Three-Factor ANOVA

PSYC214: Statistics For Group Comparisons

Mark Hurlstone Lancaster University

Week 9

Conc Rem Trace-Vi General

Learning Objectives

- Procedures for analysing and interpreting three-factor ANOVA
- How to decompose a three-way interaction:
 - splitting the design and analysing it as a series of two-factor ANOVAs
- Examples:
 - ullet 2 imes 2 imes 2 fully within-participants ANOVA
 - $2 \times 2 \times 2$ mixed ANOVA
- General things to consider

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Three-Factor

Memory and Context

ANOVA Table
Recall ANOVA Table
Recall Simple Main Effects
Table
Recognition ANOVA Table
Interaction Plots

Pronouncing

ANOVA Table
ANOVA Table
Year Old ANOVA Table
Year Old ANOVA Table
Year Old Simple Main
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Concluding Remarks Three-Way Impractic General Points

Three-Factor ANOVA

- Three-factor ANOVAs are common in psychology
- In such designs, there are three possible two-way interactions:
 - A × B
 - $\bullet \ A \times C$
 - $\bullet \ B \times C$
- There is also the possibility of a three-way interaction:
 - A × B × C
- Complexity of interpreting these designs arises when the three-way interaction is significant

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9 Year Old ANOVA Table
9 Year Old Simple Main
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Concluding Remarks

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Notes

Three-Factor ANOVA

- Basic design principles of earlier lectures still apply
- A between-participants design is still relatively simple, with only a single error term for all effects
- However, a 2 \times 2 \times 2 design would require at least 160 participants (obeying our maxim of N = 20 per cell)
- Problems with fully within-participants and mixed designs apply equally to three-factor designs
- Try to avoid exceeding two levels per factor where possible

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Three-Factor ANOVA

- The most straightforward outcome is when the three-way interaction is not significant
- Where this occurs, one or more of the two-way interactions may be significant
- In which case, each significant two-way interaction should be investigated separately of the others
- The procedures for interpreting each interaction are the same as those discussed in previous lectures
- For example, if the A \times B two-way interaction is significant, the simple main effects of factor A at B, and factor B at A can be investigated

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Notes

Three-Factor ANOVA

- The simplest case arises when none of the interactions are significant
- In this case, the outcome must be interpreted in terms of the main effects, if any of these are significant
- If nothing is significant, then unless specific pairwise comparisons are planned, the analysis is complete

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Dealing With A Significant Three-Way Interaction

- A significant three-way interaction occurs when there are different two-way interactions between two of the factors according to the levels of the third factor
- The simplest way to analyse a significant three-way interaction is to reanalyse it as a series of two-factor ANOVAs, e.g. :

 - 2 a 2 (factor A: level A_1 vs. level A_2) \times 2 (factor B: level B_1 vs. level B_2) ANOVA at level C_2 of factor C
- Any significant interactions would be followed up with a simple main effects analysis

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Concluding Remarks

Memory and Context: A 2 \times 2 \times 2 Fully Within-Participants Design

- A memory researcher wants to know if memory is better when material is tested in the same context it was learned in
- They also want to know whether recall and recognition memory are equally context dependent
- The researcher manipulates three factors in a 2 \times 2 \times 2 fully within-participants design:
 - 1 memory test (recall vs. recognition)
 - 2 learning context (learn under water vs. learn land)
 - 3 testing context (test under water vs. test land)
- Participants given words to remember in a learning context \to memory for the words tested via recall or recognition
- Dependent measure is the number of words remembered correctly

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Table: A 2 \times 2 \times 2 factorial design

Factor A: Task		Level A	A ₁ recall			Level A ₂ r	ecognition	
Factor B: Learning	Level B	under	Level E	3 ₂ land	Level B	under	Level E	3 ₂ land
Factor C: Testing	C ₁ under	C ₂ land	C ₁ under	C ₂ land	C ₁ under	C ₂ land	C ₁ under	C ₂ land
P ₁	8	5	3	7	5	5	7	6
P ₂	9	6	3	8	7	6	5	8
P ₃	7	5	4	6	6	7	5	6
P ₄	8	4	4	5	7	5	6	5
P ₅	6	3	3	8	5	4	6	4

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Table: A 2 \times 2 \times 2 factorial design

