Training on optimization of behavioral and biobehavioral interventions

September 9, 2016

Morning session:

Opening remarks

Bill Riley, Ph.D., Director, Office of Behavioral and Social Sciences Research, NIH

Introduction to the multiphase optimization strategy (MOST)

Linda M. Collins, Ph.D., Penn State

Afternoon session:

Adaptive interventions and the sequential multiple assignment randomized trial (SMART)

Daniel Almirall, Ph.D., University of Michigan

Introduction to the multiphase optimization strategy (MOST)

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Penn State

Presented at the National Institutes of Health
Rockville, MD
September 9, 2016

The Methodology Center

PennState

Overview

- Why offer this training?
- Introduction to the multiphase optimization strategy (MOST)
- Example: Building a clinic-delivered smoking cessation intervention
- Some MOST fundamentals
- Choosing an experimental design based on the resource management principle
- Factorial experiments and multilevel data
- Concluding remarks, Q and A, open discussion

Why offer this training?

Imagine…

- Behavioral and biobehavioral interventions (BBIs) are engineered to meet specific standards for efficiency, economy, and scalability
- It is known what the active ingredients are, so
  - BBIs are made up solely of active ingredients
  - The way forward for improving a BBI is clear
- Once a BBI has been developed, it is immediately scalable
- BBIs are improved incrementally over time – they get better and better

Some funded projects using MOST (that I know of)

- Prevention of drug abuse and HIV in South Africa (L. Caldwell, PSU, R01DA 029084)
- Substance use prevention program aimed at American Indian families (N. Whitesell, U. of Colorado, R01DA035111)
- Moderation of gestational weight gain (D. Downs, PSU, R01HL119245)
- Smoking cessation intervention for adults (M. Fiore & T. Baker, U of Wisconsin, P01CA180945)
- Intervention to reduce fear of recurrence in breast cancer patients (L. Wagner, now at Wake Forest, R21CA173193)

Some funded projects using MOST (that I know of)

- Weight reduction program for adults (B. Spring, NWU and L. Collins, PSU, R01DK097364)
- Adherence intervention to promote use of insulin pumps among adolescents (K. Driscoll, U of Florida, K23DK091558)
- Online intervention to prevent excessive alcohol use and risky sex in college students (L. Collins, PSU, R01AA022931)
- Positive psychology intervention for cardiac patients to improve health behaviors (J. Huffman, Harvard UR01HL113272)

Introduction to the multiphase optimization strategy (MOST)

Scenario 1: Cancer prevention: Developing a smoking cessation intervention

- Goal: choose from set of components/component levels to maximize probability of successful quitting

Multicomponent behavioral and biobehavioral interventions (BBIs)

- May be aimed at prevention or treatment
- May be aimed at health, social, behavioral, or educational outcomes
- May include both behavioral and pharmaceutical components (biobehavioral interventions)
- May include components aimed at individuals, family, school, community
- Examples of multicomponent BBIs
  - Smoking cessation treatment
  - Treatment for depression
  - School-based drug abuse prevention
  - Prevention/treatment of obesity

Definition: Intervention components

- Intervention components: *Any aspects of an intervention that can be separated out for study*
  - Parts of intervention content
    - e.g., topics in a curriculum
  - Features that promote compliance/adherence
    - e.g., reminder phone calls or text messages
  - Features aimed at improving fidelity
    - e.g., enhanced teacher training

Scenario 1. Cancer prevention: Developing a smoking cessation intervention

- Goal: choose from set of components/component levels to maximize probability of successful quitting

Scenario 1. Cancer prevention: Developing a smoking cessation intervention

- Goal: choose from set of components/component levels to maximize probability of successful quitting
- Components:
  - Precessation nicotine patch (No, Yes)
  - Precessation nicotine gum (No, Yes)
  - Precessation in-person counseling (No, Yes)
  - Cessation in-person counseling (Minimal, Intensive)
  - Cessation phone counseling (Minimal, Intensive)
  - Maintenance medication duration (Short, Long)

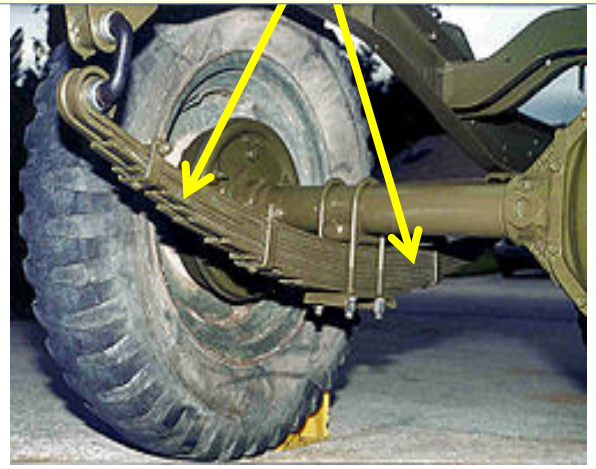
Scenario 1. Cancer prevention: Developing a smoking cessation intervention

- How to build a behavioral intervention out of these components?
- Construct new intervention by setting each component at highest level, put them together
  - Intervention = precessation patch and gum and counseling, intensive cessation in-person and phone counseling, long medication duration
- Then compare to control group via RCT
- Possibly conduct post-hoc analyses
- Let's call this the ***treatment package approach***

Scenario 2. Developing a way to manufacture truck leaf springs

- Goal: Choose from set of components/component levels to optimize amount of variability in length of leaf springs (less variability is better)

Leaf Spring:
part of truck suspension system



Pignatiello and Ramberg (1985) in Wu & Hamada (2000)

Scenario 2. Developing a way to manufacture truck leaf springs

- Goal: Choose from set of components/component levels to optimize amount of variability in length of leaf springs (less variability is better)
- Components (suppose for each one higher hypothesized to be better):
  - Furnace temperature (lower, higher)
  - Heating time (shorter, longer)
  - Transfer time on conveyor belt (shorter, longer)
  - Hold down time in high pressure press (shorter, longer)
  - Quench oil temperature range (lower temps, higher temps)

Scenario 2. If engineers thought like behavioral scientists

- Would use the treatment package approach
- Construct new manufacturing process = higher furnace temp, longer heating time, longer conveyor belt time, longer time in high pressure press, higher temp quench oil
- Compare this process as a package to the old way, see if it is demonstrably better
- Conduct post-hoc analyses

Scenario 2: Developing a way to manufacture truck leaf springs

- But an engineer would not use the treatment package approach, because
  - If the new process IS better, doesn't indicate which components make a difference
  - If the new process IS NOT better, doesn't indicate which (if any) of the components did effect an improvement
  - When repeated, no guarantee of systematic incremental improvement, so not a good long-run strategy
  - Does not take cost or other constraints into account

Scenario 2. Developing a way to manufacture truck leaf springs

- What WOULD an engineer do?
- Start with a clear idea of the goal, including constraints
  - e.g., Least variability AND must cost less than $1/spring
- Using the resources available, design an efficient experiment to gather needed information (e.g. individual effects of components)
- Based on the results of experiment, choose components and component levels to achieve stated goal. THIS IS optimization
- THEN compare new process to old process

Back to Scenario 1: If behavioral scientists thought like engineers

- We might want to optimize the smoking cessation intervention
- Using an approach that
  - Indicates which components are active
  - Ensures an incremental improvement, and therefore is the fastest way to the best intervention IN THE LONG RUN
  - Readily incorporates costs/constraints of any kind
  - Enables optimization using any desired criterion

Desiderata for BBIs

- Effectiveness
  - Extent to which the BBI does more good than harm (under real-world conditions, Flay (1986))
- Efficiency
  - Extent to which BBI avoids wasting time, money, or other valuable resources
- Economy
  - Extent to which BBI is effective without exceeding budgetary constraints, and offers a good value
- Scalability
  - Extent to which the BBI can be implemented widely with fidelity

Definition of optimization of a BBI

- *Optimization of a BBI is the process of identifying a BBI that provides the best expected outcome obtainable within key constraints imposed by the need for efficiency, economy, and/or scalability.*
- Note:
  - Process
  - Key constraints
  - Highest expected level obtainable

Comparison of evaluation and optimization

- Evaluation requires comparison of intervention package to control
  - RCT the way to do this
- Optimization requires examination of individual components
  - In a RCT all components are confounded
  - Requires a different experimental design

The multiphase optimization strategy (MOST)

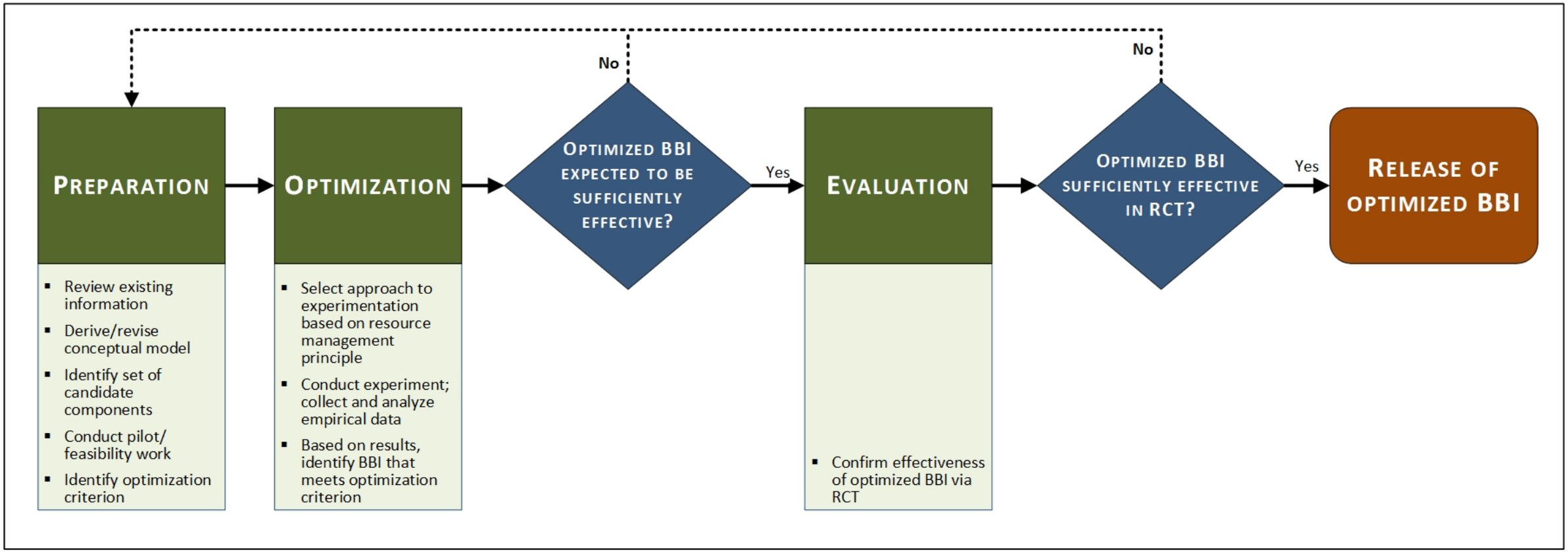
- A comprehensive strategy for optimization and evaluation
- Engineering-inspired framework
  - First, estimate individual contributions of intervention components, and interactions between components where anticipated (or feared)
  - Decide which to retain, at what levels/settings
  - THEN assemble into an intervention, and evaluate in a RCT

