

A Two-Factor
Mixed Design

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Cell Means
ANOVA Table
Simple Main Effects
Interaction Plot
Calculating F ratios

A Two-Factor
Fully Within-
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Two-Factor Mixed and Within-Participants Designs

PSYC214: Statistics For Group Comparisons

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Week 8

Learning Objectives

PSYC214:
Statistics for Group
Comparisons

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- Two-factor mixed and within-participants designs
- Focus on procedures rather than how the analysis is calculated
- How to interpret ANOVA tables and graphs
- Handling significant main effects, and simple main effects, of factors with three or more levels

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- We have now covered the three most mathematically straightforward designs:
 - 1 splitting total variability into between-group variability and within-group variability — one factor between-participants designs
 - 2 splitting within-group variability into between-participant variability and residual variability — one factor within-participants designs
 - 3 splitting between-group variability into main effect and interaction variability — 2×2 between-participants design
- There is little new to learn from analysing more complicated designs by hand

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A Two-Factor Mixed Design

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- Mixed design ANOVAs are particularly versatile and are often used in psychology
- These designs have at least one between-participants factor and at least one within-participants factor
- Allows the researcher to capitalise on the benefits of between- and within-participants designs within the same design
- Let's consider an example based on the Stroop task

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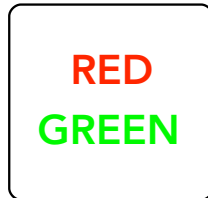
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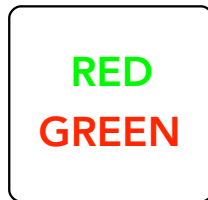
The Stroop Task

- In the Stroop task, participants must name the ink colour of a colour word as quickly as possible:
 - on **congruent trials**, the ink colour and colour name are consistent
 - on **incongruent trials**, the ink colour and colour name are inconsistent
- Stroop effect = longer RTs for incongruent, compared to congruent, trials
- A measure of **response inhibition**

Congruent Trials



Incongruent Trials



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Example of A Mixed Design

- A researcher wants to know if response inhibition is impaired in patients with Schizophrenia using the Stroop task
- She employs a 2×2 mixed design:
 - patient group: healthy vs. schizophrenia
 - trial type: congruent vs. incongruent
- patient group is necessarily a between-participants factor
- trial type is a within-participants factor
- There are $2 \times 2 = 4$ conditions; **two groups** of participants (healthy vs. schizophrenia) each complete two conditions of the experiment (congruent vs. incongruent trials)

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Hypothetical Data For Mixed Design-Stroop Experiment

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		<i>Factor B: Trial type</i>		
		<i>Level B₁</i>	<i>Level B₂</i>	
		<i>congruent</i>	<i>incongruent</i>	Overall
Factor A:	Level A ₁ healthy	630	776	703
Group	Level A ₂ schizophrenia	635	885	760
	Overall	632.5	830.5	

Error Terms In A Mixed-Design ANOVA

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- Recall that a between-participants design uses the within-group variance as its error term
- By contrast, a within-participants design uses the residual variance as its error term
- A mixed-design ANOVA produces two error terms:
 - 1 one for the between-participants main effect
 - 2 one for the within-participants main effect and the interaction
- You must be careful to ensure when reporting the ANOVA that the correct degrees of freedom are read from the table

Source	Sum of Squares	Degrees of Freedom	Mean Square	<i>F</i>	<i>P</i>
<i>A</i> (group)	19531.250	1	19531.250	4.307	0.072
Error <i>S/A</i> (Bet-ss)	36281.000	8	4535.125		
<i>B</i> (trial type)	187211.250	1	187211.250	411.793	< .001
<i>A</i> × <i>B</i>	16531.250	1	16531.250	36.362	< .001
Error <i>B</i> × <i>S/A</i>	3637.000	8	454.625		

- One error term is labelled *Error S/A (Bet-ss)* and has been used to calculate the *F* ratio for the between-participants factor
- *Error B × S/A* has been used to calculate the *F* ratio for every component linked to factor B—the within-participants factor and interaction

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ANOVA Table For Mixed-Design Stroop Experiment

Source	Sum of Squares	Degrees of Freedom	Mean Square	<i>F</i>	<i>P</i>
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Simple Main Effects Table For Mixed-Design Stroop Experiment

- There are different approaches to testing simple main effects in mixed designs
- The simplest approach uses **pooled error terms**
- We begin by calculating the between-group variance for each simple main effect
- The calculations are identical to those used for the between-participants design (see Week 7 lecture slides)
- Each pair of simple main effects is tested for significance using the same error term (hence pooled error term approach)