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 5.5
 Level C, under water
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 5.8
 5.9

 Level C, on land
 4.6
 6.8
 5.7
 Level C, on land
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 Overall
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ANOVA Table For Memory and Context Study

Source	Sum of Squares	Degrees of Freedom	Mean Square	F	P
A (memory task)	0.225	1	0.225	1.000	0.374
Error $A \times P$	0.900	4	0.225		
B (learning context)	2.025	1	2.025	1.588	0.276
Error $B \times P$	5.100	4	1.275		
C (testing context)	0.025	1	0.025	0.014	0.911
Error $C \times P$	7.100	4	1.775		
$A \times B$	3.025	1	3.025	2.951	0.161
Error $A \times B \times P$	4.100	4	1.025		
$A \times C$	0.625	1	0.625	0.714	0.446
Error $A \times C \times P$	3.500	4	0.875		
$B \times C$	30.625	1	30.625	27.222	0.006
Error $B \times C \times P$	4.500	4	1.125		
$A \times B \times C$	21.025	1	21.025	27.129	0.006
$\textit{Error A} \times \textit{B} \times \textit{C} \times \textit{P}$	3.10	4	0.775		
P (participants)	10.900	4	2.733		

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Three-Factor ANOVA

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ANOVA Table For Memory and Context Study

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Interpreting The Significant Three-Way Interaction

- To decompose our significant three-way interaction, we first need to decide which factor to split our design by
- The obvious choice is factor A (memory task: recall vs. recognition)
- Next, we perform two two-factor ANOVAs:
 - $\ensuremath{\P}$ 2 (learning context: learn under water vs. learn land) \times 2 (testing context: test under water vs. test land) ANOVA for the recall memory test condition only
 - 2 (learning context: learn under water vs. learn land) x 2 (testing context: test under water vs. test land) ANOVA for the recognition memory test condition only

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ANOVA Table For Recall Memory Task

Source	Sum of Squares	Degrees of Freedom	Mean Square	F	P
B (learning context)	5.000	1	5.000	3.636	0.129
Error $B \times P$	5.500	4	1.375		
C (testing context)	0.200	1	0.200	0.186	0.688
Error $C \times P$	4.300	4	1.075		
$B \times C$	51.200	1	51.200	62.061	0.001
$\textit{Error B} \times \textit{C} \times \textit{P}$	3.300	4	0.825		
P (participants)	5.300	4	1.333		

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ANOVA Table For Recall Memory Task

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Simple Main Effects Table For Recall Memory Task

Source	Sum of Squares	Degrees of Freedom	Mean Square	F	Р	
learning context at						
test under water	44.100	1	44.100	32.073	0.005	
test land	12.100	1	12.100	8.800	0.041	
Error term	5.50	4	1.375			
testing context at						
learn under water	22.500	1	22.500	20.930	0.010	
learn land	28.900	1	28.900	26.884	0.007	
Error term	4.300	4	1.075			

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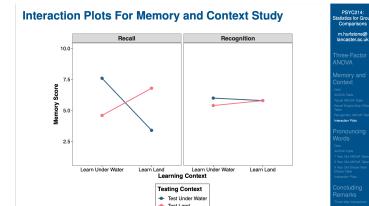
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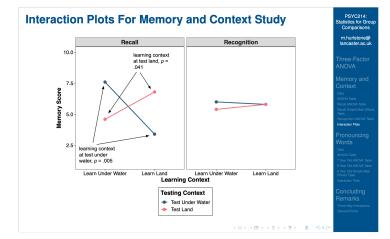
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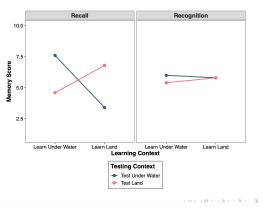
Source	Sum of Squares	Degrees of Freedom	Mean Square	F	Р
B (learning context)	0.050	1	0.050	0.054	0.828
Error $B \times P$	3.700	4	0.925		
C (testing context)	0.450	1	0.450	0.286	0.621
Error $C \times P$	6.300	4	1.575		
$B \times C$	0.450	1	0.450	0.419	0.553
$\textit{Error} \ \textit{B} \times \textit{C} \times \textit{P}$	4.300	4	1.075		
P (participants)	6.500	4	1.633		





