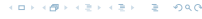


# Introduction To Factorial Designs and Interactions

PSYC214: Statistics For Group Comparisons

Mark Hurlstone  
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Week 6



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## Learning Objectives

- Introduction to factorial designs
  - two-factor designs
- Outcomes of factorial designs
  - main effects
  - simple main effects
  - interaction
- Why do we need factorial designs?
- Planning factorial designs
- Analysing factorial designs



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## Beyond Single Factor Designs

- The **single factor design** forms a minority in psychology:
  - too simple to address complex questions
  - can give a false impression of importance of a factor
- In a **factorial design**, two or more factors are varied simultaneously:
  - common in cognitive and social psychology
  - can address more complicated research questions
  - can identify interactions between factors
- Couldn't we just use multiple *t*-tests?
  - inflation of familywise Type I error rate



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## Language of Factorial Designs

- A factorial design is referenced by the number of its factors (e.g., **two-factor design**, **three-factor design** etc.)
- Factors are referenced by name (e.g., A, B)
- Levels of a factor are referenced by subscripts (e.g., A<sub>1</sub>, A<sub>2</sub>, B<sub>1</sub>, B<sub>2</sub>)
- A design with two-factors, each with two levels, is described as a 2 × 2 (read as "two-by-two") factorial design
- The total number of treatment conditions is calculated by multiplying the levels of each factor



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- **Fully between-participants factorial design:**
  - a design containing factors that are all manipulated between-participants
- **Fully within-participants factorial design:**
  - a design containing factors that are all manipulated within-participants
- **Mixed factorial design:**
  - a design containing a mixture of factors that are manipulated between- or within-participants

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Example: Fear Appeals and COVID-19 Vaccination Intentions

- Does exposure to a "fear appeal" increase people's intention to get vaccinated against COVID-19?
- Does exposure to a "self-efficacy" message increase people's intention to get vaccinated against COVID-19?
- A  $2 \times 2$  fully between-participants design:
  - 1 Fear: no fear appeal vs. fear appeal
  - 2 Efficacy: no efficacy message vs. efficacy message
- One dependent variable:
  - Likelihood of vaccinating against COVID-19: 0 (Very Unlikely) to 10 (Very Likely)

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A  $2 \times 2$  Factorial Design

Table: A  $2 \times 2$  factorial design

		Factor A: Fear	
		Level A <sub>1</sub> no fear appeal	Level A <sub>2</sub> fear appeal
Factor B:	Level B <sub>1</sub> no efficacy message	Vaccination intention scores for a group of participants who received no fear appeal and no efficacy message	Vaccination intention scores for a group of participants who received a fear appeal but no efficacy message
Efficacy	Level B <sub>2</sub> efficacy message	Vaccination intention scores for a group of participants who received no fear appeal but did receive an efficacy message	Vaccination intention scores for a group of participants who received both a fear appeal and an efficacy message

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A  $2 \times 2$  Factorial Design

Table: A  $2 \times 2$  factorial design

		Factor A: Fear		
		Level A <sub>1</sub> no fear appeal	Level A <sub>2</sub> fear appeal	
Factor B:	Level B <sub>1</sub> no efficacy message	Mean A <sub>1</sub> B <sub>1</sub>	Mean A <sub>2</sub> B <sub>1</sub>	Mean B <sub>1</sub>
Efficacy	Level B <sub>2</sub> efficacy message	Mean A <sub>1</sub> B <sub>2</sub>	Mean A <sub>2</sub> B <sub>2</sub>	Mean B <sub>2</sub>
		Mean A <sub>1</sub>	Mean A <sub>2</sub>	Grand Mean

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## A 2 × 2 Factorial Design

Table: A 2 × 2 factorial design

		Factor A: Fear	
		Level A <sub>1</sub>	Level A <sub>2</sub>
		no fear appeal	fear appeal
Factor B:	Level B <sub>1</sub> no efficacy message	1/4 of participants	1/4 of participants
Efficacy	Level B <sub>2</sub> efficacy message	1/4 of participants	1/4 of participants

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## Factors Can Have More Than Two Levels

- There is no limit on the number of levels in a factor
- Suppose we want to know if the amount of fear depicted in the fear appeal matters
- We could adopt a 3 × 2 fully between-participants design:
  - 1 Fear: low fear vs. medium fear vs. high fear
  - 2 Efficacy: no efficacy message vs. efficacy message
- As before, we measure likelihood of vaccinating against COVID-19 on a 0 (Very Unlikely) to 10 (Very Likely) scale