MOST: A comprehensive strategy for optimization and evaluation

- MOST is <u>not</u>
  - An off-the-shelf procedure that is identical for every application
  - A particular experimental design

MOST: A comprehensive strategy for optimization and evaluation

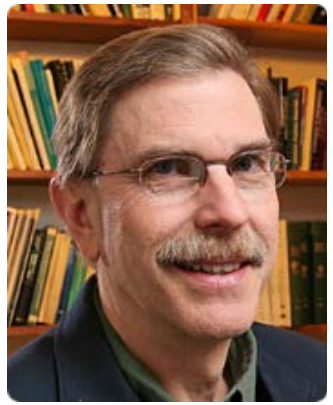
- MOST is
  - A framework for thinking through how to optimize a behavioral intervention
  - A practical way of approaching the engineering of behavioral interventions so that they meet specific optimization criteria
  - Designed to make the best use of available resources
  - Very new, and still an open area! Not everything is figured out


PREPARATION
Review existing information
Derive/revise conceptual model
Identify set of candidate components
Conduct pilot/ feasibility work
Identify optimization criterion
OPTIMIZATION
Select approach to experimentation based on resource management principle
Conduct experiment; collect and analyze empirical data
Based on results, identify BBI that meets optimization criterion
OPTIMIZED BBI EXPECTED TO BE SUFFICIENTLY EFFECTIVE?
No
Yes
EVALUATION
Confirm effectiveness of optimized BBI via RCT
OPTIMIZED BBI SUFFICIENTLY EFFECTIVE IN RCT?
No
Yes
RELEASE OF OPTIMIZED BBI

Example: Building a clinic-delivered smoking cessation intervention

Example: Clinic-based smoking cessation study funded by the National Cancer Institute

Timothy Baker, Ph.D.



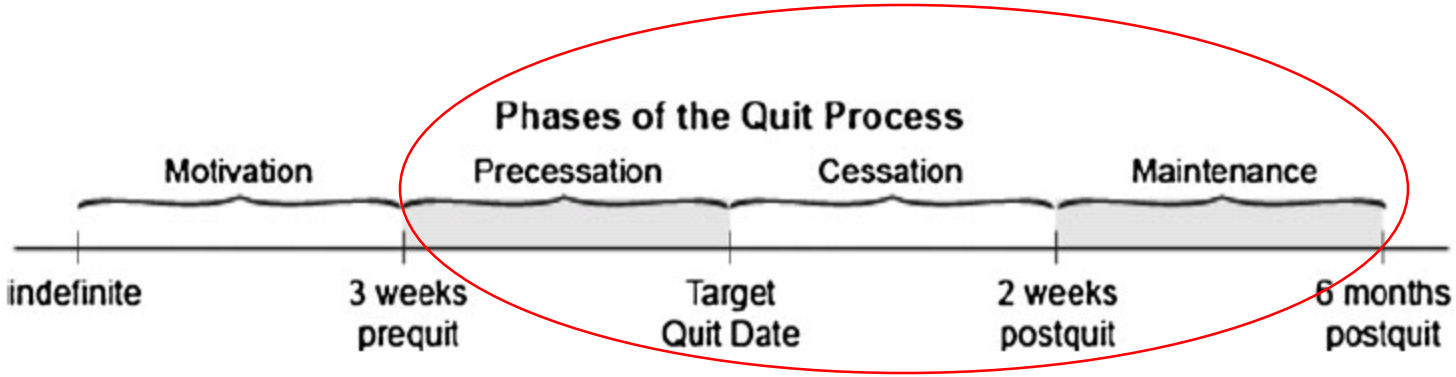
Michael Fiore, M.D.

University of Wisconsin

Center for Tobacco Research and Intervention

Purpose of intervention: To help people quit smoking successfully

Baker and Fiore's model of the smoking cessation process: Phases



- From Baker et al. (2011)

Challenges and intervention components in smoking cessation study

Phase	Challenge	Intervention component
Precessation	Smoking cues and contexts	Nicotine patch
		Nicotine gum
	Withdrawal/coping skills practice	Precessation counseling
Cessation	Decline in positive affect	In-person counseling
		Phone counseling
Maintenance	Lapses	Long-term medication

Component 1: Precessation nicotine patch

- *Background*: Research suggests nicotine patch may be helpful during precessation (as opposed to cessation where it is always used).
- *Decision*: Should intervention include use of the nicotine patch during precessation?
- *Research question*: Does precessation use of the nicotine patch improve initial cessation outcomes relative to no precessation use of the nicotine patch?
- *Intervention component*: precessation nicotine patch.
- *Levels*: patch, no patch.

Component 2: Precessation nicotine gum

- *Background*: Research suggests that use of self-administered nicotine gum ad lib (as needed) may be helpful during precessation.
- *Decision*: Should intervention include use of ad lib nicotine gum during precessation?
- *Research question*: Does precessation use of nicotine gum improve initial cessation outcomes relative to no precessation use of nicotine gum?
- *Intervention component*: precessation nicotine gum.
- *Levels*: nicotine gum, no nicotine gum.

Component 3: Precessation counseling

- *Background*: Research indicates that counseling addressing issues such as how to develop skills for coping with withdrawal may be helpful during precessation.
- *Decision*: Should intervention include precessation counseling?
- *Research question*: Does precessation counseling improve initial cessation outcomes relative to no precessation counseling?
- *Intervention component*: precessation counseling.
- *Levels*: intensive, none.

Component 4: Cessation counseling

- *Background*: It is known that counseling during the cessation phase is efficacious, but the minimal effective level is not known. Given the expense of counseling, this is an important question.
- *Decision*: Should intervention include intensive or minimal level of counseling?
- *Research question*: Does intensive counseling (defined as three 20-min sessions) during the cessation phase improve initial cessation outcomes relative to minimal counseling (one 3-min session, level based on the 2008 PHS Guideline recommendations for brief clinician counseling)?
- *Intervention component*: Cessation counseling.
- *Levels*: intensive, minimal.

Component 5: Cessation telephone counseling

- *Background*: Delivering counseling over the telephone (e.g. cessation quitline) during cessation is very efficient. The minimal effective level is unknown.
- *Decision*: Should intervention include intensive or minimal level of telephone-delivered counseling during cessation?
- *Research question*: Does intensive phone counseling during cessation (defined as three 15-min sessions) improve initial cessation outcomes relative to minimal counseling (defined as one 10-min session)?
- *Intervention component*: cessation phone counseling.
- *Levels*: intensive, minimal.

Component 6: Duration of cessation NRT

- *Background*: It is standard to recommend use of NRT for eight weeks past the quit date. There is mixed evidence that a longer duration may improve outcomes.
- *Decision*: Should intervention include standard or extended period of cessation NRT?
- *Research question*: Does an extended duration of NRT (defined as16 weeks) improve long-term cessation outcomes more than the standard 8-week duration?
- *Intervention component*: duration of cessation NRT.
- *Levels*: 16 weeks, 8 weeks.

Treatment package (traditional) approach

- Create an intervention that includes all components at most intensive levels:
  - During precessation, patient uses a nicotine patch and ad lib nicotine lozenges or gum (depending on patient preference). Patient gets intensive in-person counseling.
  - During cessation, patient gets both intensive in-person and intensive phone counseling.
  - During maintenance, patient continues NRT for 16 weeks.
- Evaluate via RCT

What the RCT cannot not tell us

An RCT that finds a <u>significant</u> effect WILL NOT tell us

- Which components are making positive contributions to overall effect
- Whether the inclusion of one component has an impact on the effect of another
- Whether a component's contribution offsets its cost
- Whether all the components are really needed
- How to make the intervention more effective, efficient, and scalable

What the RCT cannot not tell us

An RCT that finds a <u>non-significant</u> effect WILL NOT tell us

- Whether any components are worth retaining
- Whether one component had a negative effect that offset the positive effect of others
- Specifically what went wrong and how to do it better the next time

Instead, MOST

- FIRST build an optimized smoking cessation intervention, and THEN evaluate the optimized intervention
- A simple criterion: intervention comprising components with empirically demonstrated effects
- We will come back to optimization criteria

Some MOST fundamentals

Resource management principle

- How engineers think, Lesson 1
  - This is what I need to find out: _____
  - These are the resources I have: _____
  - How can I manage my resources strategically to find out what I need to know?