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- The error term for testing the significance of the between-participant effects is the pooled within-group variance for the four cells
- This is calculated identically to a fully between-participants design $\{SS_{S/AB} = [Y] - [AB]; df_{S/AB} = ab(s - 1)\}$
- This is used to test the significance of the two simple main effects of the between-participants factor:
 - group at congruent
 - group at incongruent

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Source	Sum of Squares	Degrees of Freedom	Mean Square	<i>F</i>	<i>P</i>
Group at					
congruent	62.500	1	62.500	0.014	0.909
incongruent	36000.00	1	36000.00	7.938	0.023
Error term	36281.00	8	4535.125		
Trial type at					
healthy	46240.000	1	46240.000	101.710	< .001
schizophrenia	157502.500	1	157502.500	346.445	< .001
Error term	3637.000	8	454.625		

Simple Main Effects Table For Mixed-Design Stroop Experiment

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- The other error term is the within-participants factor error term from the initial ANOVA (*Error $B \times S/A$*)
- This is used to test the two within-participants simple main effects:
 - trial type at healthy
 - trial type at schizophrenia

Simple Main Effects Table For Mixed-Design Stroop Experiment

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Simple Main Effects Table For Mixed-Design Stroop Experiment

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- An alternative to this approach would be to calculate a separate t -test for each pair of means being compared
- We would use independent-samples t -tests to test the simple main effects of the between-participants factor
- We would use repeated-measures t -tests to test the simple main effects of the within-participants factor

Simple Main Effects Table For Mixed-Design Stroop Experiment

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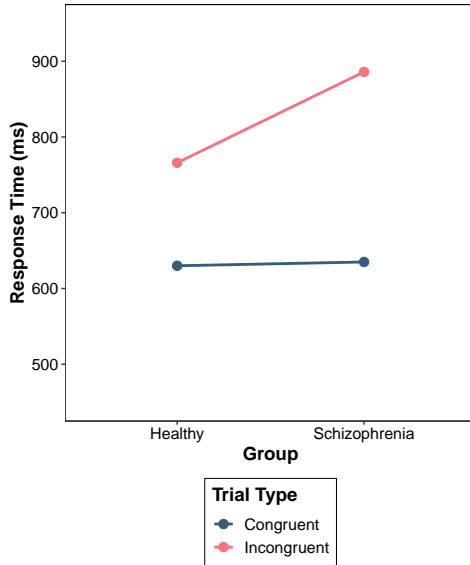
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- Once you have calculated the simple main effects, generate an interaction plot
- Locate the simple main effects in the graph to facilitate interpretation of the interaction

Interaction Plot



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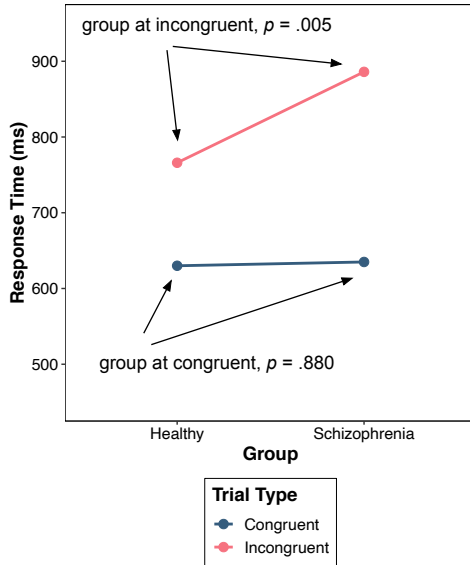
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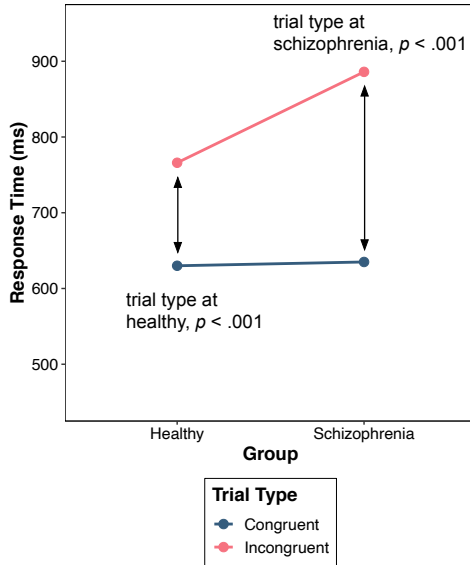
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- Once you have a graph and have calculated the simple main effects, write out the various effects as you were shown in the Week 6 lab session
- This involves reporting the F values for each simple main effect and stating the direction of the significant differences
- Once the significant effects have been identified, they must be interpreted
- Write a couple of sentences to describe the nature of the interaction (see the Week 7 lab session for an example)

What If The Design Has Three or More Levels In Either Factor?

