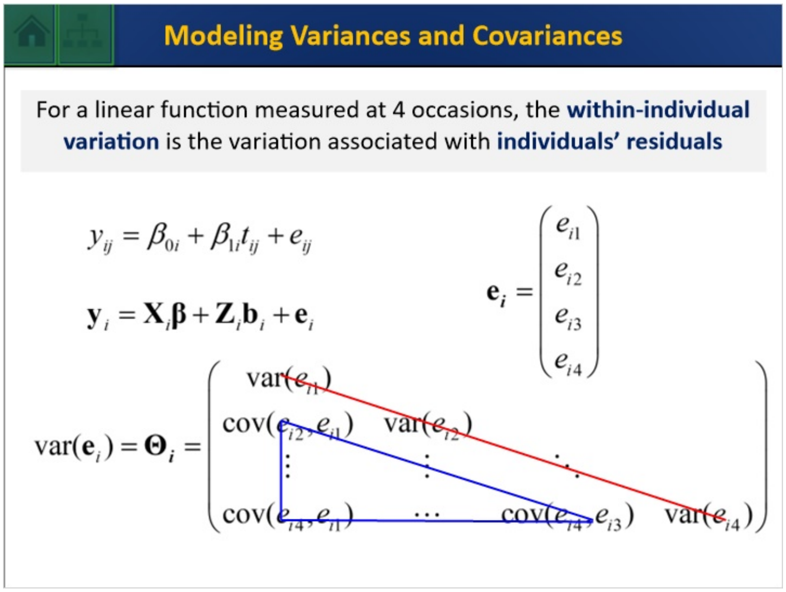
4.24 Modeling Variances and Covariances I



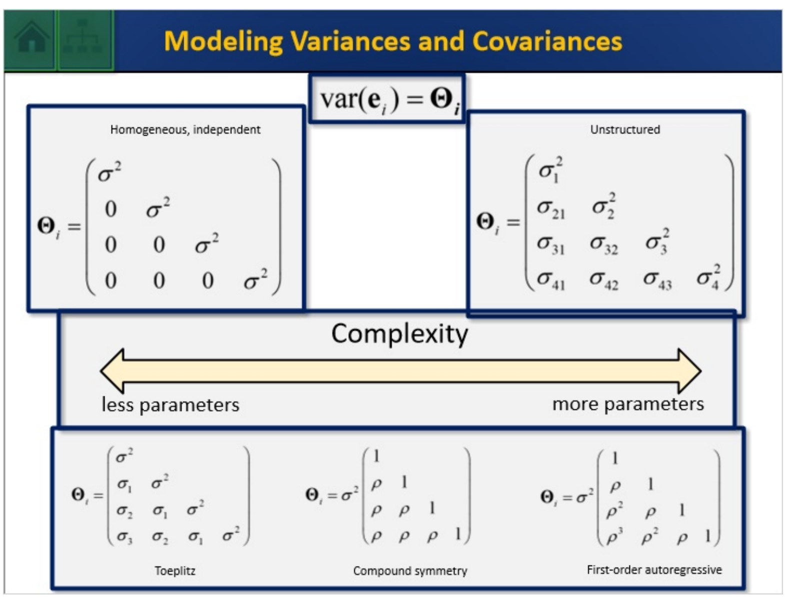
4.25 Modeling Variances and Covariances II



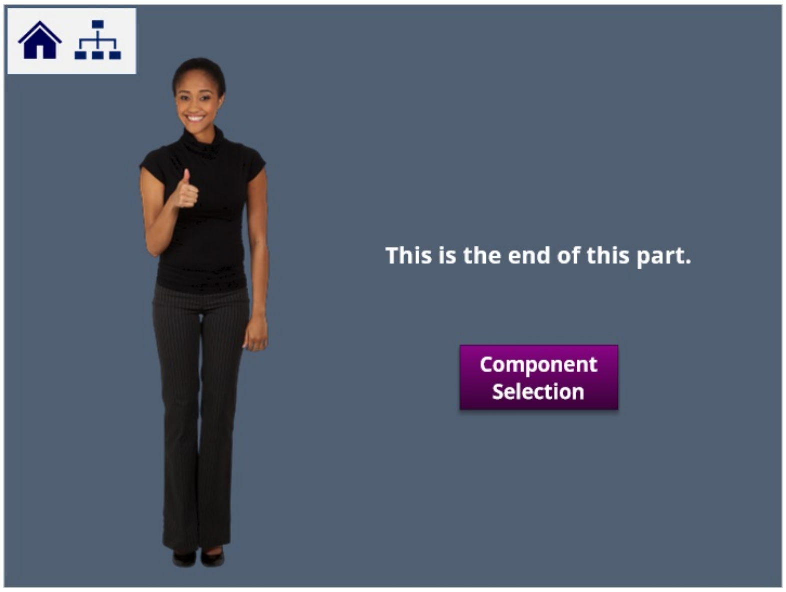
4.26 Modeling Variances and Covariances III



