Introduction To Factorial Designs and Interactions

PSYC214: Statistics For Group Comparisons

Mark Hurlstone
Lancaster University

Week 6

Notes

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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m.hurlstone@lancaster.ac.uk

Notes

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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m.hurlstone@lancaster.ac.uk

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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_1, A_2, B_1, B_2)
- 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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Language of Factorial Designs

- 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

Notes

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 × 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 × 2 Factorial Design

Table: A 2 × 2 factorial design

		Factor A: Fear	
		Level A_1 *no fear appeal*	*Level A_2* *fear appeal*
Factor *B*:	Level B_1 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_2 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 × 2 Factorial Design

Table: A 2 × 2 factorial design

		Factor A: Fear		
		Level A_1 *no fear appeal*	*Level A_2* *fear appeal*	
Factor *B*:	Level B_1 no efficacy message	Mean A_1B_1	Mean A_2B_1	Mean B_1
Efficacy	Level B_2 efficacy message	Mean A_1B_2	Mean A_2B_2	Mean B_2
		Mean A_1	Mean A_2	Grand Mean

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A 2 × 2 Factorial Design

Table: A 2 × 2 factorial design

		Factor A: Fear	
		Level A_1	*Level A_2*
		no fear appeal	*fear appeal*
Factor *B*:	Level B_1 no efficacy message	1/4 of participants	1/4 of participants
Efficacy	Level B_2 efficacy message	1/4 of participants	1/4 of participants

Notes

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_1	*Level A_2*	*Level A_3*	
		low fear	*medium fear*	*high fear*	
Factor *B*:	Level B_1 no efficacy message	Mean A_1B_1	Mean A_2B_1	Mean A_3B_1	Mean B_1
Efficacy	Level B_2 efficacy message	Mean A_1B_2	Mean A_2B_2	Mean A_3B_2	Mean B_2
		Mean A_1	Mean A_2	Mean A_3	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

RED
GREEN

Incongruent Trials

RED
GREEN

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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 × 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 × 3 = 6 conditions; a single group of participants completes each condition

Notes

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:
  - 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 × 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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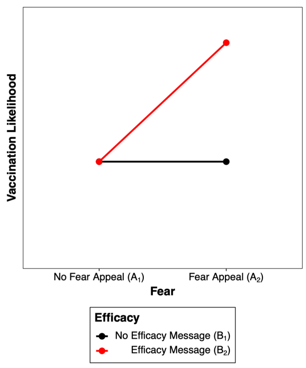
Hypothetical Data Table

Table: A 2 × 2 factorial design

		Factor A: Fear		
		Level A_1	*Level A_2*	
		no fear appeal	*fear appeal*	Mean
Factor *B*:	Level B_1 no efficacy message	4	4	4
Efficacy	Level B_2 efficacy message	4	9	6.5
	Mean	4	6.5	5.25

Notes

Hypothetical Data Plots



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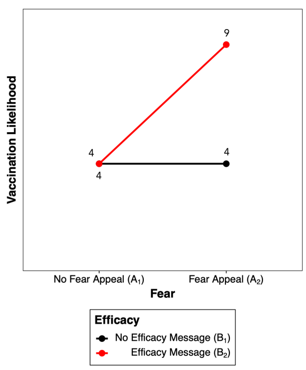

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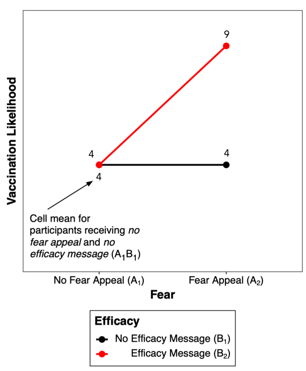

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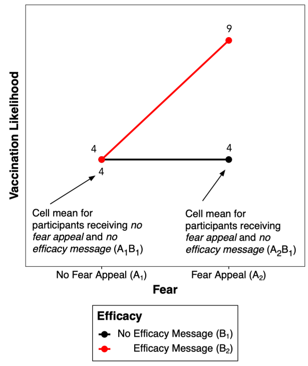

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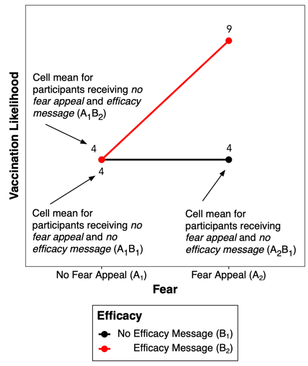
Hypothetical Data Plots