- If the interaction is not significant, any significant main effects for factors with three or more levels will need to be followed up with planned comparisons (t -tests) or post-hoc tests (Tukey test)
- When the interaction is significant, the simple main effects for a factor with three or more levels will need to be followed up with planned comparisons or post-hoc tests
- In both circumstances, planned comparisons will often be preferable
- Make sure you use the right type (independent samples vs. repeated measures) for the effect you are testing

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- The book chapter in the recommended reading includes a demonstration of how to calculate the F ratios for a mixed design by hand
- Only study this if you are curious, it is not something you will be assessed upon
- The procedure is very similar to that used when we calculated F ratios for a two-factor between-participant design—it uses the same basic ratios (plus one new ratio)

A Two-Factor Fully Within-Participants Design

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- A researcher wants to know if the size of the Stroop effect decreases with practice
- She employs a 2×3 fully within-participants design:
 - trial type: congruent vs. incongruent
 - block: 1 vs. 2 vs. 3
- Making *trial type* within-participants means we can establish each participant's susceptibility to the Stroop effect
- *block* must necessarily be a within-participants factor, as it requires experience with the task
- There are $2 \times 3 = 6$ conditions; a **single group** of participants completes each condition

Hypothetical Data For Fully Within-Participants Design Stroop Experiment

	A_1 congruent			A_2 incongruent		
	B_1 block 1	B_2 block 2	B_3 block 3	B_1 block 1	B_2 block 2	B_3 block 3
P_1	700	600	550	910	700	625
P_2	600	550	575	850	650	650
P_3	480	590	693	720	685	743
P_4	630	690	597	830	790	600
P_5	720	730	650	845	770	680
Means	626.00	632.00	613.00	831.00	719.00	659.60

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ANOVA Table For Fully Within-Participants Design Stroop Experiment

Source	Sum of Squares	Degrees of Freedom	Mean Square	<i>F</i>	<i>P</i>
<i>A</i> (trial type)	95541.63	1	95541.63	68.124	< .001
<i>Error A</i> × <i>P</i>	5609.87	4	1402.47		
<i>B</i> (block)	42821.60	2	21410.80	2.128	0.182
<i>Error B</i> × <i>P</i>	80503.40	8	10062.93		
<i>A</i> × <i>B</i>	33872.27	2	16936.13	53.537	< .001
<i>Error A</i> × <i>B</i> × <i>P</i>	2530.73	8	316.34		
<i>P</i> (participants)	28847.20	4	7211.800		

- Each effect has its own error term directly underneath it, which makes locating the degrees of freedom easier

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- To test the simple main effects, we calculate the between-group variances as we did in our Week 7 lecture
- The error terms to use are those from the original ANOVA table
- Thus, for the simple main effects of factor A (trial type) at B_1 , B_2 , and B_3 the error term for testing factor A could be used ($Error A \times P$)
- For the simple main effects of factor B (block) at A_1 and A_2 the error term for testing factor B could be used ($Error B \times P$)

Simple Main Effects Table For Fully Within-Participants Design Stroop Experiment

Source	Sum of Squares	Degrees of Freedom	Mean Square	<i>F</i>	<i>P</i>
Trial type at					
block 1	105062.50	1	105062.50	74.913	< .001
block 2	18922.50	1	18922.50	13.492	0.021
block 3	5428.90	1	5428.90	3.871	0.121
Error term	5609.87	4	1402.47		
Block at					
congruent	943.33	2	471.67	0.047	0.954
incongruent	75750.53	2	37875.27	3.764	0.041
Error term	80503.40	8	10062.93		

