Analysis of Psychological Data

Lab 12. One More Time One More Measurement: Repeated Measures ANOVA

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Announcement

Lab 11

About main effect and interaction effect $\longrightarrow$ very important!

I will upload my recording, so please watch it!

Supercharge assignment $\longrightarrow$ refill your GPA $\longrightarrow$ due November 28

Assignment 5 (final assignment) $\longrightarrow$ due December 7

Exam 3 $\longrightarrow$ You can work in pairs, so find your partner!

Announcement

We do **not** have a lab on November 26

We have our **final** lab on December 3

Will be about correlation and regression

A small remark on using p-values $\longrightarrow$ Do you remember a black bear story?

Are you happy or sad that this will be our last meeting? :)

What are we going to do?

Recap to give you a big picture

Repeated measures ANOVA

Do it together

Let's conquer ANOVA

Big idea

Goal is to compare the means of the dependent variables across different levels of the independent variables (*aka*. factor = grouping variable)

A brief example

Brandon and Michael investigate whether there are mean differences of happiness in the school type (UC Merced, Merced College, and Merced High School)

What are DV, IV, level of IV?

Let's conquer ANOVA

N-way (or N-factor) ANOVA (# of factors)

There are N independent variables (IVs = factors = grouping variables)

N = 1 $\longrightarrow$ One-way ANOVA = ANOVA with 1 IV

N = 2 or more $\longrightarrow$ Factorial ANOVA $\longrightarrow$ Start to consider interactions

A $\times$ B $\times$ C $\times$ ... $\times$ D ANOVA (# of levels)

4 $\times$ 4 $\times$ 4 ANOVA = ANOVA with 3 IVs, each with 4 levels

Let's conquer ANOVA

Between-subjects factor

Factor separates groups of **different** individuals

Each score comes from a different subject

Example?

Clinical therapy (behavioral, cognitive, control)

Place of birth (California, Oregon, Florida, Arizona)

Let's conquer ANOVA

Within-subjects factor

Factors separate multiple measures within the **same** individuals

Each subject provides scores under multiple conditions/timepoints

Example?

Time (measurements at time 1, time 2, and time 3)

Repeated measurements in general!

Repeated measures ANOVA

ANOVA with within-subjects factors

In this course, we focus on **one-way repeated measures ANOVA**

A research question investigates whether there are mean differences across the repeated measurements of the same individuals!

Repeated measures ANOVA

1. State the null and alternative hypotheses
2. Choose α level (usually 0.05)
3. Calculate ANOVA table (finding means, SS, df, MS, and observed F value)
4. Determine df1 and df2
5. Locate critical F value
6. Compare the observed F value to the critical F value
7. (If necessary) effect size

Do it together

Shelby and Vanessa are data analysts at Marvel Studios. They are investigating how much people are looking forward to watching the upcoming Spider-Man: No Way Home across three consecutive occasions (September, October, and November). They recruited 5 students at UC Merced and let them record how excited they are to see the movie each month.

Which statistical analysis should be performed?

What are the null and alternative hypotheses?

Do it together

$H_0 : \mu_{Sep} = \mu_{Oct} = \mu_{Nov}$
$\rightarrow$ The means of the degree of excitement are the same across the three months

H_1: Not all μ_{Month} are equal
$\rightarrow$ All the means of the degree of excitement are not equal

Let's use α-level (i.e., significance level) of 0.05.

Do it together

From now on, we will fill in the ANOVA table

Do you remember Sum of Squares (SS)?

ANOVA $\longrightarrow$ Analysis of Variance $\longrightarrow$ Variance
$\longrightarrow$ Sum of squares divided by the degrees of freedom $\longrightarrow$ SS is important
$\longrightarrow$ We separate SS into different sources $\longrightarrow$ In general, separation into between and within

Do it together

Separating SS

One-way ANOVA $\rightarrow SS_{Tot.} = SS_{Bet.} + SS_{With.}$

Two-way ANOVA $\rightarrow SS_{Tot.} = SS_{F1} + SS_{F2} + SS_{Int.} + SS_{With.}$

One-way repeated measures ANOVA $\rightarrow SS_{Tot.} = SS_{Bet.} + SS_{Subj.} + SS_{Err.}$

REMEMBER: $SS_{With.} = SS_{Subj.} + SS_{Err.}$ in case of one-way RM ANOVA

Rule applies to the degrees of freedom!

Do it together

Our data

Student ID	September	October	November
1	1	2	3
2	1	3	5
3	2	4	6
4	1	4	7
5	5	5	5

Do it together

Our data in a different way

Student ID	Condition	Excitement
1	September	1
1	October	2
1	November	3
2	September	1
2	October	3
2	November	5
3	September	2
3	October	4
3	November	6
4	September	1
4	October	4
4	November	7
5	September	5
5	October	5
5	November	5

Do it together

We need these means

	September	October	November
Condition (Month)	(1+1+2+1+5)/5=2	(2+3+4+4+5)/5=3.6	(3+5+6+7+5)/5=5.2

	1	2	3	4	5
Subject (Student)	(1+2+3)/3=2	(1+3+5)/3=3	(2+4+6)/3=4	(1+4+7)/3=4	(5+5+5)/3=5

Grand mean	(1+2+3+1+3+5+2+4+6+1+4+7+5+5+5)/15 = 3.6

Do it together

$SS_{Bet.}$ $\rightarrow$ subtract grand mean from the mean of each level/condition $\rightarrow$ 25.6