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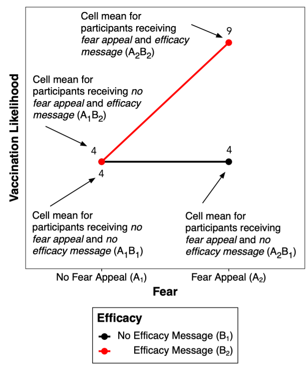
Hypothetical Data Plots



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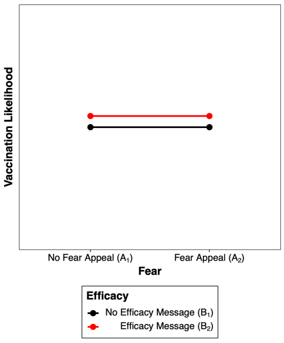
Possible Outcomes For Main Effects

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

Notes

1. No Significant Main Effects



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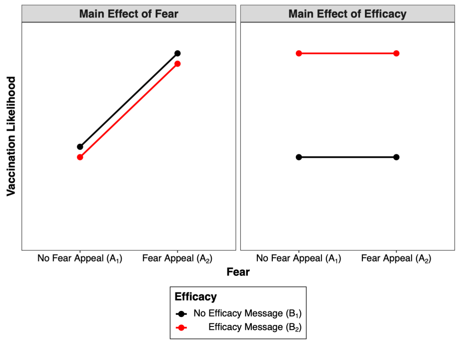
2. One Significant Main Effect



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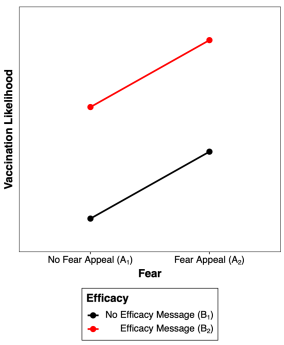
3. Two Significant Main Effects



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Simple Main Effects

- Simple main effects break down main effects into their component parts:
  1. simple main effect of factor A (no fear appeal *vs.* fear appeal) at level B_1 (no efficacy message) of factor B
  2. simple main effect of factor A (no fear appeal *vs.* fear appeal) at level B_2 (efficacy message) of factor B
  3. simple main effect of factor B (no efficacy message *vs.* efficacy message) at level A_1 (no fear appeal) of factor A
  4. simple main effect of factor B (no efficacy message *vs.* efficacy message) at level A_2 (fear appeal) of factor A
- Let's look at these effects visually ...

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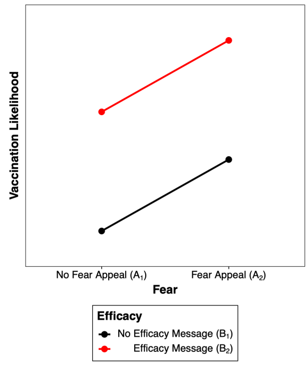
Simple Main Effects



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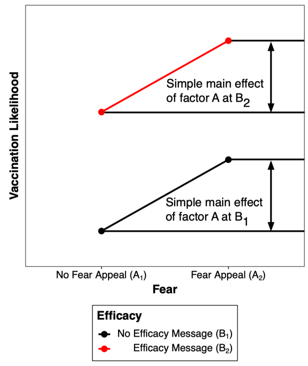
Simple Main Effects



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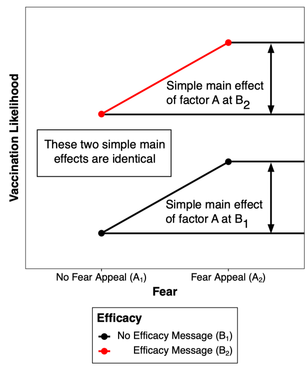

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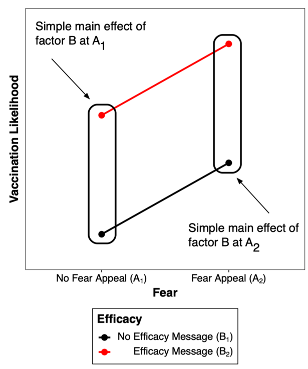

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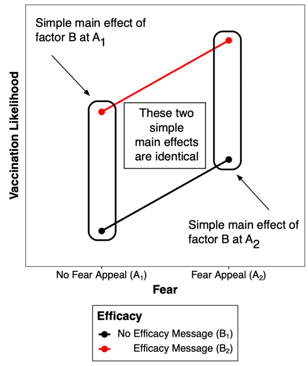

