HOW TO APPLY THE MULTIPHASE OPTIMIZATION STRATEGY (MOST) IN YOUR INTERVENTION DEVELOPMENT RESEARCH

Module 4
Some conceptual and technical aspects of the factorial experiment

Lesson 1: The regression model and coding

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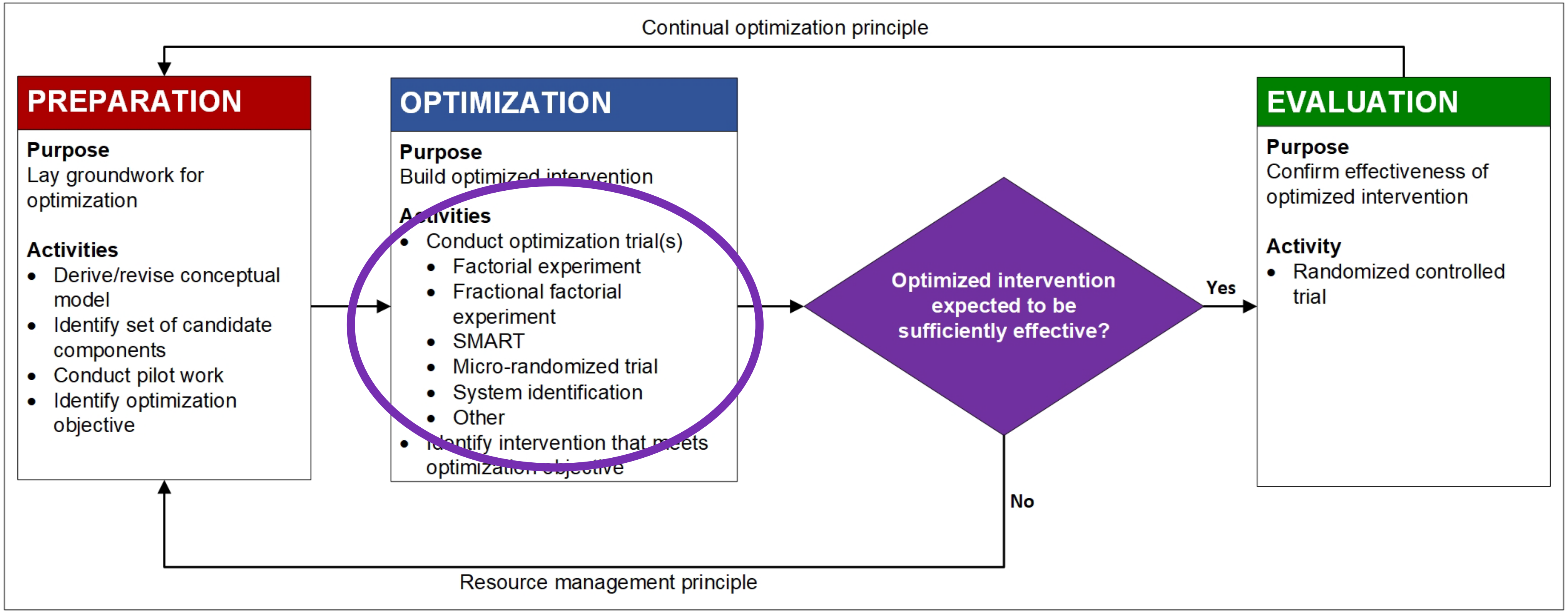
In this lesson you will learn how to:

- Describe the regression model for a factorial experiment
- Explain the difference between dummy coding and effect coding



Flow chart of the three phases of the multiphase optimization strategy (MOST). Rectangle = action. Diamond = decision.

Figure adapted from Collins, L.M. (2018)

What are we trying to estimate with a factorial experiment? Main effects and interactions

- Main effect of each factor
  - DEFINITION OF MAIN EFFECT OF FACTOR *A*:
    - Effect of Factor *A* averaged across all levels of all other factors

What are we trying to estimate with a factorial experiment? Main effects and interactions

- Interactions
  - DEFINITION OF INTERACTION BETWEEN FACTOR *A* AND FACTOR *B* (assuming each factor has two levels):
    - ½ [(effect of Factor *A* at level 1 of Factor *B*) – (effect of Factor *A* at level 2 of Factor *B*)] averaged across all levels of all other factors

- Suppose we conducted this experiment and now want to analyze the data.

