Comparing Means with Two Predictor Variables (Two-Way ANOVA)

PY 221 Statistics & Research Methods I

Dr. Valenti

Outline for **Two-Way ANOVA**

1. Overview, including review of prior statistical tests & new terms
2. Factorial designs
3. What hypotheses are being tested with two-way ANOVA?
   - main effects
   - interactions

We're doing a VERY BRIEF introduction to an advanced topic, just so that you'll have exposure to it when you encounter it in PY 222 (and future courses).

REVIEW

- What do ***t*-tests** allow you to do?
  - examine whether the apparent **differences** between **two groups** on a quantitative outcome variable are real differences (vs. produced by chance)
  - examine whether the apparent **changes** in people's quantitative scores across **two time points** are real changes (vs. produced by chance)

REVIEW

- What does **ANOVA** allow you to do?
  - examine whether apparent **differences** between **three or more groups** on a quantitative outcome variable are real differences (vs. produced by chance)

One-way ANOVA — can be used with **only ONE** qualitative predictor/IV with 3+ categories, when predictor/IV is between-subjects

Two-way ANOVA — can be used with **only TWO** qualitative predictors/IVs with 2+ categories, when predictor/IV is between-subjects

We'd need to use *repeated-measures ANOVA* (will not cover this semester) — Neither one-way nor two-way ANOVA can be used for within-subjects designs

Research questions that would involve one-way or two-way ANOVA - examples

One-way ANOVA b/c **<u>one</u> predictor/IV**

1. Does taking **notes by hand**, taking **notes w/a laptop**, or **not taking notes** in class cause better understanding of the material?

Two-way ANOVA b/c **<u>two</u> predictors/IVs**

2. Do **low-carb diets** or **low-fat diets** lead to greater energy levels in college students, and does the effect of diet on energy depend on whether the student **plays a college sport** or **does not play a college sport**?
   - 2 predictor variables: (1) type of diet, (2) whether or not play college sport
     - *In this example, each predictor has 2 levels/groups/conditions, but two-way ANOVA can also be used if the predictors have >2 levels.*

Practice with a research question that would involve TWO-WAY ANOVA

two-**factor** ANOVA

Does taking notes **by hand** or **with a laptop** cause better understanding of the material, and does it depend on whether a student has **neat or messy handwriting**?

factors

1. How many predictors/IVs are there? Name them. What are its/their levels?

2. How many outcomes/DVs are there? Name them/it.

Answer:

1. Two predictor variables: (1) note-taking method, with two levels: by hand vs. with laptop and (2) handwriting, with two levels: neat vs. messy.
2. One DV, which is understanding of the material

Outline for **Two-Way (Two-Factor) ANOVA**

1. Overview, including review of prior statistical tests & new terms
2. Factorial designs
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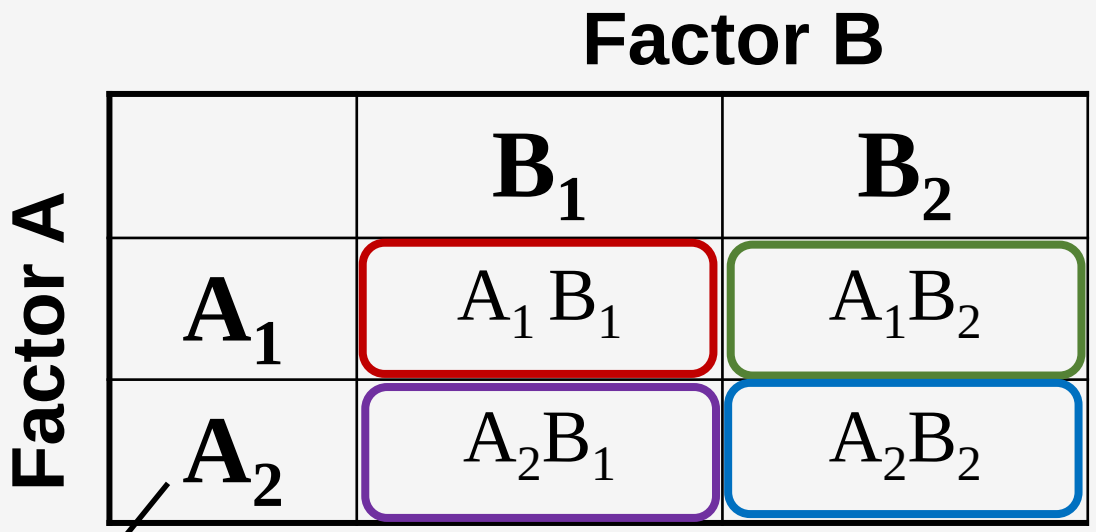
Two-way (Two-factor) ANOVA: For comparing differences among means when there are two *factors*

