OPTIMISING BEHAVIOURAL INTERVENTIONS – THE MOST MODEL AND UNDERSTANDING EFFECTIVE PREVENTION PROGRAMME COMPONENTS

A PRECONFERENCE WORKSHOP AT
THE FIFTH EUSPR RESEARCH CONFERENCE
AND MEMBERS' MEETING
PALMA DE MALLORCA, MALLORCA, SPAIN
15 OCTOBER, 2014

Contact: Prof. Linda M. Collins
lmcollins@psu.edu
The Methodology Center
Pennsylvania State University, US

Overview

- Opening remarks
- Comments from Prof. Fabrizio Faggiano
- Brief orientation to the multiphase optimisation strategy (MOST)
- An example of the application of MOST
- Identifying an optimisation criterion
- Choosing an experimental design based on the resource management principle
- Introduction to fractional factorial designs
- Making decisions based on results of an experiment
- Open discussion

Comments by
Prof. Fabrizio Faggiano

BRIEF ORIENTATION 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

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 drug abuse prevention curriculum
  - Features that promote compliance/adherence
    - e.g.: reminder phone calls
  - Features aimed at improving fidelity
    - e.g.: enhanced teacher training
- Can impact efficacy, effectiveness, cost-effectiveness

Multicomponent interventions for prevention and treatment

- May include both behavioural and pharmaceutical components (biobehavioural interventions)
- May include components aimed at individuals, family, school, community
- Examples of multicomponent interventions
  - Smoking cessation treatment
  - Treatment for depression
  - School-based drug abuse prevention
  - Prevention/treatment of obesity

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)

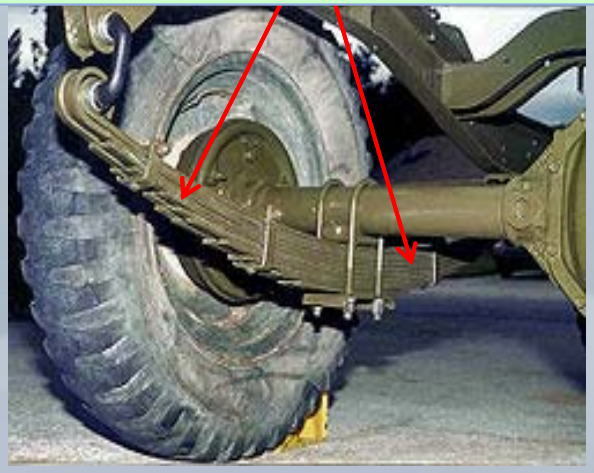
Scenario 1: Cancer prevention: Developing a smoking cessation intervention

- How to build a behavioural 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 optimise 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 optimise 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 behavioural 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 OPTIMISATION
- THEN compare new process to old process

Back to Scenario 1: If behavioural scientists thought like engineers

- We might want to optimise 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 optimisation using any desired criterion

Definition: optimisation

- "The process of finding the best possible solution to a problem… subject to given constraints." [emphasis added] (*The Concise Oxford Dictionary of Mathematics*)
- Not the best solution in an absolute or ideal sense
- A process because further improvements can always be made once more resources become available or other constraints are lifted

Evaluation and optimisation: Both important, not the same thing

	Evaluation: Is the intervention's effect statistically significant?	
Optimisation: Is the intervention the best possible, given constraints?	No	Yes
No	May wish to optimise using effect size as criterion	Intervention can probably be improved
Yes	Different intervention strategy needed	What we should be aiming for

Comparison of evaluation and optimisation

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

Optimisation requires examination of individual components, and making decisions about what to include in the intervention based on what is found

- How do you do that?
- We will spend a lot of time discussing experimental design alternatives
- We will turn now to a very brief overview (more later in the workshop)

The multiphase optimisation strategy (MOST)

- A comprehensive strategy for optimisation and evaluation
- Engineering-based **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