Experimental Condition (Cell)	Factorial Experiment				
	MI	*PEER*	*TEXT*	*outcome*	*n*
1	No	No	No	$\bar{Y}_1$	40
2	No	No	Yes	$\bar{Y}_2$	40
3	No	Yes	No	$\bar{Y}_3$	40
4	No	Yes	Yes	$\bar{Y}_4$	40
5	Yes	No	No	$\bar{Y}_5$	40
6	Yes	No	Yes	$\bar{Y}_6$	40
7	Yes	Yes	No	$\bar{Y}_7$	40
8	Yes	Yes	Yes	$\bar{Y}_8$	40

Suppose we have conducted the 2^3 experiment and want to analyze the data

- We can perform Analysis of Variance (ANOVA) via regression
- We need to specify a regression model to predict Y

Suppose we have conducted the 2^3 experiment and want to analyze the data

- In a full ANOVA model for this 2^3 experiment there are:
  - Three main effects (*MI*, *PEER*, *TEXT*)
  - Three 2-way interactions (*MI*×*PEER*, *MI*×*TEXT*, *PEER*×*TEXT*)
  - One 3-way interaction (*MI*×*PEER*×*TEXT*)
- These effects can be estimated via regression

There is a $\hat{Y}$ corresponding to each experimental condition, e.g.:

$\hat{Y}_3$ is the predicted Y when

- *MI*=No,
- *PEER*=Yes, and
- *TEXT*=No.

Experimental Condition (Cell)	Factorial Experiment				
	MI	*PEER*	*TEXT*	*predicted outcome*	*n*
1	No	No	No	$\hat{Y}_1$	40
2	No	No	Yes	$\hat{Y}_2$	40
3	No	Yes	No	$\hat{Y}_3$	40
4	No	Yes	Yes	$\hat{Y}_4$	40
5	Yes	No	No	$\hat{Y}_5$	40
6	Yes	No	Yes	$\hat{Y}_6$	40
7	Yes	Yes	No	$\hat{Y}_7$	40
8	Yes	Yes	Yes	$\hat{Y}_8$	40

The regression model

$$\hat{Y} = \underbrace{\beta_0}_{\text{Intercept}} + \underbrace{\beta_1 X_{MI} + \beta_2 X_{PEER} + \beta_3 X_{TEXT}}_{\text{Main effects}} + \underbrace{\beta_4 X_{MI \times PEER} + \beta_5 X_{MI \times TEXT} + \beta_6 X_{PEER \times TEXT} + \beta_7 X_{MI \times PEER \times TEXT}}_{\text{Interactions}}$$

The βs correspond to effect estimates.

Where do the X's come from?

Coding main effects: Dummy coding

Dummy Codes							
Experimental Condition (cell)	Main effects			Interactions			
	MI	*PEER*	*TEXT*				
	X_1	X_2	X_3				
1	0	0	0				
2	0	0	1				
3	0	1	0				
4	0	1	1				
5	1	0	0				
6	1	0	1				
7	1	1	0				
8	1	1	1				

Experimental Condition (Cell)	Factorial Experiment		
	MI	*PEER*	*TEXT*
1	No	No	No
2	No	No	Yes
3	No	Yes	No
4	No	Yes	Yes
5	Yes	No	No
6	Yes	No	Yes
7	Yes	Yes	No
8	Yes	Yes	Yes

Coding main effects: Effect coding

Effect Codes							
Experimental Condition (cell)	Main effects			Interactions			
	MI	*PEER*	*TEXT*				
	X_1	X_2	X_3				
1	-1	-1	-1				
2	-1	-1	+1				
3	-1	+1	-1				
4	-1	+1	+1				
5	+1	-1	-1				
6	+1	-1	+1				
7	+1	+1	-1				
8	+1	+1	+1				

Experimental Condition (Cell)	Factorial Experiment		
	MI	*PEER*	*TEXT*
1	No	No	No
2	No	No	Yes
3	No	Yes	No
4	No	Yes	Yes
5	Yes	No	No
6	Yes	No	Yes
7	Yes	Yes	No
8	Yes	Yes	Yes

Coding main effects: Effect coding

Effect Codes							
Experimental Condition (cell)	Main effects			Interactions			
	MI	*PEER*	*TEXT*				
	X_1	X_2	X_3				
1	-1	-1	-1				
2	-1	-1	+1				
3	-1	+1	-1				
4	-1	+1	+1				
5	+1	-1	-1				
6	+1	-1	+1				
7	+1	+1	-1				
8	+1	+1	+1				