Resource management principle

- Logic: huge (e.g., 64-arm) RCT would be definitive, but is not feasible to power
- Instead, manage research resources strategically to:
  - Gain the most information
  - Gain the most reliable information
  - Move science forward fastest
- Decide what information most important, and target resources there
- Choose designs for efficiency
- Take calculated risks

Resource management principle

- Note that the starting point is the resources you have
- By definition, MOST does not require an increase in research resources
- But in most cases will require a realignment of research resources

Continuous optimization principle

- How engineers think, Lesson 2:
  - I have finished developing this product and it is ready to market.
  - Now I am going to start developing the new, improved product.
  - Optimization is a **cyclic process**

Overview of experimentation to examine individual intervention components

- Objective is to identify the most promising components and levels/settings
- NOT to compare each combination to a control or against each other
- NOT to identify single best combination

Overview of experimentation to examine individual intervention components

- Conduct a ***component screening experiment***
- Objectives:
  - For each component, determine whether there is a difference between the highest and lowest levels
  - This information to be used in making decisions about selection of components and levels for intervention package

Overview of experimentation to examine individual intervention components

- For nicotine patch, nicotine gum, precessation counseling
  - Comparison of On vs. Off
  - Experiment must provide evidence of whether or not each has an effect on outcomes
  - If yes, consider including in intervention package
  - Depending on optimization criterion, effect *size* may be considered in relation to
    - Cost
    - Time

Overview of experimentation to examine individual intervention components

- For cessation counseling, cessation phone counseling
  - Comparison of Minimal vs. Intensive
  - Experiment must provide evidence of whether Intensive is doing more than Minimal
  - If Intensive NOT > Minimal, select Minimal
  - If Intensive > Minimal, consider selecting intensive
  - Depending on optimization criterion, effect *size* may be considered in relation to
    - Cost
    - Time

Overview of experimentation to examine individual intervention components

- For duration of cessation/maintenance NRT
  - Comparison of 8 weeks vs. 16 weeks
  - Experiment must provide evidence of whether 16 weeks is doing more than 8 weeks
  - If 16 weeks NOT > 8 weeks, select 8 weeks
  - If 16 weeks > 8 weeks, consider selecting 16 weeks
  - Depending on optimization criterion, effect *size* may be considered in relation to
    - Cost
    - Time

Assembly of optimized intervention

- Experimentation has provided empirical data about effects of each intervention component
  - Main effects and interactions from ANOVA of data from factorial experiment
- Based on this information, identify combination of components and level/doses that meets optimization criterion
- This forms the optimized intervention

Deciding on your optimization criterion

- This is the goal you want to achieve
- Constraints are
  - Set of intervention components under consideration
  - Limitations on
    - Cost to deliver intervention
    - Time to deliver intervention
    - Etc.

Some possible optimization criteria

- No inactive components
- Most effective intervention that can be implemented for less than some $$$
- Most cost-effective
- Most effective intervention that can be completed in less than some upper limit on time

Choosing an experimental design based on the resource management principle

Groundwork before selecting an experimental design

- OBJECTIVE: To gather information that will be used in <u>decision making</u>
  - Primarily, main effects
  - Secondarily, interactions
- Less interested in precise estimates of every possible effect
- Instead, need as much practical information as possible
- STARTING POINT: What decisions do I need to make?

Choice of design for component screening experiment is critical

- Any experimental design is a possibility BUT…
- **…must be selected based on Resource Management Principle!!!**

The resource management principle says:

- The investigator must carefully choose an experimental design so as to
  - Gather the information needed…
  - …while making the most of (but not exceeding) the available resources

The resource management principle says:

- Thus the experimenter must
  - Have a clearly specified set of research questions
  - Know what resources are available
  - Know what resources are required by each design under consideration
    - Different designs require different resources

The component screening experiment

- Purpose: efficient screening of intervention components
  - Weed out underperforming components
  - Get a sense of magnitude of each component's effect
  - Examine whether effect of a component is augmented or reduced in presence of another
- This information is then used to optimize the intervention

Resource management principle

- To select a design, consider several, and examine
  - The scientific information each will provide
    - And whether it is what you want!
  - What each design costs
    - Number of subjects
    - Number of experimental conditions
- NOTE that the starting point is the resources you have

Design option A: Six individual treatment/control experiments

1. Patch vs. no patch
2. Gum vs. no gum
3. Precessation counseling vs. no precessation counseling
4. Intensive cessation counseling vs. minimal
5. Intensive cessation phone counseling vs. minimal
6. 16 weeks of NRT during cessation/maintenance vs. 8 weeks

Design option B: Comparative treatment experiment

Experimental conditions:

Treatment conditions						Control
Precessation patch = *yes* All others = low	Precessation gum = *yes* All others = low	Precessation counseling = *yes* All others = low	Cessation counseling = *intensive* All others = low	Cessation phone counseling = *intensive* All others = low	Cessation NRT = *16 weeks* All others = low	All = *low*

Design option C

- 2^6 factorial experiment
- This will have 64 experimental conditions

Choosing an experimental design: Comparison of options

Comparison of Features of Design Alternatives for Smoking Cessation Study			
Design	**Number of Subjects Needed to Maintain Power ≥ .9**	**Number of Experimental Conditions**	**Interactions**
Individual Experiments	3,072	12	None can be estimated
Comparative Treatment	1,792	7	None can be estimated
Complete Factorial	512	64	All can be estimated

Factorial experiments 101

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

	Component A	
Component B	Off	On
Off	A,B off	A on, B off
On	A off, B on	A,B on

- Factorial experiments can have
  - ≥ 2 factors
  - ≥ 2 levels per factor
- On the next slide is a 2^4 factorial design

Experimental conditions in a factorial experiment with four factors

Experimental condition	Factor A	Factor B	Factor C	Factor D
1	Off	Off	Off	Off
2	Off	Off	Off	On
3	Off	Off	On	Off
4	Off	Off	On	On
5	Off	On	Off	Off
6	Off	On	Off	On
7	Off	On	On	Off
8	Off	On	On	On
9	On	Off	Off	Off
10	On	Off	Off	On
11	On	Off	On	Off
12	On	Off	On	On
13	On	On	Off	Off
14	On	On	Off	On
15	On	On	On	Off
16	On	On	On	On

What are we trying to estimate with a factorial experiment?

- Most important for decision making: Main effect of each factor
  - DEFINITION OF MAIN EFFECT OF FACTOR A:
  - Effect of Factor A averaged across all levels of all other factors
- Also selected 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))

- MAIN EFFECT OF FACTOR A is mean of conditions 1-8 vs. mean of conditions 9-16

Experimental condition	Factor A	Factor B	Factor C	Factor D
1	Off	Off	Off	Off
2	Off	Off	Off	On
3	Off	Off	On	Off
4	Off	Off	On	On
5	Off	On	Off	Off
6	Off	On	Off	On
7	Off	On	On	Off
8	Off	On	On	On
9	On	Off	Off	Off
10	On	Off	Off	On
11	On	Off	On	Off
12	On	Off	On	On
13	On	On	Off	Off
14	On	On	Off	On
15	On	On	On	Off
16	On	On	On	On

- MAIN EFFECT OF FACTOR B is mean of conditions 5—8 and 13—16 vs. mean of conditions 1—4 and 9—12

Experimental condition	Factor A	Factor B	Factor C	Factor D
1	Off	Off	Off	Off
2	Off	Off	Off	On
3	Off	Off	On	Off
4	Off	Off	On	On
5	Off	On	Off	Off
6	Off	On	Off	On
7	Off	On	On	Off
8	Off	On	On	On
9	On	Off	Off	Off
10	On	Off	Off	On
11	On	Off	On	Off
12	On	Off	On	On
13	On	On	Off	Off
14	On	On	Off	On
15	On	On	On	Off
16	On	On	On	On

- MAIN EFFECT OF FACTOR C is mean of conditions 3,4,7,8,11,12,15, and 16 vs. mean of conditions 1,2,5,6,9,10, 13, and 14

Experimental condition	Factor A	Factor B	Factor C	Factor D
1	Off	Off	Off	Off
2	Off	Off	Off	On
3	Off	Off	On	Off
4	Off	Off	On	On
5	Off	On	Off	Off
6	Off	On	Off	On
7	Off	On	On	Off
8	Off	On	On	On
9	On	Off	Off	Off
10	On	Off	Off	On
11	On	Off	On	Off
12	On	Off	On	On
13	On	On	Off	Off
14	On	On	Off	On
15	On	On	On	Off
16	On	On	On	On

- MAIN EFFECT OF FACTOR D is mean of conditions 1,3,5,7,9,11,13,15 vs. mean of conditions 2,4,6,8,10,12,14,16

Experimental condition	Factor A	Factor B	Factor C	Factor D
1	Off	Off	Off	Off
2	Off	Off	Off	On
3	Off	Off	On	Off
4	Off	Off	On	On
5	Off	On	Off	Off
6	Off	On	Off	On
7	Off	On	On	Off
8	Off	On	On	On
9	On	Off	Off	Off
10	On	Off	Off	On
11	On	Off	On	Off
12	On	Off	On	On
13	On	On	Off	Off
14	On	On	Off	On
15	On	On	On	Off
16	On	On	On	On

You might be interested to know…

- When used to address suitable research questions, balanced factorial experimental designs often require many FEWER subjects than alternative designs.
- It is often possible to add one or more factors to a factorial experiment and maintain the same level of power WITHOUT ANY INCREASE IN THE NUMBER OF SUBJECTS.
- The primary motivation for conducting a factorial experiment may be economy rather than examination of interactions.
- When effect coding is used to analyze data from a balanced factorial experiment, all effect estimates are uncorrelated.

Choosing an experimental design: Comparison of options

Comparison of Features of Design Alternatives for Smoking Cessation Study			
Design	**Number of Subjects Needed to Maintain Power ≥ .9**	**Number of Experimental Conditions**	**Interactions**
Individual Experiments	3,072	12	None can be estimated
Comparative Treatment	1,792	7	None can be estimated
Complete Factorial	512	64	All can be estimated

Design option D: Fractional factorial experiment

- A special type of factorial experiment
- Specially selected subset of experimental conditions is run

What are fractional factorial (FF) designs?

- Factorial designs in which only a SUBSET of experimental conditions are run
- But not just any subset! Carefully chosen to preserve balance properties
- FF designs require at most ½ the cells of a complete factorial, often many fewer
- Statisticians have developed many FF designs to choose from; software can be used to select one

Why run just a subset of conditions?

