Hypothesis Testing – SPSS Practice

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Based on Chapter 6 of Human-Computer Interaction by I. S. MacKenzie

1. One-way repeated measure ANOVA Example #1 - Details



Note: Within-subjects design

Note: *SD* is the square root of the variance

[TODO] With SPSS (Example #1 – ANOVA)

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0	5.10	5.60					-		

[TODO] With SPSS (Example #1 – ANOVA)





[TODO] With SPSS (Example #1 – ANOVA)

Effect	df	======================================	MS	 F	p
Participant F1 F1_x_Par	9 1 9	4.884 4.140 3.885	0.543 4.140 0.432	9.593	0.0128

Tests of \	Within-Subj	ects	Effects
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Source		Type III Sum of Squares	df	Mean Square	F	Sig.
factor1	Sphericity Assumed	4.141	1	4.141	9.593	.013
	Greenhouse-Geisser	4.141	1.000	4.141	9.593	.013
	Huynh-Feldt	4.141	1.000	4.141	9.593	.013
	Lower-bound	4.141	1.000	4.141	9.593	.013
Error(factor1)	Sphericity Assumed	3.885	9	.432		
	Greenhouse-Geisser	3.885	9.000	.432		
	Huynh-Feldt	3.885	9.000	.432		
	Lower-bound	3.885	9.000	.432		

1. One-way repeated measure ANOVA Example #2 - Details



[TODO] With SPSS (Example #2 – ANOVA)

Tests of Within-Subjects Effects

Measure: Time

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
factor1	Sphericity Assumed	4.324	1	4.324	.626	.449
	Greenhouse-Geisser	4.324	1.000	4.324	.626	.449
	Huynh-Feldt	4.324	1.000	4.324	.626	.449
	Lower-bound	4.324	1.000	4.324	.626	.449
Error(factor1)	Sphericity Assumed	62.140	9	6.904		
	Greenhouse-Geisser	62.140	9.000	6.904		
	Huynh-Feldt	62.140	9.000	6.904		
	Lower-bound	62.140	9.000	6.904		

2. Post hoc comparison of (One-way RM ANOVA)

More Than Two Test Conditions (Levels)

Participant		Test C	ondition	
Fanticipant	Α	В	С	D
1	11	11	21	16
2	18	11	22	15
3	17	10	18	13
4	19	15	21	20
5	13	17	23	10
6	10	15	15	20
7	14	14	15	13
8	13	14	19	18
9	19	18	16	12
10	10	17	21	18
11	10	19	22	13
12	16	14	18	20
13	10	20	17	19
14	10	13	21	18
15	20	17	14	18
16	18	17	17	14
Mean	14.25	15.13	18.75	16.06
SD	3.84	2.94	2.89	3.23



2. Post hoc comparison of (One-way RM ANOVA) [TODO] With SPSS



<u>F</u> ile <u>E</u>	dit	<u>V</u> iew	<u>D</u> ata	<u>T</u> ransform	<u>A</u> nalyze	<u>G</u> raphs	<u>U</u> tilitie
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15 : D			15.0	0			
		\$	A	🛷 В	🧳 C	-	D
1			11.00	17.00	17.0)0	14.00
2			18.00	17.00	14.0	00	18.00
3			17.00	13.00	21.0	00	18.00
4			19.00	20.00	17.0)0	19.00
5			13.00	14.00	18.0	00	20.00
6			10.00	19.00	22.0	00	13.00
7			14.00	17.00	21.0	00	18.00
8			13.00	18.00	16.0	00	12.00
9			19.00	14.00	19.0	00	18.00
10			10.00	14.00	15.0	00	13.00
11			10.00	15.00	15.0	00	20.00
12			16.00	17.00	23.0	00	10.00
13			10.00	15.00	21.0)0	20.00
14			10.00	10.00	18.0	00	13.00
15			20.00	11.00	22.0	00	15.00
16			18.00	11.00	21.0	00	16.00

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-	Co <u>m</u> p	are Means	;	*				
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-	Gener	rali <u>z</u> ed Line	ear Models	•	SIM M	ultivaria	ate	-
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-	<u>C</u> orrel	late		*	V	ariance	Compo	nents
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2. Post hoc comparison of (One-way RM ANOVA) [TODO] With SPSS

(3)	Repeated Measures Define Factor(s)	× A	Pepeated Measures			×
	Within-Subject Factor Name: factor1 Number of Levels: factor1(4) Change			* + \	Within-Subjects Variables (factor1): A(1,DependentV) B(2,DependentV) C(3,DependentV) D(4,DependentV)	Model Contrasts Plots Post <u>Hoc</u> EM Means Save Options
	Remove Measure Name:]		*	Between-Subjects Factor(s):	
	Add DependentV Change Remove		ОК	Paste E	Covariates:	
	Define Reset Cancel Help					