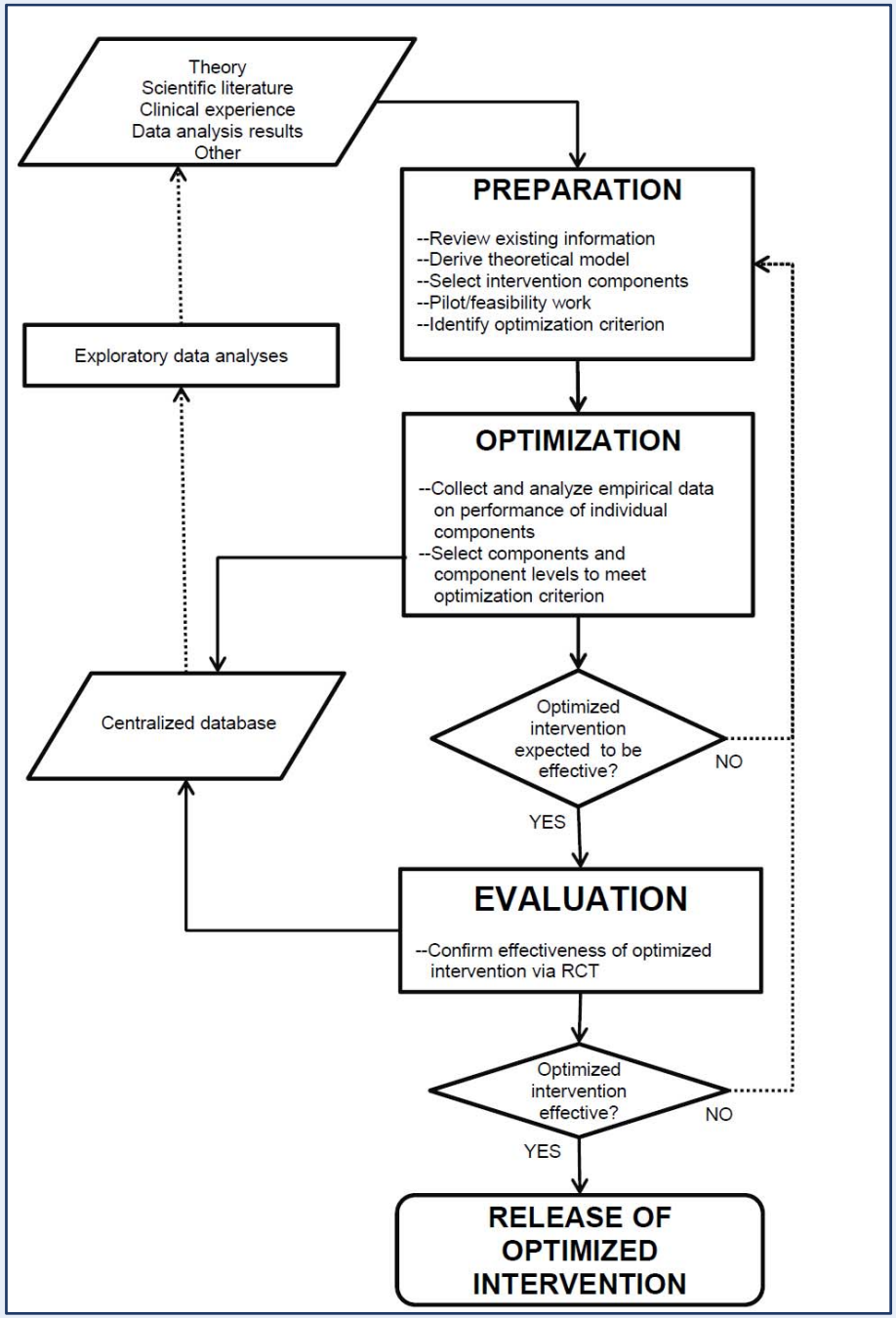
MOST: A comprehensive strategy for optimisation and evaluation