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Simple Main Effects

- 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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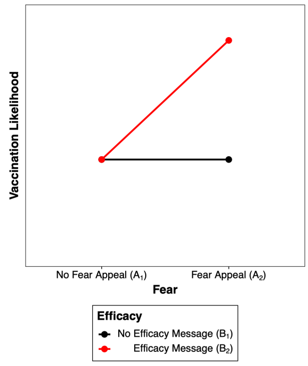

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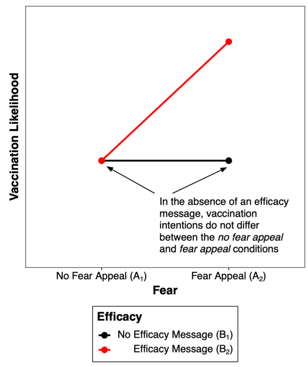

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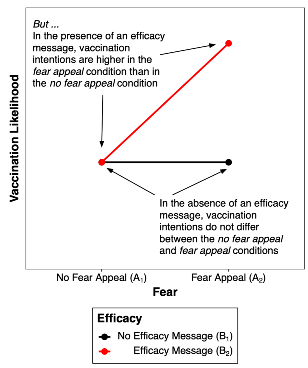

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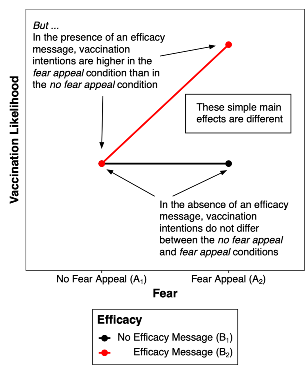

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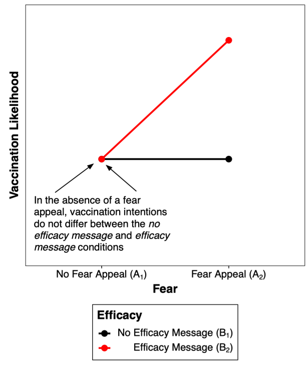

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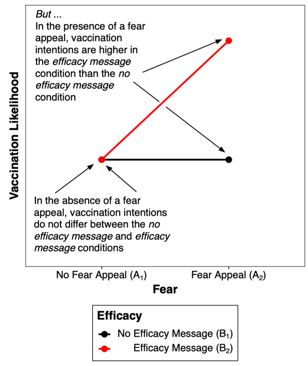

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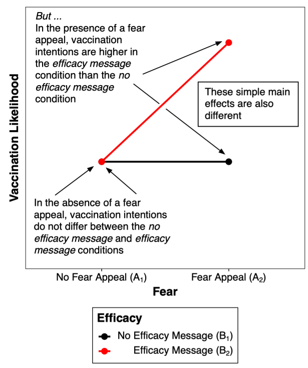

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How To Spot An Interaction

- 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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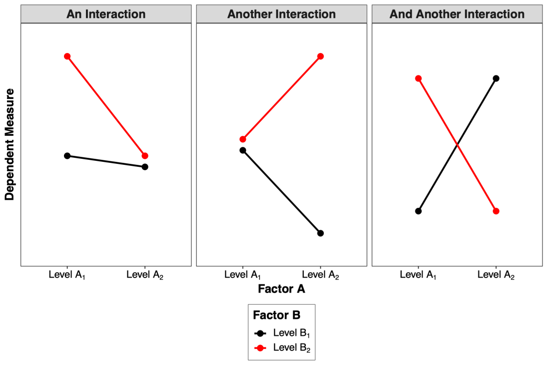
Examples of Interactions: All Have Non-Parallel Lines



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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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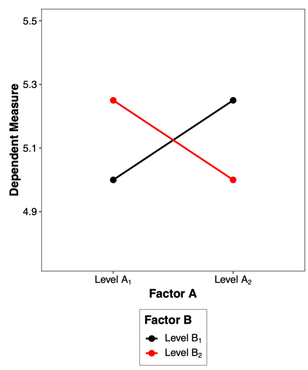
Example of "Illusory Interaction" Due to Scale Compression



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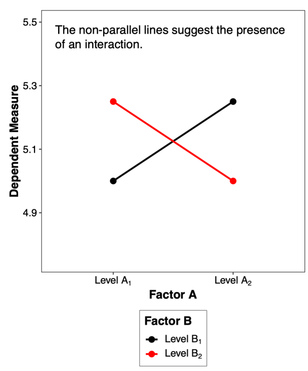

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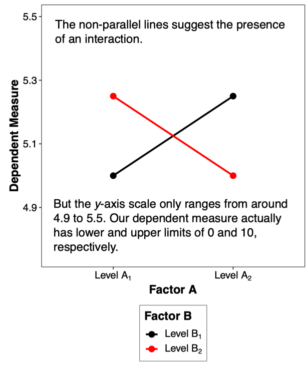

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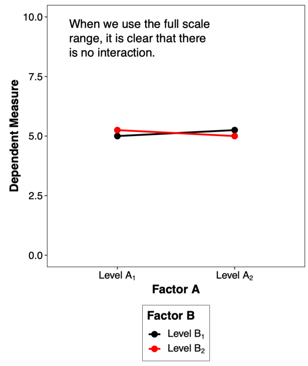
Example of “Illusory Interaction” Due to Scale Compression



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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 $\times$ 3 design ...