* In SPSS, we'll use paired sample t-test for post hoc comparison

2. Post hoc comparison of (One-way RM ANOVA) [TODO] With SPSS



2. Post hoc comparison of (O

[TODO] With SPSS

ne-way RI	Pannise	Côn,	arisons	(Sch	effe)
Pair 1:2> Pair 1:3> Pair 1:4> Pair 2:3> Pair 2:4> Pair 3:4>	0.88 4.50 1.81 3.63 0.94 2.69	~ ~ ~ ~ ~ ~ ~ ~	3.30 3.30 3.30 3.30 3.30 3.30 3.30	????????	- * (significant) - * (significant) - -

Pairwise Comparisons

		Mean Difference (I			95% Confiden Differ	ce Interval for ence ^b
(I) factor1	(J) factor1	J) J	Std. Error	Sig. ^b	Lower Bound	Upper Bound
1	2	875	1.258	1.000	-4.694	2.944
	3	-4.500	1.065	.004	-7.732	-1.268
	4	-1.812	1.148	.812	-5.299	1.674
2	1	.875	1.258	1.000	-2.944	4.694
	3	-3.625	1.118	.033	-7.018	232
	4	937	1.112	1.000	-4.315	2.440
3	1	4.500	1.065	.004	1.268	7.732
	2	3.625	1.118	.033	.232	7.018
	4	2.688	1.175	.223	881	6.256
4	1	1.813	1.148	.812	-1.674	5.299
	2	.938	1.112	1.000	-2.440	4.315
	3	-2.687	1.175	.223	-6.256	.881

Measure: DependentV

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

* In SPSS, we'll use paired sample t-test for post hoc comparison

3. One-way ANOVA (Between-subjects) Between-subjects Design

- Research question:
 - Do left-handed users and right-handed users differ in the time to complete an interaction task?
- The independent variable (handedness) must be assigned between-subjects
- Example data set →

Participant	Task Completion Time (s)	Handedness
1	23	L
2	19	L
3	22	L
4	21	L
5	23	L
6	20	L
7	25	L
8	23	L
9	17	R
10	19	R
11	16	R
12	21	R
13	23	R
14	20	R
15	22	R
16	21	R
Mean	20.9	
SD	2.38	

3. One-way ANOVA (Between-subjects) [TODO] With SPSS



3. One-way ANOVA (Between-subjects) [TODO] With SPSS



3. One-way ANOVA (Between-subjects)

[TODO] With SPSS

Effect	df	SS	MS	F	p
F3 Residual	1 14	18.063 66.875	18.063 4.777	3.781	0.0722

Oneway

ANOVA

Time

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	18.063	1	18.063	3.781	.072
Within Groups	66.875	14	4.777		
Total	84.938	15			

4. Two-way repeated measures ANOVA

Data Set

Darticipant	Dev	ice 1	Dev	ice 2	Dev	ice 3
Panicipani	Task 1	Task 2	Task 1	Task 2	Task 1	Task 2
1	11	18	15	13	20	14
2	10	14	17	15	11	13
3	10	23	13	20	20	16
4	18	18	11	12	11	10
5	20	21	19	14	19	8
6	14	21	20	11	17	13
7	14	16	15	20	16	12
8	20	21	18	20	14	12
9	14	15	13	17	16	14
10	20	15	18	10	11	16
11	14	20	15	16	10	9
12	20	20	16	16	20	9
Mean	15.4	18.5	15.8	15.3	15.4	12.2
SD	4.01	2.94	2.69	3.50	3.92	2.69

4. Two-way repeated measures ANOVA [TODO] With SPSS

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3	}		10.00	23.00	13.00	20.00	20.00	16.00
4	Ļ		18.00	18.00	11.00) 12.00	11.00	10.00
5	5		20.00	21.00	19.00) 14.00	19.00	8.00
6	6		14.00	21.00	20.00) 11.00	17.00	13.00
7	7		14.00	16.00	15.00	20.00	16.00	12.00
8	}		20.00	21.00	18.00	20.00	14.00	12.00
9)		14.00	15.00	13.00) 17.00	16.00	14.00
1	0		20.00	15.00	18.00) 10.00	11.00	16.00
1	1		14.00	20.00	15.00) 16.00	10.00	9.00
12	2		20.00	20.00	16.00) 16.00	20.00	9.00

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<u>C</u> orre	late		•	1042	/anian -			
Regre	ession		•	7	arianc	e Compo	nents	i