4.27 Modeling Variances and Covariances IV

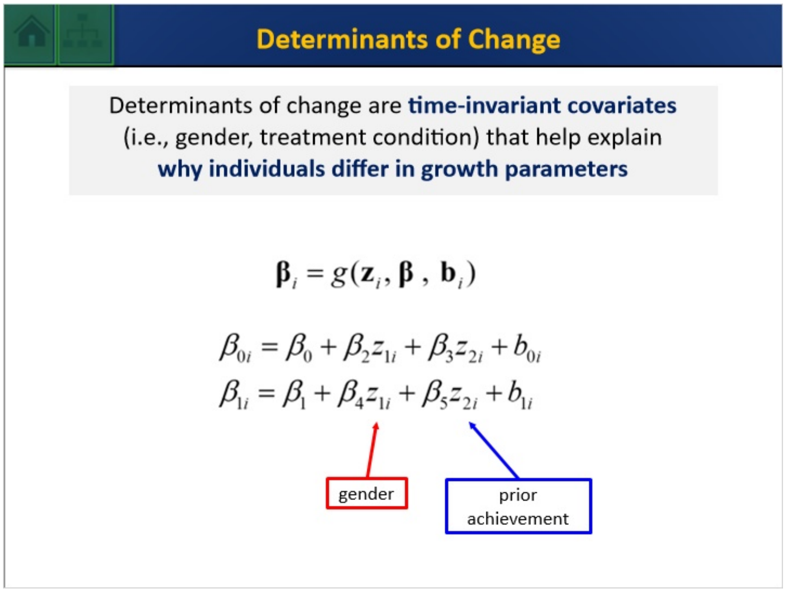


4.28 Bookend: Variances and Covariances

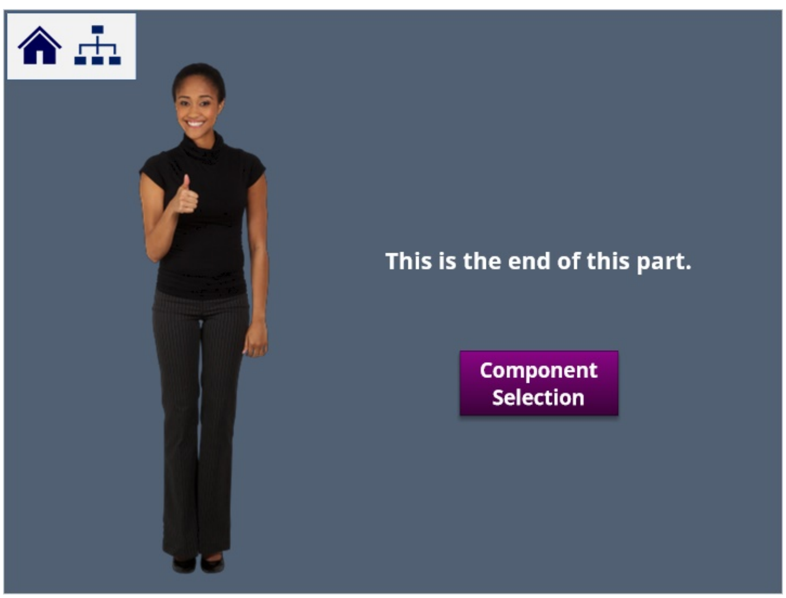


4.29 Bookmark: Determinants of Change

4.30 Determinants of Change

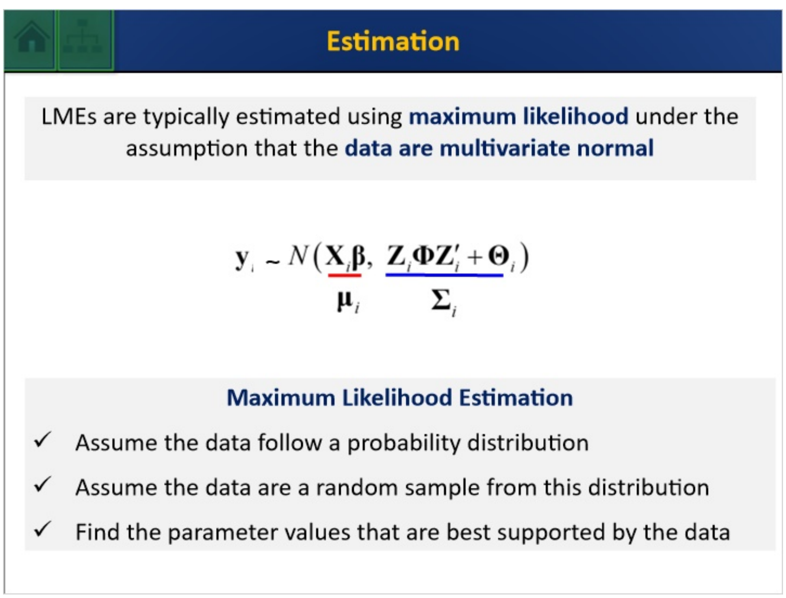


4.31 Bookend: Determinants of Change

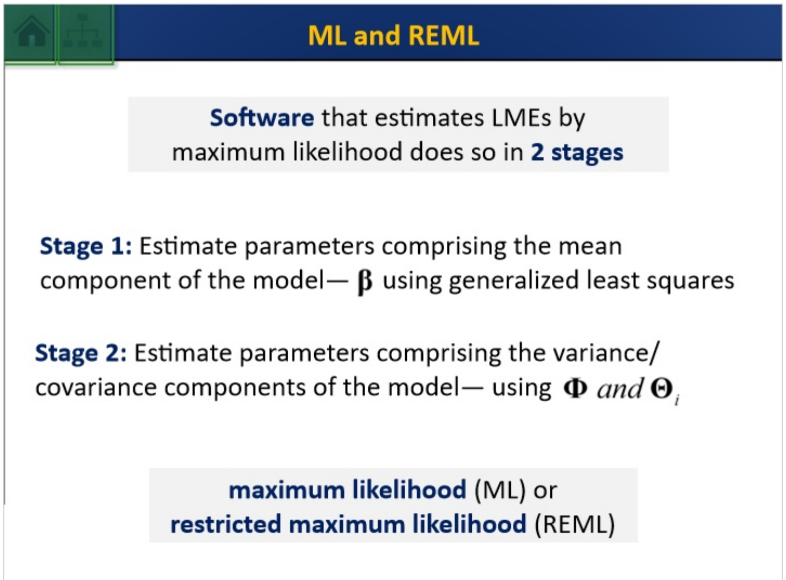


4.32 Bookmark: Estimation

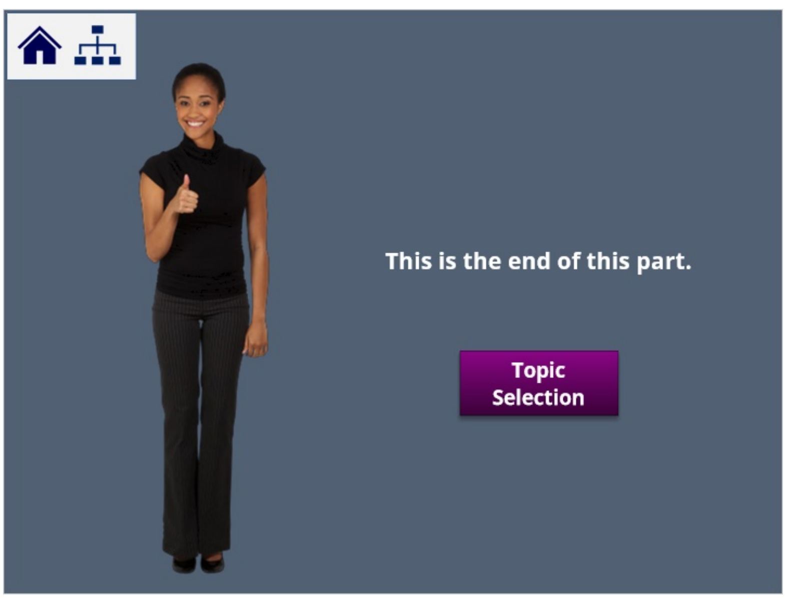
4.33 Estimation



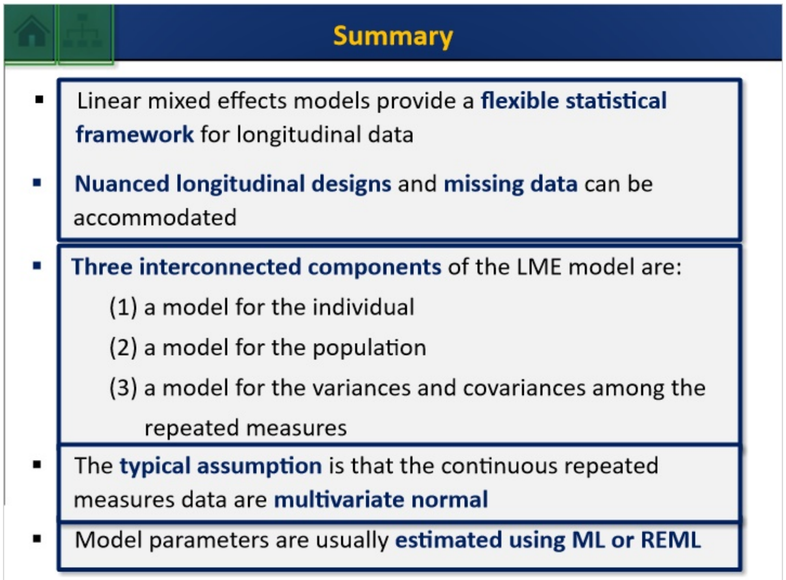
4.34 ML and REML



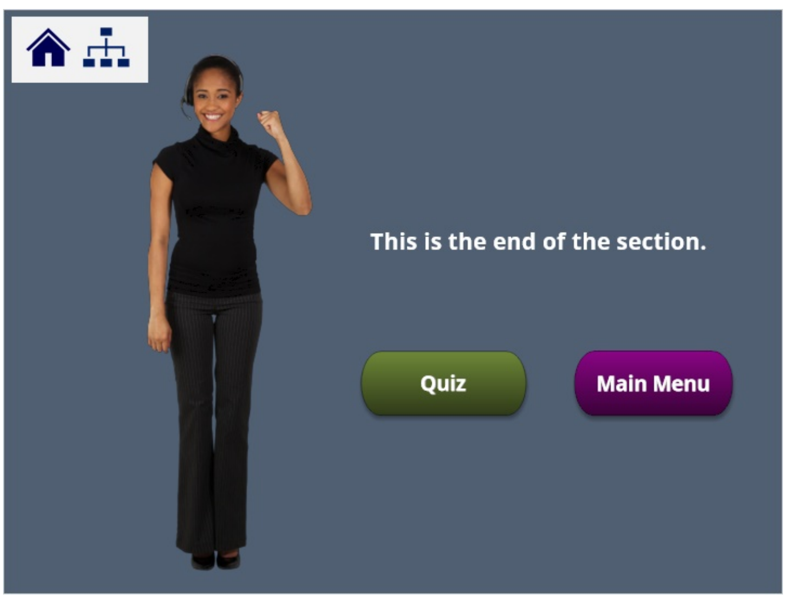
4.35 Bookend: Estimation



4.36 Summary



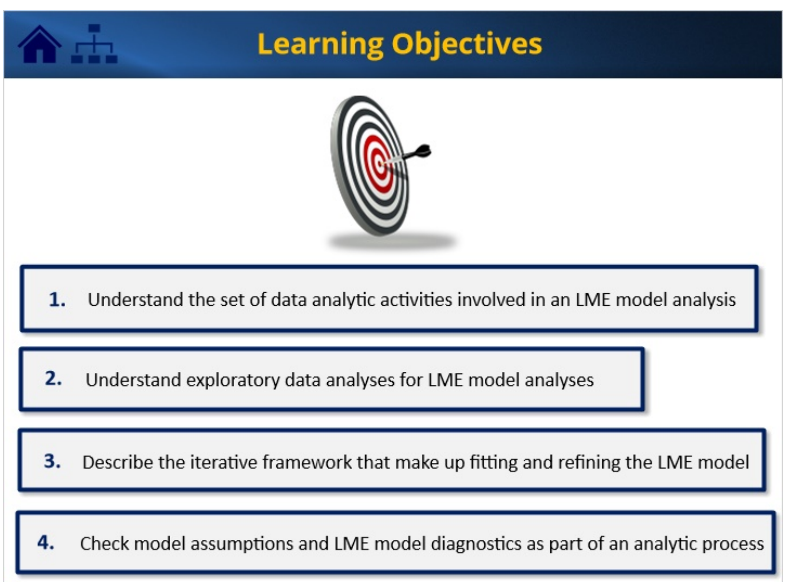
4.37 Bookend: Section 3



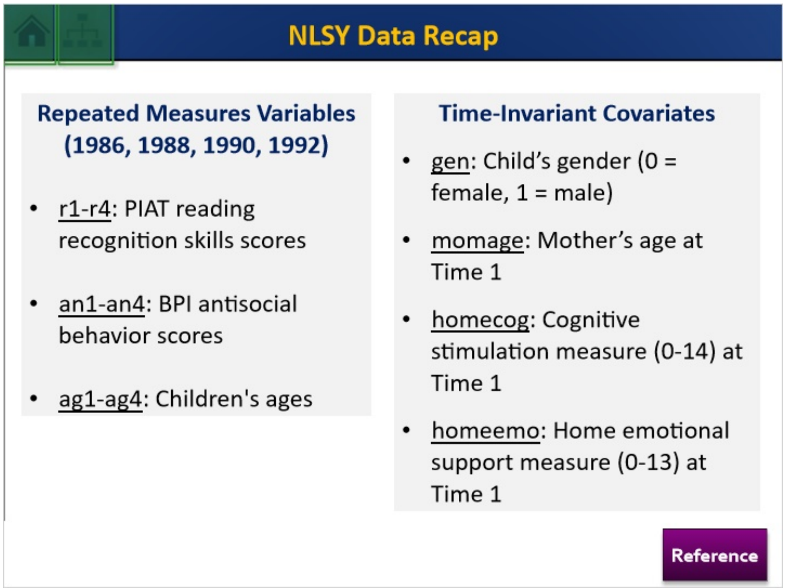
5. Section 4: LME Analyses

5.1 Cover: Section 4

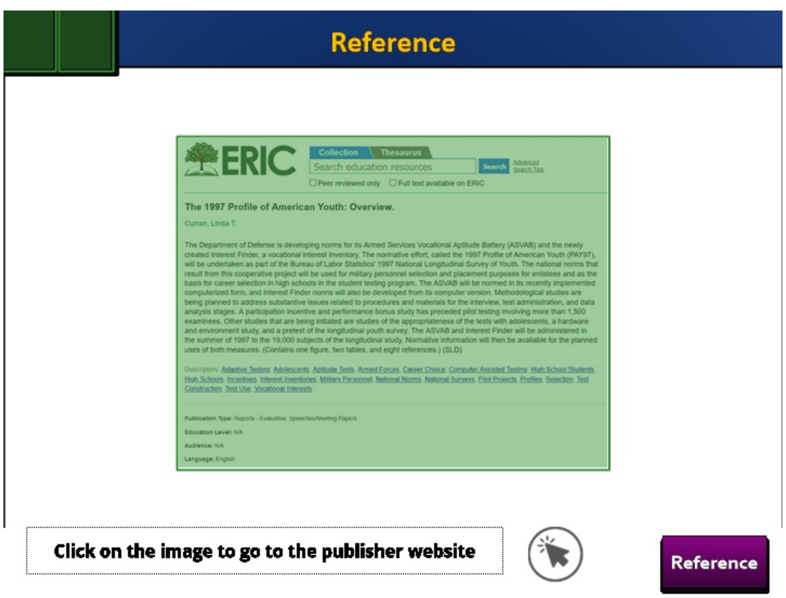
5.2 Learning Objectives: Section 4



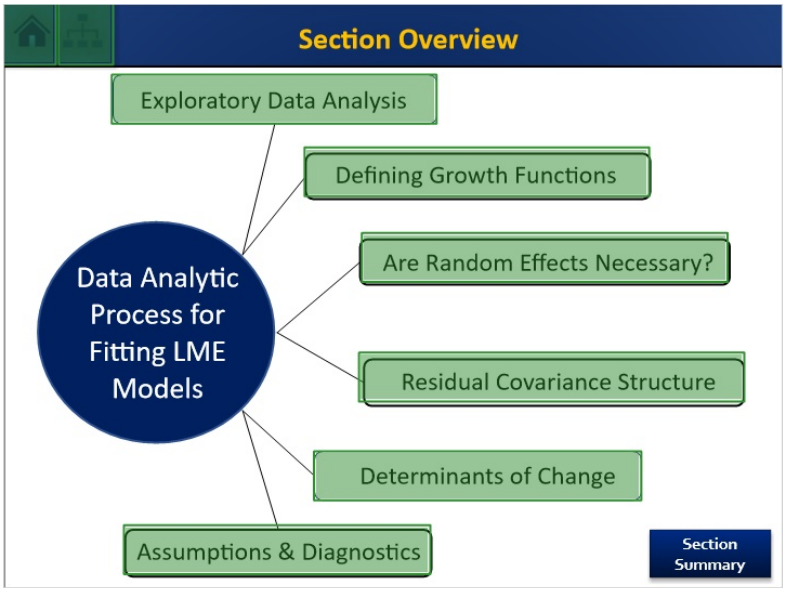
5.3 NLSY Data Recap



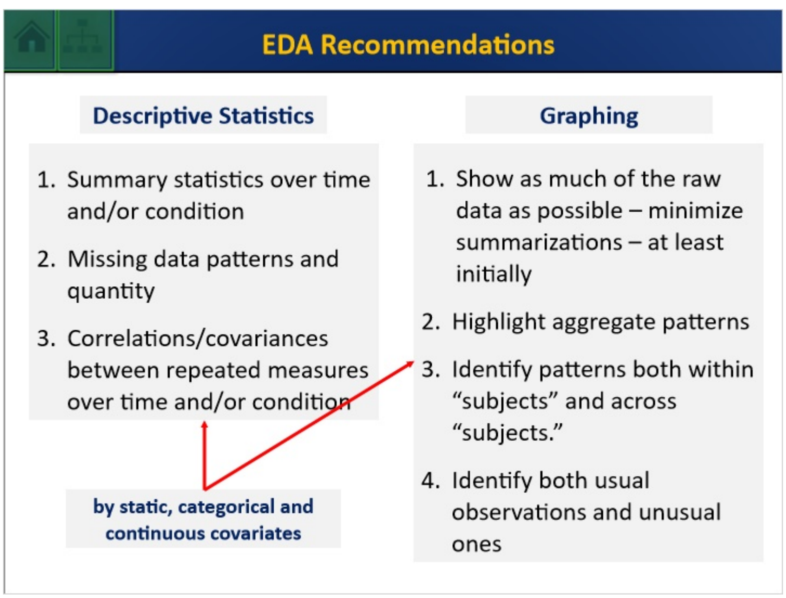
Reference (Slide Layer)



5.4 Topic Selection



5.5 EDA Recommendations



5.6 Descriptive Summaries I

Descriptive Summaries

```
Means
      r1       r2       r3       r4
25.22716 40.76000 50.05091 57.74074
```

```
SDs
      r1        r2        r3        r4
9.249445 10.836461 11.609725 12.480446
```

```
Corr
          r1        r2        r3        r4
r1 1.0000000 0.6246212 0.5324771 0.4513588
r2 0.6246212 1.0000000 0.8085688 0.7520729
r3 0.5324771 0.8085688 1.0000000 0.8134315
r4 0.4513588 0.7520729 0.8134315 1.0000000
```

Summary Statistics Across Time

5.7 Descriptive Summaries II

Descriptive Summaries

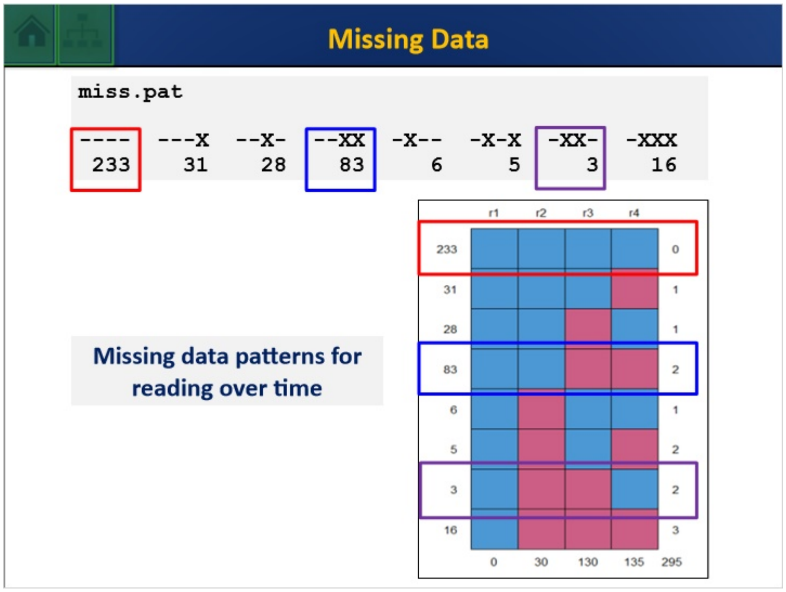
year	gender	read
0	0	25.75743
0	1	24.69951
2	0	41.42391
2	1	40.12042
4	0	50.87218
4	1	49.28169
6	0	57.70677
6	1	57.77372

by gender across time

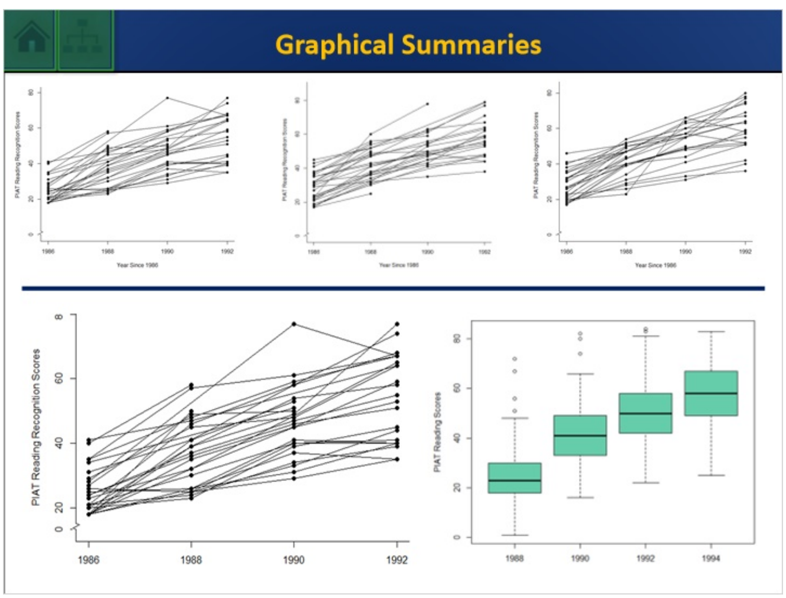
year	(homeemo, g=3)	read
0	[0, 9)	25.20438
0	[9,12)	25.19024
0	[12,13]	25.39683
2	[0, 9)	39.62400
2	[9,12)	40.52062
2	[12,13]	44.12500
4	[0, 9)	47.59091
4	[9,12)	51.08904
4	[12,13]	51.63415
6	[0, 9)	54.27586
6	[9,12)	58.86525
6	[12,13]	61.14286

