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

Module 3
Introduction to the optimization trial

Lesson 2: Introduction to the factorial experiment

NYU | SCHOOL OF GLOBAL PUBLIC HEALTH

Intervention Optimization Initiative

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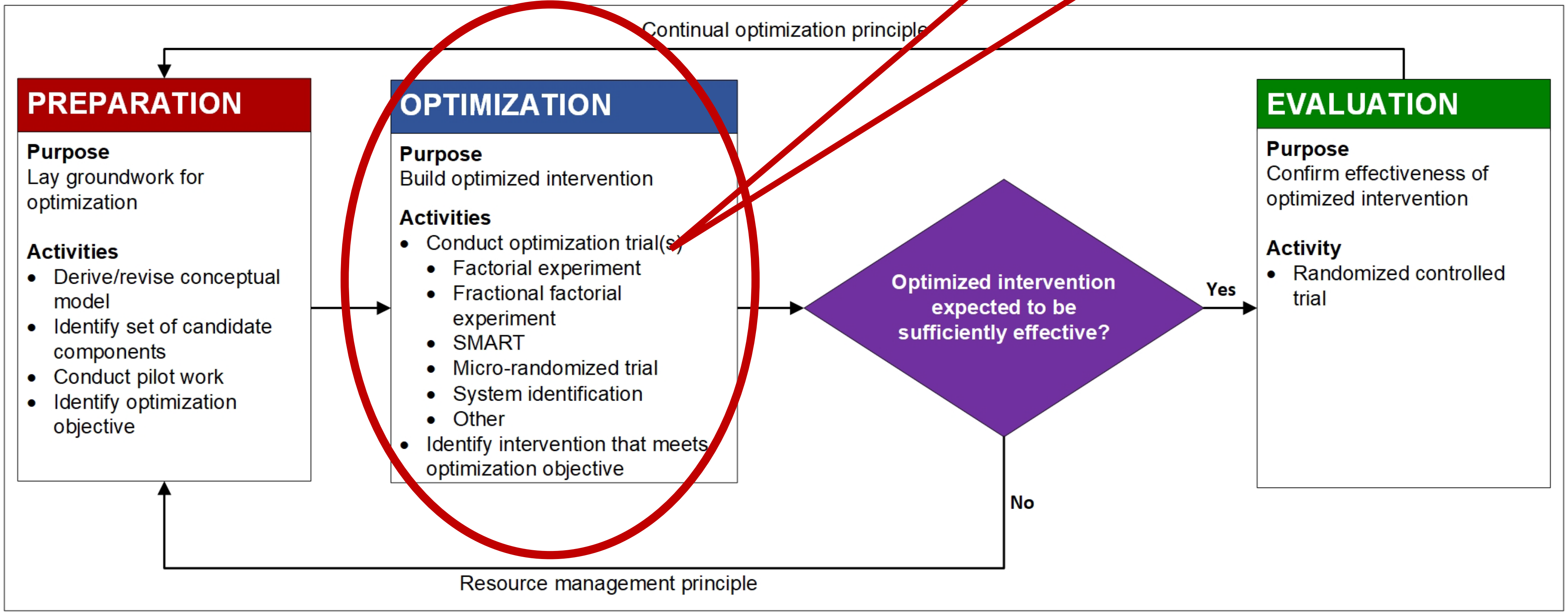
In the previous lesson you learned how to:

- Recognize the importance of basing the selection of an optimization trial design on the resource management principle.

In this course we will be focusing on the factorial design



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

Figure adapted from Collins (2018)

In this lesson you will learn how to:

- Describe the factorial experiment and what it is intended to estimate: main effects and interactions.
- Recognize that coding can have implications for interpretation of results.

The factorial experiment: A brief review

- Some people refer to factorial experiments as “MOST designs.” THIS IS INCORRECT.

- PLEASE DO NOT DO THAT.