Interaction Plots For Memory and Context Study 10.0 Learn Land Learn Under Learning Context Testing Context

Interaction Plots For Memory and Context Study



Notes

Learning To Pronounce Irregular Words: A 2 \times 2 \times 2 Mixed Design

- A researcher wants to investigate the development in children's ability to pronounce regular and irregular words
- \bullet The researcher adopts a 2 \times 2 \times 2 mixed design:
 - 1 age (7 years old vs. 9 years old) is between-participants
 - 2 word frequency (low vs. high) is within-participants
 - 3 word type (regular vs. irregular) is within-participants
- Participants are given 10 words to pronounce in each category (40 words in total)
- Dependent measure is the number of pronunciation errors

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Three-Factor

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Raw Data For Word Pronunciation Study

Table: A 2×2	× 2	factorial	design
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Factor A: Age	Le	evel A ₁ 7	years-ol	d		Level A ₂ 9-years-old			d
Factor B: Frequency	Level B ₁ high		Level B ₂ low			Level E	3 ₁ high	Level B ₂ low	
Factor C: Word type	C ₁ reg	C ₂ irr	C ₁ reg	C ₂ irr		C ₁ reg	C ₂ irr	C ₁ reg	C ₂ irr
P ₁	6	7	5	6	P ₆	4	4	3	6
P ₂	7	5	6	7	P_7	3	4	4	7
P ₃	5	6	7	6	P_8	4	3	5	9
P ₄	6	7	5	7	P_9	5	5	3	8
P ₅	6	6	5	7	P_{10}	3	4	3	7

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Aggregate Data For Word Pronunciation Study

Table: A 2 \times 2 \times 2 factorial design

	Level A ₁ 7-years-old				Level A ₂ 9-years-old		
	Level B ₁ high	Level B ₂ low	Overall		Level B ₁ high	Level B ₂ low	Overall
Level C ₁ regular	6.0	5.6	5.8	Level C ₁ regular	3.8	3.6	3.7
Level C2 irregular	6.2	6.6	6.4	Level C ₂ irregular	4.0	7.4	5.7
Overall	6.1	6.1	6.1		3.9	5.5	4.7

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ANOVA Table For Word Pronunciation Study

Source	Sum of Squares	Degrees of Freedom	Mean Square	F	P
A (age)	19.600	1	19.600	34.844	< .001
Between error S/A	4.500	8	0.562		
B (frequency)	6.400	1	6.400	5.885	0.042
Error B × S/A	8.700	8	1.087		
C (word type)	16.900	1	16.900	36.541	< .001
Error C × S/A	3.700	8	0.462		
$A \times B$	6.400	1	6.400	5.885	0.042
Error B × S/A	8.700	8	1.087		
$A \times C$	4.900	1	4.900	10.595	0.012
Error C × S/A	3.700	8	0.462		
$B \times C$	12.100	1	12.100	17.600	0.003
$\textit{Error B} \times \textit{C} \times \textit{S/A}$	5.500	8	0.688		
$A \times B \times C$	4.900	1	4.900	7.127	0.028
Error $B \times C \times S/A$	5.500	8	0.688		

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ANOVA Table For Word Pronunciation Study

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Three-Factor ANOVA

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Interpreting The Significant Three-Way Interaction

- To decompose our significant three-way interaction, we first need to decide which factor to split our design by
- The obvious choice is our between-participants factor A (age: 7 year olds vs. 9 year olds)
- Next, we perform two two-factor ANOVAs:
 - $\mbox{\Large 1}$ 2 (frequency: low vs. high) \times 2 (word type: regular vs. irregular) ANOVA for the 7 year olds only
 - $\mbox{\Large @}$ 2 (frequency: low vs. high) \times 2 (word type: regular vs. irregular) ANOVA for the 9 year olds only

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Three-Factor

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ANOVA Table For 7 Year Olds

Source	Sum of Squares	Degrees of Freedom	Mean Square	F	P
B (frequency)	0.000	1	0.000	0.000	1.000
$\textit{Error B} \times \textit{P}$	2.500	4	0.625		
C (word type)	1.800	1	1.800	5.885	0.178
Error $C \times P$	2.700	4	0.675		
$B \times C$	0.800	1	0.800	5.885	0.405
$\textit{Error B} \times \textit{C} \times \textit{P}$	3.700	4	0.925		
P (participants)	0.300	4	0.075		