by continuous covariate across time

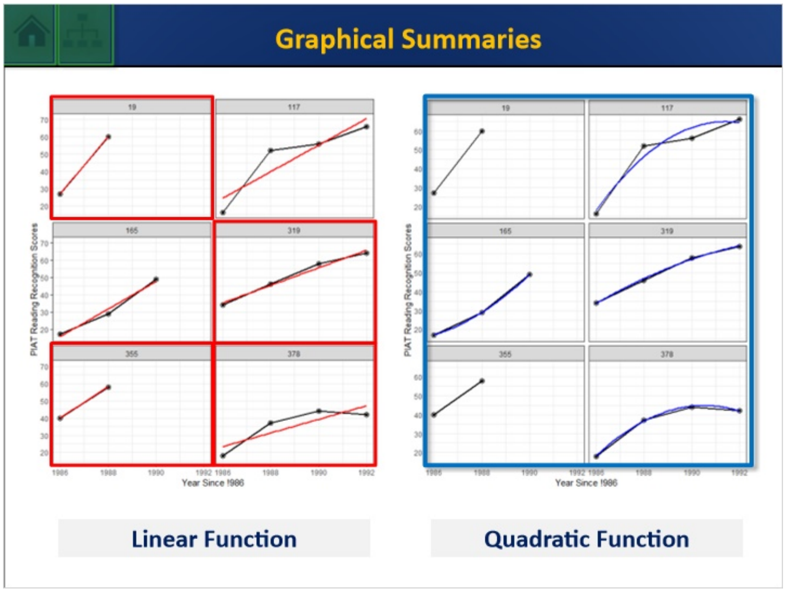
5.8 Missing Data



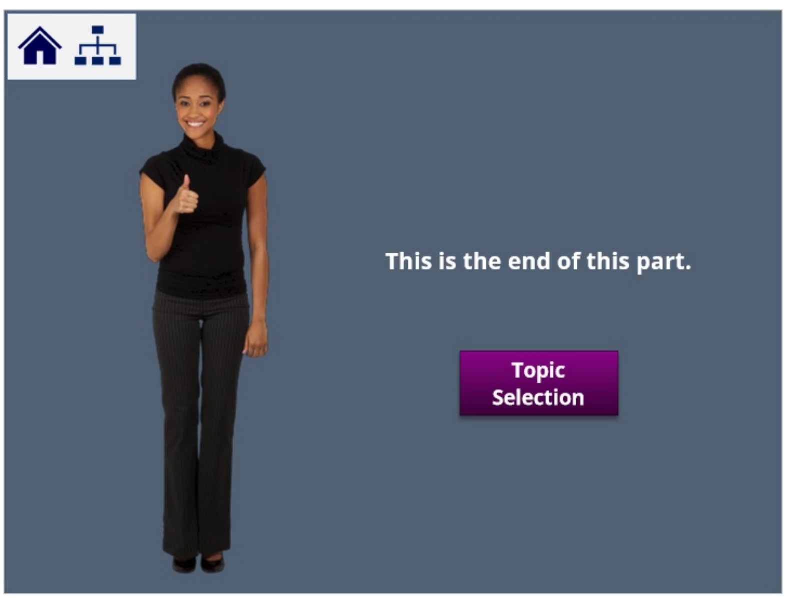
5.9 Graphical Summaries I



5.10 Graphical Summaries II

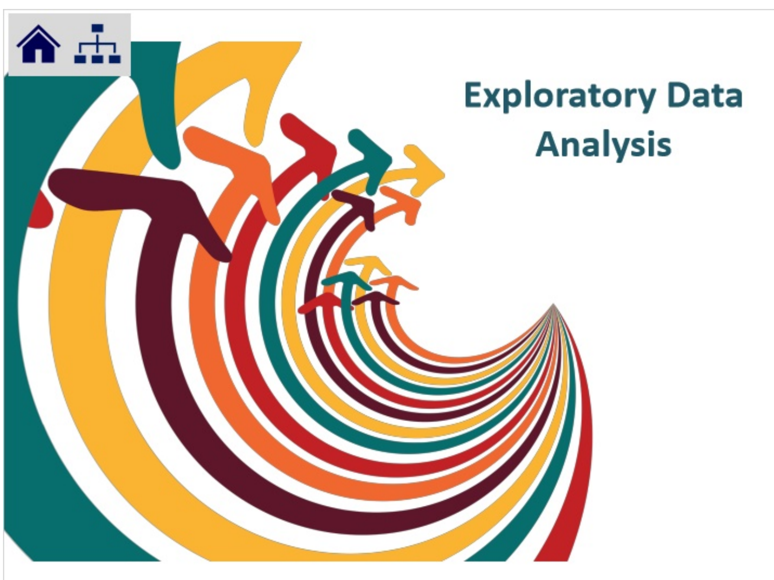


5.11 Bookend: Exploratory Data Analysis

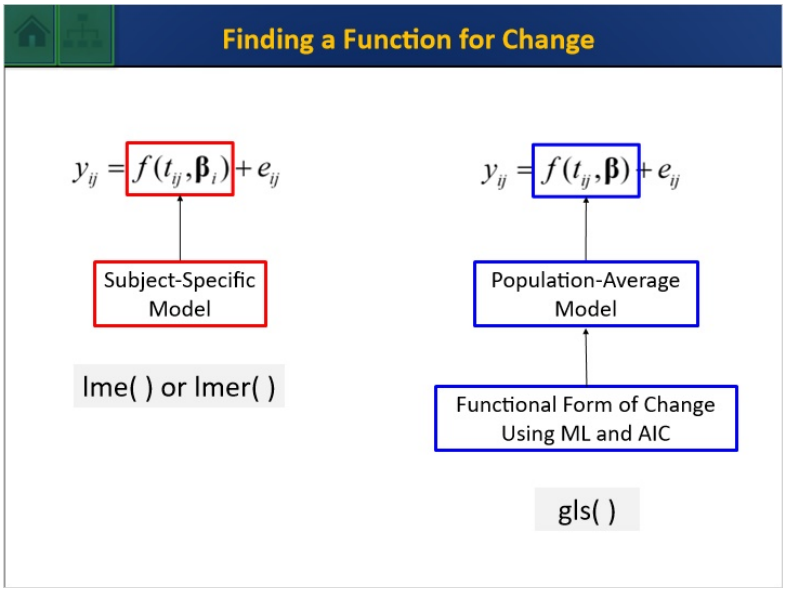


5.12 Bookmark: Defining Growth Functions

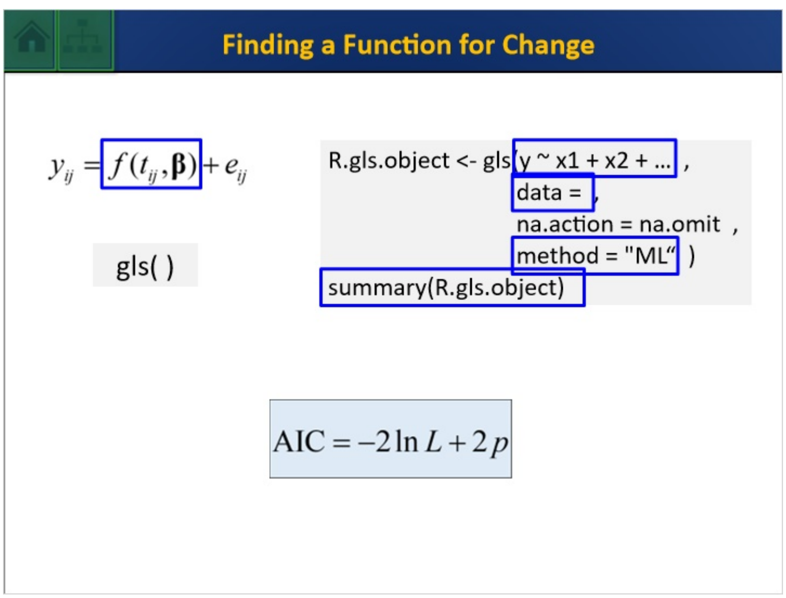
5.13 Bookmark: Exploratory Data Analysis



5.14 Finding a Function for Change I



5.15 Finding a Function for Change II

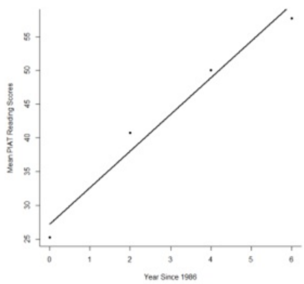


5.16 Finding a Function for Change III

Finding a Function for Change

Linear Function

$$f(t_{ij}, \boldsymbol{\beta}) = \boxed{\beta_0 + \beta_1 t_{ij}}$$




```
p.1 <- gls( read ~ 1 + year ,
           data = read.long  ,
           na.action = na.omit  ,
           method = "ML“ )

summary(p.1)
```

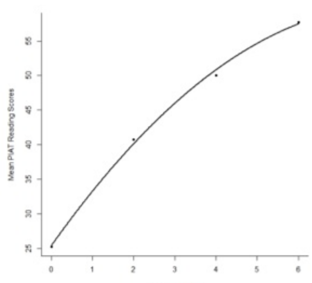
$\text{AIC} = 10143.32$

5.17 Finding a Function for Change IV

Finding a Function for Change

Quadratic Function

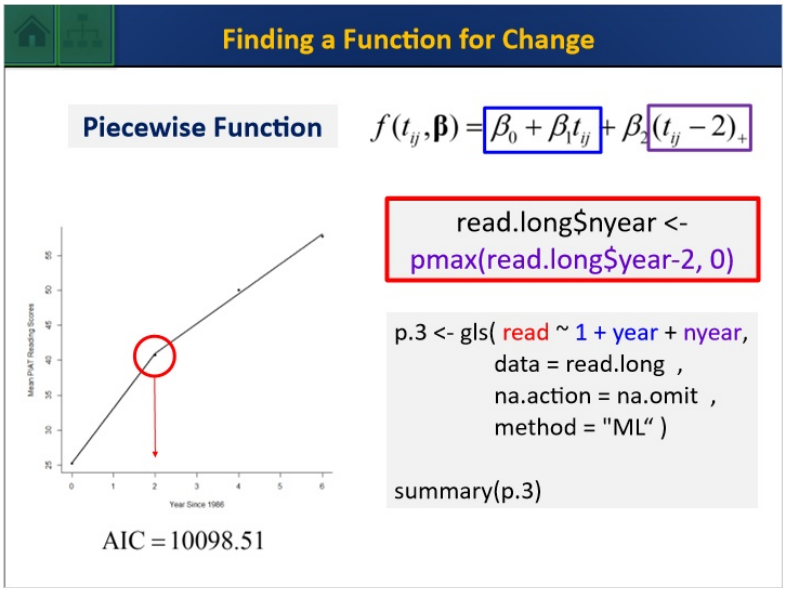
$$f(t_{ij}, \boldsymbol{\beta}) = \boxed{\beta_0 + \beta_1 t_{ij} + \beta_2 t_{ij}^2}$$



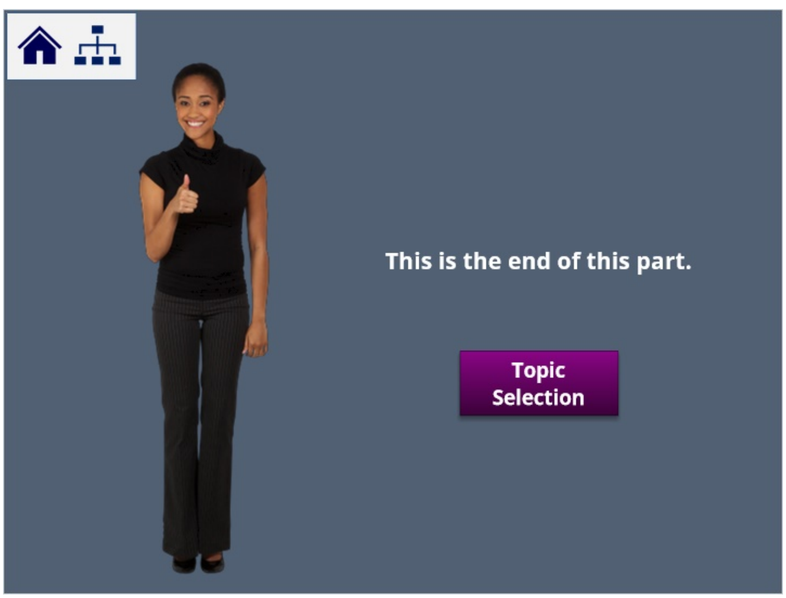

```
p.2 <- gls( read ~ 1 + year + I(year^2) ,
           data = read.long  ,
           na.action = na.omit  ,
           method = "ML“ )

summary(p.2)
```

$\text{AIC} = 10100.36$

5.18 Finding a Function for Change V

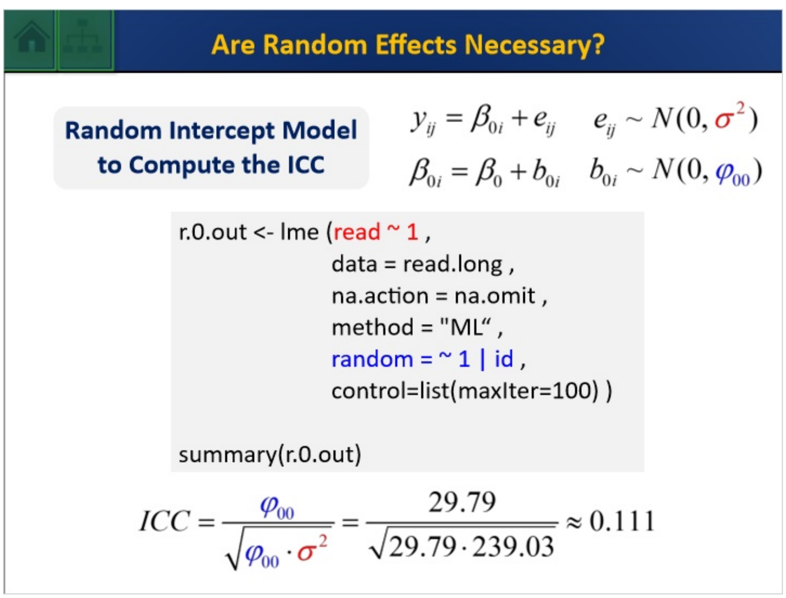


5.19 Bookend: Defining Growth Functions

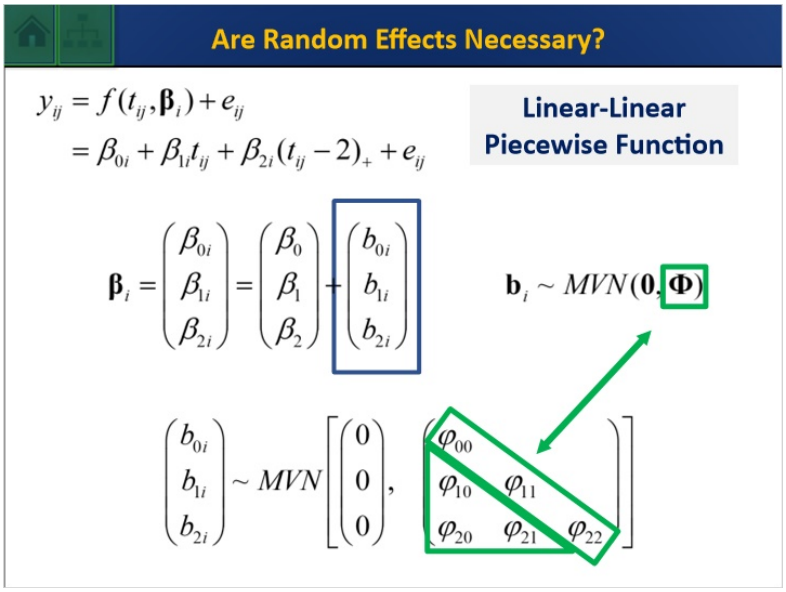


5.20 Bookmark: Are Random Effects Necessary

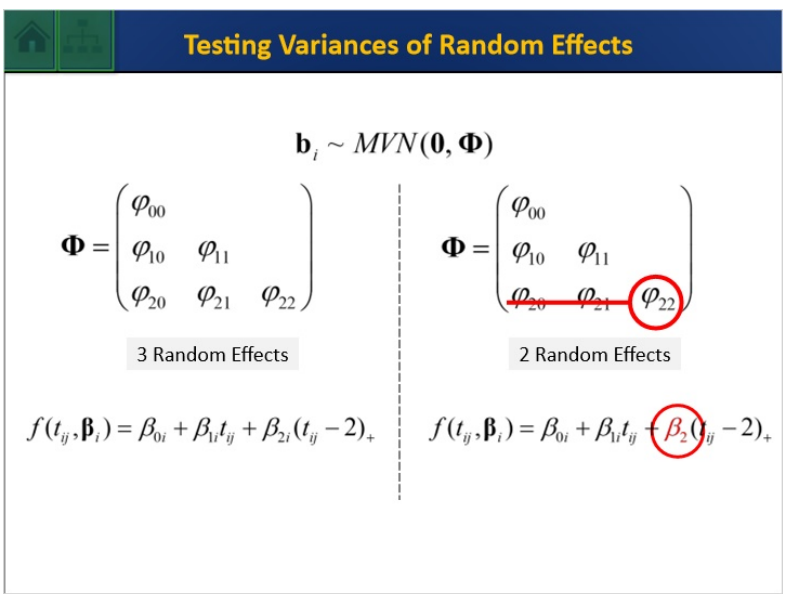
5.21 Are Random Effects Necessary I



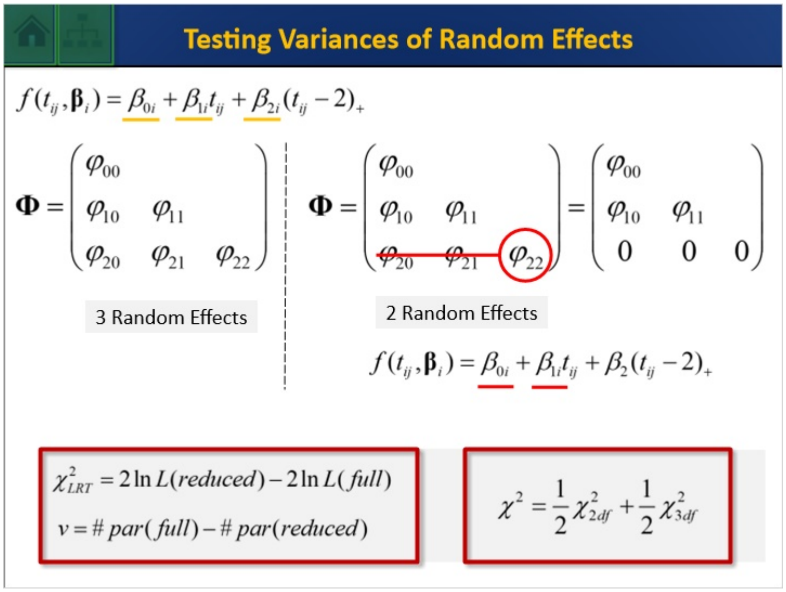
5.22 Are Random Effects Necessary II



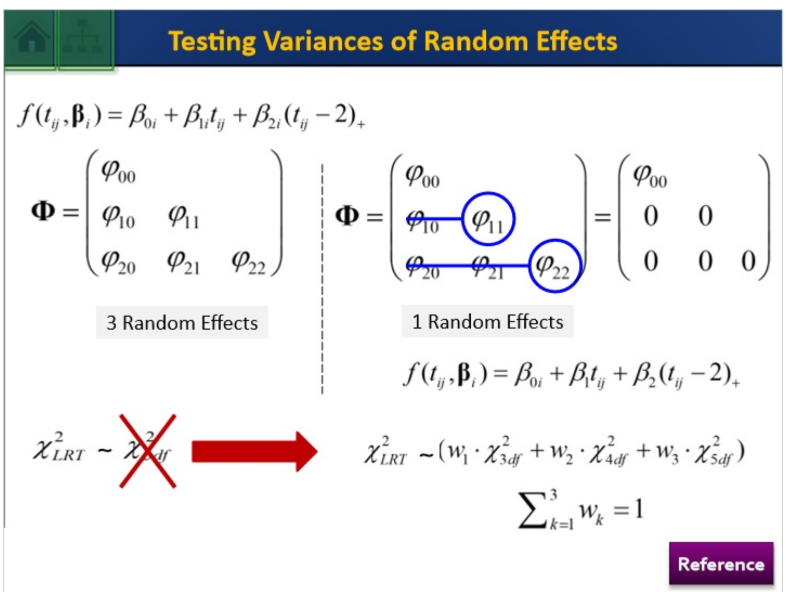
5.23 Testing Variances of Random Effects I