- Economy
- A lot of factors = REALLY a lot of conditions
- 2^6=64; 2^7=128; 2^8=256; etc.
- Example: using a FF designs it is possible to conduct a 2^8 experiment with only 16 conditions
- BUT there are important tradeoffs we will discuss shortly

When you might consider a FF design

- 5 or more factors
  - Although FF's exist for 3 and 4 factors
- Overhead costs associated with new experimental conditions are relatively high
- You are primarily interested in **main effects** and **lower-order interactions**
- Most of the remaining effects are expected to be negligible in size

Let's be clear which interactions we are talking about

- There are two categories of interactions of potential interest to intervention scientists
  - Interactions between the factors in a factorial experiment
  - Interactions between uncontrolled factors outside the experiment and experimental factors
    - e.g. Interaction between gender and an intervention component
- Here we are talking about interactions between factors

Remember this about power

- Using a FF design does NOT change required *N*
- **FF designs are powered same as complete factorials**
- Compared to the corresponding complete factorial, in a FF design
  - Each condition will have more subjects than the corresponding complete factorial
  - But each effect estimate based on SAME number of subjects

The logic behind FF designs

- OK, what would happen if we removed half of the experimental conditions from a 2^5 factorial design, so that instead of 32 conditions there were 16?
- IT DEPENDS ON WHICH CONDITIONS YOU REMOVE, but one thing is certain:
- **There will be aliasing**

The logic behind FF designs

- What is aliasing?
  - This term refers to the combining of two or more effects, so that it is impossible to determine which effect is responsible for what has been observed
  - Recall that in a complete 2^5 there are 32 experimental conditions, so you can estimate 32 effects
  - Once you remove half of the experimental conditions, you can estimate only 16 effects
  - As a result, each of these 16 effects is a combination of two of the effects from the complete factorial
- THIS IS NOT NECESSARILY ALL BAD

The logic behind FF designs

- Statisticians have figured out what aliasing occurs when different conditions are removed
- SO it follows that it is possible to select a FF design with conditions that produce characteristics we like!
- The idea: select a design in which effects of primary scientific interest (main effects, lower-order interactions) are aliased with effects expected to be negligible (higher-order interactions)

The logic behind FF designs

- Some writers use the term "confounding" of effects
- I prefer to reserve the term "confounding" for accidental combining of effects (such as in a nonexperimental or quasiexperimental study)…
- …and to reserve the term "aliasing" for situations in which the combining of effects is done deliberately and strategically
  - As it is in fractional factorial experiments

How do I select the experimental conditions to include in the design?

- Statisticians have developed many FF designs to choose from; different designs have different properties
- Starting point: An idea of which effects you are willing to assume are negligible
- Then software can be used to select a design, e.g.,
  - PROC FACTEX in SAS
  - FRF2 in R

Choosing an experimental design: Comparison of options

Comparison of Features of Design Alternatives for Smoking Cessation Study			
Design	**Number of Subjects Needed to Maintain Power ≥ .9**	**Number of Experimental Conditions**	**Interactions**
Individual Experiments	3,072	12	None can be estimated
Comparative Treatment	1,792	7	None can be estimated
Complete Factorial	512	64	All can be estimated
Fractional Factorial	512	8, 16, or 32 depending on design chosen	Selected subset can be estimated

- We chose a fractional factorial design requiring 32 conditions

Experimental design used to examine components of smoking cessation intervention

- Factorial experiment with six factors.
- It is a 2^{6-1} fractional factorial.
- The design has 32 experimental conditions.
- Each main effect aliased with one 5-way interaction; each 2-way aliased with one 4-way; each 3-way with one 3-way
- HEY! Where is the control group???

Table 1. Experimental Conditions

	Precessation Interventions			Pericessation Interventions		
Condition	Precessation Medication Type (Patch vs. none)	Precessation Medication Type (Ad Lib NRT vs. none)	Precessation Counseling (Intensive vs. none)	In-Person Counseling (Minimal vs. Intensive)	Phone Counseling (Minimal vs. Intensive)	Medication (8 weeks vs. 16 weeks)
1	Patch	Ad Lib	Intensive	Minimal	Minimal	Standard
2	Patch	Ad Lib	Intensive	Minimal	Intensive	Long-term
3	Patch	Ad Lib	Intensive	Intensive	Minimal	Long-term
4	Patch	Ad Lib	Intensive	Intensive	Intensive	Standard
5	Patch	Ad Lib	None	Minimal	Minimal	Long-term
6	Patch	Ad Lib	None	Minimal	Intensive	Standard
7	Patch	Ad Lib	None	Intensive	Minimal	Standard
8	Patch	Ad Lib	None	Intensive	Intensive	Long-term
9	Patch	None	Intensive	Minimal	Minimal	Long-term
10	Patch	None	Intensive	Minimal	Intensive	Standard
11	Patch	None	Intensive	Intensive	Minimal	Standard
12	Patch	None	Intensive	Intensive	Intensive	Long-term
13	Patch	None	None	Minimal	Minimal	Standard
14	Patch	None	None	Minimal	Intensive	Long-term
15	Patch	None	None	Intensive	Minimal	Long-term
16	Patch	None	None	Intensive	Intensive	Standard
17	None	Ad Lib	Intensive	Minimal	Minimal	Long-term
18	None	Ad Lib	Intensive	Minimal	Intensive	Standard
19	None	Ad Lib	Intensive	Intensive	Minimal	Standard
20	None	Ad Lib	Intensive	Intensive	Intensive	Long-term
21	None	Ad Lib	None	Minimal	Minimal	Standard
22	None	Ad Lib	None	Minimal	Intensive	Long-term
23	None	Ad Lib	None	Intensive	Minimal	Long-term
24	None	Ad Lib	None	Intensive	Intensive	Standard
25	None	None	Intensive	Minimal	Minimal	Standard
26	None	None	Intensive	Minimal	Intensive	Long-term
27	None	None	Intensive	Intensive	Minimal	Long-term
28	None	None	Intensive	Intensive	Intensive	Standard
29	None	None	None	Minimal	Minimal	Long-term
30	None	None	None	Minimal	Intensive	Standard
31	None	None	None	Intensive	Minimal	Standard
32	None	None	None	Intensive	Intensive	Long-term

How can I ever be comfortable assuming that an interaction is negligible?

- You have two choices:
  1. Assume that all of the higher-order interactions (3-way and above) are large enough to be scientifically important, or to be a factor in decision making, unless proven otherwise.
  2. Assume that the higher-order interactions are probably not large enough to be scientifically important or a factor in decision making, unless theory or prior research specifically predict otherwise.
- (note that we have almost no empirical knowledge about interactions)

How can I ever be comfortable assuming that an interaction is negligible?

- If you choose (1)
  - Ask yourself for each interaction: do I *really* have a rational reason, based on theory or empirical evidence, for predicting that this specific interaction will be important?
  - It is always *possible* that an interaction effect will be large – but how likely is it?
  - Remember you don't have to assume the interactions are exactly zero, just small enough to be unimportant in decision making

How can I ever be comfortable assuming that an interaction is negligible?

- If you choose (2)
  - You can take advantage of the economy of FF designs
  - With the same level of resources, you can make more scientific progress
  - You can devote resources to key interactions that have a rational scientific basis

Fractional factorial designs: Trade-offs

- Sometimes maximizing efficiency calls for taking calculated risks
- There are opportunity costs associated with the "less risky" option
- *This is the Resource Management Principle in action*

	Suppose in reality the higher-order effects are	
And suppose we made this choice for Opt-In:	Negligible	Large (some)
Complete factorial (four components)	Resources wasted; cannot investigate important research questions	Move science forward faster
Fractional factorial (five components)	Move science forward faster	Possibility of some incorrect decisions about component selection

Fractional factorial designs: summary of trade-offs

- WHAT WE CAN GAIN USING A FRACTIONAL FACTORIAL DESIGN:
  - Reduce number of experimental conditions by half or more
  - Ability to examine more components
- WHAT WE GIVE UP:
  - Certain effects are combined with certain other effects (aliasing)

Powering factorial experiments

- Power for main effects: sample size requirements for a *k*-factor experiment about the same as for a *t*-test
- Power the experiment for the smallest effect size
- Adding a factor generally does not increase sample size requirements, unless that factor is expected to have a smaller effect size
- For component screening experiments, power the study for the smallest effect size that you would accept for inclusion in the intervention

Powering factorial experiments

- A resource to help you do a power analysis when planning a factorial experiment:
- Go to http://methodology.psu.edu/downloads

- Look for the macro

FactorialPowerPlan

Factorial experiments and multilevel data

Can I use a factorial design if I have multilevel data?

- Two different situations:
  - Within-cluster randomization
    - e.g., clinic-based research
  - Individuals assigned to experimental conditions
    - Not worried about contamination
    - Effects at individual level
  - Question: Is power loss so great that examination of individual components is impractical?

  - (see Dziak, Nahum-Shani, & Collins, 2012)

Can I use a factorial design if I have multilevel data?

- Two different situations:
  - Between-cluster randomization (often called cluster randomization)
    - e.g. school-based research
  - Entire clusters (e.g. schools) assigned to treatment conditions
    - Contamination would be potential issue with individual assignment
    - May be effects at cluster level in addition to individual effects
  - Question: Will I have enough units to assign to conditions?
  - Question: Is power loss so great that examination of individual components is impractical?

Can I use a factorial design if I have multilevel data?

- The concern: any two individuals sampled from within a unit tend to be more alike than any two individuals sampled from different units
- The measure of this is the intraclass correlation
- Can reduce power, sometimes severely

Can I use a factorial design if I have multilevel data?

- The design effect expresses how sample size requirements can increase as a function of the multilevel structure

$$D = 1 + (n - 1)\rho_X \rho_{Y|X}$$

- ρ_X is the intraclass correlation of the X's
- $\rho_{Y|X}$ is the intraclass correlation of the Y's
- It's a multiplier: If you would need *N* subjects without a multilevel structure you would need *DN* with a multilevel structure

Can I use a factorial design if I have multilevel data?

$$D = 1 + (n - 1)\rho_X \rho_{Y|X}$$

- With within-cluster randomization, provided that all subjects have the same assignment probabilities, $\rho_x \approx 0$
- Therefore, $D = 1$
- Conclusion: very little, if any, effect on power
- However, other possible issues (e.g., cluster × treatment interaction)

Can I use a factorial design if I have multilevel data?

$$D = 1 + (n - 1)\rho_X \rho_{Y|X}$$

- With between-cluster randomization: For a given individual cluster membership determines assignment, so $\rho_X = 1$
- So, *D* can be large

Can I use a factorial design if I have multilevel data?