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## A 3 × 2 Factorial Design

Table: A 3 × 2 factorial design

		Factor A: Fear				
		Level A <sub>1</sub>	Level A <sub>2</sub>	Level A <sub>3</sub>		
		low fear	medium fear	high fear		
Factor B:	Level B <sub>1</sub> no efficacy message	Mean A <sub>1</sub> B <sub>1</sub>	Mean A <sub>2</sub> B <sub>1</sub>	Mean A <sub>3</sub> B <sub>1</sub>	Mean B <sub>1</sub>	
Efficacy	Level B <sub>2</sub> efficacy message	Mean A <sub>1</sub> B <sub>2</sub>	Mean A <sub>2</sub> B <sub>2</sub>	Mean A <sub>3</sub> B <sub>2</sub>	Mean B <sub>2</sub>	
		Mean A <sub>1</sub>	Mean A <sub>2</sub>	Mean A <sub>3</sub>	Grand Mean	

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## Examples of Fully Within-Participants and Mixed Designs

- In the Stroop task, participants 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 Fully Within-Participants Design

- A researcher wants to know if the size of the Stroop effect decreases with practice
- She employs a  $2 \times 3$  fully within-participants design:
  - trial type: congruent vs. incongruent
  - trial block: 1 vs. 2 vs. 3
- Making *trial type* within-participants means we can establish each participant's susceptibility to the Stroop effect
- *trial block* must 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

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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  $2 \times 2$  mixed design:
  - trial type: congruent vs. incongruent
  - patient group: healthy vs. Schizophrenia
- *trial type* is once again a within-participants factor
- *patient group* must be a between-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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## Outcomes of Factorial Designs

- In a factorial experiment, various different outcomes are possible:
  - main effects
  - simple main effects
  - interaction

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## Outcomes of Factorial Designs: Main Effects

- The simplest outcomes are the *main effects*
- They represent the overall difference in means of one factor, ignoring the other(s)
- If people given a fear appeal have higher vaccination intentions than those that weren't overall, there is a *significant main effect of fear*
- If people given a self-efficacy message have higher vaccination intentions than those that weren't overall, there is a *significant main effect of efficacy*

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## Hypothetical Data Table

Table: A 2 × 2 factorial design

		Factor A: Fear		Mean
		Level A <sub>1</sub> <i>no fear appeal</i>	Level A <sub>2</sub> <i>fear appeal</i>	
Factor B: Efficacy	Level B <sub>1</sub> no efficacy message	4	4	4
	Level B <sub>2</sub> efficacy message	4	9	6.5
Mean		4	6.5	5.25

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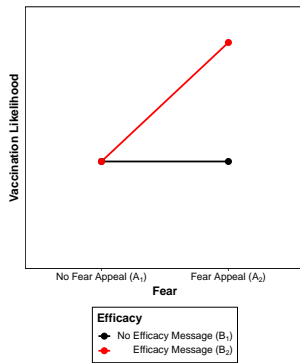
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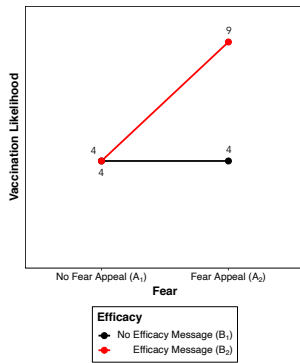
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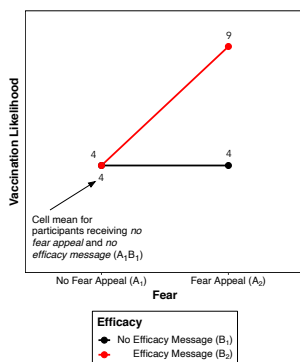
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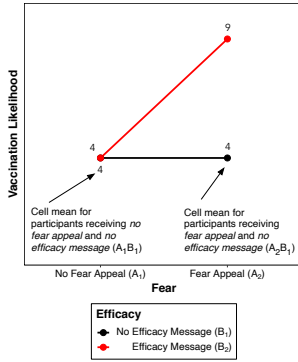
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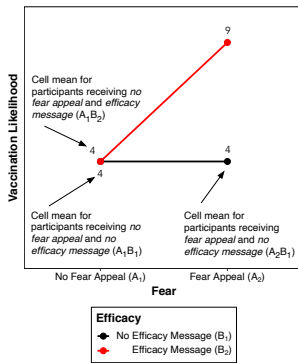
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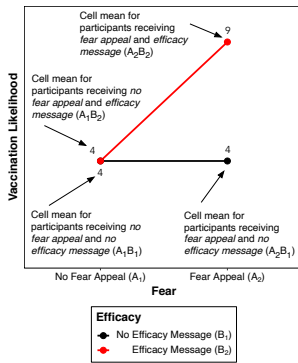
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## Possible Outcomes For Main Effects