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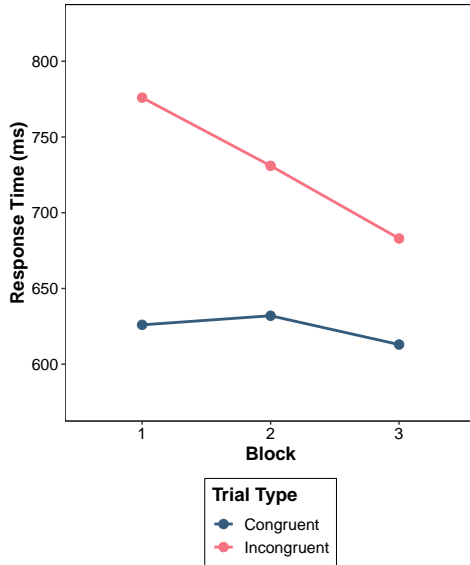
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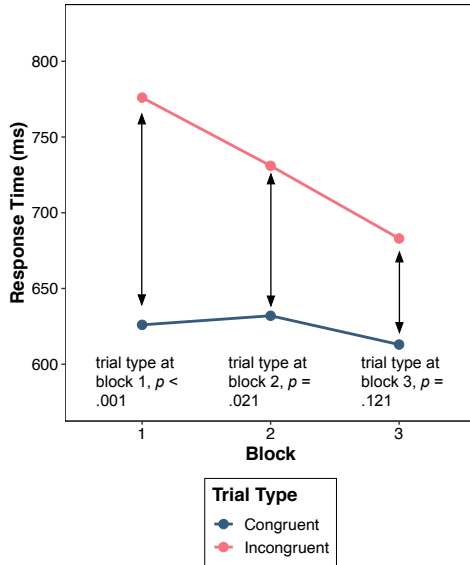
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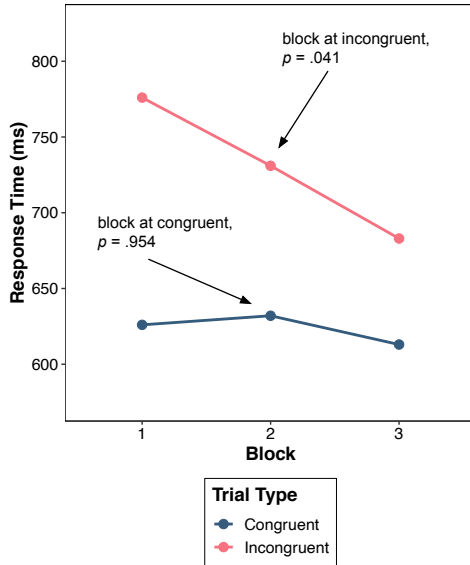
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Follow Up Tests For Simple Main effects Of Factors With Three Or More Levels

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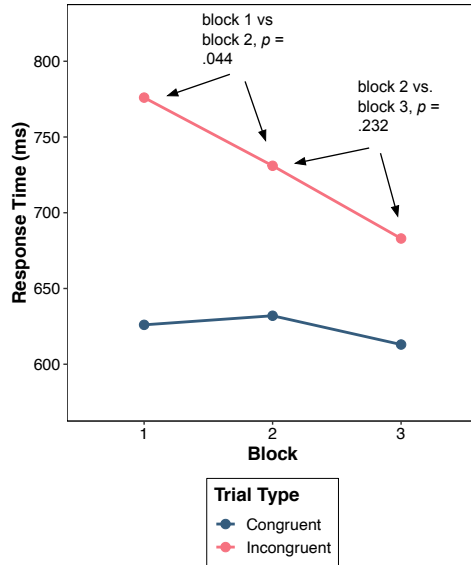
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- In this instance, one of the simple main effects of our factor with three levels (block at incongruent) was significant
- We therefore need to perform follow up tests (planned comparisons or post-hoc tests) to determine where the differences are located
- I recommend using planned comparisons where possible
- We will evaluate the simple main effect of block at incongruent trials by performing two repeated-measures t -tests comparing block 1 vs. block 2 and block 2 vs. block 3 (i.e., planned comparisons)

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References

- The book chapter in the recommended reading includes a demonstration of how to calculate the F ratios for a within-participants design by hand
- Only study this if you are curious, it is not something you will be assessed upon
- The procedure is very similar to that used when we calculated F ratios for a two-factor between-participant design—it uses the same basic ratios (plus one new ratio)

A Note On The Sphericity Assumption

PSYC214:
Statistics for Group
Comparisons

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- The sphericity assumption extends to within-participants factorial designs with factors containing three or more levels
- It also applies to within-participant factors with three or more levels in mixed designs
- R will apply the Greenhouse and Geisser correction if the sphericity assumption is violated
- We'll cover this in more detail in next week's lab

- The R code for all plots generated in this lecture (minus annotations) has been uploaded with these slides to the Week 8 lecture folder (R Plots For Lecture 8.R)

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In Next Week's Lab ...

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References

- Running a 2×3 mixed/within-participants ANOVA in R
- Follow-up tests for factors with more than two levels

Roberts, M. J., & Russo, R. (1999, Chapter 11). *A student's guide to Analysis of Variance*. Routledge: London.

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