- Factor: an independent variable (IV), or a measured predictor variable
  - Remember: with ANOVA, our factors are always qualitative (rather than quantitative)

- Factorial design: any study design with 2 or more factors
  - Each factor will always have 2 or more levels (otherwise it wouldn't be a variable!)
  - **Two-factor** ANOVA involves study designs with **only 2** factors
    - A sub-set of these two-factor designs has <u>two factors that each have **only two levels**</u>
      These are known as 2 x 2 factorial designs

Table Depiction of a 2 x 2 Factorial Design & Terminology



A *level* of Factor A

Each combination of factors (E.g., A_1 B_1) is called a *cell*.

Assume equal #s of Ps in each cell.
Assume there are different Ps in each cell (fully between-subjects).

2 x 2 factorial design

This *first* "2" refers to the *first* factor, factor **A**, and the "2" indicates that factor A has 2 levels (A_1 and A_2).

This *second* "2" refers to the *second* factor, factor **B**, and the "2" indicates that factor B has 2 levels (B_1 and B_2).

How would you describe these 2x2 designs using APA style?

Research Question: Does taking **notes by hand** or taking **notes w/a laptop** cause better understanding of the material, and does it depend on whether a student has **neat or messy handwriting**?

Using APA Style to describe the study design

Design:

This study has a 2 (note-taking method: by hand vs. laptop) x 2 (handwriting: neat vs. messy) factorial design.

OR

This study has a 2 (handwriting: neat vs. messy) x 2 (note-taking method: by hand vs. laptop) factorial design.

*Notice how the **design** itself does not mention the outcome variable (DV).*

Practice writing the design using APA style…

Does watching the movie ***Scream***, or watching the **news** produce greater anxiety, and does the relationship between stimulus watched and anxiety depend on whether the **room** for watching **is completely dark vs. very bright**?

Practice writing the design using APA style…

Does watching the movie ***Scream*** or watching the **news** produce greater anxiety, and does the relationship between stimulus watched and anxiety depend on whether the **room** for watching **is completely dark vs. very bright**?

This study has a 2 (stimulus watched: *Scream* vs. the news) x 2 (amount of light in room: dark vs. bright) factorial design.

or

This study has a 2 (amount of light in room: dark vs. bright) x 2 (stimulus watched: *Scream* vs. the news) factorial design.

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REVIEW: What does a one-way ANOVA tell us?

- We're testing a hypothesis about… the size of the difference between multiple groups *when those groups all come from one IV/predictor*.

- Hypotheses tested with one-way ANOVA (i.e., an *F*-test)
  - **null hypothesis**: the difference between our group means = 0.

(e.g., There's NO effect of note-taking method (IV) on understanding (DV).)

  - **alternative hypothesis**: the difference between our group means ≠ 0.

(e.g., There IS an effect of note-taking method (IV) on understanding (DV).)

Hypothesis testing for two-factor ANOVA

- We're essentially doing **three separate** (independent) hypothesis tests.
- By **separate**, I mean that the results of one test tell us nothing about (are unrelated to) the results of any of the other tests.

- With our three tests, we are learning:
  1. whether or not **Factor A** has an effect on the DV,
  2. whether or not **Factor B** has an effect on the DV,
  3. whether or not the effect of one of these factors on the DV depends on the other factor.

Hypothesis testing for two-factor ANOVA

- We're essentially doing three separate (independent) hypothesis tests.
- We are learning:

Another way of saying the same thing…

1. whether there's a difference in means of the DV across the conditions of **Factor A**,
2. whether there's a difference in means of the DV across the conditions of **Factor B**,
3. whether or not the differences in the DV across conditions of Factor A are different across each level of Factor B.

Hypothesis testing for two-factor ANOVA

- We're essentially doing three separate (independent) hypothesis tests.