Student ID	Condition	Excitement	$SS_{between}$
1	September	1	$(2-3.6)^2$
1	October	2	$(3.6-3.6)^2$
1	November	3	$(5.2-3.6)^2$
2	September	1	$(2-3.6)^2$
2	October	3	$(3.6-3.6)^2$
2	November	5	$(5.2-3.6)^2$
3	September	2	$(2-3.6)^2$
3	October	4	$(3.6-3.6)^2$
3	November	6	$(5.2-3.6)^2$
4	September	1	$(2-3.6)^2$
4	October	4	$(3.6-3.6)^2$
4	November	7	$(5.2-3.6)^2$
5	September	5	$(2-3.6)^2$
5	October	5	$(3.6-3.6)^2$
5	November	5	$(5.2-3.6)^2$

Do it together

$SS_{With.}$ $\rightarrow$ subtract the mean of each level/condition from individual scores $\rightarrow$ 36

Student ID	Condition	Excitement	SS_{within}
1	September	1	$(1-2)^2$
1	October	2	$(2-3.6)^2$
1	November	3	$(3-5.2)^2$
2	September	1	$(1-2)^2$
2	October	3	$(3-3.6)^2$
2	November	5	$(5-5.2)^2$
3	September	2	$(2-2)^2$
3	October	4	$(4-3.6)^2$
3	November	6	$(6-5.2)^2$
4	September	1	$(1-2)^2$
4	October	4	$(4-3.6)^2$
4	November	7	$(7-5.2)^2$
5	September	5	$(5-2)^2$
5	October	5	$(5-3.6)^2$
5	November	5	$(5-5.2)^2$

Do it together

$SS_{Subj.}$ $\rightarrow$ subtract grand mean from the mean of subjects $\rightarrow$ 15.6

Student ID	Condition	Excitement	$SS_{subject}$
1	September	1	$(2-3.6)^2$
1	October	2	$(2-3.6)^2$
1	November	3	$(2-3.6)^2$
2	September	1	$(3-3.6)^2$
2	October	3	$(3-3.6)^2$
2	November	5	$(3-3.6)^2$
3	September	2	$(4-3.6)^2$
3	October	4	$(4-3.6)^2$
3	November	6	$(4-3.6)^2$
4	September	1	$(4-3.6)^2$
4	October	4	$(4-3.6)^2$
4	November	7	$(4-3.6)^2$
5	September	5	$(5-3.6)^2$
5	October	5	$(5-3.6)^2$
5	November	5	$(5-3.6)^2$

Do it together

Fill in the ANOVA table

REMEMBER: $SS_{With.} = SS_{Subj.} + SS_{Err.}$ in case of one-way RM ANOVA
That is, $SS_{Err.} = SS_{With.} - SS_{Subj.}$

Source	SS	df	MS	$F_{observed}$	$F_{critical}$
Between	$SS_{between}$	J-1	$MS_{between}$	$MS_{between}/MS_{error}$	F table with $df_{between}$ & df_{error}
Subject	$SS_{subject}$	S-1	$MS_{subject}$		
Error	SS_{error}	(J-1)(S-1)	MS_{error}		
Total	SS_{total}	N-1			

Do it together

Fill in the ANOVA table

REMEMBER: $SS_{With.} = SS_{Subj.} + SS_{Err.}$ in case of one-way RM ANOVA
That is, $SS_{Err.} = SS_{With.} - SS_{Subj.} = 36 - 15.6 = 20.4$

Source	SS	df	MS	$F_{observed}$	$F_{critical}$
Between	25.6	2	12.8	5.02	4.46
Subject	15.6	4	3.9		
Error	20.4	8	2.55		
Total	61.6	14			

Do it together

F-table associed with df1 of 2 and df2 of 8

df1 / df2	1	2	3	4	5	
3	10.13	9.55	9.28	9.12	9.01	8
4	7.71	6.94	6.59	6.39	6.26	6
5	6.61	5.79	5.41	5.19	5.05	4
6	5.99	5.14	4.76	4.53	4.39	4
7	5.59	4.74	4.35	4.12	3.97	3
8	5.32	4.46	4.07	3.84	3.69	3
9	5.12	4.26	3.86	3.63	3.48	3
10	4.96	4.10	3.71	3.48	3.33	3
11	4.84	3.98	3.59	3.36	3.20	3
12	4.75	3.89	3.49	3.26	3.11	3
13	4.67	3.81	3.41	3.18	3.03	2
14	4.60	3.74	3.34	3.11	2.96	2
15	4.54	3.68	3.29	3.06	2.90	2

Do it together

Decision: reject or fail to reject the null hypothesis? $\rightarrow F_{observed} > F_{critical}$

Source	SS	df	MS	$F_{observed}$	$F_{critical}$
Between	25.6	2	12.8	5.02	4.46
Subject	15.6	4	3.9		
Error	20.4	8	2.55		
Total	61.6	14			

$H_0 : \mu_{Sep} = \mu_{Oct} = \mu_{Nov}$

$\rightarrow$ The means of the degree of excitement are the same across the three months

$\rightarrow$ Reject H_0

Do it together

Effect size for repeated measures ANOVA: Partial eta-squared $\eta^2_{partial}$

$$\eta^2_{partial} = \frac{SS_{Bet.}}{SS_{Bet.} + SS_{Err.}}$$

Do it together

Effect size for repeated measures ANOVA: Partial eta-squared $\eta^2_{partial}$

Source	SS	df	MS	$F_{observed}$	$F_{critical}$
Between	25.6	2	12.8	5.02	4.46
Subject	15.6	4	3.9		
Error	20.4	8	2.55		
Total	61.6	14			

$$\eta^2_{partial} = \frac{SS_{Bet.}}{SS_{Bet.}+SS_{Err.}} = \frac{25.6}{25.6+20.4} = \frac{25.6}{46} = 0.56$$

Interpretation: Months explain 56% of the variance in excitement

Before you go home...

Any questions or comments?

Happy Thanksgiving!!!