- Cluster randomization:
  - Question: Will I have enough units to assign to experimental conditions?
  - With a complete factorial, maybe no
  - With a fractional factorial, maybe yes
    - In fact, this may be the only option
  - Question: Is power loss due to the design effect so great that examination of individual components is impossible?

Low ICC=.05

Medium ICC=.15

High ICC=.30

For main effects, *d* = .2

5 factors

From Dziak, Nahum-Shani, & Collins (2012)

Table 7

Observed and Predicted Power and Type I Error for Main Effects in Simulated Between-Clusters Experiments (∝=.05)

		Complete Factorial			Fractional Factorial		
		Power		T1E	Power		T1E
#Clusters	#Members	Obs.	Pred.	Obs.	Obs.	Pred.	Obs.
Low ICC							
25	20				0.594	0.618	0.038
	100				0.885	0.897	0.056
30	20				0.744	0.733	0.048
	100				0.964	0.959	0.062
40	20	0.875	0.867	0.046	0.887	0.867	0.057
	100	0.993	0.993	0.044	0.993	0.993	0.065
50	20	0.943	0.936	0.047	0.959	0.936	0.059
	100	0.999	0.999	0.046	0.999	0.999	0.074
Medium ICC							
25	20				0.379	0.398	0.053
	100				0.493	0.523	0.054
30	20				0.504	0.493	0.054
	100				0.639	0.635	0.055
40	20	0.635	0.638	0.049	0.645	0.638	0.053
	100	0.777	0.783	0.049	0.787	0.783	0.056
50	20	0.744	0.744	0.049	0.767	0.744	0.061
	100	0.871	0.874	0.047	0.889	0.874	0.058
High ICC							
25	20				0.236	0.252	0.051
	100				0.262	0.292	0.053
30	20				0.310	0.312	0.050
	100				0.355	0.363	0.050
40	20	0.402	0.416	0.051	0.414	0.416	0.053
	100	0.464	0.481	0.050	0.469	0.481	0.051
50	20	0.492	0.507	0.048	0.515	0.507	0.055
	100	0.559	0.581	0.046	0.594	0.581	0.056

Can I use a factorial design if I have multilevel data?

- YES!
- It has often been assumed you would not have enough power. NOT NECESSARILY TRUE!
- Situation is challenging though
- In a component screening experiment, may consider raising Type I error rate

Concluding remarks

Table 1
Some Differences in Perspective between the Classical Approach and MOST

	Classical Approach	MOST
Objective	To develop a BBI that demonstrates a statistically and clinically significant effect in an RCT	To engineer a BBI that meets specific predetermined standards of effectiveness, efficiency, cost-effectiveness, and/or scalability, AND demonstrates a statistically and clinically significant result in an RCT
Next steps after identification and pilot testing of components	BBI is assembled and then evaluated as a package	An optimized BBI is engineered, then evaluated as a package if it is sufficiently promising
Experimental designs used	Primarily the RCT	For optimization, experimental designs selected based on resource management principle; for evaluation of BBI as a package, primarily the RCT
Examination of effectiveness of individual components	Relatively low priority; conducted primarily via post-hoc analyses on data from RCT of BBI	High priority; conducted primarily via experimental manipulation of components
Examination of interactions between intervention components	Low priority; RCT does not permit this	High priority; experimental designs selected to enable this wherever possible
Inert or counterproductive components in BBI	Generally tolerated as long as overall effectiveness of BBI can be demonstrated	Generally not tolerated
Cost-effectiveness of BBI	Assessed during or after evaluation	BBI can be engineered to meet a specific standard of cost-effectiveness before evaluation
Scalability of BBI	Usually dealt with after evaluation of BBI, sometimes via ad hoc modifications	BBI engineered for immediate scalability
Research aimed at measureable incremental improvement of BBIs over time	Not emphasized	Emphasized in continuous optimization principle

Resources

- http://methodology.psu.edu/ra/most

Above contains LOTS of information about MOST, including (a) suggestions for articles to read (b) FAQ (c) tips for people writing grant proposals involving MOST

- http://methodology.psu.edu/downloads

Methodology Center download page

Resources

- Member of the Society of Behavioral Medicine? JOIN the special interest group (SIG) on optimization of behavioral interventions
- WATCH for 5-day training in optimization of behavioral interventions in 2018

Resources

- SIGN UP FOR Methodology Center e-news (http://methodology.psu.edu, scroll down to lower left corner of home page)
- WATCH for 2 books on optimization of behavioral and biobehavioral interventions in early 2018. Springer.
  - (1) Collins; (2) Collins & Kugler (edited)

Making decisions based on experimental results

The idea

- You've identified an optimization criterion that you want to meet
- You've conducted an experiment to estimate the individual effects of intervention components, and selected interactions
- You may also have other information that is important (e.g. cost)
- You want to make decisions about which components and/or component levels constitute the optimized BBI

An open area

- In many ways this is an open research area
- It is on the interface of experimental design, decision analysis and intervention science

Some possible optimization criteria

- No inactive components
- Most effective intervention that can be implemented for less than some $$$
- Most cost-effective
- Most effective intervention that can be completed in less than some upper limit on time

Some considerations when making decisions

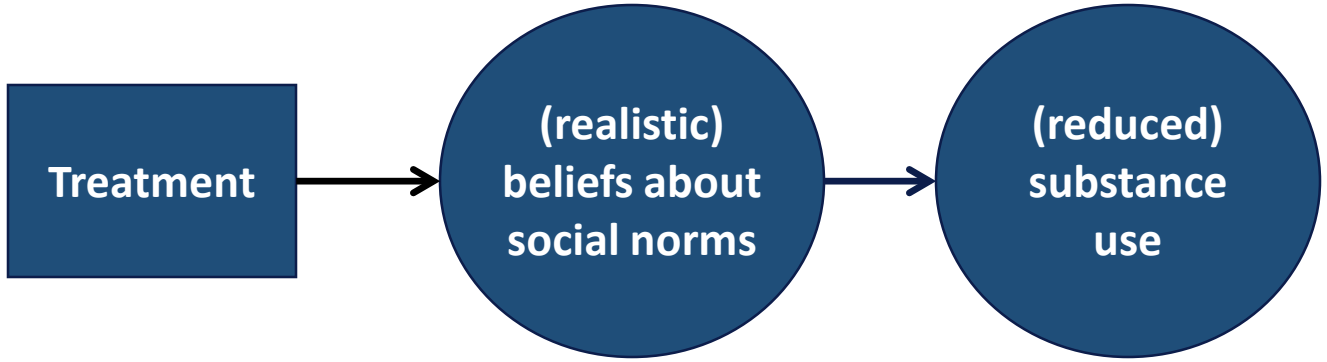
- Make sure you know what effect you are basing your decisions on
  - Effect coding vs. dummy coding makes a difference (use effect coding)
  - Be clear on whether there is aliasing and which effects are aliased, particularly with
    - Main effects
    - Scientifically important interactions
  - Be clear on which interactions you are expecting to be important

Some considerations when making decisions

- Different outcomes for different components
- Often measures of mediators are used as short-term outcomes
- Usually a component will correspond to 1-2 mediators

Some considerations when making decisions

- What if the outcome of most interest is years away?
  - Example: school-based drug abuse prevention
- Go back to the conceptual model – usually will involve mediators



- Beliefs about social norms can serve as a short-term outcome for purposes of component selection

Some considerations when making decisions

- How do you incorporate information from different dependent variables?
- Frequently you will want to do this
  - More than one outcome may be important (e.g. alcohol use AND safe sex practices)
  - Or you are using mediators as outcomes and different mediators pertain to different components
- May require tradeoffs between DV's – which is most important?
- What if results conflict across DV's?
- This is an open research area

Some considerations when making decisions

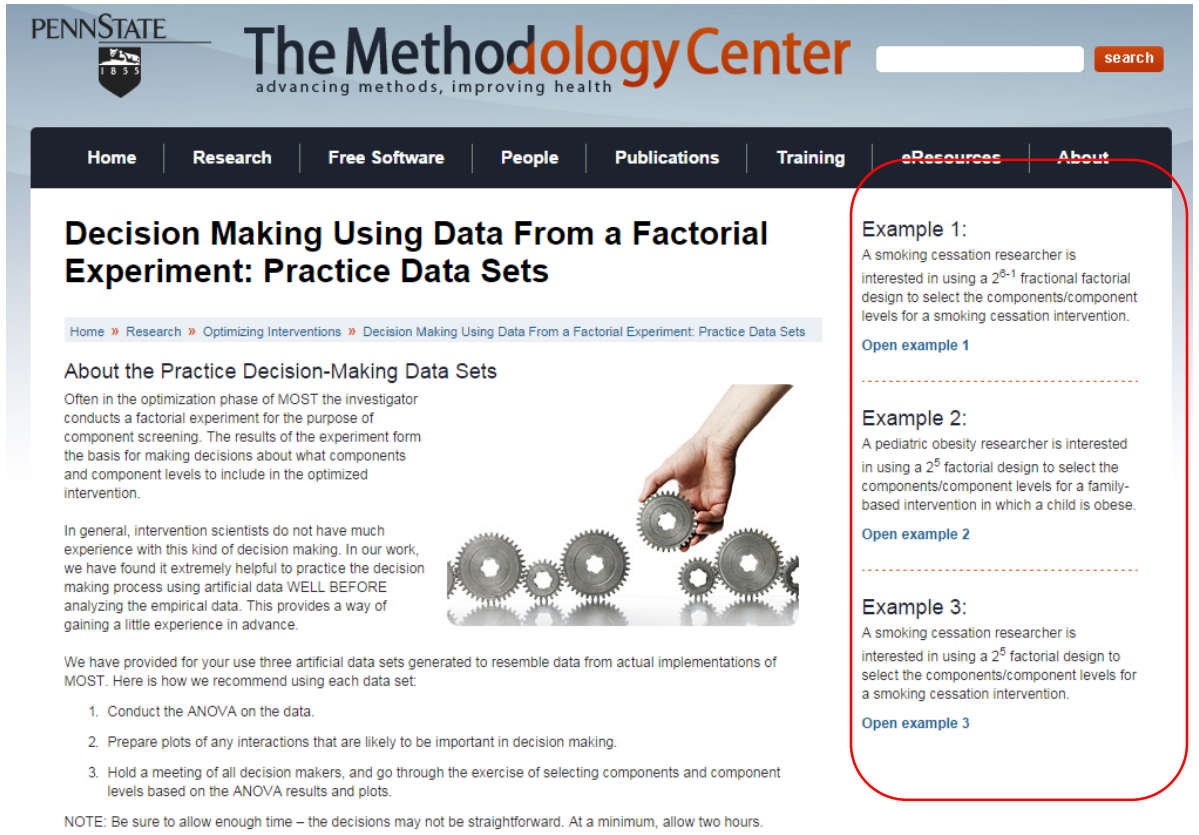
- **Important considerations that are not outcomes per se:**
  - Attrition
  - Compliance
  - Practicality
  - Etc.