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

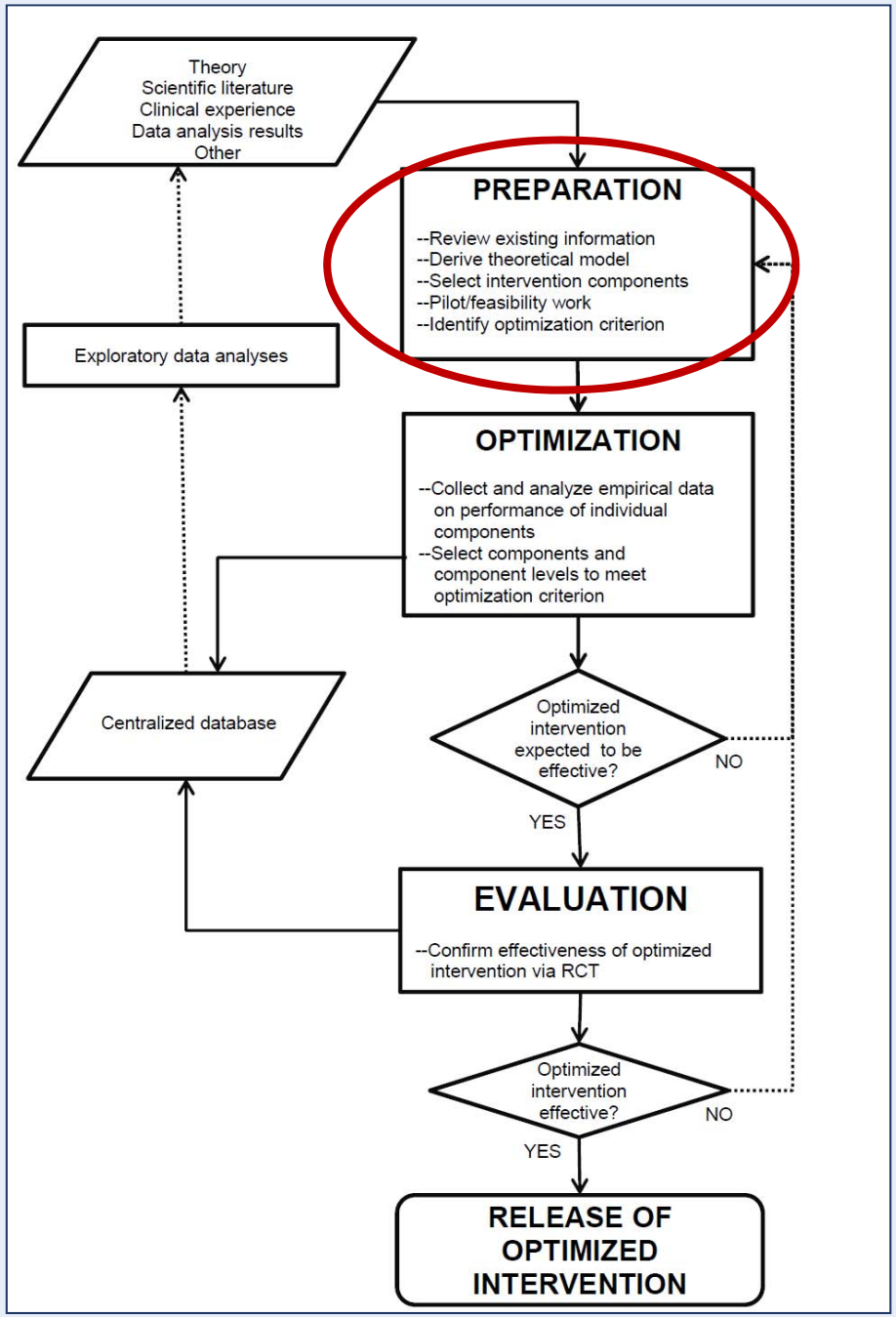
MOST: A comprehensive strategy for optimisation and evaluation