- In a two-factor design, there are three possible outcomes in terms of the main effects:
  - no significant main effects
  - one significant main effect
  - two significant main effects

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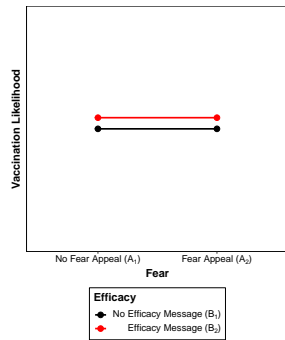
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## 1. No Significant Main Effects



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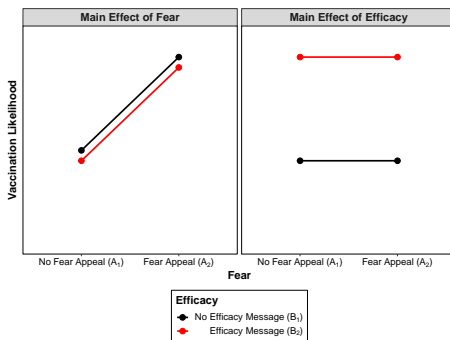
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## 2. One Significant Main Effect



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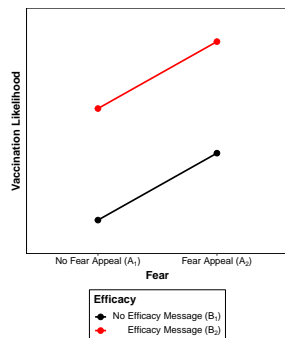
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## 3. Two Significant Main Effects



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## Simple Main Effects

- Simple main effects break down main effects into their component parts:
  - simple main effect of factor A (no fear appeal vs. fear appeal) at level B<sub>1</sub> (no efficacy message) of factor B
  - simple main effect of factor A (no fear appeal vs. fear appeal) at level B<sub>2</sub> (efficacy message) of factor B
  - simple main effect of factor B (no efficacy message vs. efficacy message) at level A<sub>1</sub> (no fear appeal) of factor A
  - simple main effect of factor B (no efficacy message vs. efficacy message) at level A<sub>2</sub> (fear appeal) of factor A
- Let's look at these effects visually ...

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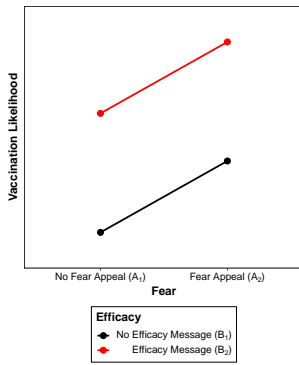
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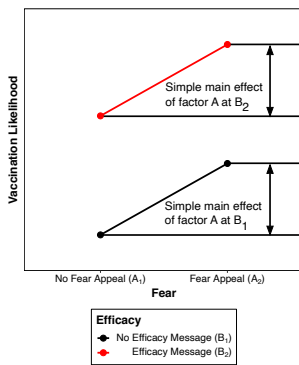
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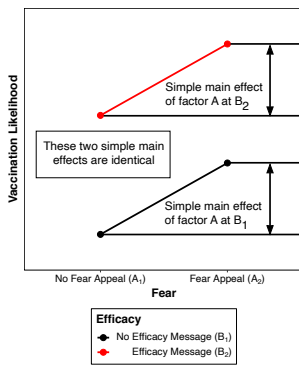
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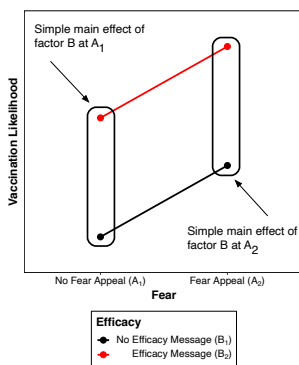
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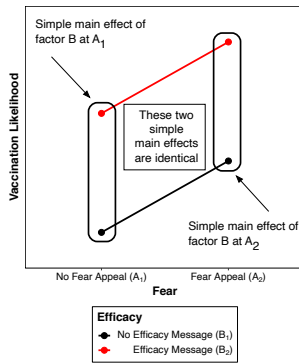
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## Simple Main Effects