Some considerations when making decisions

- It's a process that requires a lot of thought
- May be a complex decision – allow sufficient time!

On The Methodology Center web site there are some artificial data sets for use in practice decision making

http://methodology.psu.edu/ra/most/datasets



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Decision Making Using Data From a Factorial Experiment: Practice Data Sets

Home » Research » Optimizing Interventions » Decision Making Using Data From a Factorial Experiment: Practice Data Sets

About the Practice Decision-Making Data Sets

Often in the optimization phase of MOST the investigator conducts a factorial experiment for the purpose of component screening. The results of the experiment form the basis for making decisions about what components and component levels to include in the optimized intervention.

In general, intervention scientists do not have much experience with this kind of decision making. In our work, we have found it extremely helpful to practice the decision making process using artificial data WELL BEFORE analyzing the empirical data. This provides a way of gaining a little experience in advance.

We have provided for your use three artificial data sets generated to resemble data from actual implementations of MOST. Here is how we recommend using each data set:

1. Conduct the ANOVA on the data.
2. Prepare plots of any interactions that are likely to be important in decision making.
3. Hold a meeting of all decision makers, and go through the exercise of selecting components and component levels based on the ANOVA results and plots.

NOTE: Be sure to allow enough time – the decisions may not be straightforward. At a minimum, allow two hours.

Example 1:

A smoking cessation researcher is interested in using a 2^{8-1} fractional factorial design to select the components/component levels for a smoking cessation intervention.

Open example 1

Example 2:

A pediatric obesity researcher is interested in using a 2^5 factorial design to select the components/component levels for a family-based intervention in which a child is obese.

Open example 2

Example 3:

A smoking cessation researcher is interested in using a 2^5 factorial design to select the components/component levels for a smoking cessation intervention.

Open example 3

Incorrect decisions happen

- Sometimes the evidence will support the wrong decision
  - Type I or Type II error
  - "Junk" effect aliased with an interesting effect unexpectedly large
  - Higher-order interaction unexpectedly large
- This approach does not ALWAYS point to the right decision, but ***in the long run*** it will move science forward faster

Why do interactions cause us angst when we want to take an approach like MOST?

1. When considering a FF design for the component screening experiment, the possibility of interactions makes us feel uncomfortable assuming some will be negligible.
2. When making decisions based on the results of the component screening experiment, if we focus on main effects and do not pay enough attention to interactions we could make the wrong decision about which components/levels to select.

Definitions

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

$$\mu_{A1} - \mu_{A2}$$

- 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))

$$\tfrac{1}{2}\left((\mu_{A1,B=1} - \mu_{A2,B=1}) - (\mu_{A1,B=2} - \mu_{A2,B=2})\right)$$

Interactions and selecting components/levels

- If we do not pay enough attention to interactions we could make the wrong decision about which components /levels to select.
- Why?
  - Maybe A looks like it is working great, but in reality, in the presence of B, it is ineffective.
    - Doomsday scenario: A and B individually look like they are working great, but together they have no effect or, worse, a negative effect!

Interactions and selecting components/levels

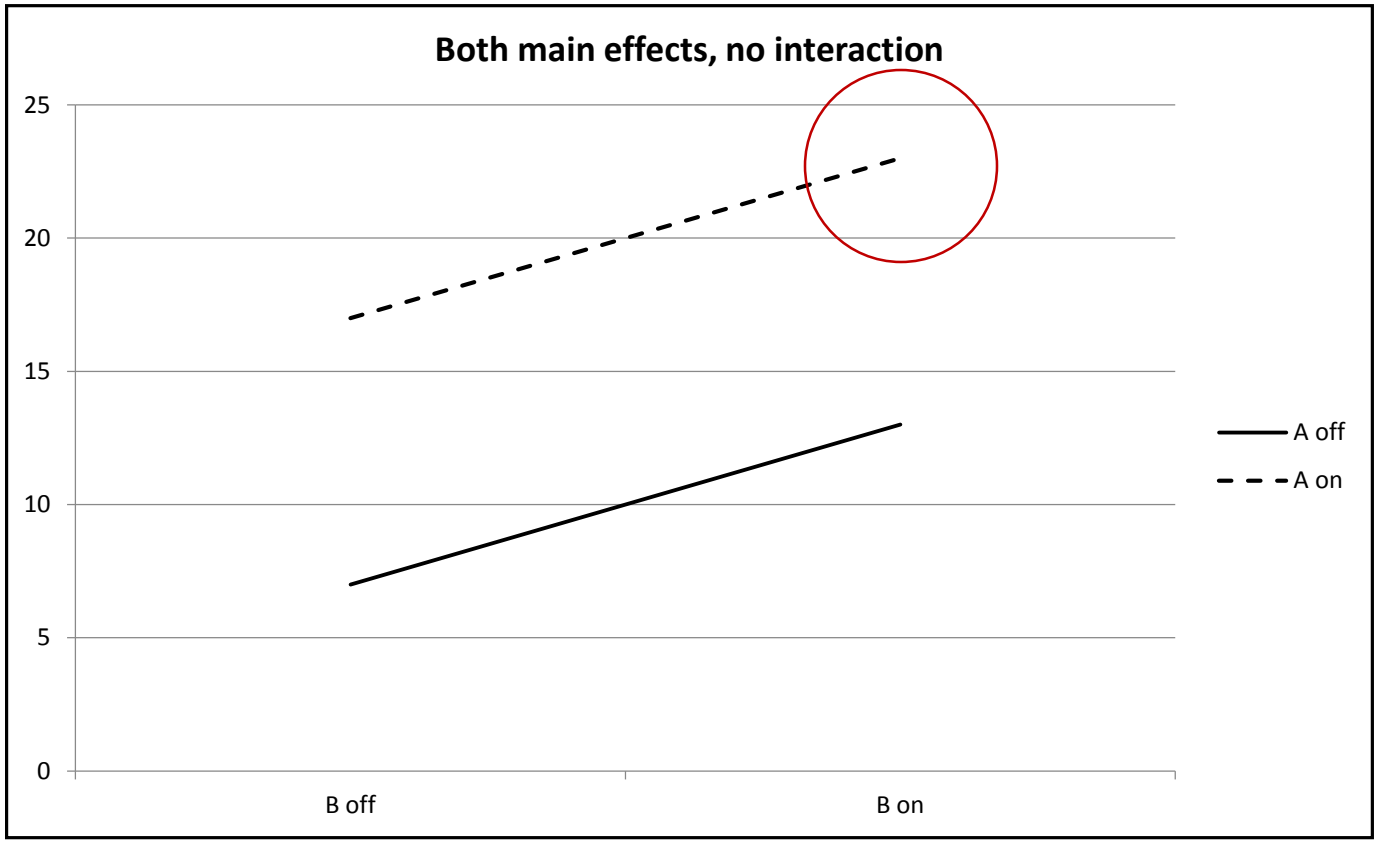
- Main concern: If we focus on main effects and do not pay enough attention to interactions we could make the wrong decision about which components /levels to select.
- Why?
  - Power to detect interactions may be low
    - Given the same regression coefficient, power is identical for main effects and interactions when effect coding is used
  - Might be hard to decide when to pay serious attention to an interaction

Interactions and selecting components/levels

- REMEMBER that when effect coding (as opposed to dummy coding) is used the main effects and interactions are uncorrelated (if equal *n*'s)
- ALSO REMEMBER that the effect sizes for interactions may be smaller than those for main effects
  - If an interaction is important, be sure to power for it

Sometimes what people think of as an interaction is two main effects

- Here, the A on, B on condition is clearly best, but there is no interaction



Today's theories don't help very much

- Most theories and theoretical models don't say anything about interactions
- This gives us little to go on in choosing designs and making decisions
- There always MIGHT be an interaction!

Today's theories don't help very much

- Ask: does my conceptual model clearly predict an interaction?
- If yes, power to detect the interaction (if it is expected to make a difference in decision making)
- If no, you have two choices:
  - (a) Devote resources to examining the interaction
  - (b) Do not devote resources to examining it

How do engineers deal with interactions (in the absence of theory)?

- Effect sparsity (Pareto) principle
  - Only a small subset of the effects important
- Hierarchical ordering principle
  - Look at lower-order effects first, and only if these are significant, examine interaction
  - So if of *A* and *B* only one main effect significant, an engineer does not usually care about the $A \times B$ interaction (unless there is a compelling a priori reason to think otherwise)
    - Wu & Hamada, 2000

A suggested approach to decision making

- Any rational approach to decision making can be used! There isn't one single approach.
- We will review one suggested approach that was outlined in Collins, Trail, Kugler, Baker, Piper, & Mermelstein (2014), *Translational Behavioral Medicine*

A suggested approach to decision making

- When the main effect of Factor *A* is significant, examine all two-way interactions that involve *A*.
- When the $A \times B$ interaction is significant, examine $A \times B \times C$ (and all three-way interactions that involve *A* and *B*).
- If both *A* and *B* nonsignificant, do not bother with $A \times B$ (unless a <u>specific</u> a priori reason to think otherwise)
  - Why? We want the intervention to be made up primarily of components that are robust, i.e. have main effects
  - If you selected *A* and *B*, you would have to make sure that every participant got both, otherwise neither would work
- Interactions above 3-way unlikely to be important (unless a <u>specific</u> a priori reason to think otherwise).