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

Flow Chart of MOST



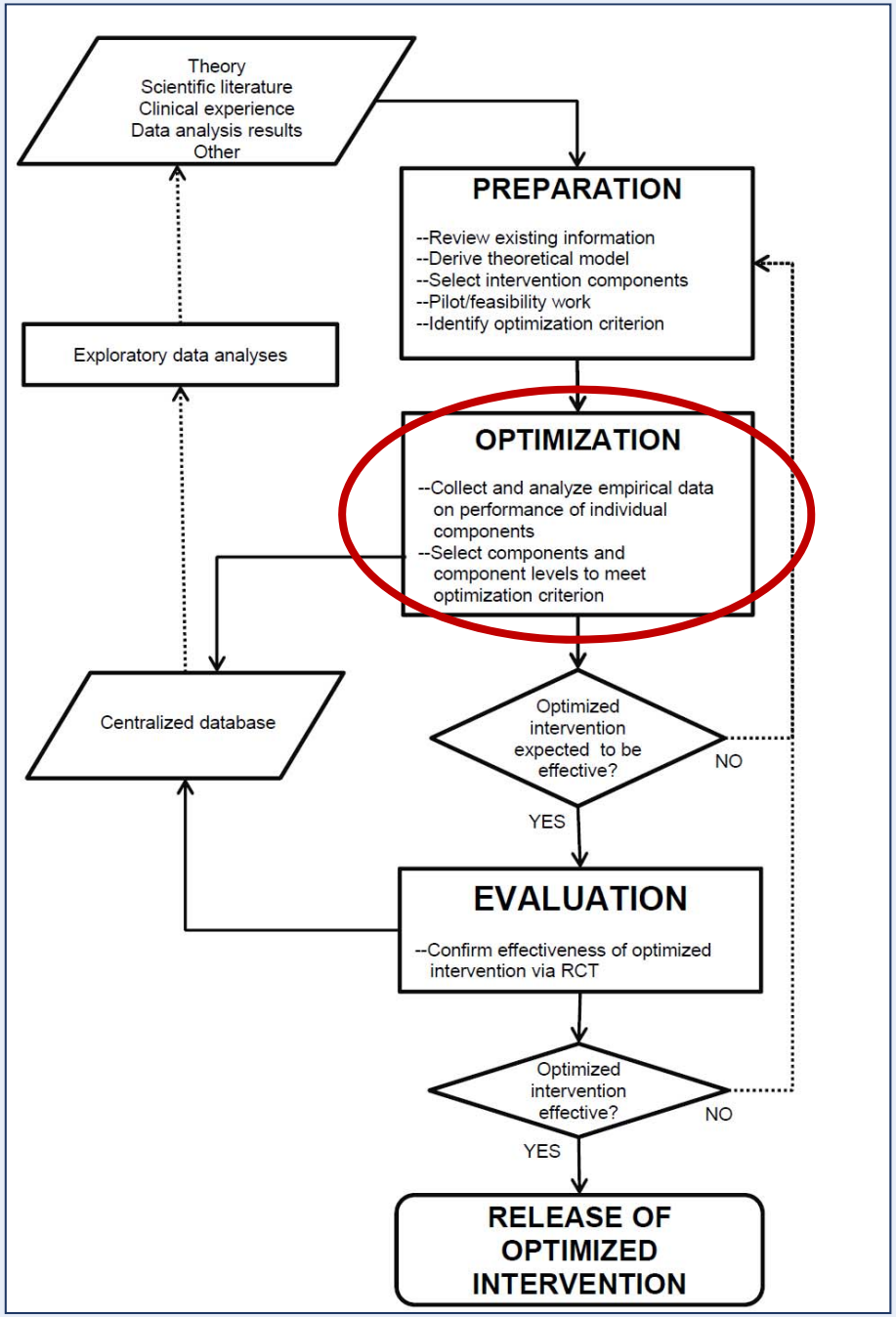
Flow Chart of MOST



MOST: Preparation, optimisation, Evaluation

- Preparation
  - Purpose: to lay groundwork for optimisation
    - Review prior research, take stock of clinical experience, conduct secondary analyses, etc.
    - Derive theoretical model
    - Select intervention components to examine
    - Conduct pilot/feasibility work
    - Identify optimisation criterion