4. Two-way repeated measures ANOVA [TODO] With SPSS



4. Two-way repeated measures ANOVA [TODO] With SPSS

Measure: Time

Effect	df	SS	MS	F	p
Participant	11	134.778	12.253		
F1	2	121.028	60.514	5.865	0.0091
F1_x_Par	22	226.972	10.317		
F2 -		0.889	0.889	0.076	0.7875
F2_x_Par	11	128.111	11.646		
F1_x_F2	2	121.028	60.514	5.435	0.0121
F1_x_F2_x_Par	22	244.972	11.135		

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Device	Sphericity Assumed	121.028	2	60.514	5.865	.009
	Greenhouse-Geisser	121.028	1.713	70.671	5.865	.013
	Huynh-Feldt	121.028	1.997	60.593	5.865	.009
	Lower-bound	121.028	1.000	121.028	5.865	.034
Error(Device)	Sphericity Assumed	226.972	22	10.317		
	Greenhouse-Geisser	226.972	18.838	12.049		
	Huynh-Feldt	226.972	21.971	10.330		
	Lower-bound	226.972	11.000	20.634		
Task	Sphericity Assumed	.889	1	.889	.076	.787
	Greenhouse-Geisser	.889	1.000	.889	.076	.787
	Huynh-Feldt	.889	1.000	.889	.076	.787
	Lower-bound	.889	1.000	.889	.076	.787
Error(Task)	Sphericity Assumed	128.111	11	11.646		
	Greenhouse-Geisser	128.111	11.000	11.646		
	Huynh-Feldt	128.111	11.000	11.646		
	Lower-bound	128.111	11.000	11.646		
Device * Task	Sphericity Assumed	121.028	2	60.514	5.435	.012
	Greenhouse-Geisser	121.028	1.838	65.839	5.435	.015
	Huynh-Feldt	121.028	2.000	60.514	5.435	.012
	Lower-bound	121.028	1.000	121.028	5.435	.040
Error(Device*Task)	Sphericity Assumed	244.972	22	11.135		
	Greenhouse-Geisser	244.972	20.221	12.115		
	Huynh-Feldt	244.972	22.000	11.135		
	Lower-bound	244,972	11.000	22.270		

5. Chi-square test

Chi-square – Example #1

- Research question:
 - Do males and females differ in their method of scrolling on desktop systems?



Gender

MW = mouse wheel CD = clicking, dragging KB = keyboard

5. Chi-square test

Chi-square – Example #2

- Research question:
 - Do students, professors, and parents differ in their responses to the question: Students should be allowed to use mobile phones during classroom lectures?
- Data:

Observed Number of People								
Oninion	Opinion Category Student Professor Parent							
Opinion								
Agree	10	12	98	120				
Disagree	30	180						
Total	40	40 60 200						

- Result: significant difference in responses ($\chi^2 = 20.5$, p < .0001)
- Q: Then, which of the three pairs is different?

1)					
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	104 :					
			🔏 Ge	nder	Scrolling Method	
	1		Male		MW	
	2		Male		MW	
	3		Male		MW	
	4		Male		MW	
	5		Male		MW	
	6		Male		MW	
	7	'	Male		MW	
	8		Male		MW	

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🛅 Lambda	📄 Kendali's tau- <u>b</u>
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text≻java ChiSquare chisquare-ex1.txt Chi-square(2) = 1.462 p = 0.4814	
text>	▼ }

Chi-Square Tests								
	Value	df	Asymptotic Significance (2-sided)					
Pearson Chi-Square	1.462 ^a	2	.481					
Likelihood Ratio	1.462	2	.481					
N of Valid Cases	101							
a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 10.69.								

(1)	<u>F</u> ile <u>E</u> dit	<u>V</u> iew <u>D</u> ata	<u>T</u> ransform	2	ta Crosstabs		
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	9	Student	Agree	-	Suppress tables		
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	11	Student	Disagree	-			
	12	Student	Disagree	-			
	13	Student	Disagree	-			

 $(\mathbf{3}$

😭 Crosstabs: Cell Display	×
Counts © Observed © Expected	 Z-test ✓ Compare column proportions ✓ Adjust p-values (Bonferroni method)
Ess than 5	
Percentages	Residuals
 Noninteger Weights Round cell counts Truncate cell counts No adjustments 	 ○ Round case weights ○ Truncate case weights
	ue Cancel Help

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	20.500 ^a	2	.000
Likelihood Ratio	21.593	2	.000
N of Valid Cases	300		

 a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 16.00.