Suggested decision process for selecting components in presence of interactions

Scenario	Main effect of A	Main effect of B	Action	Decision rule
1	Positive	Positive	Check whether AXB interaction is large.	If no, select A=+ and B=+. If yes, 1. Select factor with larger main effect. Suppose it is A. 2. Examine simple effect of B when A = +. 3. If simple effect is large and positive, select A = + and B = +. 4. If simple effect is small, zero, or negative, select A = + and B = –.
2	Positive	Zero or negative	Check whether AXB interaction is large.	If no, select A = + and B = –. If yes, 1. Examine simple effect of B when A = +. 2. If simple effect is large and positive, select A = + and B = +. 3. If simple effect is small, zero, or negative, select A = + and B = –.
3	Zero or negative	Zero or negative	*If you would consider retaining A and B if neither has a positive main effect*, check whether AXB interaction is large.	If no, select A = – and B = –. If yes, examine plot of interaction.

Notes. (1) This assumes effect coding used. (2) These decision rules do not take cost or other factors into account. (3) We recommend examining a plot of any interaction of interest.

Suggested decision process for selecting components in presence of interactions

Scenario	Main effect of A	Main effect of B	Action	Decision rule
1	Positive	Positive	Check whether AXB interaction is large.	If no, select A=+ and B=+. If yes, 1. Select factor with larger main effect. Suppose it is A. 2. Examine simple effect of B when A = +. 3. If simple effect is large and positive, select A = + and B = +. 4. If simple effect is small, zero, or negative, select A = + and B = –.
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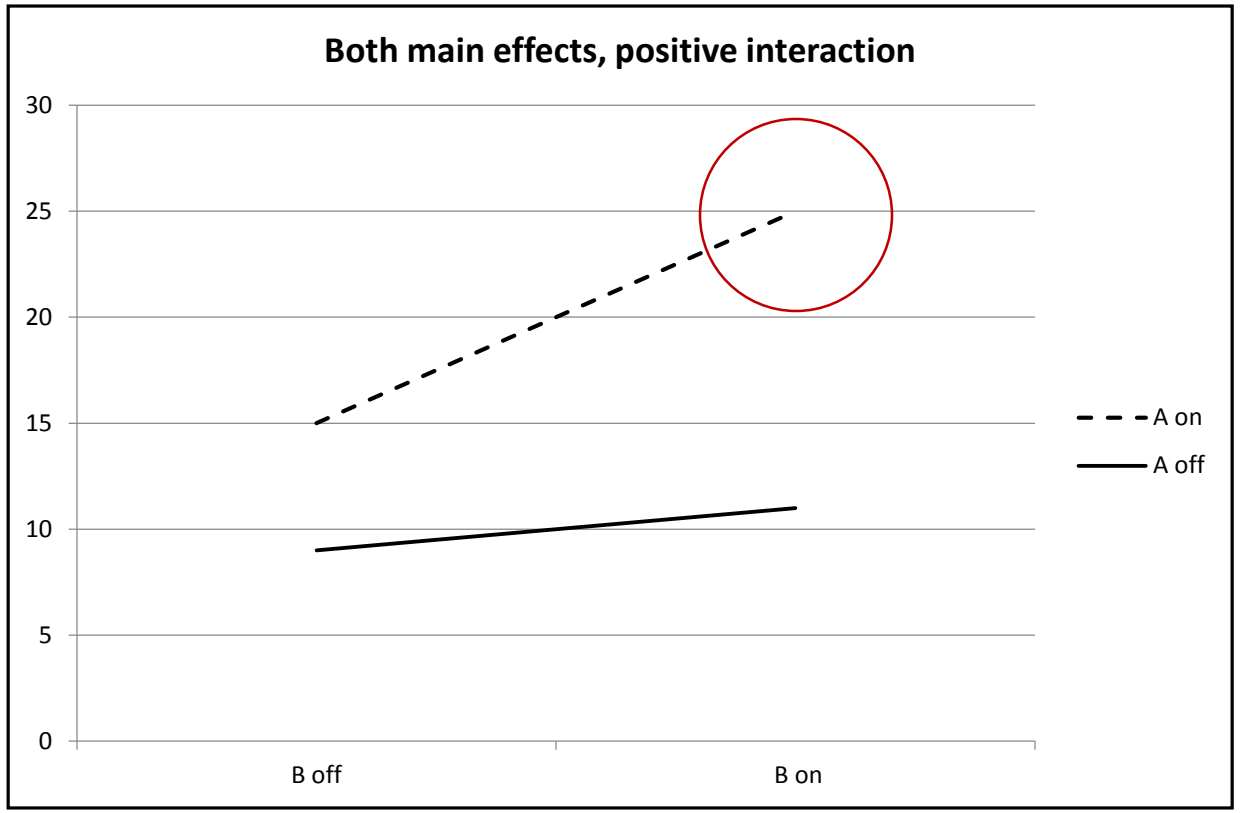
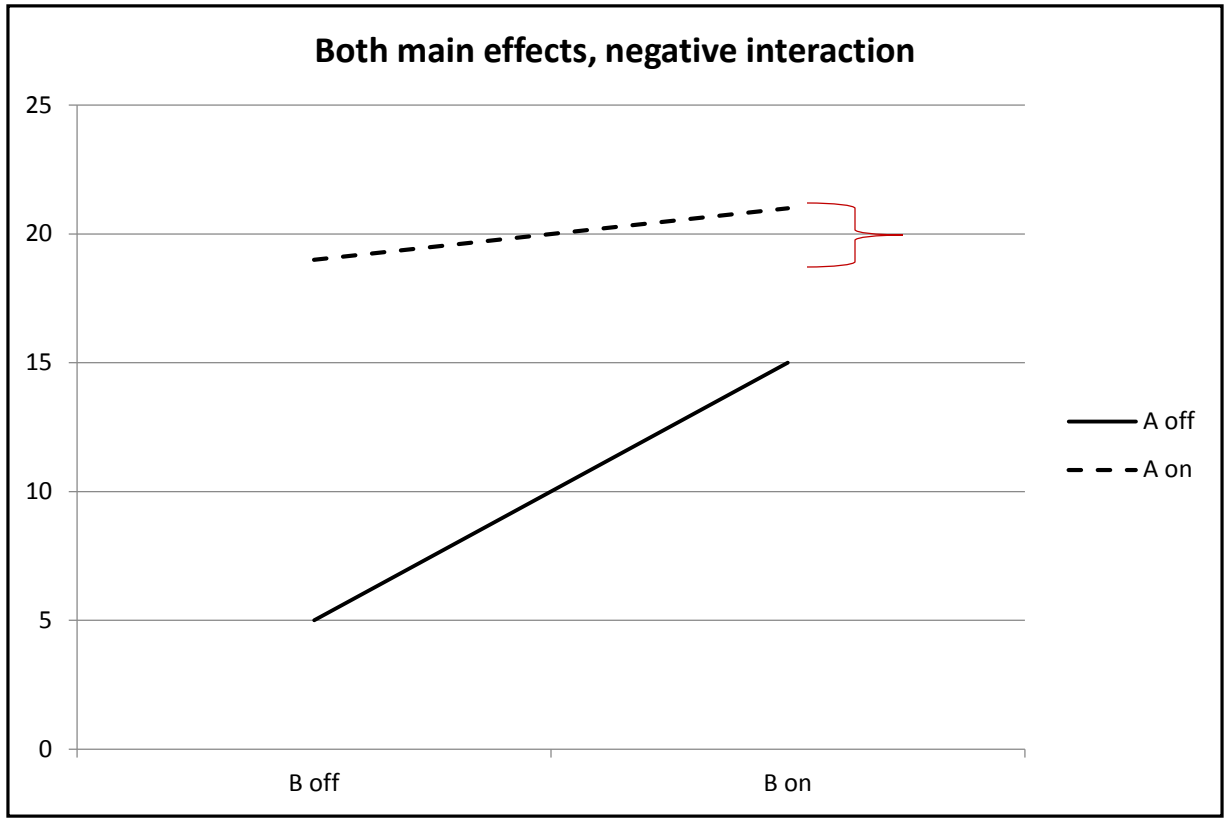

Both main effects, positive interaction
30
25
20
15
10
5
0
B off
B on
A on
A off


Both main effects, negative interaction
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20
15
10
5
0
B off
B on
A off
A on