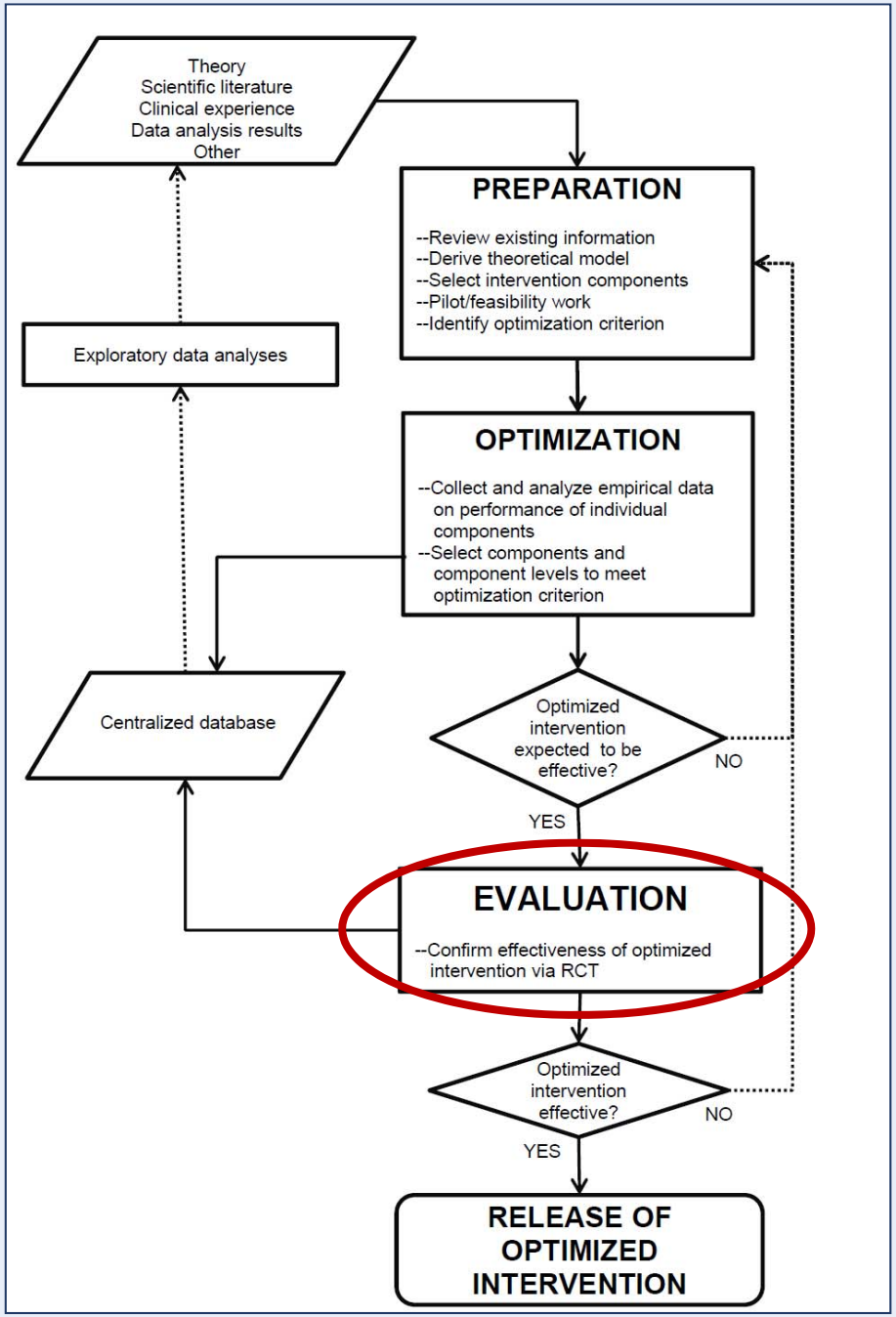
Flow Chart of MOST



MOST: Preparation, optimisation, Evaluation

- Optimisation
  - Objective: To form a treatment package that meets the optimisation criterion
    - Collect and analyze empirical data on performance of individual intervention components relying on efficient randomized experiments
    - Based on information gathered, select components and levels that meet optimisation criterion.

Flow Chart of MOST



MOST: Preparation, optimisation, Evaluation

- Evaluation
  - Objective: To establish whether the optimised intervention has a statistically significant effect compared to a control or alternative intervention
    - Conduct an RCT

AN EXAMPLE OF THE APPLICATION OF MOST

Example: Clinic-based smoking cessation study funded by the National Cancer Institute (part of the US National Institutes of Health)

Timothy Baker, Ph.D.