5.24 Testing Variances of Random Effects II

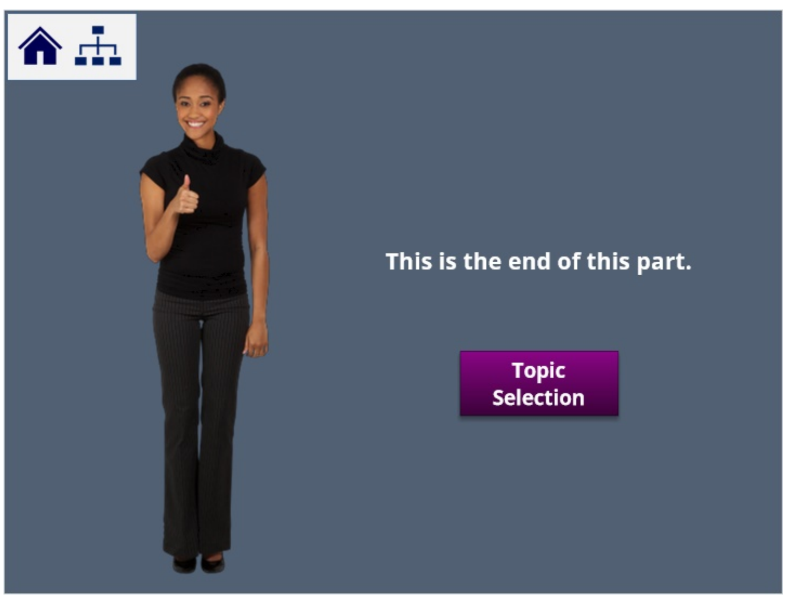


5.25 Testing Variances of Random Effects III



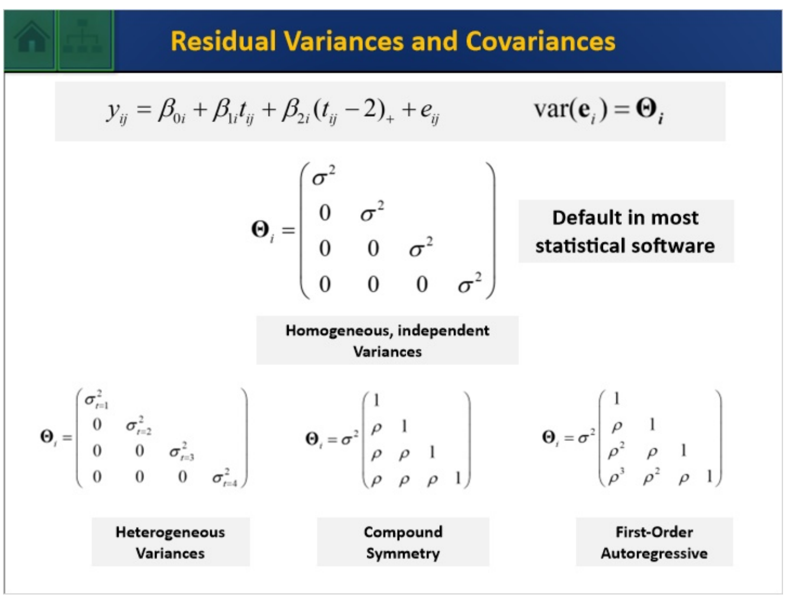
Reference (Slide Layer)

5.26 Bookend: Random Effects

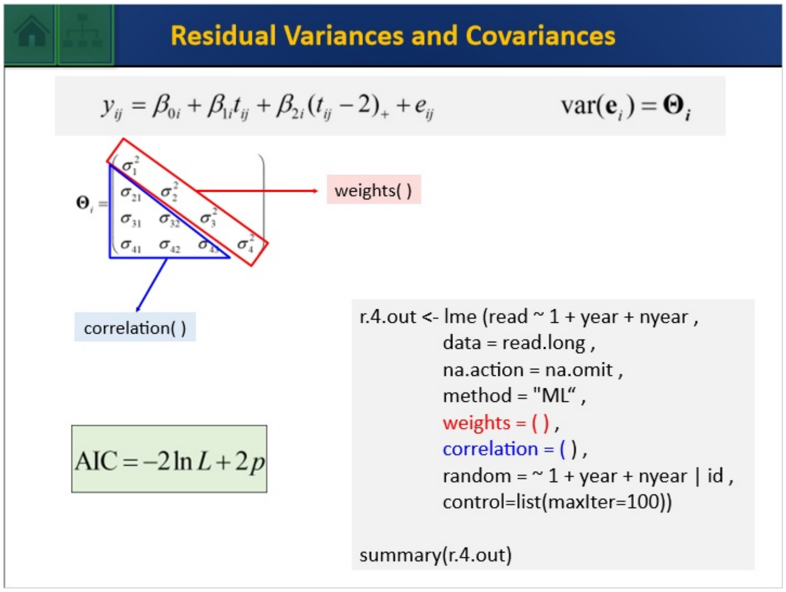


5.27 Bookmark: Residual Covariance Structure

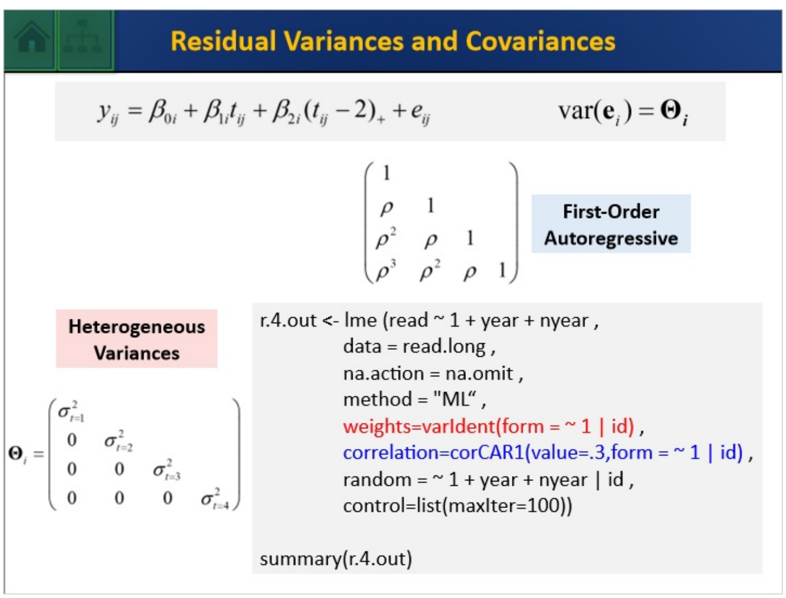
5.28 Residual Variances and Covariances I



5.29 Residual Variances and Covariances II



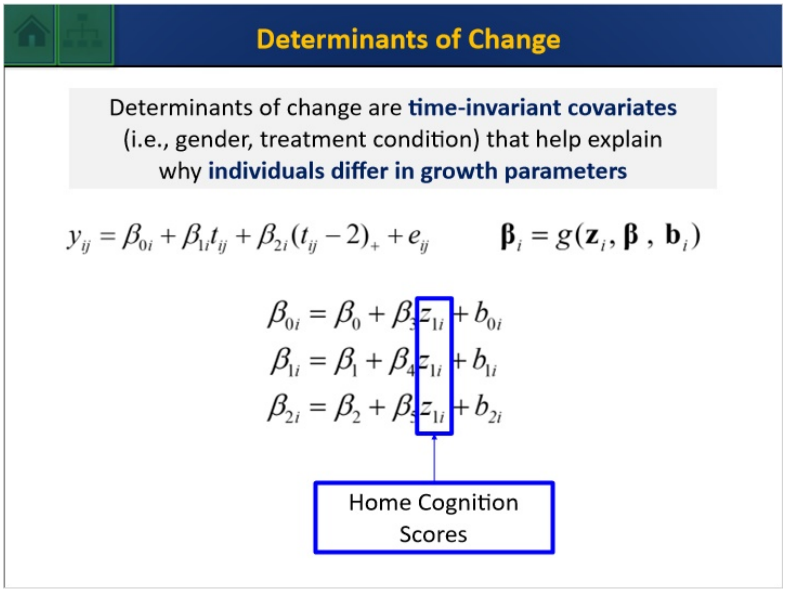
5.30 Residual Variances and Covariances III