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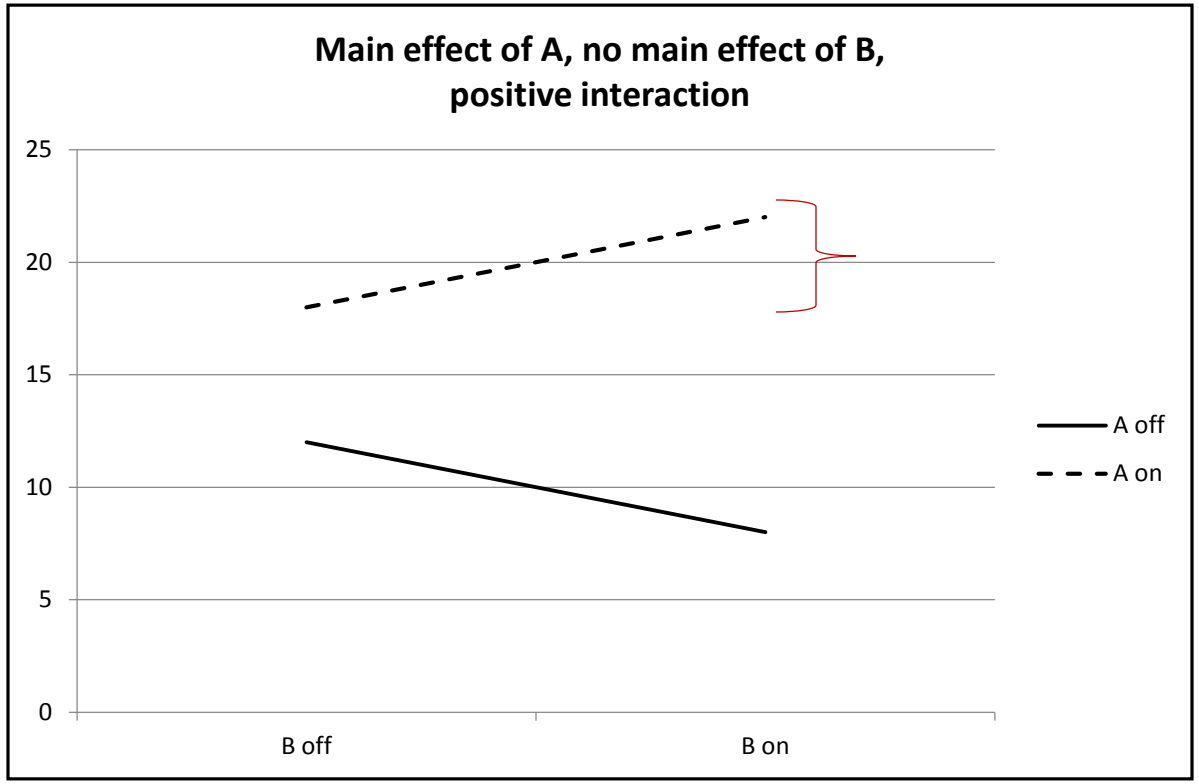
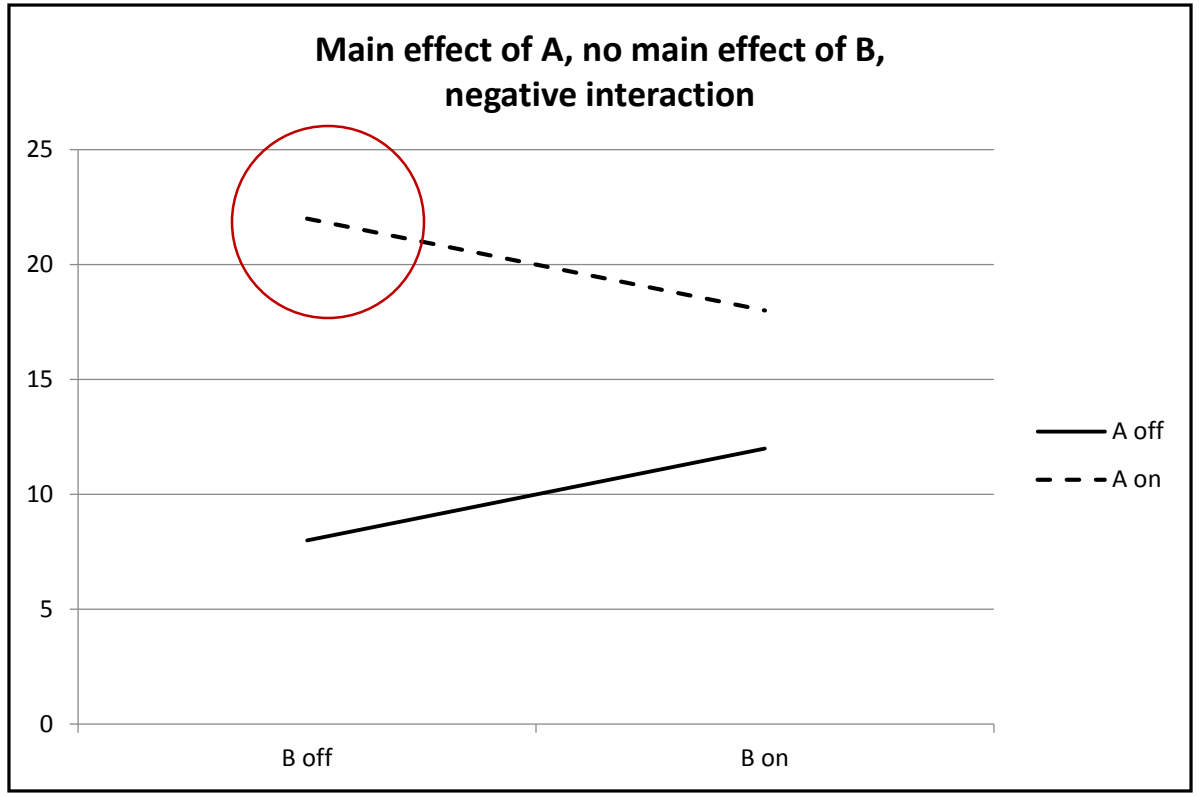
3	Zero or negative	Zero or negative	*If you would consider retaining A and B if neither has a positive main effect*, check whether AXB interaction is large.	If no, select A = – and B = –. If yes, examine plot of interaction.

Notes. (1) This assumes effect coding used. (2) These decision rules do not take cost or other factors into account. (3) We recommend examining a plot of any interaction of interest.


Main effect of A, no main effect of B, positive interaction
25
20
15
10
5
0
B off
B on
A off
A on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25
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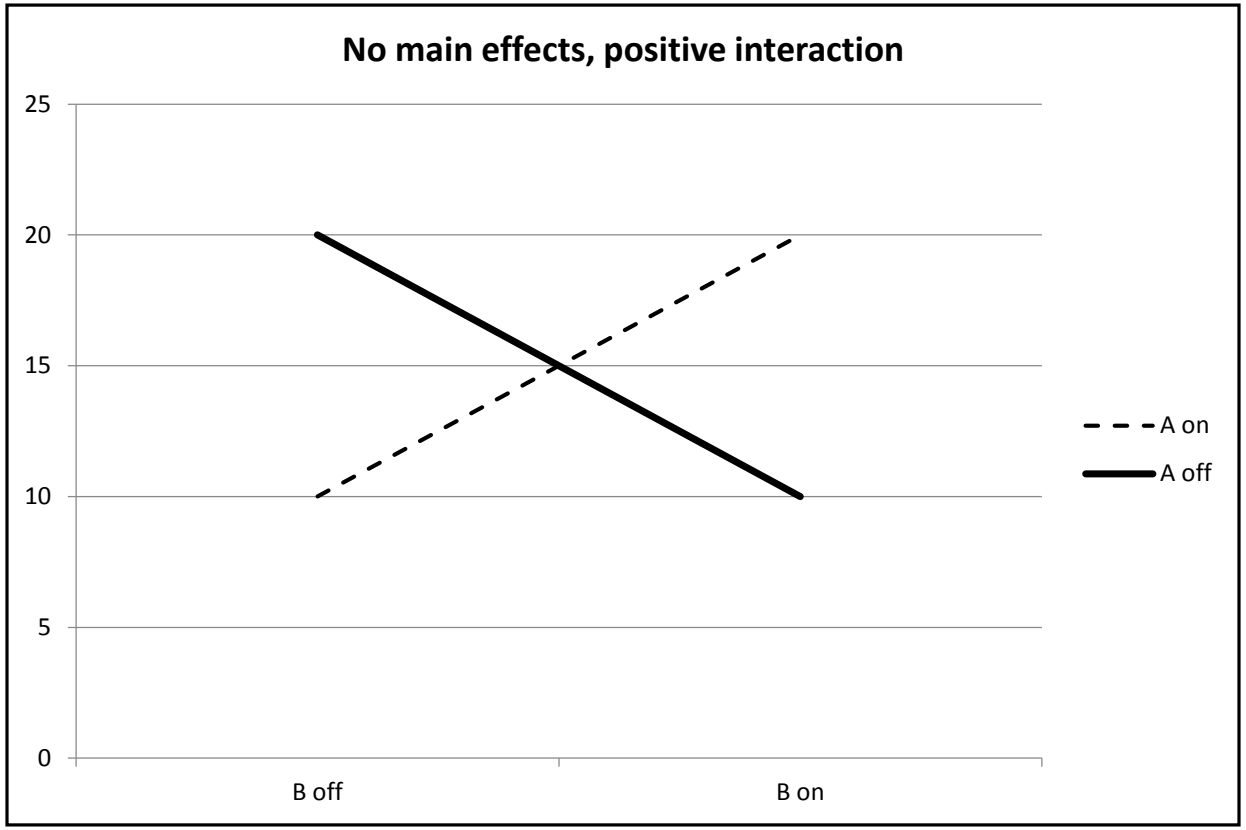
15
10
5
0
B off
B on
A off
A on

Suggested decision process for selecting components in presence of interactions

Scenario	Main effect of A	Main effect of B	Action	Decision rule
1	Positive	Positive	Check whether AXB interaction is large.	If no, select A=+ and B=+. If yes, 1. Select factor with larger main effect. Suppose it is A. 2. Examine simple effect of B when A = +. 3. If simple effect is large and positive, select A = + and B = +. 4. If simple effect is small, zero, or negative, select A = + and B = –.
2	Positive	Zero or negative	Check whether AXB interaction is large.	If no, select A = + and B = –. If yes, 1. Examine simple effect of B when A = +. 2. If simple effect is large and positive, select A = + and B = +. 3. If simple effect is small, zero, or negative, select A = + and B = –.
3	Zero or negative	Zero or negative	*If you would consider retaining A and B if neither has a positive main effect*, check whether AXB interaction is large.	If no, select A = – and B = –. If yes, examine plot of interaction.

Notes. (1) This assumes effect coding used. (2) These decision rules do not take cost or other factors into account. (3) We recommend examining a plot of any interaction of interest.


No main effects, positive interaction
25
20
15
10
5
0
B off
B on
A on
A off

Scenario 3: no main effects, large interaction

- This is an unusual situation
- Neither one alone has an effect on average, but there is a large effect if EITHER both are on or both are off
- What does this mean?
- The two components must ALWAYS BOTH be set to +
  - If you select them, must ensure this
- But the effect is just as big if both are set to -!
  - Are these two separate components?
  - Choose the cheaper alternative but be sure to yoke the components