The factorial experiment: A brief review

- Factorial experiments have a long and distinguished history.
- They were first used in the 19th century in agriculture
- R. A. Fisher created the factorial Analysis of Variance (ANOVA), a method of analyzing the data from a factorial experiment

The factorial experiment: A brief review

- In a factorial experiment, several independent variables are manipulated in a coordinated fashion
  - These independent variables are called <u>factors</u>
- Ideally, there are equal numbers of participants in each experimental condition

The factorial experiment: A brief review

- Example: 2×2, or 2^2, factorial design

	Factor *A*	
Factor *B*	No	Yes
No	*A*,*B* = no	*A* = yes, *B* = no
Yes	*A* = no, *B* = yes	*A*,*B* = yes

The factorial experiment: A brief review

- Example: 2×2, or 2^2, factorial design

Factor *B*	Factor *A*: No	Factor *A*: Yes
No	*A*,*B* = no	*A* = yes, *B* = no
Yes	*A* = no, *B* = yes	*A*,*B* = yes

- Main effect of Factor *A*: Mean of conditions where Factor *A* = yes MINUS mean of conditions where Factor *A* = no

The factorial experiment: A brief review

- Example: 2×2, or 2^2, factorial design

	Factor *A*	
Factor *B*	No	Yes
No	*A*,*B* = no	*A* = yes, *B* = no
Yes	*A* = no, *B* = yes	*A*,*B* = yes

- Main effect of Factor *B*: Mean of conditions where Factor *B* = yes MINUS mean of conditions where Factor *B* = no

The factorial experiment: A brief review

- Example: 2×2, or 2^2, factorial design

	Factor *A*	
Factor *B*	No	Yes
No	*A*,*B* = no	*A* = yes, *B* = no
Yes	*A* = no, *B* = yes	*A*,*B* = yes

- Factorial experiments may have
  - > 2 factors
  - > 2 levels/factor

We will usually use a tabular representation of factorial experiments

Factor *B*	Factor *A*: No	Factor *A*: Yes
No	*A*,*B* = no	*A* = yes, *B* = no
Yes	*A* = no, *B* = yes	*A*,*B* = yes

Experimental condition	Factor *A*	Factor *B*	Outcome
1	No	No	$\overline{Y}_1$
2	No	Yes	$\overline{Y}_2$
3	Yes	No	$\overline{Y}_3$
4	Yes	Yes	$\overline{Y}_4$

The factorial experiment: Notation

- 2×2 = two factors, each with two levels = 2^2

- $2\times2\times3$ = three factors, two with two levels and one with three levels = $2^2\times3$ or $2^2 3$

The factorial experiment: Notation

- 2×3 = one factor with two levels and one factor with three levels.

- $2 \times 2 \times 2$ = three factors, each with two levels = 2^3. THIS IS **NOT** A 2×3!

This is a 2^3 or 2×2×2 factorial design.

It has 3 factors, each with 2 levels.

Experimental condition	Factor *A*	Factor *B*	Factor *C*	*Outcome*
1	No	No	No	$\overline{Y}_1$
2	No	No	No	$\overline{Y}_2$
3	No	No	Yes	$\overline{Y}_3$
4	No	No	Yes	$\overline{Y}_4$
5	No	Yes	No	$\overline{Y}_5$
6	No	Yes	No	$\overline{Y}_6$
7	No	Yes	Yes	$\overline{Y}_7$
8	No	Yes	Yes	$\overline{Y}_8$

This is a 2×3 factorial design.

It has 2 factors, one with 2 levels and one with 3 levels.

Experimental condition	Factor *A*	Factor *B*	*Outcome*
1	No	No	$\overline{Y}_1$
2	No	Medium	$\overline{Y}_2$
3	No	High	$\overline{Y}_3$
4	Yes	No	$\overline{Y}_4$
5	Yes	Medium	$\overline{Y}_5$
6	Yes	High	$\overline{Y}_6$

The factorial experiment: Notation

- In this course we will focus on experiments in which all k factors have 2 levels
- These are referred to as 2^k experiments

Main effect of Factor *A*

Experimental condition	Factor *A*	Factor *B*	*Outcome*
1	No	No	$\bar{Y}_1$
2	No	Yes	$\bar{Y}_2$
3	Yes	No	$\bar{Y}_3$
4	Yes	Yes	$\bar{Y}_4$