		Opinion * Catego	ry Crossta	abulation			
		Category					
			Parent	Prof	Student	Total	
Opinion	Agree	Count	98a	12 _b	10 _b	120	
		Adjusted Residual	4.5	-3.5	-2.1		
	Disagree	Count	102 _a	48 _b	30 _b	180	
		Adjusted Residual	-4.5	3.5	2.1		
Total		Count	200	60	40	300	

"within each row,

percentages that don't share a subscript are significantly different." (Parent vs. Student: p < .05), (Prof vs. Student: p < .05)

Reference: https://www.spss-tutorials.com/spss-chi-square-test-with-pairwise-z-tests/

6. Mann Whitney U test Data (Example #1)

- Means:
 - 3.7 (Mac users)
 - 4.5 (PC users)
- Data suggest PC users more right-leaning, but is the difference statistically significant?
- Data are ordinal (at least),
 .: a non-parametric test is used
- Which test?

Docign	Conditions					
Design	2	3 or more				
Between-subjects (independent samples)	Mann-Whitney U	Kruskal-Wallis				
Within-subjects (correlated samples)	Wilcoxon Signed-Rank	Friedman				

Mac Users	PC Users
2	4
3	6
2	5
4	4
9	8
2	3
5	4
3	2
4	4
3	5
3.7	4.5

Means for interval data?

6. Mann Whitney U test [TODO] With SPSS

<u>V</u>iew

<u>D</u>ata

Transform

C

File

Edit

11:		
	💰 Group	💑 Leaning
1	1.00	2.00
2	1.00	3.00
3	1.00	2.00
4	1.00	4.00
5	1.00	9.00
6	1.00	2.00
7	1.00	5.00
8	1.00	3.00
9	1.00	4.00
10	1.00	3.00
11	2.00	4.00
12	2.00	6.00
13	2.00	5.00
14	2.00	4.00
15	2.00	8.00
16	2.00	3.00
17	2.00	4.00
18	2.00	2.00
19	2.00	4.00
20	2.00	5.00

<u>A</u> nalyze	<u>G</u> raphs	<u>U</u> tilities	E <u>x</u> tensions	<u>W</u> in	dow <u>H</u>	elp	Meta An	alysis	Korea <u>P</u>	lus(P)	
Repo	orts		۲.			A Ital	6				
D <u>e</u> so	riptive Stati	stics	*			19					
<u>B</u> aye	sian Statist	ics	*								1
. Ta <u>b</u> le	s		*	ar	var		var		var	var	var
. Co <u>m</u>	pare Means	3	•					_			
<u>G</u> ene	ral Linear I	Model	*					_			
Gene	ralized Line	ear Models	•								
Mi <u>x</u> eo	l Models		•								
<u>C</u> orre	elate		*								
<u>R</u> egr	ession		•								
L <u>o</u> gli	near		•								
Neur	al Net <u>w</u> orks	6	•								
Clas	si <u>f</u> y		*								
Dime	nsion Red	uction	•								
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Moses extreme reactions 🦳 Wald-Wolfowitz runs

Paste

OK

Cancel

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Help



6. Mann Whitney U test [TODO] With SPSS





6. Mann Whitney U test [TODO] With SPSS

Mann-Whitney Test

CHD		
hook	tune mannwhitneuu-ex1 txt	
2	4	
3	6	
2	5	
4	Ĩ.	
ġ	8	
2	3	
5	<u>4</u>	
3	2	
4	4	
3	5	
book>;	java MannWhitneyU mannwhitneyu-ex1.txt	
U = 31	1.0	
z = -:	1.436, p = 0.1509	
z' = -	-1.469, p' = 0.1418	
book>		
4		

Ranks

	Group	Ν	Mean Rank	Sum of Ranks
Leaning	1.00	10	8.60	86.00
	2.00	10	12.40	124.00
	Total	20		

Test Statistics^a

	Leaning
Mann-Whitney U	31.000
Wilcoxon W	86.000
Z	-1.469
Asymp. Sig. (2-tailed)	.142
Exact Sig. [2*(1-tailed Sig.)]	.165 ^b

a. Grouping Variable: Group

b. Not corrected for ties.

7. Wilcoxon signed-rank test Data (Example #2)

- Means
 - 6.4 (MPA)
 - 3.7 (MPB)
- Data suggest MPA has more "cool appeal", but is the difference statistically significant?
- Data are ordinal (at least),
 .: a non-parametric test is used
- Which test?