- In the preceding example, the two factors had independent effects on the dependent measure
- **The two simple effects for each factor were identical to the overall main effect from which they were obtained:**
  - *Vaccination intention scores were higher with vs. without a fear appeal, regardless of whether or not participants received an efficacy message*
  - *Vaccination intention scores were higher with vs. without an efficacy message, regardless of whether or not participants received a fear appeal*

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## Simple Main Effects

- Sometimes the simple main effects of one factor will be different at different levels of the second factor
- *In other words, the way one factor is related to the dependent variable may depend on the level of the second factor*
- When this happens, we have an **interaction**
- When there is an interaction, you cannot interpret the results in terms of the main effects
- Instead, you must determine how the factors are combining to influence the dependent variable by looking at the simple main effects

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## Significant Interaction

- You may now have realised that the hypothetical data presented earlier are an example of an interaction
- Let's revisit those data ...

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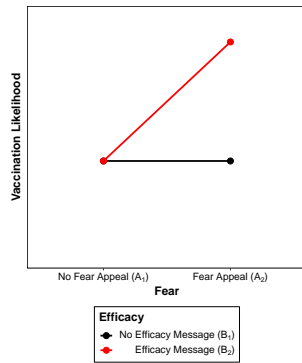
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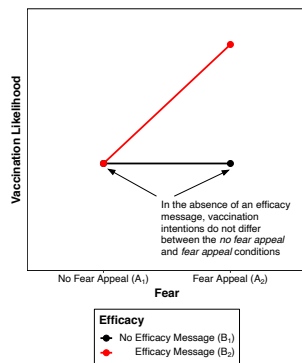
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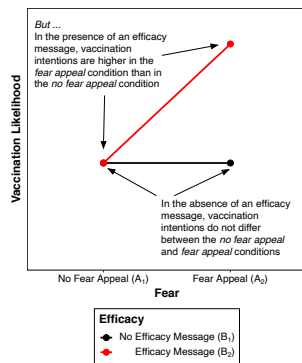
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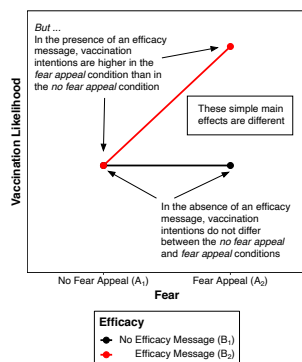
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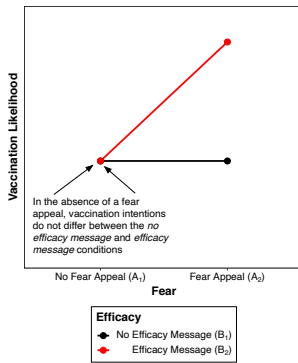
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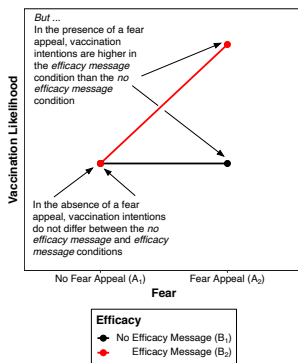
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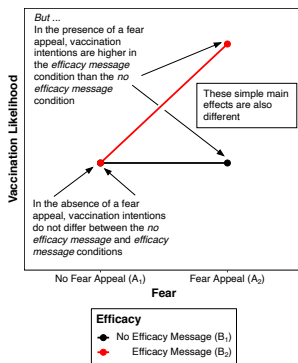
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## How To Spot An Interaction

- If a line plot of the data (also known as an **interaction plot**) has non-parallel lines, then this is indicative of the presence of an interaction
- This is the case for the hypothetical data we just considered
- Here are some additional examples ...