Experimental Condition (Cell)	Factorial Experiment		
	MI	*PEER*	*TEXT*
1	No	No	No
2	No	No	Yes
3	No	Yes	No
4	No	Yes	Yes
5	Yes	No	No
6	Yes	No	Yes
7	Yes	Yes	No
8	Yes	Yes	Yes

Coding main effects: Effect coding

Effect Codes							
Experimental Condition (cell)	Main effects			Interactions			
	MI	*PEER*	*TEXT*				
	X_1	X_2	X_3				
1	-1	-1	-1				
2	-1	-1	+1				
3	-1	+1	-1				
4	-1	+1	+1				
5	+1	-1	-1				
6	+1	-1	+1				
7	+1	+1	-1				
8	+1	+1	+1				

Experimental Condition (Cell)	Factorial Experiment		
	MI	*PEER*	*TEXT*
1	No	No	No
2	No	No	Yes
3	No	Yes	No
4	No	Yes	Yes
5	Yes	No	No
6	Yes	No	Yes
7	Yes	Yes	No
8	Yes	Yes	Yes

Coding main effects: Effect coding

Effect Codes							
Experimental Condition (cell)	Main effects			Interactions			
	MI	*PEER*	*TEXT*				
	X_1	X_2	X_3				
1	-1	-1	-1				
2	-1	-1	+1				
3	-1	+1	-1				
4	-1	+1	+1				
5	+1	-1	-1				
6	+1	-1	+1				
7	+1	+1	-1				
8	+1	+1	+1				

Experimental Condition (Cell)	Factorial Experiment		
	MI	*PEER*	*TEXT*
1	No	No	No
2	No	No	Yes
3	No	Yes	No
4	No	Yes	Yes
5	Yes	No	No
6	Yes	No	Yes
7	Yes	Yes	No
8	Yes	Yes	Yes

Coding interaction effects: Effect coding

Effect Codes							
Experimental Condition (cell)	Main effects			Interactions			
	MI	*PEER*	*TEXT*	*MI × PEER*	*MI × TEXT*	*PEER × TEXT*	*MI ×PEER × TEXT*
	X_1	X_2	X_3	X_4	X_5	X_6	X_7
1	-1	-1	-1	+1	+1	+1	-1
2	-1	-1	+1	+1	-1	-1	+1
3	-1	+1	-1	-1	+1	-1	+1
4	-1	+1	+1	-1	-1	+1	-1
5	+1	-1	-1	-1	-1	+1	+1
6	+1	-1	+1	-1	+1	-1	-1
7	+1	+1	-1	+1	-1	-1	-1
8	+1	+1	+1	+1	+1	+1	+1

Coding interaction effects: Effect coding

Effect Codes							
Experimental Condition (cell)	Main effects			Interactions			
	MI	*PEER*	*TEXT*	*MI × PEER*	*MI × TEXT*	*PEER × TEXT*	*MI ×PEER × TEXT*
	X_1	X_2	X_3	X_4	X_5	X_6	X_7
1	-1	-1	-1	+1	+1	+1	-1
2	-1	-1	+1	+1	-1	-1	+1
3	-1	+1	-1	-1	+1	-1	+1
4	-1	+1	+1	-1	-1	+1	-1
5	+1	-1	-1	-1	-1	+1	+1
6	+1	-1	+1	-1	+1	-1	-1
7	+1	+1	-1	+1	-1	-1	-1
8	+1	+1	+1	+1	+1	+1	+1

Coding interaction effects: Effect coding

Effect Codes							
Experimental Condition (cell)	Main effects			Interactions			
	MI	*PEER*	*TEXT*	*MI × PEER*	*MI × TEXT*	*PEER × TEXT*	*MI ×PEER × TEXT*
	X_1	X_2	X_3	X_4	X_5	X_6	X_7
1	-1	-1	-1	+1	+1	+1	-1
2	-1	-1	+1	+1	-1	-1	+1
3	-1	+1	-1	-1	+1	-1	+1
4	-1	+1	+1	-1	-1	+1	-1
5	+1	-1	-1	-1	-1	+1	+1
6	+1	-1	+1	-1	+1	-1	-1
7	+1	+1	-1	+1	-1	-1	-1
8	+1	+1	+1	+1	+1	+1	+1