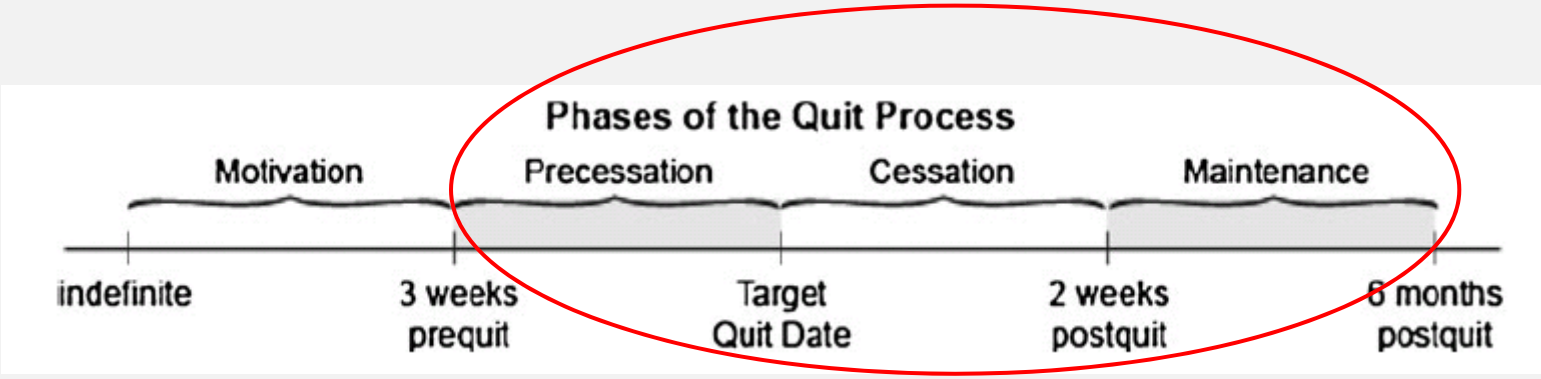
Michael Fiore, M.D.

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 pericessation, patient gets both intensive in-person and intensive phone counseling.
  - During maintenance, patient continues NRT for 16 weeks.
- Evaluate via RCT

Treatment package approach

- This RCT would evaluate whether the treatment has a statistically significant effect
- It would NOT show
  - Which components are active
  - Optimal component levels

Instead, MOST

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

Two principles underlying MOST

- Resource management principle
- Continuous optimisation principle

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 optimisation 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.

Optimisation is a cyclic process

Overview of experimentation to examine individual intervention components

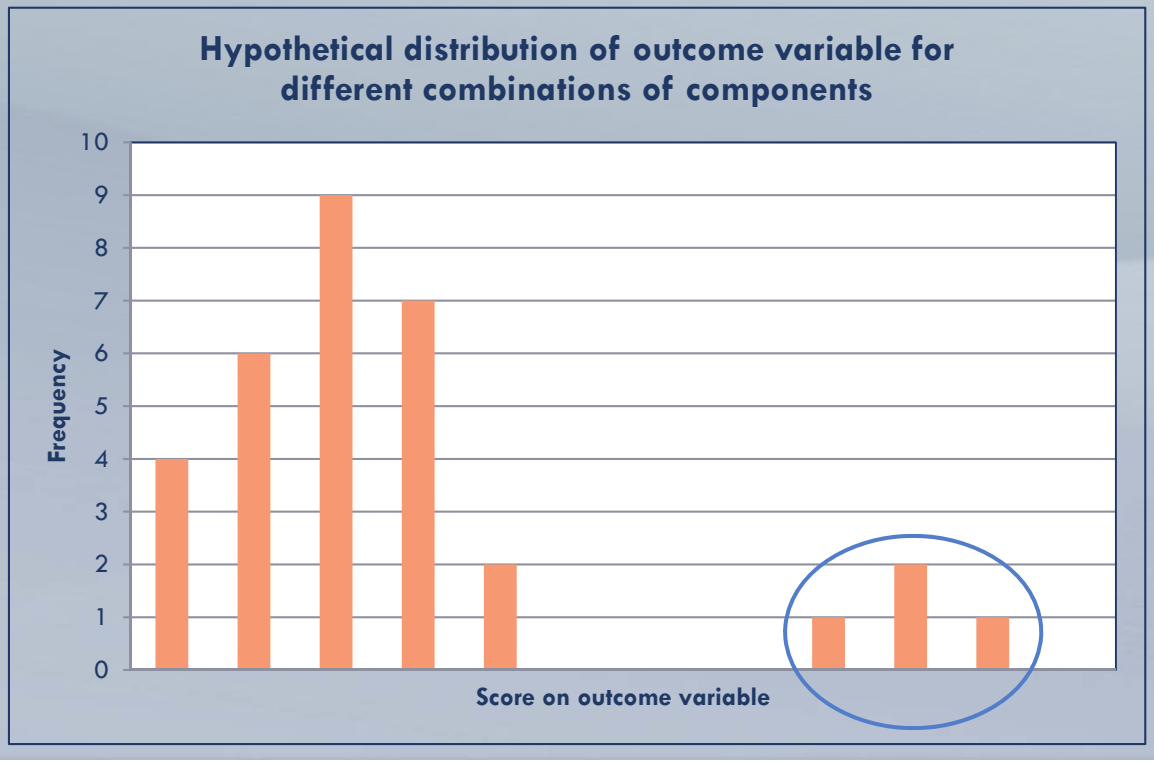
- Objective is to identify the most promising components and levels/settings
- NOT to compare each combination to a control or against each other
- NOT to identify single best combination