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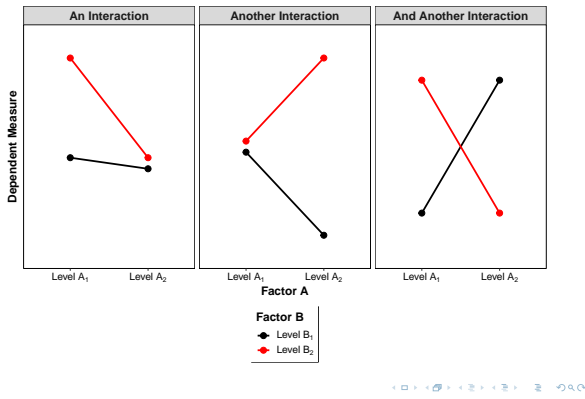
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## Examples of Interactions: All Have Non-Parallel Lines



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## How To Spot An Interaction

- When inspecting interaction plots, check the scale limits on the y-axis
- A tightly compressed scale can create the “illusion of an interaction”

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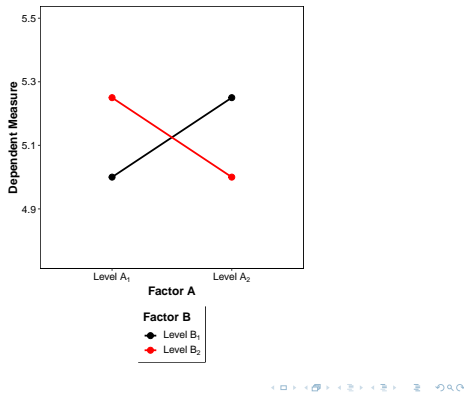
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## Example of “Illusory Interaction” Due to Scale Compression



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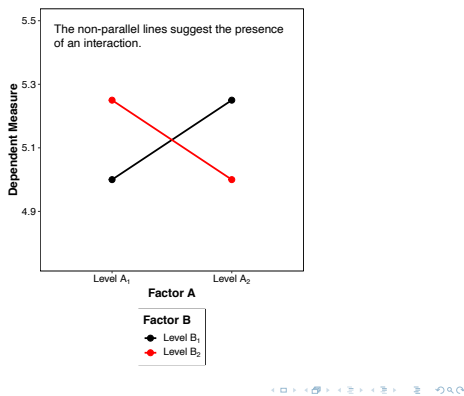
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## Example of “Illusory Interaction” Due to Scale Compression



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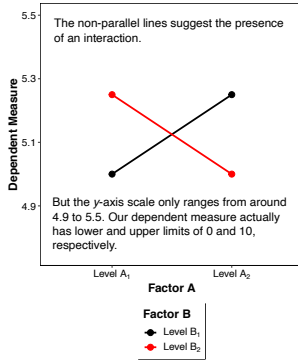
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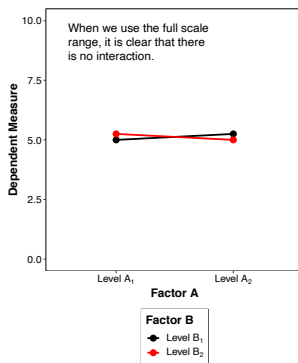


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## Independence of Sets of Simple Main Effects

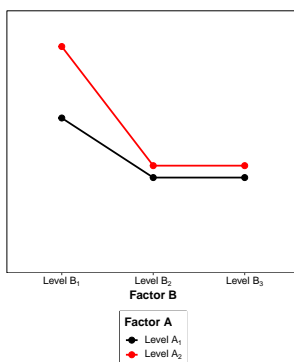
- Remember, if there is a significant interaction we must examine the simple main effects
- Keep in mind that sets of simple main effects are *independent*.
  - some simple main effects of one factor may be significant and others not ...
  - ... but this does not mean that some simple main effects of the other factor will also be significant and others not
- Here's an example using a 2 × 3 design ...

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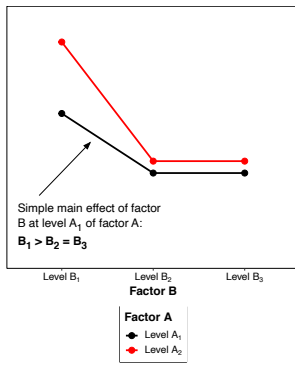


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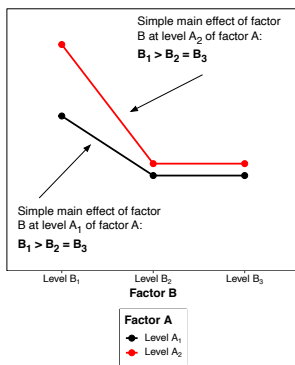