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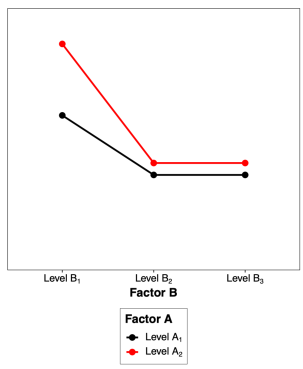

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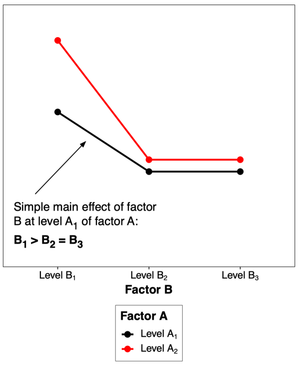

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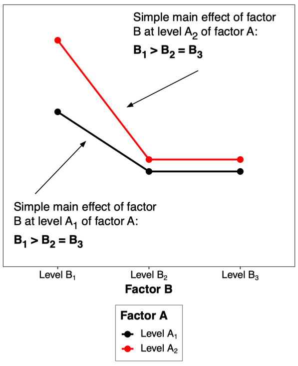

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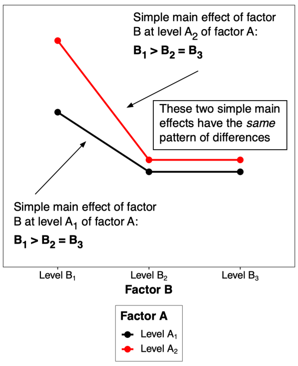

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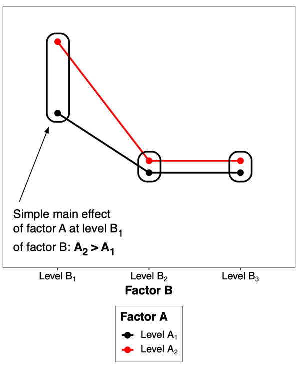

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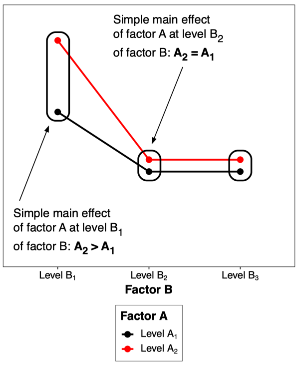

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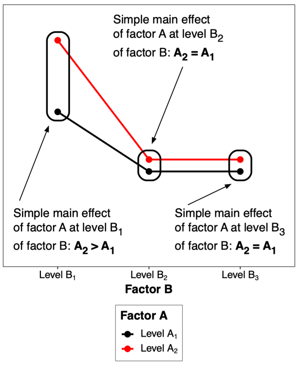

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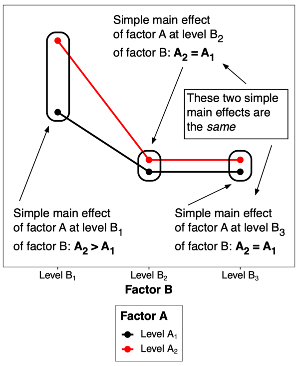

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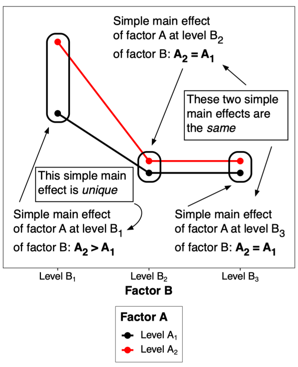

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Why Factorial Designs?

- 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?

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- 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

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- 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

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- 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

Notes

Additional Resources

- The R code for all plots generated in this lecture (minus annotations) has been uploaded with these slides to the Week 6 lecture folder (R Plots For Lecture 6.R)

Notes

In Next Week's Lab ...

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

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