Design	Conditions				
Design	2	3 or more			
Between-subjects (independent samples)	Mann-Whitney U	Kruskal-Wallis			
Within-subjects (correlated samples)	Wilcoxon Signed-Rank	Friedman			

Participant	MPA	MPB
1	3	3
2	6	6
3	4	3
4	10	3
5	6	5
6	5	6
7	9	2
8	7	4
9	6	2
10	8	3

6.4 3.7

7. Wilcoxon signed-rank test [TODO] With SPSS

2

(1)

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	4		10.00	3	3.00	
	5	6.00		ŧ	5.00	
	6		5.00	6	5.00	
	7		9.00	2	2.00	
	8		7.00	4	1.00	
	9		6.00	2	2.00	
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7. Wilcoxon signed-rank test [TODO] With SPSS



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OK Paste Reset Cancel Help						

7. Wilcoxon signed-rank test [TODO] With SPSS

Participant	MPA	MPB
1	3	3
2	6	6
3	4	3
4	10	3
5	6	5
6	5	6
7	9	2
8	7	4
9	6	2
10	8	3

Test Statistics^a

MPB - MPA

Z	-2.254 ^b
Asymp. Sig. (2-tailed)	.024

- a. Wilcoxon Signed Ranks Test
- b. Based on positive ranks.

6.4 3.7

8. Kruskal-Wallis Test

Data (Example #3)

- Means
 - 7.1 (20-29)
 - 4.0 (30-39)
 - 2.9 (40-49)
- Data suggest differences by age, but are differences statistically significant?
- Data are ordinal (at least),
 .: a non-parametric is used

A20-29	A30-39	A40-49
9	7	4
9	3	5
4	5	5
9	3	2
6	2	2
3	1	1
8	4	2
9	7	2
7.1	4.0	2.9

• Which test?

Design	Conditions			
Design	2	3 or more		
Between-subjects (independent samples)	Mann-Whitney U	Kruskal-Wallis		
Within-subjects (correlated samples)	Wilcoxon Signed-Rank	Friedman		

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	2		1.00	9.00
	3		1.00	4.00
	4		1.00	9.00
	5		1.00	6.00
	6		1.00	3.00
	7		1.00	8.00
	8		1.00	9.00
	9		2.00	7.00
	10		2.00	3.00
	11		2.00	5.00

2

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wonparametric rests. Two or more indep	sendent samples		
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(4)
J

An Nonparametric Tests: Two or More Independent Samples

Choose Tests	Automatically choose the tests based on the data	
Test Options User-Missing Values	Compare Distributions across Groups Mann-Wgitney U (2 samples)	ANOVA (k samples) s: All pairwise
	 Kolmogoroy-Smirnov (2 samples) Test seguence for randomness (Wald-Wolfowitz for 2 samples) Hypothesis order: Multiple companies Compare Ranges across Groups Compare Ranges across Groups Moses egtreme reaction (2 samples) Median test (§ samples) Compute outliers from sample Custom number of outliers Cuttions: 	Smallest to targest (*) a. All pairwise (*) ross Groups nples) a median.

×

THE CMD	_ 🗆 🗡
book>java KruskalWallis kruskalwallis-ex1.txt -ph H = 9.421, p = 0.0090 H' = 9.605, p' = 0.0082	×
Multiple Comparisons Test (alpha = .05)	
Pair 1:2> 1.4375 >= 7.6103 ? - Pair 1:3> 10.5625 >= 7.6103 ? • (significant) Pair 2:3> 3.1250 >= 7.6103 ? -	
book>_	<u>ح</u>

Independent-Samples Kruskal-Wallis Test Summary

Total N	24
Test Statistic	9.605 ^a
Degree Of Freedom	2
Asymptotic Sig.(2-sided test)	.008
a. The test statistic is adj	usted for ties.

A20-29	A30-39	A40-49
9	7	4
9	3	5
4	5	5
9	3	2
6	2	2
3	1	1
8	4	2
9	7	2
7.1	4.0	2.9

Pairwise Comparisons of Group

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig. ^a
3.00-2.00	3.125	3.502	.892	.372	1.000
3.00-1.00	10.563	3.502	3.017	.003	.008
2.00-1.00	7.438	3.502	2.124	.034	.101

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.

Asymptotic significances (2-sided tests) are displayed. The significance level is .05.

 a. Significance values have been adjusted by the Bonferroni correction for multiple tests.

9. Friedman test

Data (Example #4)

- Means
 - 71.0 (A), 68.1 (B), 60.9 (C), 69.8 (D)
- Data suggest a difference in quality of results, but are the differences statistically significant?
- Data are ordinal (at least),
 .: a non-parametric test is used

Participant	А	В	С	D
1	66	80	67	73
2	79	64	61	66
3	67	58	61	67
4	71	73	54	75
5	72	66	59	78
6	68	67	57	69
7	71	68	59	64
8	74	69	69	66

71.0 68.1 60.9 69.8

• Which test?