Main effect of *A* = mean of $(\bar{Y}_3 + \bar{Y}_4)$ – mean of $(\bar{Y}_1 + \bar{Y}_2)$
Interpretation: Effect of Factor *A* averaged across levels of Factor *B*

Main effect of Factor *B*

Experimental condition	Factor *A*	Factor *B*	*Outcome*
1	No	No	$\bar{Y}_1$
2	No	Yes	$\bar{Y}_2$
3	Yes	No	$\bar{Y}_3$
4	Yes	Yes	$\bar{Y}_4$

Main effect of *B* = mean of $(\bar{Y}_2 + \bar{Y}_4)$ – mean of $(\bar{Y}_1 + \bar{Y}_3)$

Interpretation: Effect of Factor *B* averaged across levels of Factor *A*

Interaction involving Factor *A* and Factor *B*

Experimental condition	Factor *A*	Factor *B*	*Outcome*
1	No	No	$\bar{Y}_1$
2	No	Yes	$\bar{Y}_2$
3	Yes	No	$\bar{Y}_3$
4	Yes	Yes	$\bar{Y}_4$

A×*B* interaction = $[(\bar{Y}_4 - \bar{Y}_3) - (\bar{Y}_2 - \bar{Y}_1)]/2$

Interpretation: Difference in the effect of Factor *B* across the levels of Factor *A*

Or equivalently:

Experimental condition	Factor *A*	Factor *B*	*Outcome*
1	No	No	$\bar{Y}_1$
2	No	Yes	$\bar{Y}_2$
3	Yes	No	$\bar{Y}_3$
4	Yes	Yes	$\bar{Y}_4$

A×*B* interaction = $[(\bar{Y}_4 - \bar{Y}_2) - (\bar{Y}_3 - \bar{Y}_1)]/2$

Interpretation: Difference in the effect of Factor *A* across the levels of Factor *B*

How does this relate to intervention optimization?

- Each factor in a factorial experiment can be used to evaluate the performance of a component

Coding matters in interpretation of effects

- Coding refers to how the levels of a factor are represented numerically in data analysis
- In this course we are using effect coding.
  - Where a factor has two levels: -1, 1
- You may be more accustomed to dummy coding
  - Where a factor has two levels: 0, 1

Coding matters in interpretation of effects

- In a factorial ANOVA, the effect estimates are generally NOT THE SAME across the two types of coding
  - Although the overall fit is the same
  - i.e., omnibus F's are identical

Coding matters in interpretation of effects

- Effect-coded main effects and interactions should be interpreted as we have described here
- Dummy-coded main effects and interactions generally SHOULD NOT be interpreted as we have described here

Two points about effect coding: #1

- In a properly conducted factorial experiment, effect coding produces main effect and interaction estimates that are all uncorrelated if *n*s are equal across experimental conditions
  - If *n*s are unequal, they will usually be only modestly correlated
- By contrast, with dummy coding effects are usually highly correlated

Two points about effect coding: #1

- This is explained further in Section 3.11.2 of Collins (2018)
- It is explained in detail in Kugler, Dziak, & Trail (2018)

Two points about effect coding: #2

- In a properly conducted 2^k factorial experiment with equal *n*s, the standard errors are identical for all effect estimates

- This applies to main effects and interactions up to the *k*-way interaction

In this lesson you learned how to:

- Describe the factorial experiment and what it is intended to estimate: main effects and interactions
- Recognize that coding can have implications for interpretation of results

In the next lesson you will learn how to:

- Express the fundamental differences between the logical underpinnings of an RCT and those of a factorial experiment
- Explain why the factorial experiment usually requires many fewer experimental participants than alternative designs

References cited

- Collins, L.M. (2018). *Optimization of behavioral, biobehavioral, and biomedical interventions: The multiphase optimization strategy (MOST)*. New York: Springer.
- Collins, L.M., & Kugler, K.C. (2018). *Optimization of behavioral, biobehavioral, and biomedical interventions: Advanced topics.* New York: Springer.