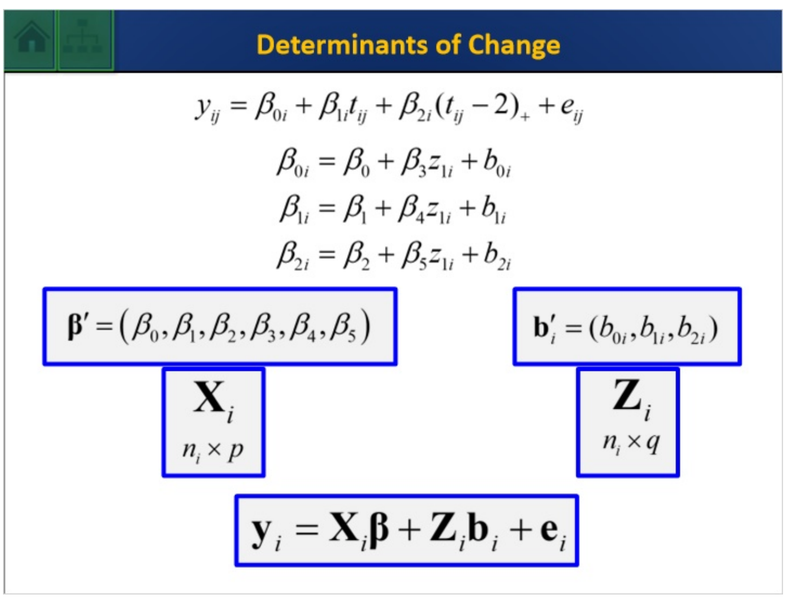
5.31 Bookend: Residual Covariances

5.32 Bookmark: Determinants of Change

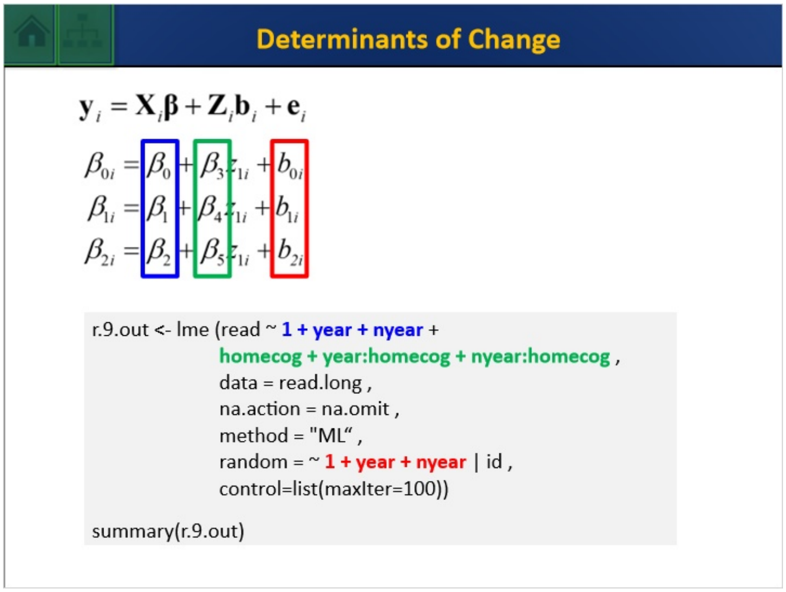
5.33 Determinants of Change I



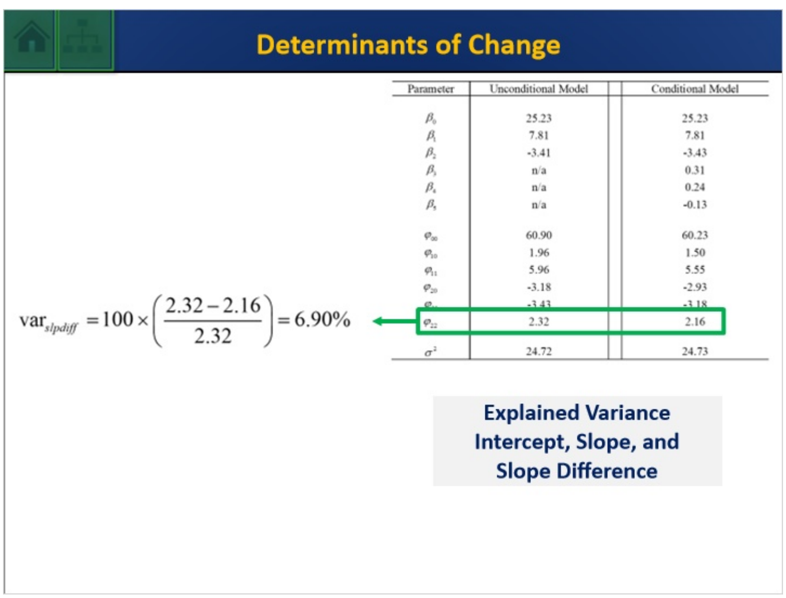
5.34 Determinants of Change II



5.35 Determinants of Change III



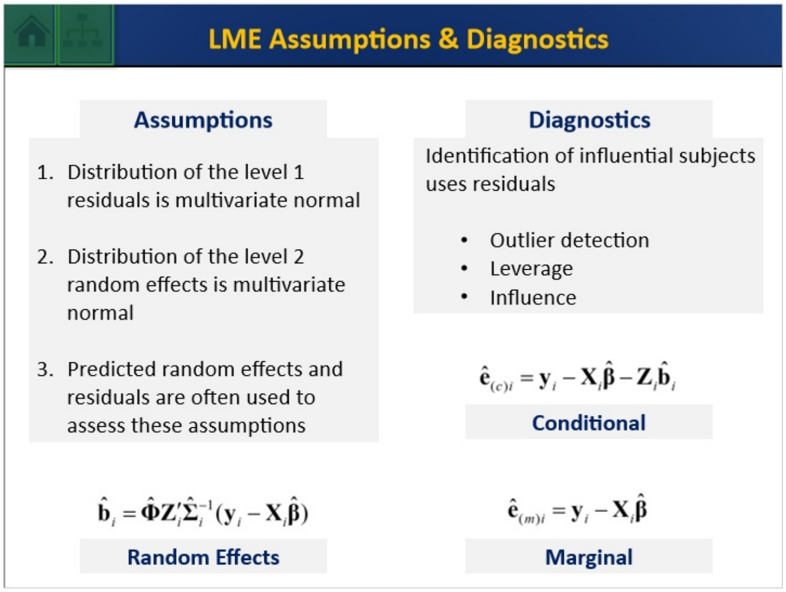
5.36 Determinants of Change IV



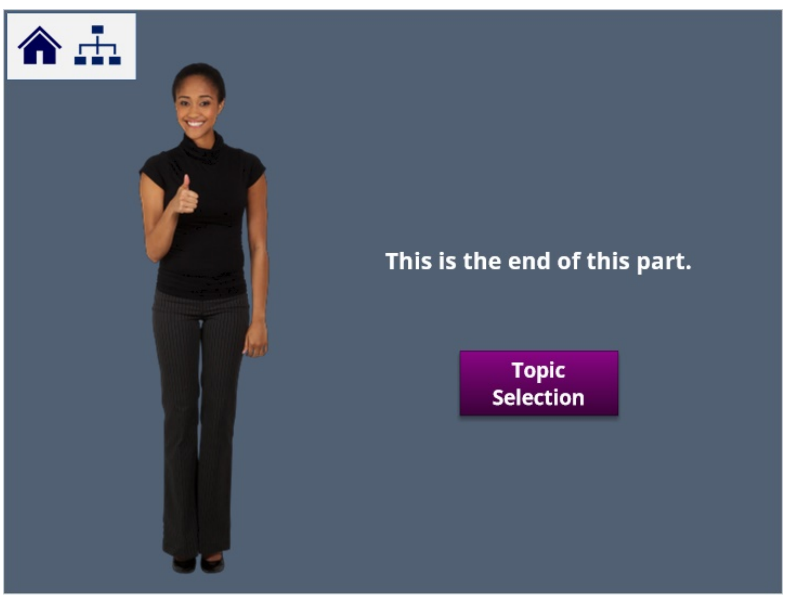
5.37 Bookend: Determinants of Change

5.38 Bookmark: Assumptions and Diagnostics

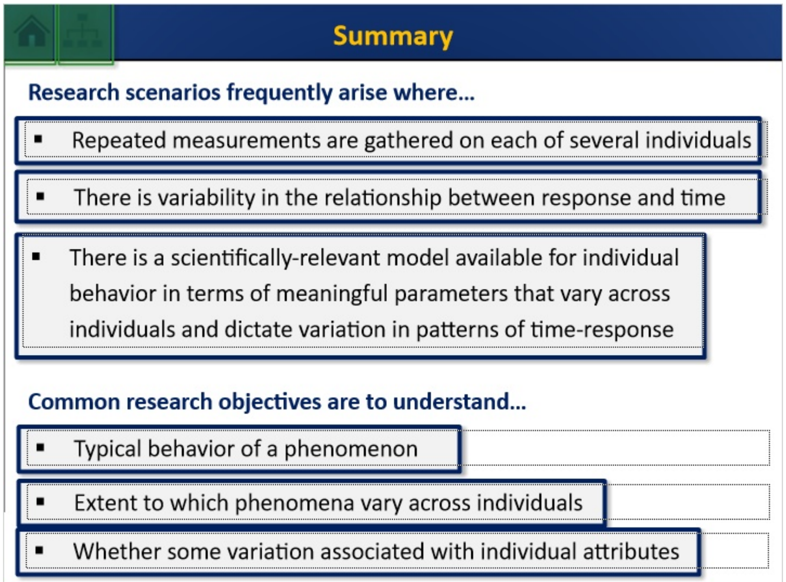
5.39 LME Assumptions & Diagnostics



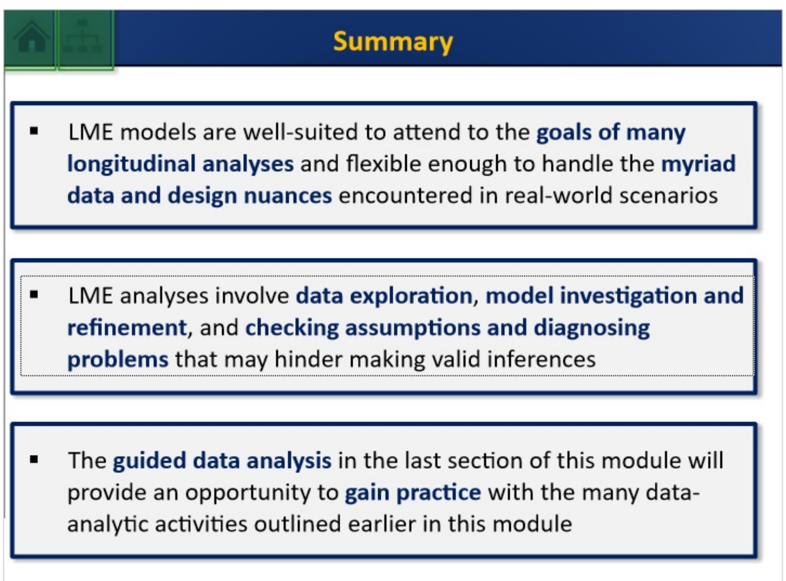
5.40 Bookend: Assumptions & Diagnostics



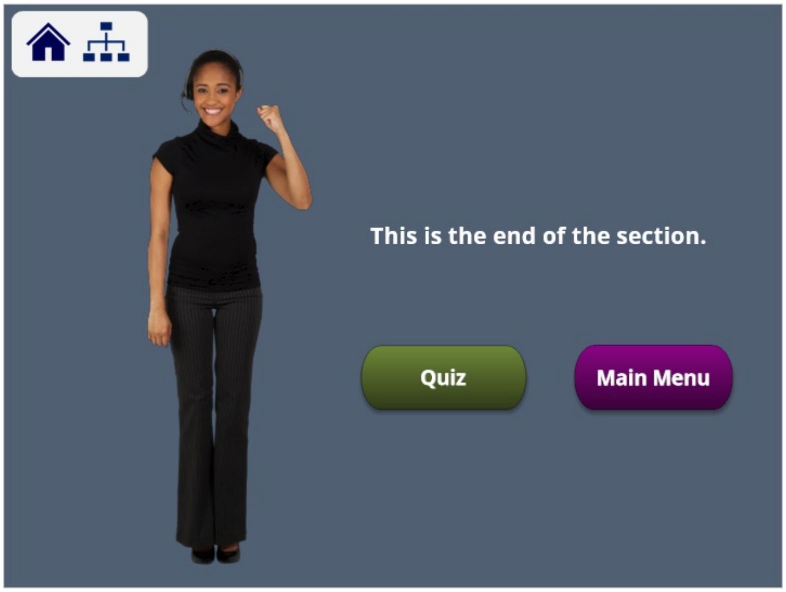
5.41 Summary I



5.42 Summary II



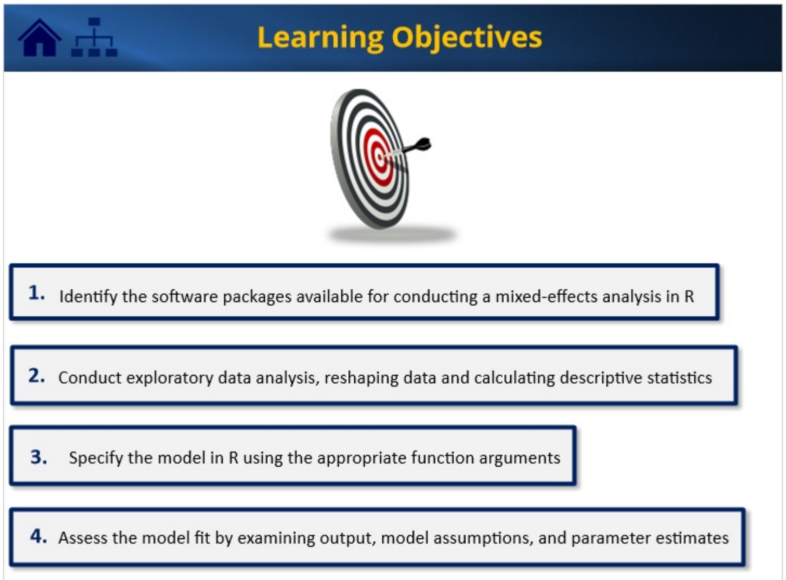
5.43 Bookend: Section 4



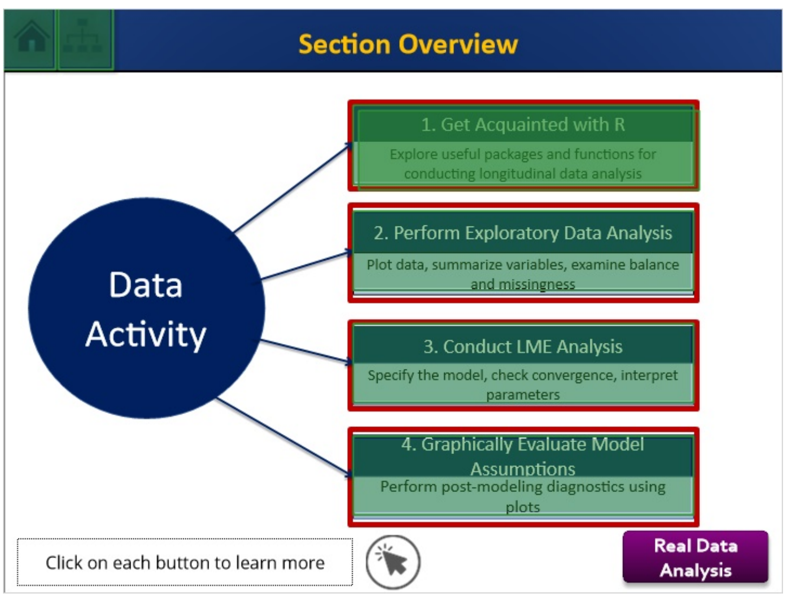
6. Section 5: Data Activity

6.1 Cover: Section 5

6.2 Learning Objectives

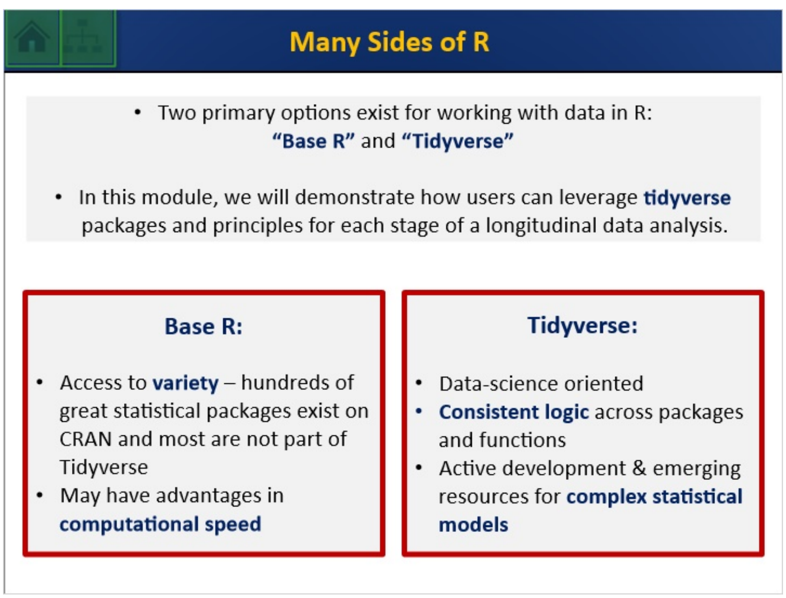


6.3 Topic Selection

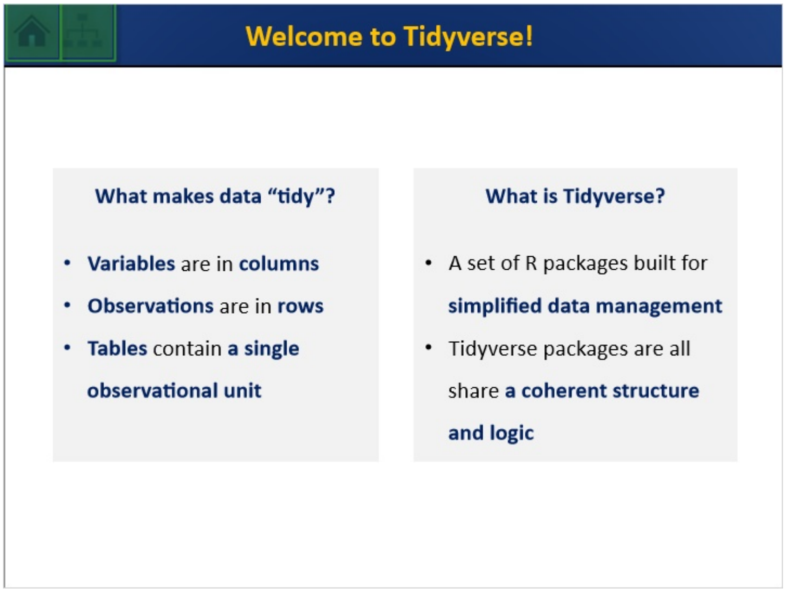


6.4 Bookmark: Get Acquainted with R

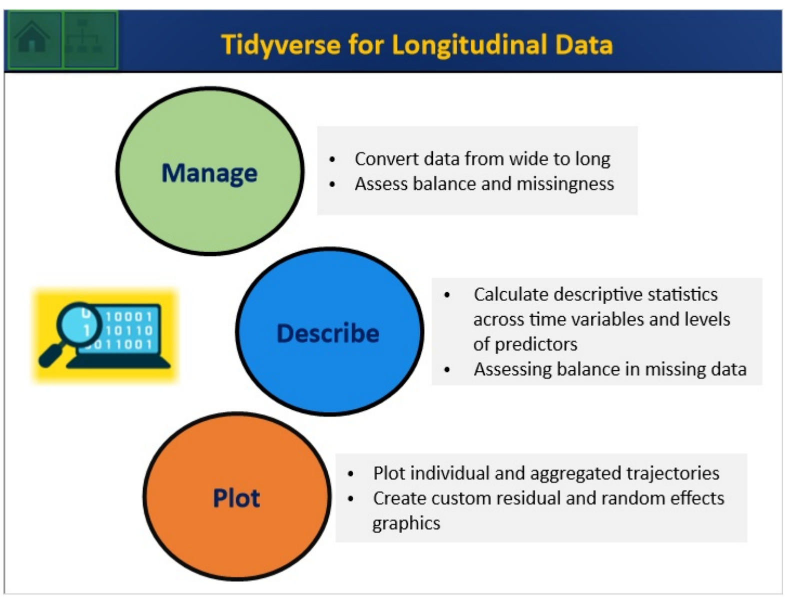
6.5 Many Sides of R



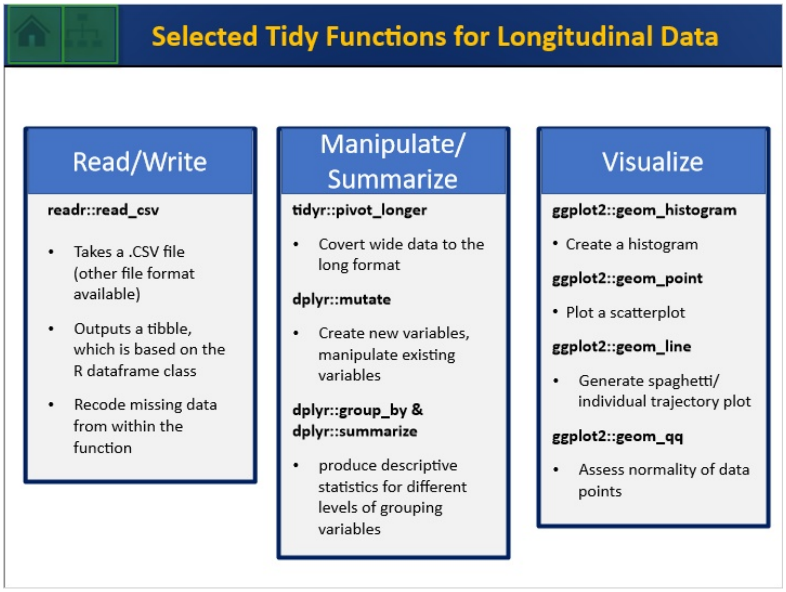
6.6 Welcome to Tidyverse



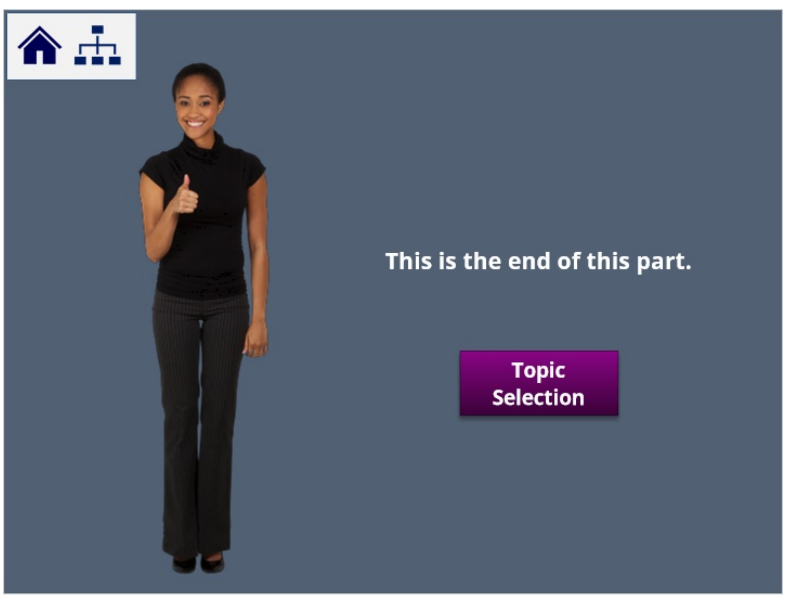
6.7 Tidyverse for Longtitudinal Data



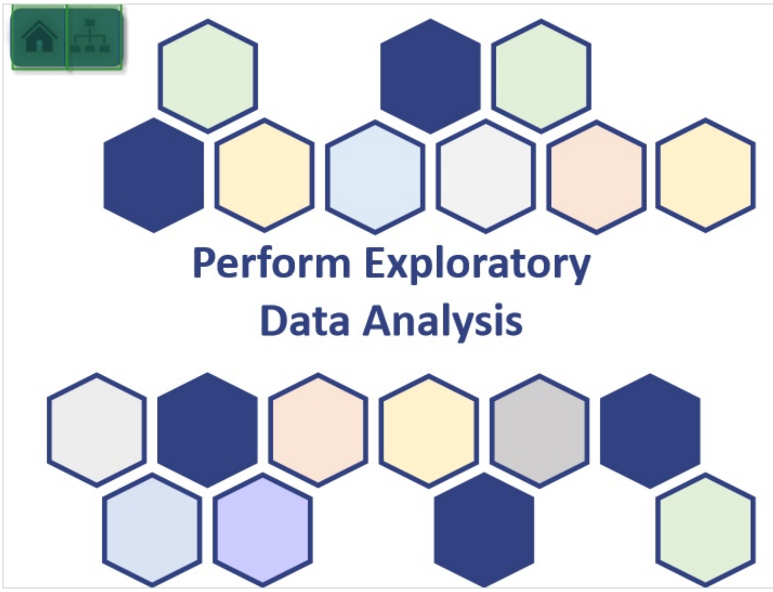
6.8 Selected Tidy Functions for Longitudinal Data