Design	Conditions			
	2	3 or more		
Between-subjects (independent samples)	Mann-Whitney U	Kruskal-Wallis		
Within-subjects (correlated samples)	Wilcoxon Signed-Rank	Friedman		

9. Friedman test [TODO] With SPSS

1)									
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	:	2		79.00	64.	00	61.0	0	66.00	
		3		67.00	58.	00	61.0	0	67.00	
	4	4		71.00	73.	00	54.0	0	75.00	
		5		72.00	66.	00	59.0	0	78.00	
	(6		68.00	67.	00	57.0	0	69.00	
		7		71.00	68.	00	59.0	0	64.00	
	1	B		74.00	69.	00	69.0	0	66.00	

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9. Friedman test [TODO] With SPSS

3

tests for Several Related Samples	\times						
Test Variables:	Exact Statistics						
Test Type Friedman Mendall's W Cochran's Q							
OK Paste Reset Cancel Help							

9. Friedman test [TODO] With SPSS

Test Statistics^a

Ν	8
Chi-Square	8.692
df	3
Asymp. Sig.	.034

a. Friedman Test

9. Friedman test [TODO] With SPSS – Post hoc comparison

(1)

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	-								

* We'll use Wilcoxon signed-rank test for post hoc comparison

9. Friedman test [TODO] With SPSS – Post hoc comparison



9. Friedman test

[TODO] With SPSS – Post hoc comparison

Test Statistics ^a									
	B - A	C - A	D - A	С-В	D - B	D - C			
Z	-1.260 ^b	-2.380 ^b	593 ^b	-2.117 ^b	422°	-2.386°			
Asymp. Sig. (2-tailed) .208 .017 .553 .034					.673	.017			
a. Wilcoxon Signed F	Ranks Test								
b. Based on positive ranks.									
c. Based on negative	e ranks.								

Hypothesis Testing – R Practice (ART)

Based on Chapter 6 of Human-Computer Interaction by I. S. MacKenzie

IDE and R download

R-4.1.1 for Windows (32/64 bit)

• R version – 4.1.1

Download R 4.1.1 for Windows (86 megabytes, 32/64 bit) Installation and other instructions New features in this version

- Download: <u>https://cran.rstudio.com/</u>
- Rstudio version 1.4.1717 (latest)
 - Download: https://www.rstudio.com/products/rstudio/download/#download





Requires Windows 10 (64-bit)

Rstudio

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+ +		Miscellaneous Material			
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No documentation for 'car' in specified packages and libraries: you could try '??car'		About R Authors License FAQ	Resou Thank	urces Ks	- 1

Working directory

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R 4,1,1 · C:/Users/HCIL/Desktop/2021_10_15_R/ 
R version 4.1.1 (2021-08-10) -- "Kick Things"
Copyright (C) 2021 The R Foundation for Statistical Computing
Platform: x86_64-w64-mingw32/x64 (64-bit)
R is free software and comes with ABSOLUTELY NO WARRANTY.
You are welcome to redistribute it under certain conditions.
Type 'license()' or 'licence()' for distribution details.
R is a collaborative project with many contributors.
Type 'contributors()' for more information and
'citation()' on how to cite R or R packages in publications.
Type 'demo()' for some demos, 'help()' for on-line help, or
'help.start()' for an HTML browser interface to help.
Type 'q()' to quit R.
[Workspace loaded from ~/.RData]
> setwd("C:/Users/HCIL/Desktop/2021_10_15_R")
>
```

Basic R grammar for this class

Useful document

<u>https://cran.r-project.org/doc/contrib/Paradis-rdebuts_en.pdf</u>

The on-line help of R

- If you want to find the Im() (linear model)
 - ?lm
 - help(lm)
 - Help("lm")

"help" only searches in the packages which are loaded in memory

- If no documentation for 'lm' in specified packages and libraries: you could try
 - 'help.search("lm")
 - ??lm

aov {formula, data, ...}

- Fit an Analysis of Variance Model by a call to Im (linear model) for each stratum
- In "stats" package which is default package if you install R

Formula

- Y ~ model
 - Y: the analyzed response (dependent variable)
 - Model: a set of terms for which some parameters are to be estimated.
 - For this class..
 - A : estimate the effect of A, for one-way ANOVA (one independent variable)
 - A + B : estimate the effects of A and B, but not consider the interaction effect between A, B (two independent variables: A, B)
 - A:B : interactive effect between A and B
 - A*B : estimate the effects of A and B, and interactive effect between A and B
 - It is same to A + B + A:B

aov {formula, data, ...}

aov() accepts a particular syntax to define random effects (within-subjects design)

For repeated measure (within)

• Y ~ A + Error(Subjects/A)

ANOVA Example #1

```
data = read.table("anova-ex1a.txt", header = FALSE,
col.names = c("DV", "IV", "Participant"))
```

str(data) # check a data mode

```
The result:
```

```
> str(data)
'data.frame': 20 obs. of 3 variables:
  $ DV : num 5.3 3.6 5.2 3.6 4.6 4.1 4 4.8 5.2 5.1 ...
  $ IV : int 1 1 1 1 1 1 1 1 1 ...
  $ Participant: int 1 2 3 4 5 6 7 8 9 10 ...
```

ANOVA Example #1

Because the data mode is numeric or integer, we change to the mode of independent variable to factor.