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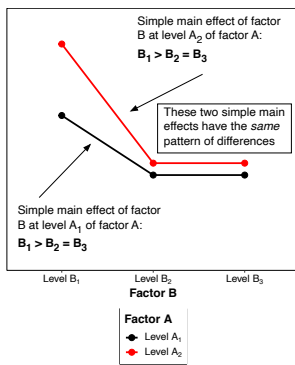


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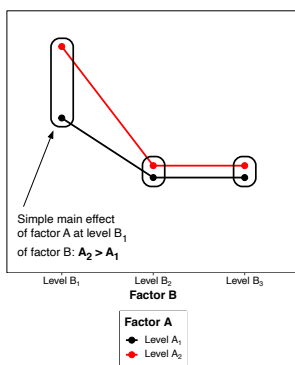


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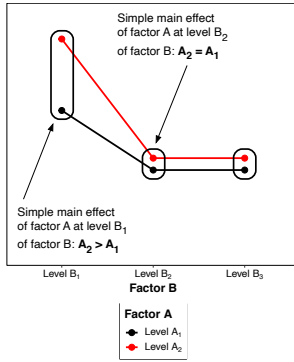


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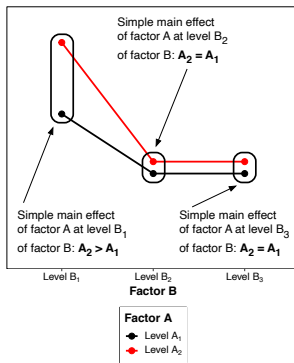
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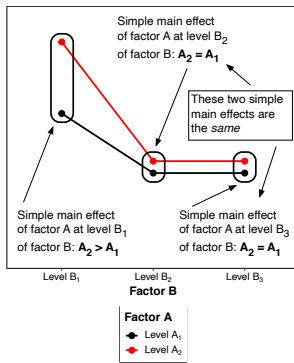
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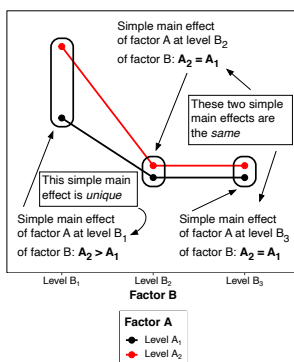
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## Why Factorial Designs?

- The effect of a factor in a single-factor design can be misleading and conceal a potential interaction
- If we just compare COVID-19 vaccination intentions in the absence and presence of a fear appeal, we would conclude the fear appeal has no effect
- We would dismiss as ineffective the use of fear-based messages to increase COVID-19 vaccination rates
- However, we know from our factorial experiment example that this result is misleading—fear appeals work when combined with a self-efficacy message



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## Why Factorial Designs?

- In PSYC204 (Week 4), we considered the TV viewing habits of children and their future High-School grades
- When viewing habits are ignored, time watching TV (small vs. large amount) as a child has no effect on grades
- When viewing habits are factored into account, there is an interaction:
  - for educational content, High-School grades increase with time watching TV
  - for noneducational content, High-School grades decrease with time watching TV
- In both of these examples, a factorial design was required to reach an appropriate conclusion



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## Planning Factorial Designs

- Fully between-participants designs are generally easier to interpret but require more participants
- Make sure you have adequate sample size per cell ( $\approx 20$ ) to protect against Type II errors
- There are tradeoffs between the complexity of a design, how practical it is to run, and the interpretability of its results
- Try to avoid designing studies with more than three factors
- Ideally, no factor should have more than two levels



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## Analysing Factorial Designs

- We cannot know for certain from "eyeballing" our data what outcomes are significant or not
- A factorial ANOVA produces an  $F$ -ratio and  $p$  value for each main effect and interaction
- In a two-factor design, this means:
  - an  $F$ -ratio and  $p$  value for the main effect of factor A
  - an  $F$ -ratio and  $p$  value for the main effect of factor B
  - an  $F$ -ratio and  $p$  value for the  $A \times B$  interaction
- Each simple main effect also has an  $F$ -ratio and  $p$  value, but we only generate these if the interaction is significant
- Follow up tests will be required for simple main effects with three or more levels



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## In Next Week's Lab ...

- Producing line plots and bar graphs for factorial studies
- Interpreting simple main effects



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