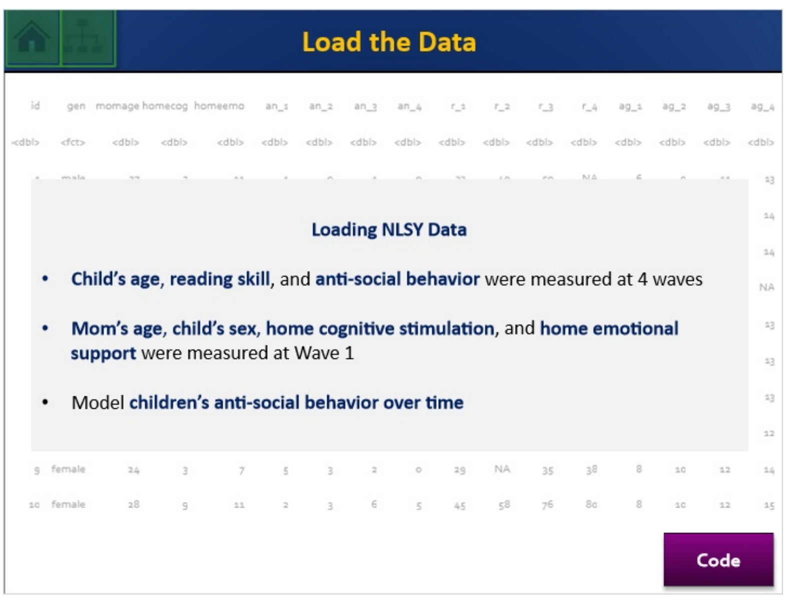
6.9 Bookend: Get Acquainted with R



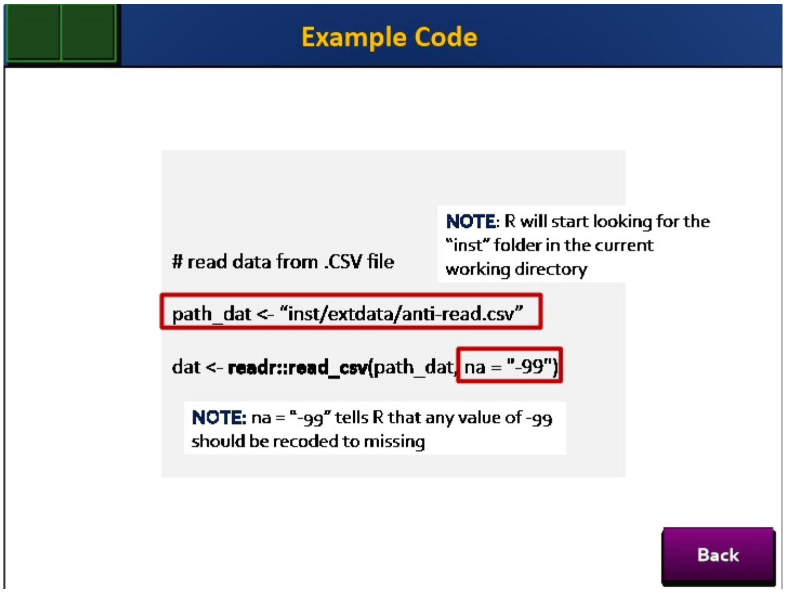
6.10 Bookmark: Perform Exploratory Data Analysis



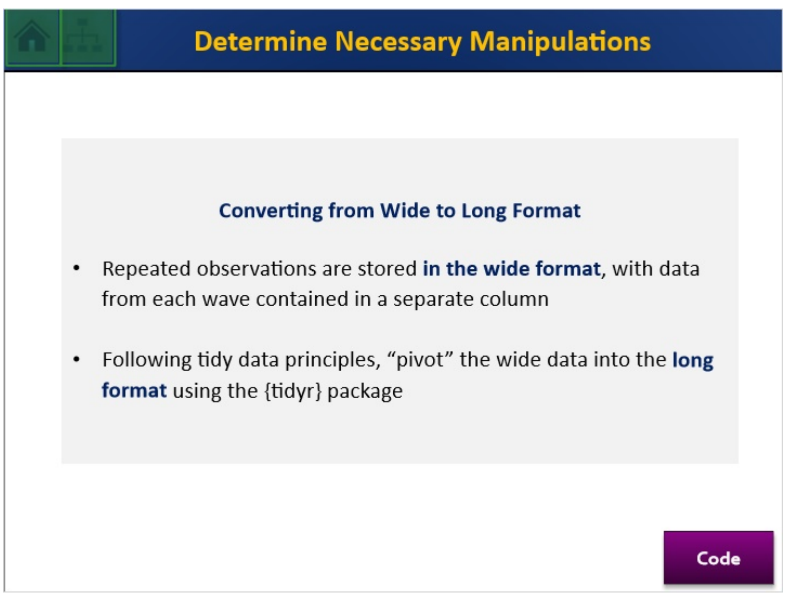
6.11 EDA1:Load the Data



Code (Slide Layer)



6.12 EDA 2: Determine Necessary Manipulations



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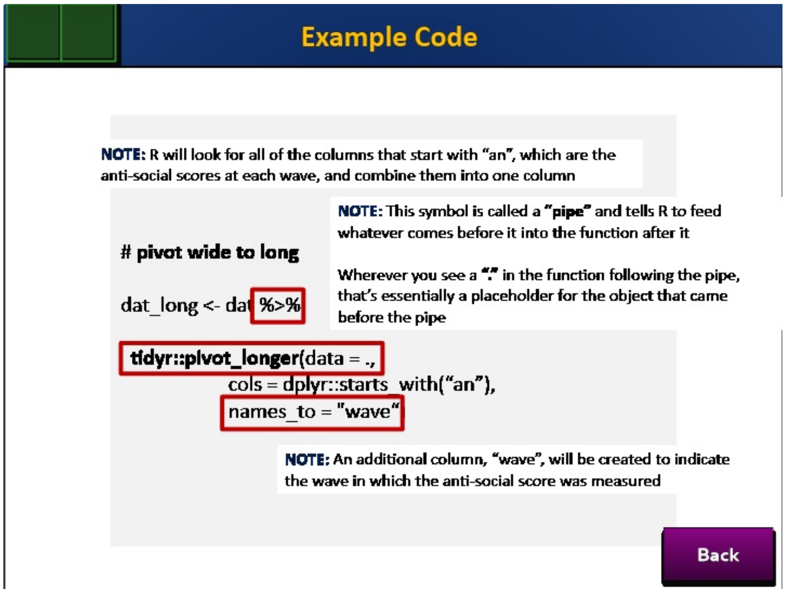
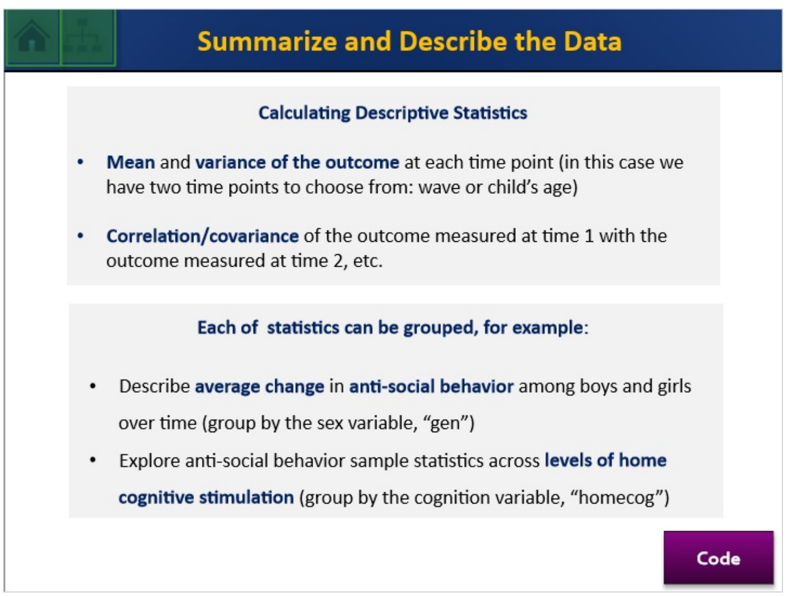


6.13 EDA 3: Summarize and Describe the Data



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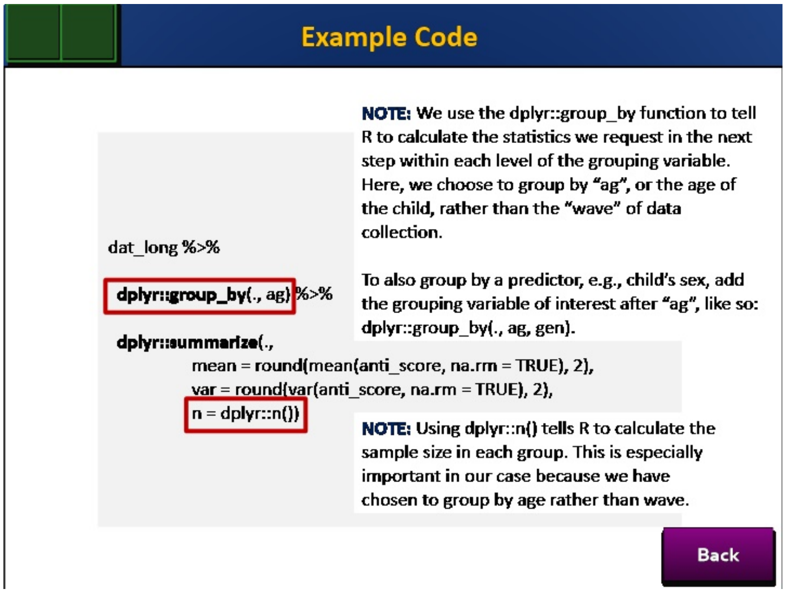
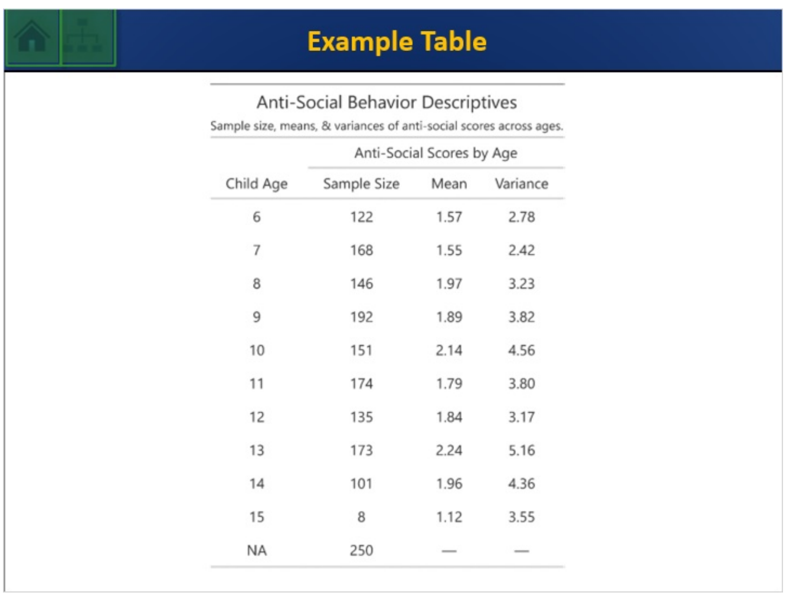


6.14 EDA 3: Example Table

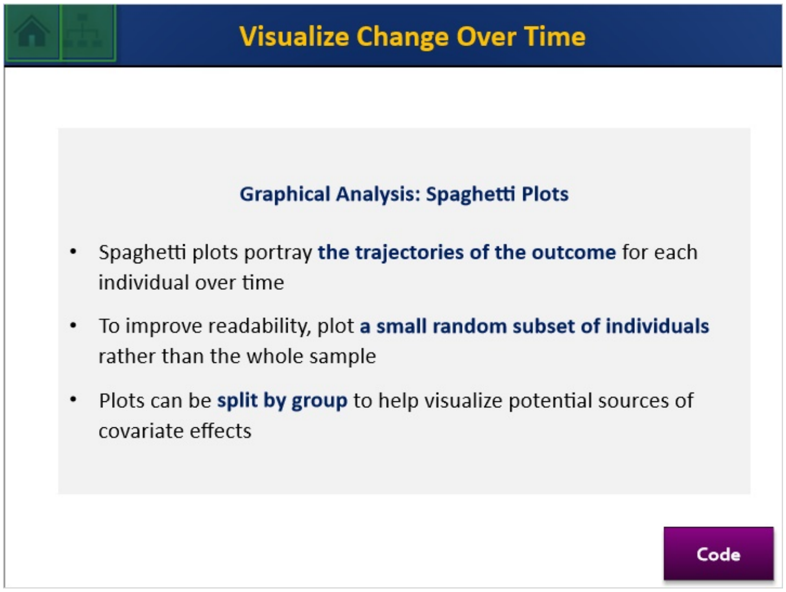


Anti-Social Behavior Descriptives

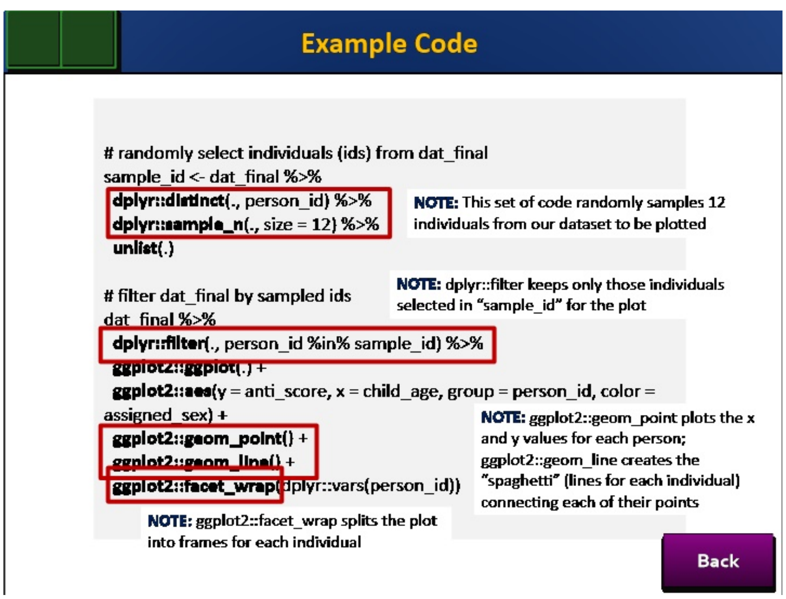
Sample size, means, & variances of anti-social scores across ages.