```
# ANOVA (within)
fit <- aov(DV ~ factor(IV) +
Error(factor(Participant)/factor(IV)), data)</pre>
```

```
# result
summary(fit)
```

```
Error: factor(Participant)

Df Sum Sq Mean Sq F value Pr(>F)

Residuals 9 4.884 0.5427

Error: factor(Participant):factor(IV)

Df Sum Sq Mean Sq F value Pr(>F)

factor(IV) 1 4.141 4.141 9.593 0.0128 *

Residuals 9 3.884 0.432

---

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Example #1 – ANOVA

Effect	df	SS	MS	F	р
Participant F1 F1_x_Par	9 1 9	4.884 4.140 3.885	0.543 4.140 0.432	9.593	0.0128

\$ java Anova2 anova-ex1.txt 10 2 . . -a

Probability of obtaining the observed data if the null hypothesis is true.

Thresholds for "p"

.05, .01, .005, .001, .0005, .0001

The mean task completion time for Method A was 4.5 s. This was 20.1% less than the mean of 5.5 s observed for Method B. The difference was statistically significant ($F_{1.9} = 9.593$, p < 0.05).

ANOVA Example #1 (cont.)

In order to change the mode, you can use as.factor()
 data\$Participant <- as.factor(data\$Participant)
 data\$IV <- as.factor(data\$IV)
 str(data)</pre>

```
# same function
fit <- aov(DV ~ IV + Error(Participant/IV), data)
summary(fit)</pre>
```

Example #2 – Do It your self



```
data = read.table("anova-ex2a.txt", header = FALSE,
col.names = c("DV", "IV", "Participant"))
```

Estimate the effect of IV on the DV. All participants performed two methods, A and B (within-subject design)

```
fit <- aov(DV ~ factor(IV) +
Error(factor(Participant)/factor(IV)), data)
summary(fit)</pre>
```

```
Error: factor(Participant)

Df Sum Sq Mean Sq F value Pr(>F)

Residuals 9 37.37 4.152

Error: factor(Participant):factor(IV)

Df Sum Sq Mean Sq F value Pr(>F)

factor(IV) 1 4.32 4.325 0.626 0.449

Residuals 9 62.14 6.904
```

Example #2 – ANOVA (Compare to the result)

\$ java Anova2 anova-ex2.txt 10 2 . . -a

======================================	df	======================================	MS	======== F	p
Participant F1 F1_X_Par	9 1 9	37.373 4.324 62.140	4.153 4.324 6.904	0.626	0.4491

Probability of obtaining the observed data if the null hypothesis is true.

Note: For non-significant effects, use " ns" if F < 1.0, or "p > .05" if F > 1.0.

The mean task completion time was 4.5 s for Method A and 5.5 s for Method B. As there was substantial variation in the observations across participants, the difference was not statistically significant as revealed in an analysis of variance ($F_{1,9} = 0.626$, ns).

Between-subjects Design

```
data = read.table("anova-ex3.txt", header = FALSE,
col.names = c("DV", "IV"))
fit <- aov(DV ~ factor(IV), data)
summary(fit)
```

Effect			df	SS	MS	F	р
F3 Residual			1 14	18.063 66.875	18.063 4.777	3.781	0.0722
factor(IV) Residuals	Df 9 1 14	5um Sq 18.06 66.88	Mean Sq 1 18.063 4.777	F value Pr(>F) 3.781 0.0722) 2 .		

```
0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

What is difference of the command from within-subject design?

Two-way ANOVA (within)

```
data <- read.table("anova-ex4a.txt", header = FALSE)
colnames(data) <- c("Participant", "Device", "Task", "DV")
head(data)
str(data)</pre>
```

The formula for two-way anova

- Y ~ A * B
 - Identical to $Y \sim A + B + A:B$
- + Error (subjects / (A*B))
 - For within-subject design
 - Because A, B is nested condition under the subjects

Two-way ANOVA (within)

```
# check the error term
fit <- aov(DV ~ factor(Device) * factor(Task) +
Error(factor(Participant)/(factor(Device) * factor(Task))),
data)</pre>
```

summary(fit)

Two-way ANOVA (within)

Result:

```
Error: factor(Participant)
         Df Sum Sq Mean Sq F value Pr(>F)
Residuals 11 134.8 12.25
Error: factor(Participant):factor(Device)
              Df Sum Sq Mean Sq F value _Pr(>F)
factor(Device) 2 121 60.51 5.865 0.00909 **
Residuals 22 227 10.32
Signif. codes:
0 ****' 0.001 ***' 0.01 **' 0.05 *.' 0.1 * ' 1
Error: factor(Participant):factor(Task)
            Df Sum Sq Mean Sq F value Pr(>F)
factor(Task) 1 0.89 0.889 0.076 0.787
Residuals 11 128.11 11.646
Error: factor(Participant):factor(Device):factor(Task)
                          Df Sum Sq Mean Sq F value
factor(Device):factor(Task)
                           2
                             121 60.51
                                              5.435
Residuals
                           22
                                245
                                      11.14
                          Pr(>F)
factor(Device):factor(Task) 0.0121 *
Residuals.
Signif. codes:
0 ****' 0.001 ***' 0.01 **' 0.05 *.' 0.1 * ' 1
```



\$ java Anova2 anova-ex4.txt 12 3 2 . -a

======================================	 df	SS	 MS	F	p
Participant F1 F1_x_Par F2 F2_x_Par F1_x_F2	11 2 22 1 11 2	134.778 121.028 226.972 0.889 128.111 121.028	12.253 60.514 10.317 0.889 11.646 60.514	5.865 0.076 5.435	0.0091 0.7875 0.0121
F1_x_F2_x_Par	22	244.972	11.135		

ART : Aligned ranked transform in R

- For Multi-factor Non-parametric Data
 - Preprocess data before ANOVA
 - Aligning step
 - Remove the effects of all factors and interactions except for one.
 - Rank-transform
 - Remove the skewness of the distribution.
 - ANOVA
 - Calculate the effect of the factor in focus.
 - (Repeat for other factors and interactions)
- The "ARTool" package allows very easy way to use ART
 - Install.packages("ARTool")
 - Library(ARTool)
 - reference: <u>http://depts.washington.edu/acelab/proj/art/index.html</u>

ART example

Data: Higgins1990Table5

library(ARTool)
data(Higgins1990Table5, package = "ARTool")

str(Higgins1990Table5)
head(Higgins1990Table5, n=8)

ART example

Step 1: Transform the data (Between)

```
m <- art(DryMatter ~ Moisture * Fertilizer , data =
Higgins1990Table5)</pre>
```

m\$residuals
m\$estimated.effects
m\$aligned
m\$aligned.ranks

In this process,

- 1) Step 1: Compute residuals: Y cell mean
- 2) Compute estimated effects for all main and interaction effects
- 3) Compute aligned response Y'
- 4) Assign averaged ranks Y"
ART example

Step 2: Verify appropriateness of ART

To verify that the ART procedure was correctly applied and is appropriate for this dataset, we can look at the output of summary

```
Summary(m)
```

```
> summary(m)
Aligned Rank Transform of Factorial Model
call:
art(formula = DryMatter ~ Moisture * Fertilizer, data = Higgins1990Table5)
Column sums of aligned responses (should all be ~0):
                             Fertilizer Moisture:Fertilizer
           Moisture
                  0
                                       0
                                                           0
F values of ANOVAs on aligned responses not of interest (should all be ~0):
  Min. 1st Qu. Median
                           Mean 3rd Qu.
                                            Max.
              0
                      0
                                       0
      0
                              0
                                               0
> |
```

ART example

Step 3: Run the ANOVA

anova(m)

> anova(m) Analysis of Variance of Aligned Rank Transformed Data

```
      Table Type: Anova Table (Type III tests)

      Model: No Repeated Measures (lm)

      Response: art(DryMatter)

      Df Df.res F value
      Pr(>F)

      1 Moisture
      3
      32 41.5199 3.8513e-11 ***

      2 Fertilizer
      3
      32 69.4604 4.2015e-14 ***

      3 Moisture:Fertilizer
      9
      32 2.9388
      0.011685 *

      ---
      ---
      ---

      Signif. codes:
      0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

If you want to use different model like repeated measures ANOVA, you add Error() term to the art() formula as using aov().

ART homework

CS584 Homework 6

Problem 7. (ART)

- Data: Dataset(p1-p12).csv
- Within-subjects (SubjectName)
- Independent variables: Radius (level: 6, 8, 10), and itemNum (level: 4, 6)
- Dependent variable: time

Using ARTool, 1) Estimate the effects of Radius and itemNum on time, and 2) report the p-value and F-value of the estimations. (You can use read.csv() instead of read.table())