Understanding the Hypothesis

Course developed by
Deborah H. Glueck and Keith E. Muller

Slides developed by Jessica R. Shaw, Keith E. Muller, Albert D. Ritzhaupt and Deborah H. Glueck

 1

Learning Objectives

Define statistical models.

Describe how statistical models facilitate outcome prediction.

Describe how statistical models facilitate hypothesis testing.

2

Learning Objectives

Map
- scientific goals to research hypotheses,
- research hypotheses to statistical models,

and
- statistical models to study designs.

3

Learning Objectives

Define between-ISU hypothesis.

Define within-ISU hypothesis.

Define concept of interaction.

4

Defining statistical models for prediction and testing

5

Statistical models help summarize associations between outcomes and predictors

Accurate power and sample size calculation requires a basic understanding of statistical models.

6

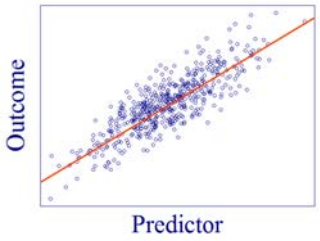
Models are used to predict outcomes and generate testable hypotheses

Statistical models calculate a predicted value of a response variable for each value or level of a predictor.

Predicted values inform hypotheses tests, which ask whether observed values are significantly different than we would expect.

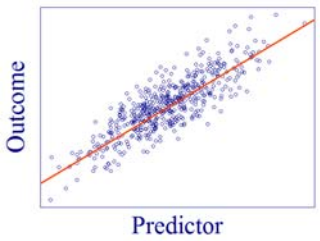
Plotting the predicted values produces a line of prediction

The line of prediction is the line that fits best when drawn through observed values of the response variable.



Hypothesis tests often evaluate whether the slope of the predicted line is equal to zero

The standardized slope of the predicted line reflects the magnitude of the association between the predictor and the response variables.



9

Statisticians aim to select a good enough statistical model to represent reality

Statistical models approximate reality using information available.

"Essentially, all models are wrong, but some are useful." Box and Draper (1987)

Box et al., 1987
Chang et al., 2010

10

Mapping scientific goals to research hypotheses, statistical models, and study designs.

11

The last step requires accounting for different terminology for statistical models and study designs

Understanding diverse terminology can ease interdisciplinary collaboration.

12

Understanding statistical terminology will prepare you to use GLIMMPSE

Recall, **GLIMMPSE** is a free, point-and-click, open-source software package for multilevel and longitudinal power and sample size calculations.

13

Terminology changes but the role of each study element remains the same

Differential Terminology by Context

Study design	Statistical model
Level	Cluster
Unit of observation	Single observed response
Between- ISU factors	Predictors or covariates
Within-ISU factors	Repeated measures

14

GLIMMPSE uses the terminology for a statistical model

Statistical Model Terminology

Term	Example
Cluster	Students in classrooms
Single observed response	Test scores measured 6 months after treatment
Predictor	Instructional method
Repeated measures	Test scores measured once per year for three years

15

Predictors are ISU factors that affect the outcome(s) of interest

Predictors may:

Be interventional or observational

Be fixed or chosen by design

Be random and unknown before the experiment is observed, but known without appreciable error once observed

Note: ISU = Independent sampling unit

16

Fixed predictors are chosen by design

Most often, the scientific goal is to understand the association between fixed **predictors** and response variables.

17

Fixed predictors are explanatory variables of interest defined by sample selection or randomization

Example	Predictor	Design Decision
Sample selection	Sex	Inclusion of 100 male participants and 100 female participants
Randomization	Treatment	Random assignment of 100 participants to the treatment condition and 100 to the control condition

18

Random predictors are quantifiable factors that vary by chance but are of experimental interest

Examples include:

- Blood pressure
- Alcohol intake

Note: ISU = Independent sampling unit

19

Random covariates are factors which impact the outcome but are not the primary explanatory variable

The value of a random covariate is not known before an experiment is observed.

Including a random covariate can help isolate the true effect of the predictor on the outcome(s) of interest by reducing the error variance.

20

A repeated measures model describes a study in which a response variable is measured multiple times

Repeated measures may take many forms:

- Longitudinal repeated measures
- Multivariate repeated measures
- Spatial repeated measures

21

Longitudinal repeated measures are within-independent sampling unit factors that vary with time

Example:

Distance walked by each participant, on each day, over one month.

Bray and Maxwell, 1985
Doncaster and Davey, 2007

22

Spatial repeated measures are within-independent sampling unit factors that vary over space

Example:

Pollution levels measured once per kilometer along a river.

Bray and Maxwell, 1985
Doncaster and Davey, 2007

23

Multivariate repeated measures are observations measured multiple times for multiple outcomes

Important note:

MultiVARIATE ≠ MultiVARIABLE

24

MultiVARIATE ≠ MultiVARIABLE

Multivariate →Multiple outcomes

Multivariable → Multiple predictors or covariates

25

COMMON STATISTICAL MODELS

26

Three statistical models are often used for multilevel and longitudinal studies

Three models:

1. The univariate linear model
2. The multivariate linear model
3. The mixed linear model

We will not discuss how to fit the models for data analysis.

27

Univariate, multivariate and mixed linear models have a common form

A model is a statement about a population:

response = prediction + error.

The adjective linear reflects the additive error and says how the parameters act on predictors.