	Anti-Social Scores by Age		
Child Age	Sample Size	Mean	Variance
6	122	1.57	2.78
7	168	1.55	2.42
8	146	1.97	3.23
9	192	1.89	3.82
10	151	2.14	4.56
11	174	1.79	3.80
12	135	1.84	3.17
13	173	2.24	5.16
14	101	1.96	4.36
15	8	1.12	3.55
NA	250	—	—

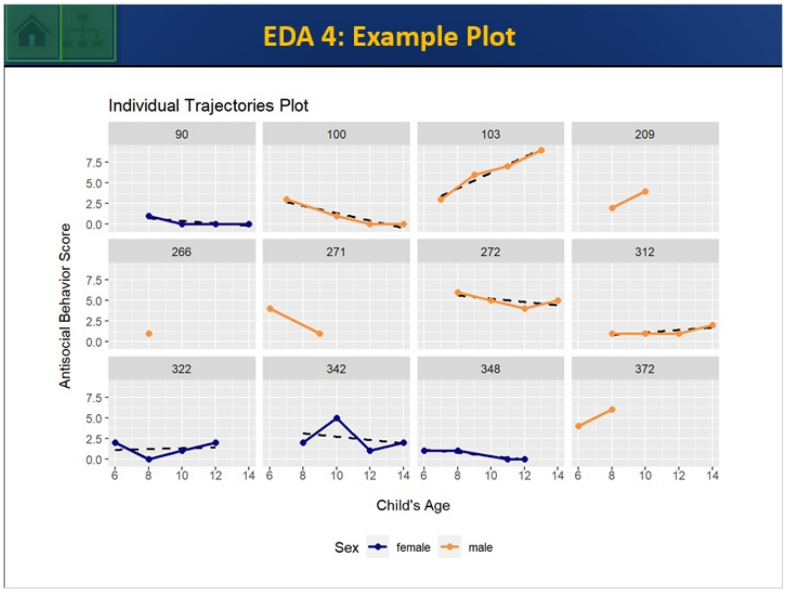
6.15 EDA 4: Visualize Change Over Time



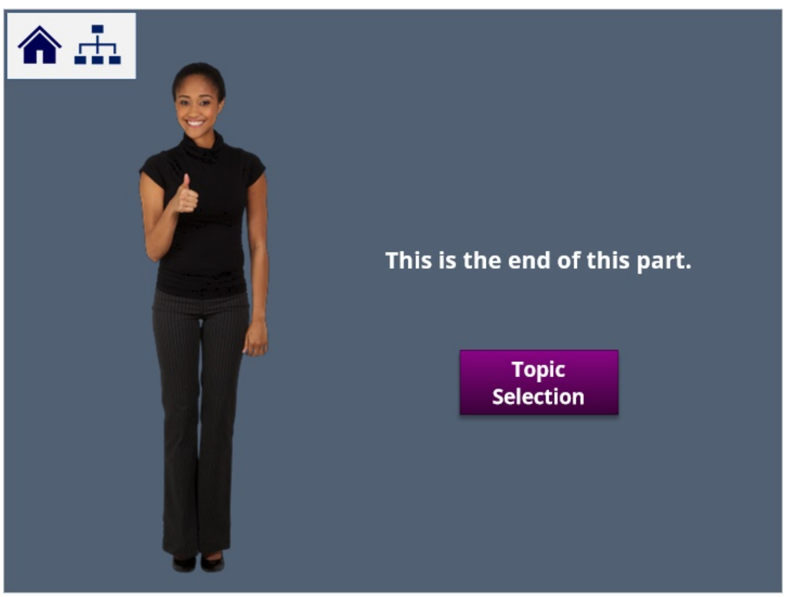
Code (Slide Layer)



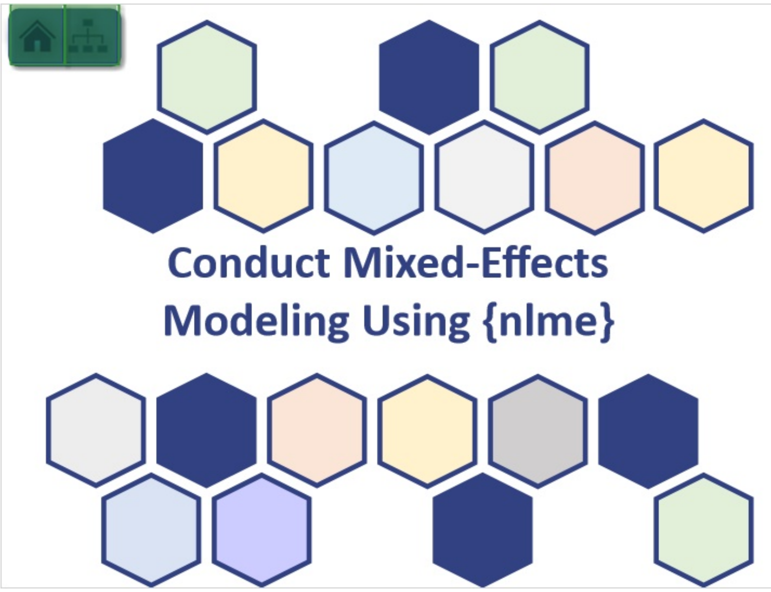
6.16 EDA 4: Example Plot



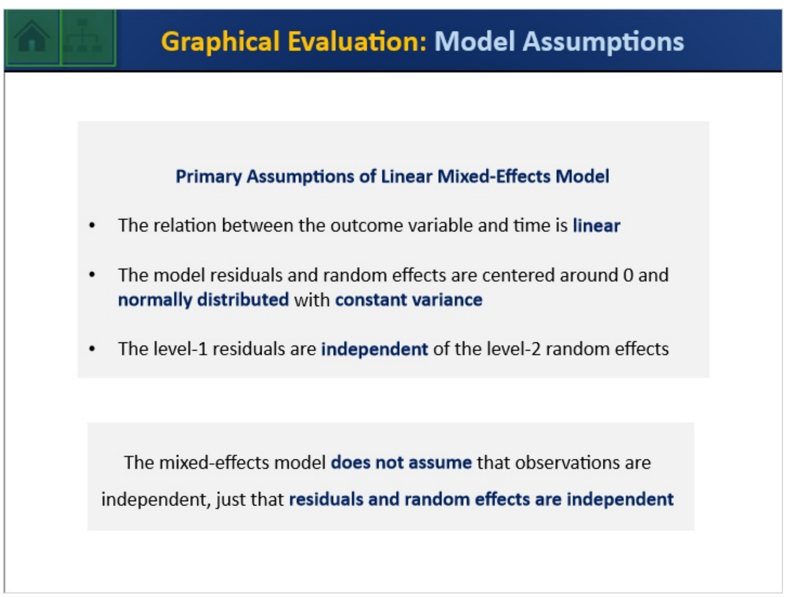
6.17 Bookend: Perform Exploratory Data Analysis



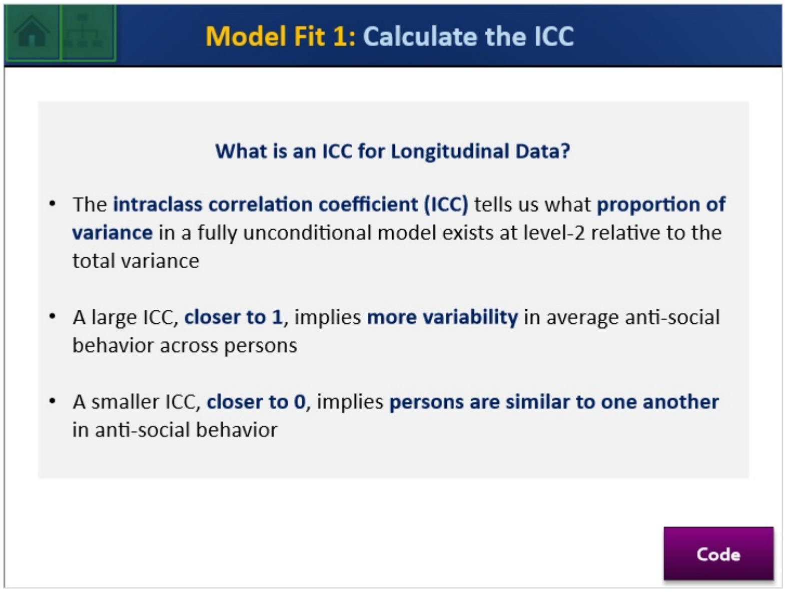
6.18 Bookmark: Conduct Mixed-Effects Modeling Using {nlme}



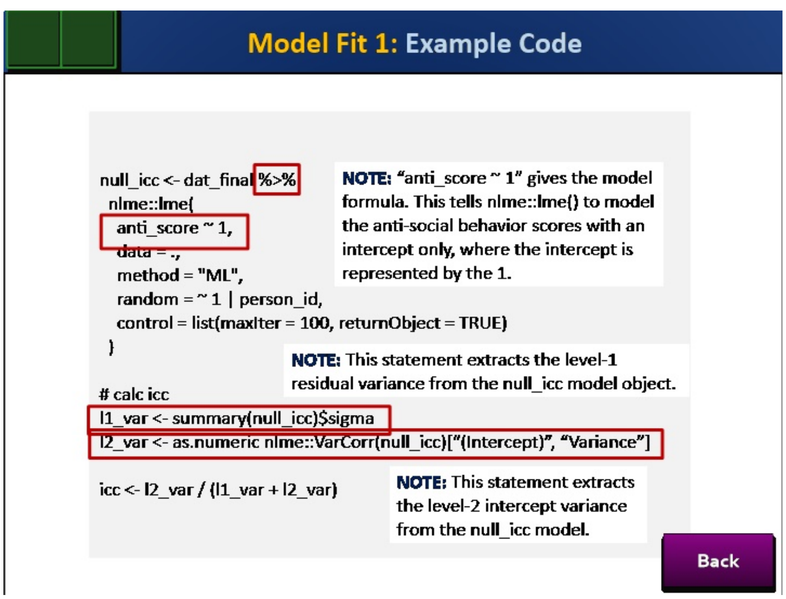
6.19 Graphical Eval: Model Assumptions



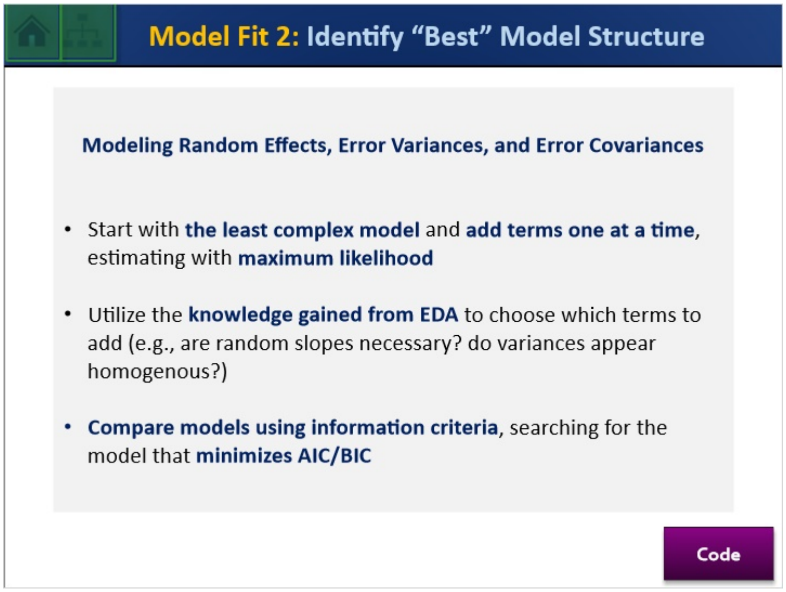
6.20 Model Fit 1: Calculate the ICC



Code (Slide Layer)



6.21 Model Fit 2: Identify "Best" Model Structure



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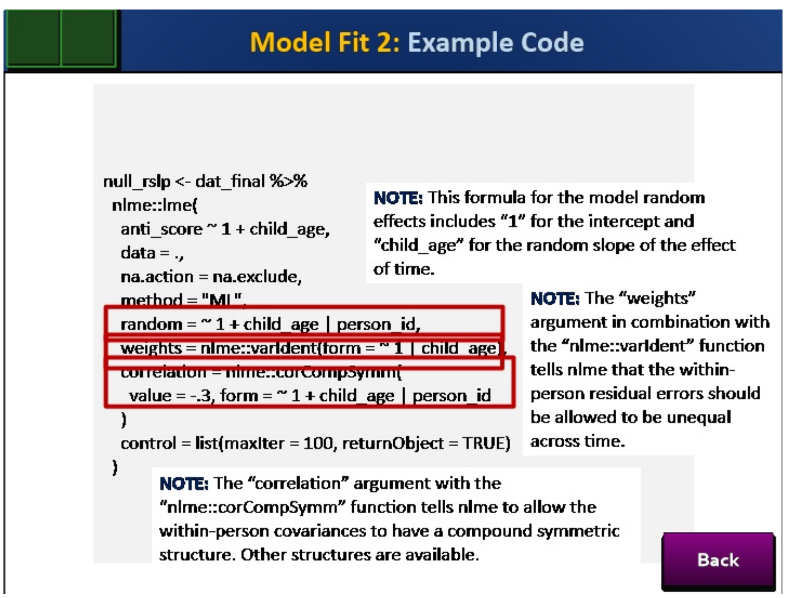
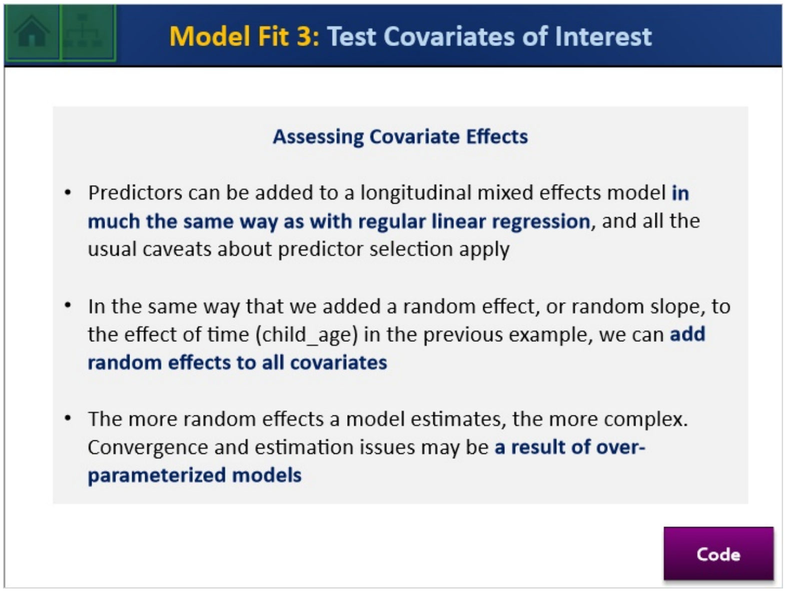


6.22 Model Fit 3: Test Covariates of Interest



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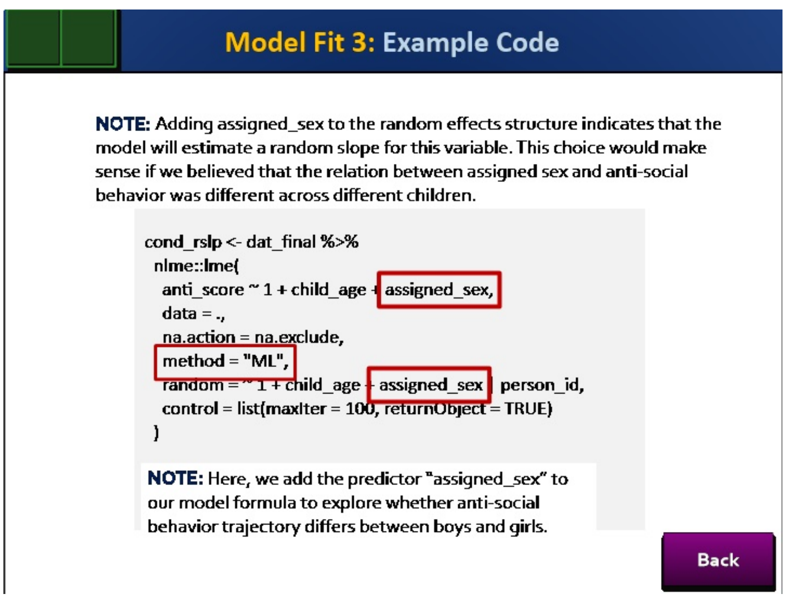
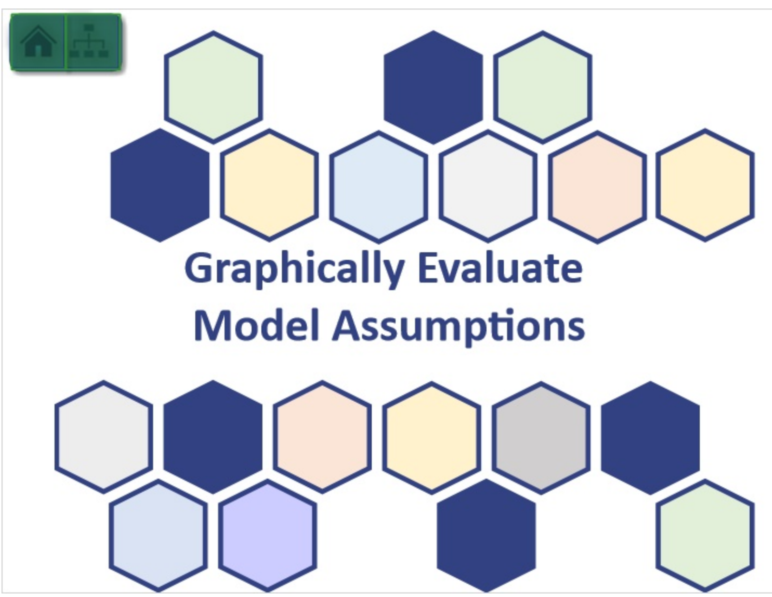
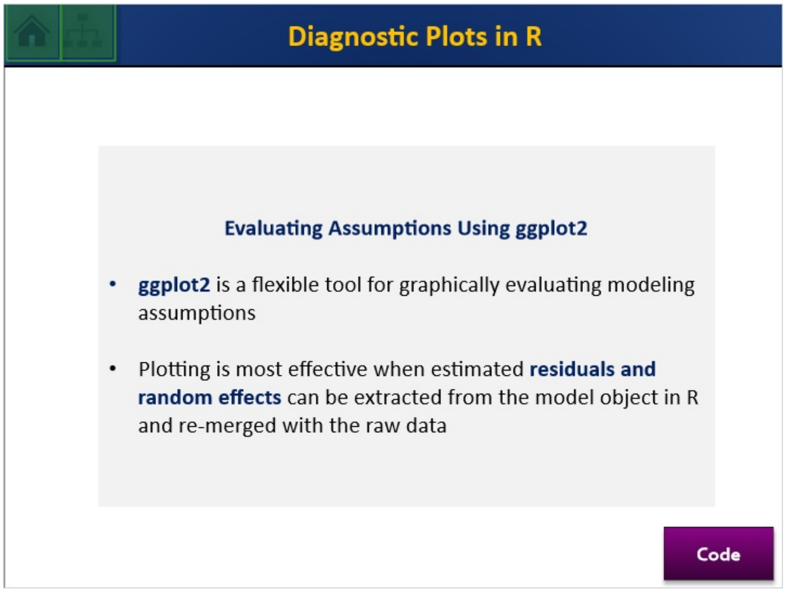