Another way of saying the same thing…

- We are learning:
  1. whether there's a main effect of **Factor A** on the DV,
  2. whether there's a main effect of **Factor B** on the DV,
  3. whether there's an interaction between Factor A and Factor B when predicting the DV.

* Do not reverse the IV and DV. We always say "main effect of [IV] on [DV]"

Example: Hypothesis Testing for the **Note-Taking Study**

- DV/outcome = **understanding** of material (quiz score)
- Factor A = note-taking method (by hand vs. w/laptop) *randomly assigned*
- Factor B = handwriting (neat vs. messy) *known ahead of time for all Ps*

We're essentially doing three separate (independent) hypothesis tests.

We are learning:

1. whether or not **note-taking method** has an effect on **understanding of material**,
2. whether or not **handwriting** has an effect on **understanding of material**,
3. whether or not the effect of note-taking method on understanding of the material depends on a student's handwriting.

Example: Hypothesis Testing for the **Note-Taking Study**

- DV/outcome = **understanding** of material
- Factor A = note-taking method (by hand vs. w/laptop)
- Factor B = handwriting (neat vs. messy)

We're essentially doing three separate (independent) hypothesis tests.

We are learning:

1. whether there's a difference in mean **understanding** across the 2 conditions of **note-taking method**,
2. whether there's a difference in mean **understanding** across the 2 conditions of **handwriting**,
3. whether or not the differences in understanding caused by note-taking method are different across each level of student handwriting.

Example: Hypothesis Testing for the **Note-Taking Study**

- DV/outcome = **understanding** of material
- Factor A = note-taking method (by hand vs. w/laptop)
- Factor B = handwriting (neat vs. messy)

We're essentially doing three separate (independent) hypothesis tests.

We are learning:

1. whether there's a main effect of **note-taking method** on **understanding**,
2. whether there's a main effect of **handwriting** on **understanding**,
3. whether or not there's an interaction between note-taking method and a student's handwriting when predicting understanding.

DV = understanding of material, as measured by scores on quiz at end of class

Factor B

Handwriting (known prior to study)

Factor A: Note-taking Method	Neat	Messy
By hand		
Laptop		

DV = understanding of material, as measured by scores on quiz at end of class

N = 60

n = 15 per cell

Factor B

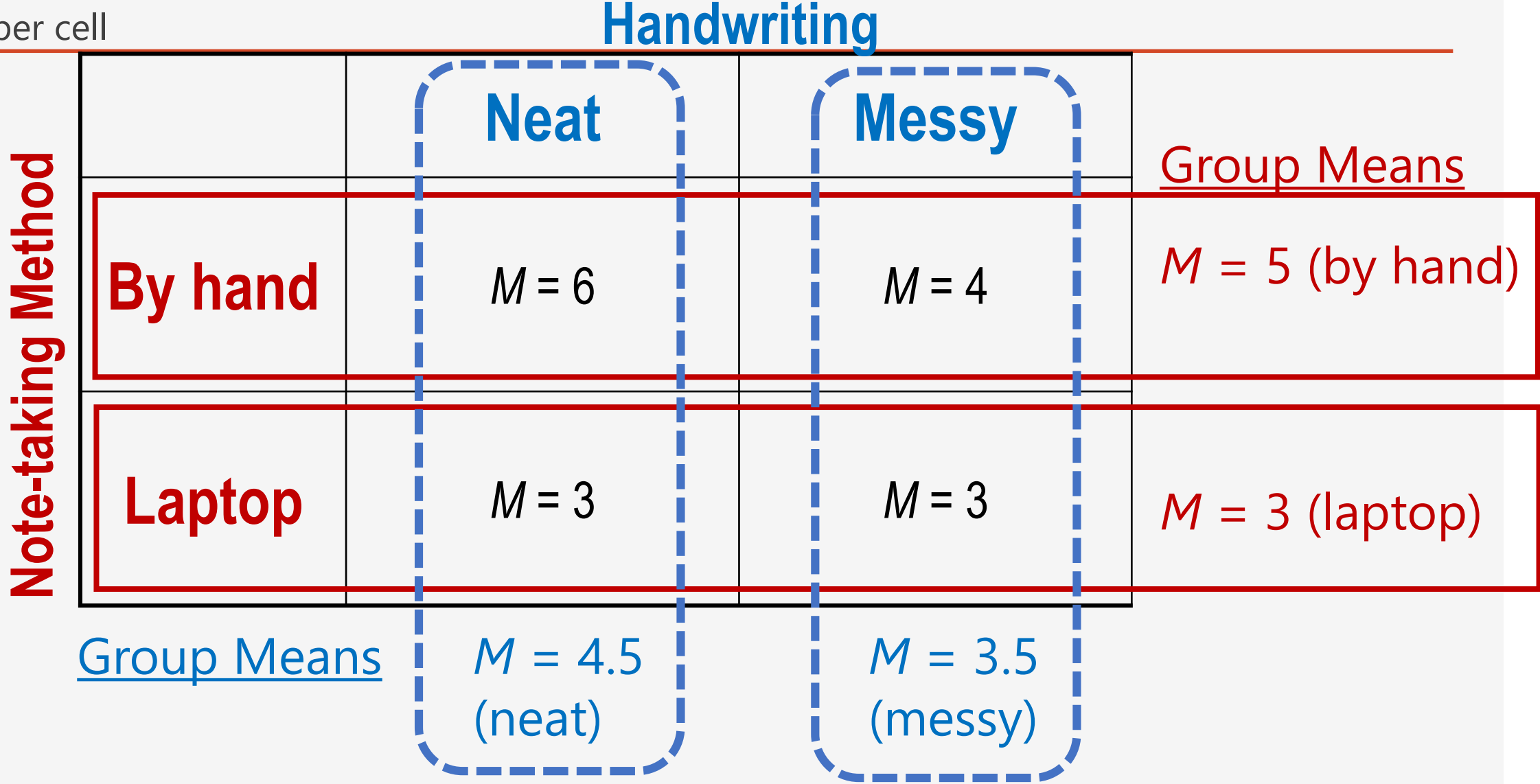
Handwriting (known prior to study)