Data analysis uses a sample of data to find estimates of the parts of the model.

We observe the response values.

28

The univariate linear model is used to analyze experiments with a single outcome measured at only one point in time

Univariate models can only be applied to uncorrelated data, as found in studies with no clustering and a single outcome measure.

29

The multivariate linear model is used to analyze experiments with multiple outcomes or hypotheses

Multivariate outcomes may be multiple time points, multiple outcome variables measured at one time point, or multiple outcome variables measured at multiple time points.

30

The mixed linear model is a more flexible model for analyzing experiments with multiple outcomes

The mixed model is more flexible because it makes fewer assumptions than the multivariate model.

We will discuss model assumptions in the next lecture.

31

Both multivariate and mixed linear models are used often for correlated data

Multivariate and mixed models are employed in studies with:

A single level and multiple outcomes;

Multiple levels and a single outcome;

Multiple levels and multiple outcomes.

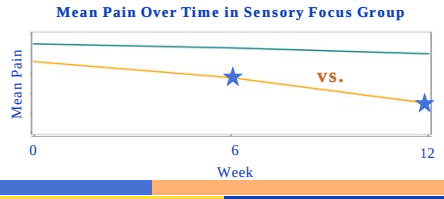
32

DEFINING STUDY HYPOTHESES

33

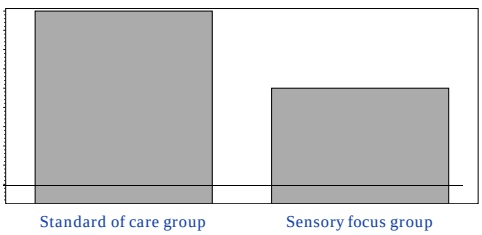
Within-ISU hypotheses are useful for tracking changes in an ISU over time

Within-independent sampling unit hypotheses compare measurements over time or space.



34

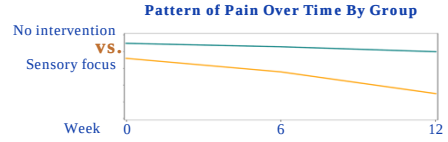
Between-ISU hypotheses help identify differences between study groups



35

Within by between-ISU hypotheses evaluate outcomes over multiple dimensions

Within by between-independent sampling unit hypotheses compare the patterns of an outcome over repeated measures across groups.



36

REVIEW OF LEARNING OBJECTIVES

37

Recall the longitudinal study of pain perceived after a root canal

Vignette

Researchers conducted a study to determine if dental patients who are instructed to use a sensory focus have a different pattern of long-term memory of pain than participants who did not.

Adapted from Logan et al., 1995

38

Vignette, continued

Participants were selected and randomly assigned to either intervention or no intervention.

Adapted from Logan et al., 1995

39

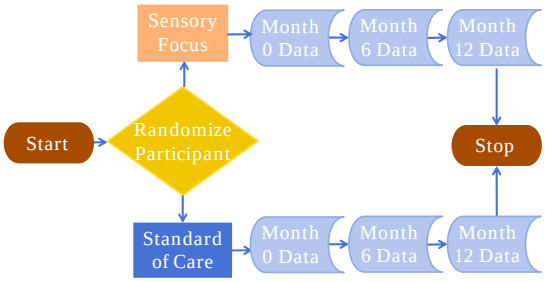
Vignette, continued

Those in the intervention group listened to automated audio instructions to pay close attention only to the physical sensations in their mouth. Patients in the no intervention group listened to automated audio instruction on a neutral topic to control for media and attention effects.

Adapted from Logan et al., 1995

40

Observed pain after root canal was measured at 0, 6, and 12 months



Adapted from Logan et al., 1995

41

Researchers analyzed three distinct hypotheses

1 Between-independent sampling unit null hypothesis:

Mean pain experienced by patients in the sensory focus treatment group does not significantly differ from that experienced by patients in the standard of care group.

Adapted from Logan et al., 1995

42

Researchers analyzed three distinct hypotheses

2 Within-independent sampling unit null hypothesis:

Mean pain experienced does not vary significantly over time.

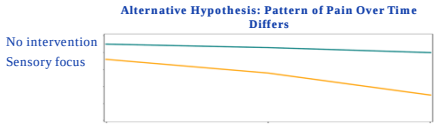
Adapted from Logan et al., 1995

43

Researchers analyzed three distinct hypotheses

3 Between by within-independent sampling unit null hypothesis:

The **pattern** of pain over time is no different for the sensory-focus group than for the control group.



Adapted from Logan et al., 1995

44

What was the independent sampling unit?

Answer: Patient

Adapted from Logan et al., 1995

45

What was the unit of observation?

Answer: Pain reported at a specific time

Adapted from Logan et al., 1995

46

What was the between-ISU factor?

Answer: Intervention group (standard-of-care or sensory focus)

Adapted from Logan et al., 1995

47

What was the between-ISU hypothesis?

There is no significant difference in the mean pain experienced by patients in the sensory focus group and the standard-of-care group.

48

What was the within-ISU factor?

Answer: Time

Adapted from Logan, Baron, and Kohout, 1995

49

What was the within-ISU hypothesis?

There is no significant difference in mean pain reported over time.

50

What was the between by within-ISU hypothesis?

The pattern of pain experienced over time does not differ between patients in the sensory focus group and those in the standard of care group.

51


Questions?
52