Coding interaction effects: Effect coding

Effect Codes							
Experimental Condition (cell)	Main effects			Interactions			
	MI	*PEER*	*TEXT*	*MI × PEER*	*MI × TEXT*	*PEER × TEXT*	*MI ×PEER × TEXT*
	X_1	X_2	X_3	X_4	X_5	X_6	X_7
1	-1	-1	-1	+1	+1	+1	-1
2	-1	-1	+1	+1	-1	-1	+1
3	-1	+1	-1	-1	+1	-1	+1
4	-1	+1	+1	-1	-1	+1	-1
5	+1	-1	-1	-1	-1	+1	+1
6	+1	-1	+1	-1	+1	-1	-1
7	+1	+1	-1	+1	-1	-1	-1
8	+1	+1	+1	+1	+1	+1	+1

To sum up:

- To analyze the data from a factorial experiment using a regression model, it's necessary to use numeric codes to represent each main effect and interaction
- This can be done using dummy codes (0,1) or effect codes (for a 2^k, -1,1)

To sum up:

- All else being equal, effect coding and dummy coding produce the same omnibus F
- However, these two approaches define the main effects and interactions differently
- This means hypothesis tests for individual main and interaction effects will be different!

To sum up:

- In this course, we use ONLY effect (-1,1) coding
- In your data analysis, be sure you know which coding is being used
- For more about this, see the Kugler, Dziak, and Trail chapter in Collins & Kugler (2018)

The regression model

$$\hat{Y} = \underset{\text{Intercept}}{\beta_0} + \underbrace{\beta_1 X_{MI} + \beta_2 X_{PEER} + \beta_3 X_{TEXT}}_{\text{Main effects}} + \underbrace{\beta_4 X_{MI \times PEER} + \beta_5 X_{MI \times TEXT} + \beta_6 X_{PEER \times TEXT} + \beta_7 X_{MI \times PEER \times TEXT}}_{\text{Interactions}}$$

The βs correspond to effect estimates.

Recall: Definition of optimization of an intervention used in MOST

Optimization of a multicomponent intervention is the process of identifying an intervention that provides the best expected outcome obtainable within key constraints imposed by the need for affordability, scalability, and/or efficiency.

The $\hat{Y}$s are estimates of the **expected outcome** associated with each experimental condition.

The regression model

$$\hat{Y} = \underbrace{\beta_0}_{\text{Intercept}} + \underbrace{\boxed{\beta_1 X_{MI}} + \beta_2 X_{PEER} + \beta_3 X_{TEXT}}_{\text{Main effects}} + \underbrace{\beta_4 X_{MI \times PEER} + \beta_5 X_{MI \times TEXT} + \beta_6 X_{PEER \times TEXT} + \beta_7 X_{MI \times PEER \times TEXT}}_{\text{Interactions}}$$

The βs correspond to effect estimates.

Coding effects

Through tedious but not difficult algebra you can show that

$$\beta_1 = Main\ Effect_{MI}/2$$

The regression model

$$\hat{Y} = \underbrace{\beta_0}_{\text{Intercept}} + \underbrace{\beta_1 X_{MI} + \beta_2 X_{PEER} + \beta_3 X_{TEXT}}_{\text{Main effects}} + \underbrace{\boxed{\beta_4 X_{MI \times PEER}} + \beta_5 X_{MI \times TEXT} + \beta_6 X_{PEER \times TEXT} + \beta_7 X_{MI \times PEER \times TEXT}}_{\text{Interactions}}$$

The βs correspond to effect estimates.

Coding effects

Through tedious but not difficult algebra you can show that for a 2^k experiment (**BUT THERE IS AN IMPORTANT CAVEAT****):

$$\beta_4 = Interaction_{MI \times PEER}/2$$

****IMPORTANT CAVEAT:** This equation holds for one definition of the interaction. See sections 3.14 and 4.7 in Collins (2018).

In this lesson you learned how to:

- Describe the regression model for a factorial experiment
- Explain the difference between dummy coding and effect coding

In the next lesson you will learn how to:

- Interpret main effects and interaction effects

References cited

- Collins, L.M. (2018). *Optimization of behavioral, biobehavioral, and biomedical interventions: The multiphase optimization strategy (MOST).* New York: Springer.
- Kugler, K.C., Dziak, J.J., & Trail, J. (2018). Coding and interpretation of effects in analysis of data from a factorial experiment. In L.M. Collins & K.C. Kugler (Eds.), *Optimization of behavioral, biobehavioral, and biomedical interventions: Advanced topics.* New York: Springer.