Factor A: Note-taking Method	Neat	Messy
By hand		
Laptop		

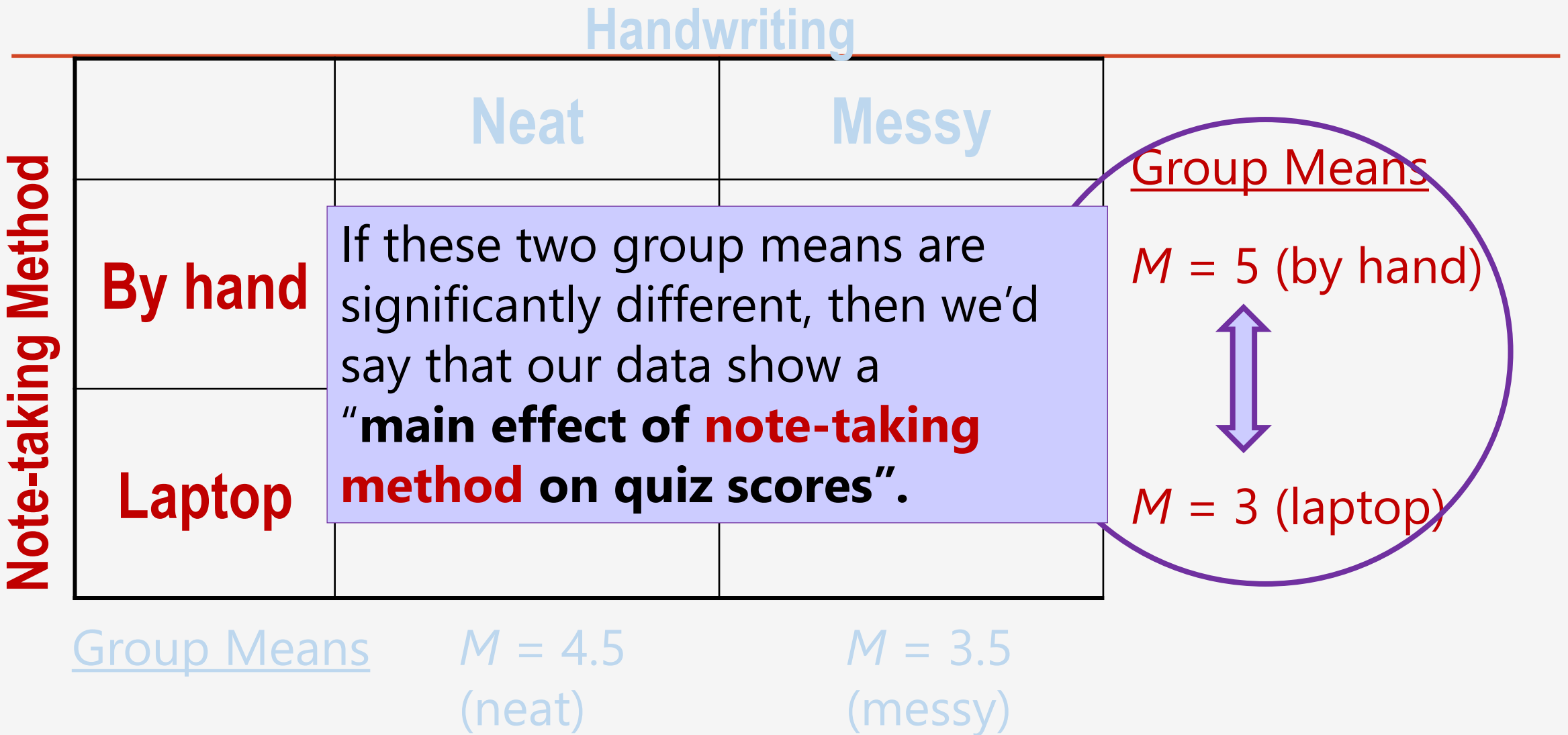
DV = understanding of material, as measured by scores on quiz at end of class