6.23 Bookend: Conduct Mixed-Effects Modeling Using {nlme}

6.24 Bookmark: Graphically Evaluate Model Assumptions



6.25 Graphical Eval: Diagnostic Plots in R



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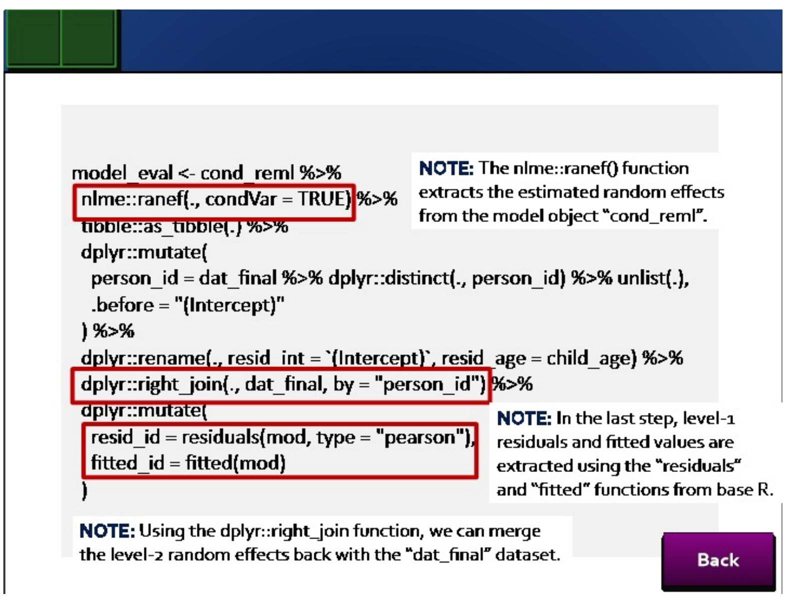
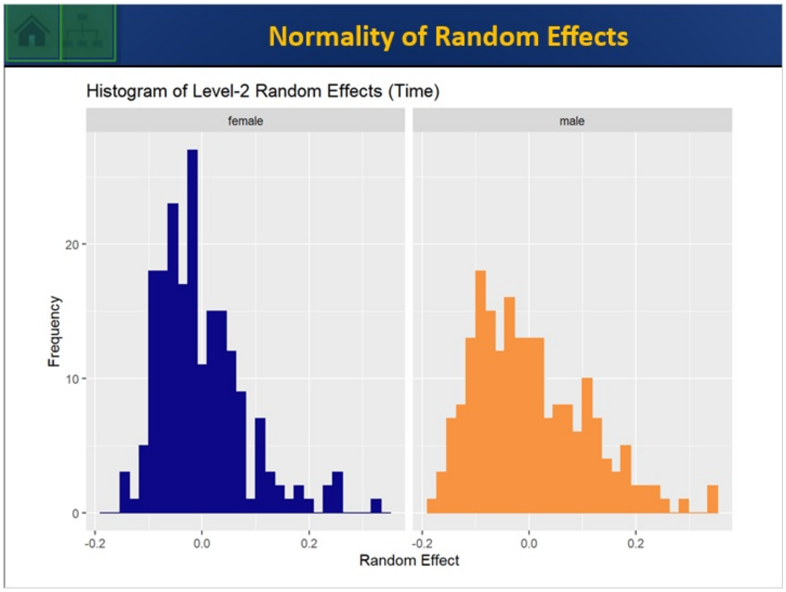
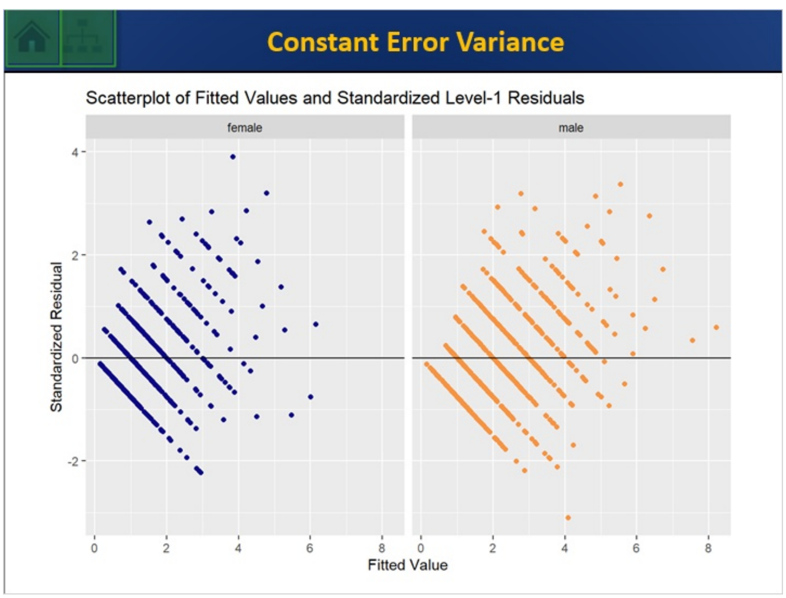


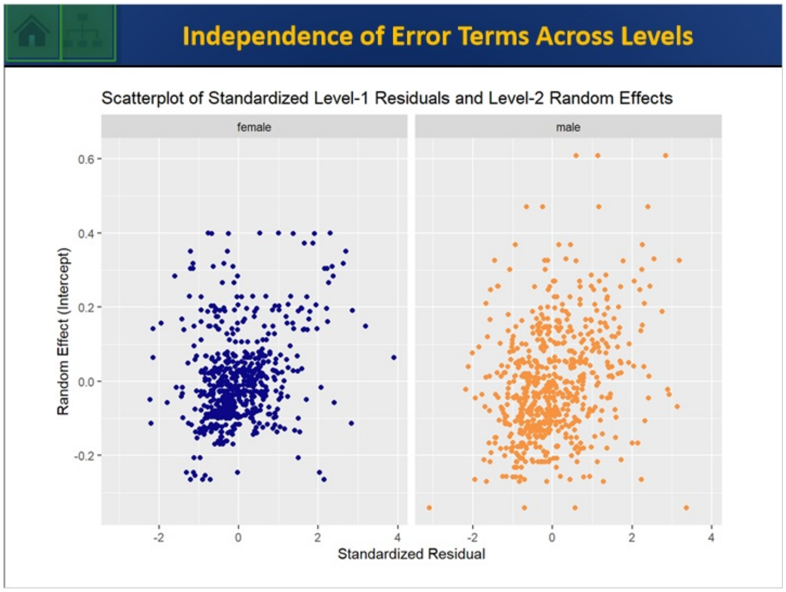
6.26 Graphical Eval: Normality of Random Effects



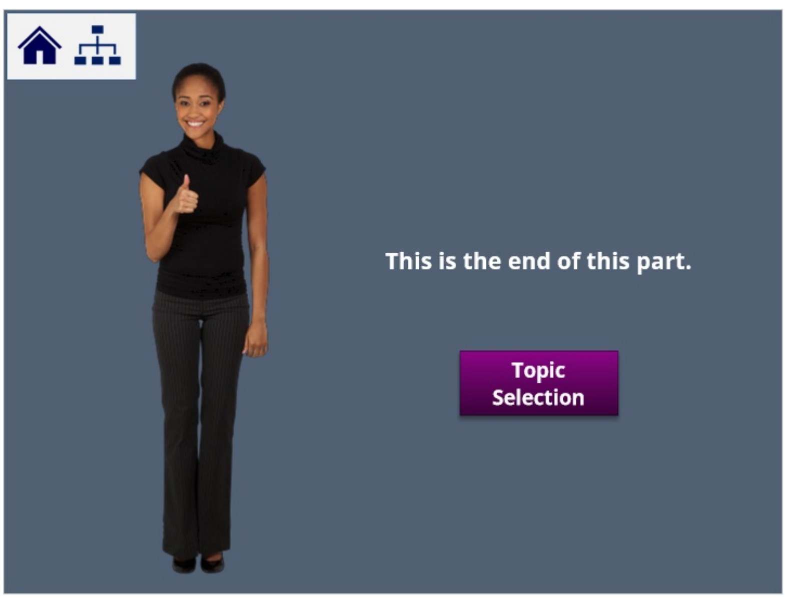
6.27 Graphical Eval: Constant Error Variance



6.28 Graphical Eval: Independence of Error Terms Across Levels

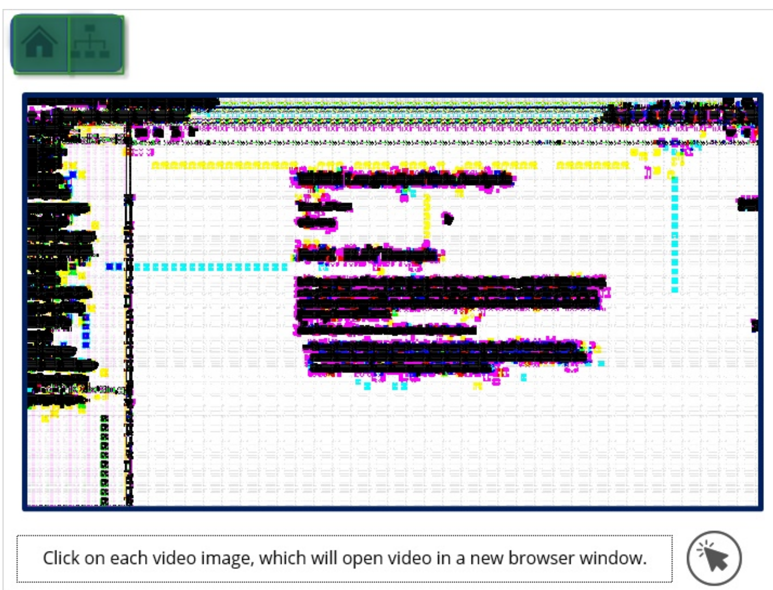


6.29 Bookend: Graphical Evaluation

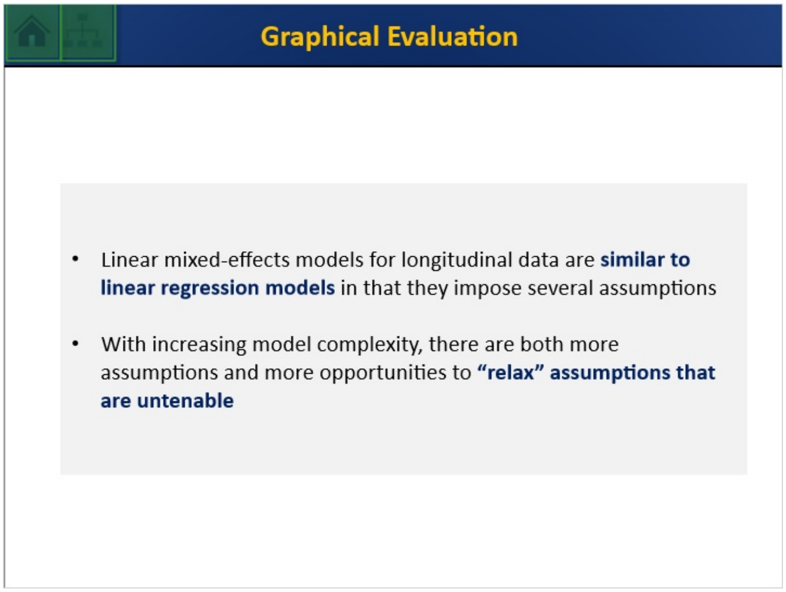


6.30 Bookmark: Real Data Analysis

6.31 Example 1

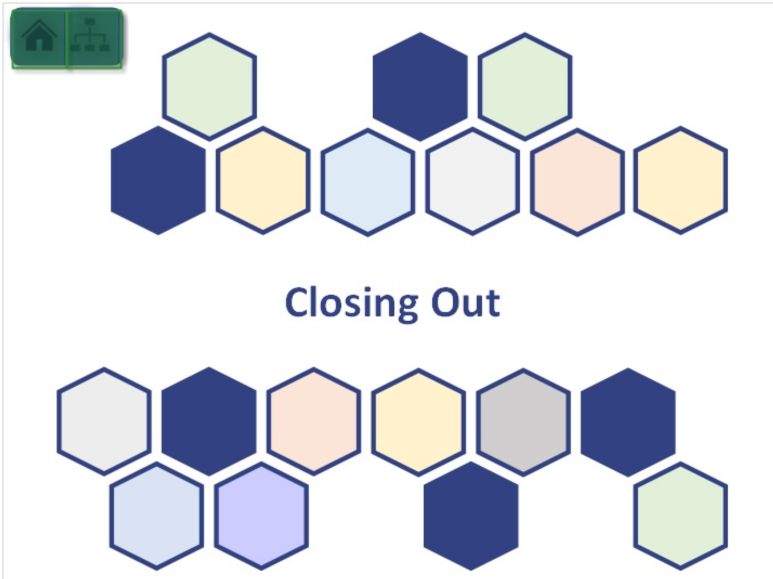


6.32 Graphical Evaluation

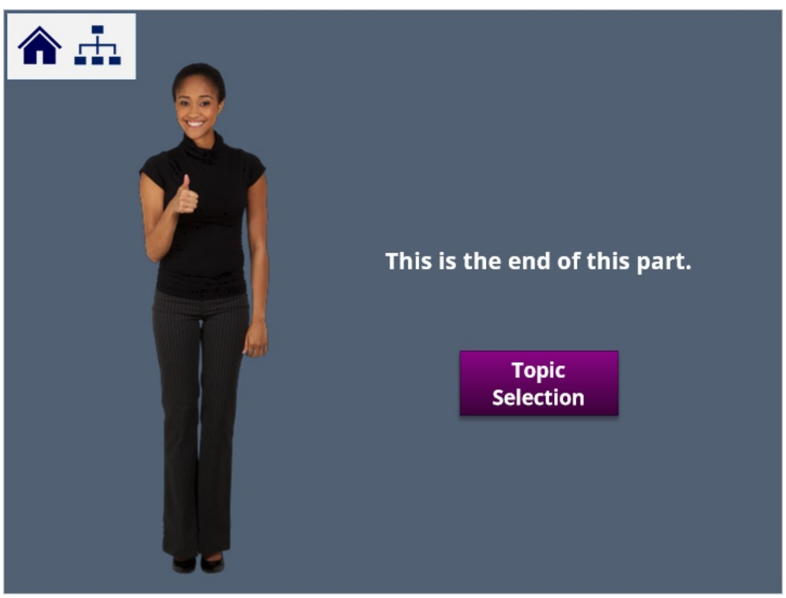


6.33 Example 2

6.34 End of Section



6.35 Bookend: Data Activity



6.36 Module Cover (END)