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ANOVA Table For 9 Year Olds

Source	Sum of Squares	Degrees of Freedom	Mean Square	F	P
B (frequency)	12.800	1	12.800	8.258	0.045
Error $B \times P$	6.200	4	1.550		
C (word type)	20.000	1	20.000	80.000	< .001
Error $C \times P$	1.000	4	0.250		
$B \times C$	16.200	1	16.200	36.000	0.004
$\textit{Error B} \times \textit{C} \times \textit{P}$	1.800	4	0.450		
P (participants)	4.200	4	1.050		

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Three-Facto ANOVA

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ANOVA Table For 9 Year Olds

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P (participants)	4.200	4	1.050		

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Simple Main Effects Table For 9 Year Olds

Source	Sum of Squares	Degrees of Freedom	Mean Square	F	Ρ
word frequency at					
regular words	0.100	1	0.100	0.065	0.812
irregular words	28.900	1	28.900	18.645	0.013
Error term	6.200	4	1.550		
word type at					
low frequency	36.100	1	36.100	144.400	< .001
high frequency	0.100	1	0.100	0.400	0.561
Error term	1.000	4	0.250		

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Three-Factor

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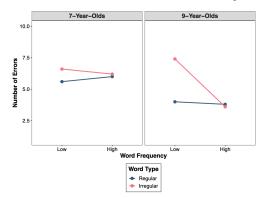
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Interaction Plots For Word Pronunciation Study



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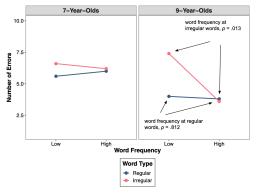
Year Old Simple Main

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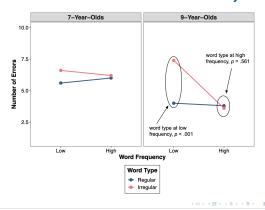
Concluding

Interaction Plots For Word Pronunciation Study



Note

Interaction Plots For Word Pronunciation Study



Three-Factor
ANOVA
Memory and
Context

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And Anova Time
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And Anova Time

A Final Note On Interpreting Three-Way Interactions

- In both of these examples, one of the two-factor ANOVAs returned a significant interaction, whereas the other returned a non-significant interaction
- This will not always be the case
- Sometimes the interaction for each two-factor ANOVA will be significant and both will need to be followed up with a simple main effects analysis
- Under these conditions, the simple main effects for the two interactions will differ in direction and/or size of their trends

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Notes

General Points

- As always, start at the bottom of the ANOVA table and work your way up
- If the three-way interaction is significant, then this must be analysed
- If not, then each of the significant two-way interactions should be analysed independently
- If none of the two-way interactions is significant, the ANOVA results may be described in terms of the main effects, with follow-up tests for any factors with three or more levels

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hree-Factor

Memory and Context

Data ANOVA Table Recall ANOVA Table Recall Simple Main Effect Table Recognition ANOVA Table Interaction Plots

Data ANDWA Table F Year Old ANDWA Tab 9 Year Old ANDWA Tab 9 Year Old Simple Mail Effects Table Interaction Plots

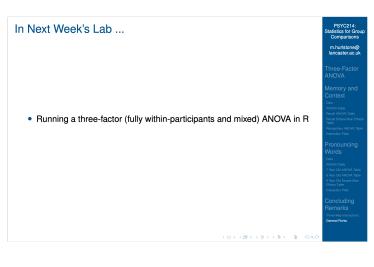
Interaction Piots

Concluding

Remarks

Three-Way Interact

General Priors



References	PSYC214: Statistics for Gr Comparison
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	Three-Facto ANOVA
Roberts, M. J., & Russo, R. (1999, Chapter 12). A student's guide to Analysis of Variance. Routledge: London.	Memory and Context Data ANCVA Table Plecal ANCVA Table Plecal Strepe Main E Table Recognition ANCVA : Interaction Plots
	Pronouncing Words Data ANDWA Table 7 Neor Old ANDWA To 9 Neor Old ANDWA To 9 Neor Old Simple Ma Effects Table Interaction Plots
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