N = 60

n = 15 per cell



DV = understanding of material, as measured by scores on quiz at end of class



DV = understanding of material, as measured by scores on quiz at end of class

Handwriting

Note-taking Method	Neat	Messy	Group Means
By hand			M = 5 (by hand)
Laptop			M = 3 (laptop)
Group Means	M = 4.5 (neat)	M = 3.5 (messy)	

If these two group means are significantly different, then we'd say that our data show a "**main effect of handwriting on quiz scores**".

Outline for Two-Way ANOVA

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2. What hypotheses are being tested with two-way ANOVA?
   - Main effects
   - Interactions

First, an example . . .

What is the effect on your health of taking drug A?

- Drug **interaction** (DV)
  - The effect on your health (DV) of whether or not you take drug A (IV #1, factor A) *depends on* whether or not you are taking drug B (IV #2, factor B).

(factor B)

Whether or not you are taking drug B

(factor A)

Whether or not you are taking drug A

	You take drug B	**You don't take drug B**
You take drug A	*Severe risk for a heart attack*	*Good health*
You don't take drug A	*Poor health*	*Poor health*

Hypothesis testing for two-factor ANOVA

- We're essentially doing three separate (independent) hypothesis tests.
- We are learning:
  1. whether or not **Factor A** has an effect on the DV,
  2. whether or not **Factor B** has an effect on the DV,
  3. whether or not the effect of one of these factors on the DV depends on the other factor.

Hypothesis testing for two-factor ANOVA

- We're essentially doing three separate (independent) hypothesis tests.

Same meaning as prior slide, but re-stated…

- We are learning:
  1. whether there's a difference in means of the DV across the conditions of Factor A,
  2. whether there's a difference in means of the DV across the conditions of Factor B,
  3. whether or not the differences in the DV across conditions of Factor A are different across each level of Factor B.

Hypothesis testing for two-factor ANOVA

- We're essentially doing three separate (independent) hypothesis tests.

Same as prior 2 slides, but re-stated…

- We are learning:
  1. whether there's a main effect of Factor A on the DV,
  2. whether there's a main effect of Factor B on the DV,
  3. whether there's an interaction between **Factor A** and **Factor B** when predicting the DV.
     - Also called a "two-way interaction"

Two-way Interactions

- **Two**-way interactions are interactions between **two** *factors*, when predicting a ***DV***

- *Two-way interaction, defined*
  - When the effect of one factor on the **DV** depends on the different levels of a second factor.

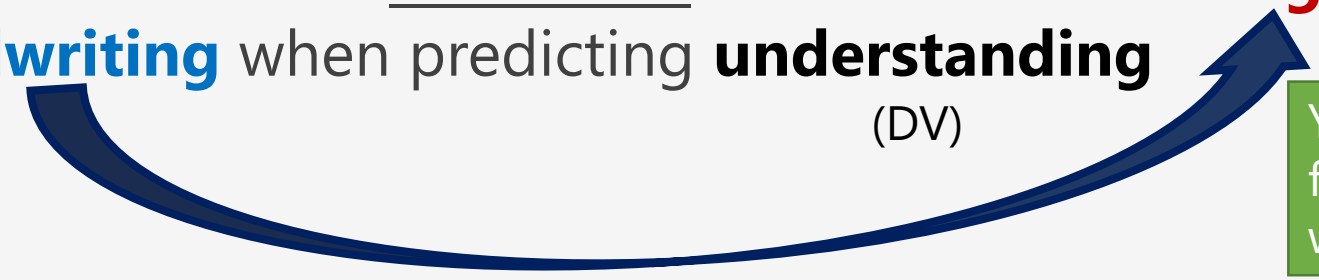
"is different across"

Example: Hypothesis Testing for Note-Taking Study

- DV/outcome = post-class level of understanding of material
- Factor A = note-taking method (by hand vs. laptop)
- Factor B = handwriting (neat vs. messy)

We're essentially doing three separate (independent) hypothesis tests.

1. whether there's a main effect of **note-taking method** on **understanding**,
2. whether there's a main effect of **handwriting** on **understanding**,
3. whether there's an interaction between **note-taking method** and **handwriting** when predicting **understanding** (DV)



You can also reverse the two factors (predictors/IVs), and this would mean the same thing.

Example: Hypothesis Testing for Note-Taking Study

- DV/outcome = post-class level of understanding of material
- Factor A = note-taking method (by hand vs. laptop) *randomly assigned*
- Factor B = handwriting (neat vs. messy) *known ahead of time for all Ps*

We're essentially doing three separate (independent) hypothesis tests.

1. whether or not **note-taking method** has an effect on **understanding of material**, and
2. whether or not **handwriting** has an effect on the **understanding of material**, and
3. whether or not the effect of **note-taking method** on **understanding of material** depends on **handwriting**.

(DV)

You can also reverse the two factors (predictors/IVs), and this would mean the same thing.

Example: Hypothesis Testing for Note-Taking Study

- DV/outcome = post-class level of understanding of material
- Factor A = note-taking method (by hand vs. laptop)
- Factor B = handwriting (neat vs. messy)

We're essentially doing three separate (independent) hypothesis tests.

1. whether there's a difference in mean **understanding** across the 2 conditions of **note-taking method**, *and*
2. whether there's a difference in mean **understanding** across the 2 conditions of **handwriting**, *and*
3. whether the differences in mean **understanding** (DV) across the conditions of **note-taking method** are different across each level of **handwriting**

You can also reverse the two factors (predictors/IVs), and this would mean the same thing.

DV = understanding of material, as measured by scores on quiz at end of class

N = 60

n = 15 per cell

Handwriting

Note-taking Method	Neat	Messy
By hand	*M* = 6	*M* = 4
Laptop	*M* = 3	*M* = 3

If there is a two-way interaction, then the effect of note-taking method on quiz score will look different depending on whether handwriting is **neat** vs. **messy**.

Q: When handwriting is **NEAT**, how does note-taking affect quiz score?

Q: When handwriting is **MESSY**, how does note-taking affect quiz score?

If the two answers are the same → **no interaction**

If the two answers are different → there ***is* an interaction**

DV = understanding of material, as measured by scores on quiz at end of class

N = 60

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Handwriting

Note-taking Method

	Neat	Messy
By hand	*M* = 6	*M* = 4
Laptop	*M* = 3	*M* = 3

If there is a two-way interaction, then the effect of note-taking method on quiz score will look different depending on whether handwriting is **neat** vs. **messy**.

The hypothesis test for the interaction reveals whether these apparent differences are *real* (i.e., produced by chance or *significantly different*).

Q: When handwriting is **NEAT**, how does note-taking affect quiz score?

Q: When handwriting is **MESSY**, how does note-taking affect quiz score?

If the two answers are the same → **no interaction**

If the two answers are different → there ***is* an interaction**

A: By hand is ***3 pts greater*** than *laptop* when handwriting is NEAT

A: By hand is *only* ***1 pt greater*** than *laptop* when handwriting is MESSY