Overview of experimentation to examine individual intervention components

- **Don't we want to identify the single best combination of components????**
- Yes, but only way to do this definitively would be an enormous, impractical RCT
- In reality, two options:
  - (a) Treatment package approach
  - (b) Phased experimental approach like MOST

- Treatment package approach
  - Strategy: Identify best combination of components/levels a priori, evaluate as a package
  - Potential payoff: Find single best combination of components/levels first time
  - Risks:
    - Repeated failed trials that yield little information
    - Never find a good combination
- Phased experimental approach like MOST
  - Strategy: Empirically identify best components/levels, assemble and evaluate package
  - Risk: Do not find single best combination of components/levels first time
  - Payoff:
    - Very likely to find good combination, even if not best
    - Every experiment yields information useful in working toward identification of best combination of components/levels IN THE LONG RUN

- Instead of trying to identify the ONE BEST with a high probability of FAILURE, make good use of your resources (RESOURCE MANAGEMENT PRINCIPLE) to identify ONE OF THE BEST with a high probability of SUCCESS
- In subsequent studies, build on results to come closer to the one best (CONTINUOUS OPTIMIZATION PRINCIPLE)



Overview of experimentation to examine individual intervention components

- Conduct a ***component selection 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 will provide evidence of whether or not each has an effect on outcomes
  - If yes, consider including in intervention package
  - Depending on optimisation 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 will provide evidence of whether Intensive is doing more than Minimal
  - If Intensive NOT > Minimal, select Minimal
  - If Intensive > Minimal, consider selecting intensive
  - Depending on optimisation 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 will 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 optimisation criterion, effect *size* may be considered in relation to
    - Cost
    - Time

Assembly of optimised 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 optimisation criterion
- This forms the optimised intervention

IDENTIFYING AN OPTIMISATION CRITERION

Deciding on your optimisation criterion

- Operational definition of "best possible given constraints"
- 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.

(1) No inactive components

- Best possible = most effective
- Constraints = set of components under consideration
- Cost, length unimportant
- No money, time wasted on "dead wood"
- Must specify an inclusion criterion to define "active"
  - Statistical significance (not necessarily $p<.05$)
  - Effect size

(2) Most effective that can be delivered for ≤ some $$

- Best possible = most effective
- Constraints
  - Set of components under consideration
  - Upper limit on cost
- Need an inclusion criterion (assuming we want no inactive components)

(3) Most cost-effective

- Similar to (2), except there is no stated upper limit on cost
- Instead, the idea is to find the best combination of economy and effectiveness
- To an extent, a judgment call

(4) Most effective that can be delivered for ≤ some amount of time

- Best = most effective
- Constraints
  - Set of components under consideration
  - Upper limit on amount of time that can be spent

(5) Most time-effective

- Similar to (3) in concept
- Similar to (4), except there is no stated upper limit on cost
- Instead, the idea is to find the best combination of time-economy and effectiveness
- Like cost-effectiveness, a judgment call to an extent

Some considerations when selecting an optimisation criterion

- What would be the ideal intervention if there were no constraints? (usually, most effective)
- What are the most important constraints on implementation of the intervention?
  - Limited time?
  - Limited money?
  - Something else?

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 decision making
- 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?

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

Resource demands in intervention science

- Every experiment requires resources
  - Subjects
    - Access and acquisition
    - Securing their participation
    - Keeping them engaged
  - Overhead associated with experimental conditions
    - Training of personnel
    - Equipment and supplies
    - Space
    - Logistical coordination
    - Preventing contamination between conditions

What we want to find out from a component selection experiment

- Information to be used in making decisions about which components/component levels to select
  - Primarily, main effects
  - Secondarily, interactions
- Estimates of effect sizes

PENNSTATE

The Methodology Center
advancing methods, improving health

Example: "Opt-in" weight reduction intervention study

Objective: Develop a highly effective weight reduction intervention that can be delivered for ≤ $500/person

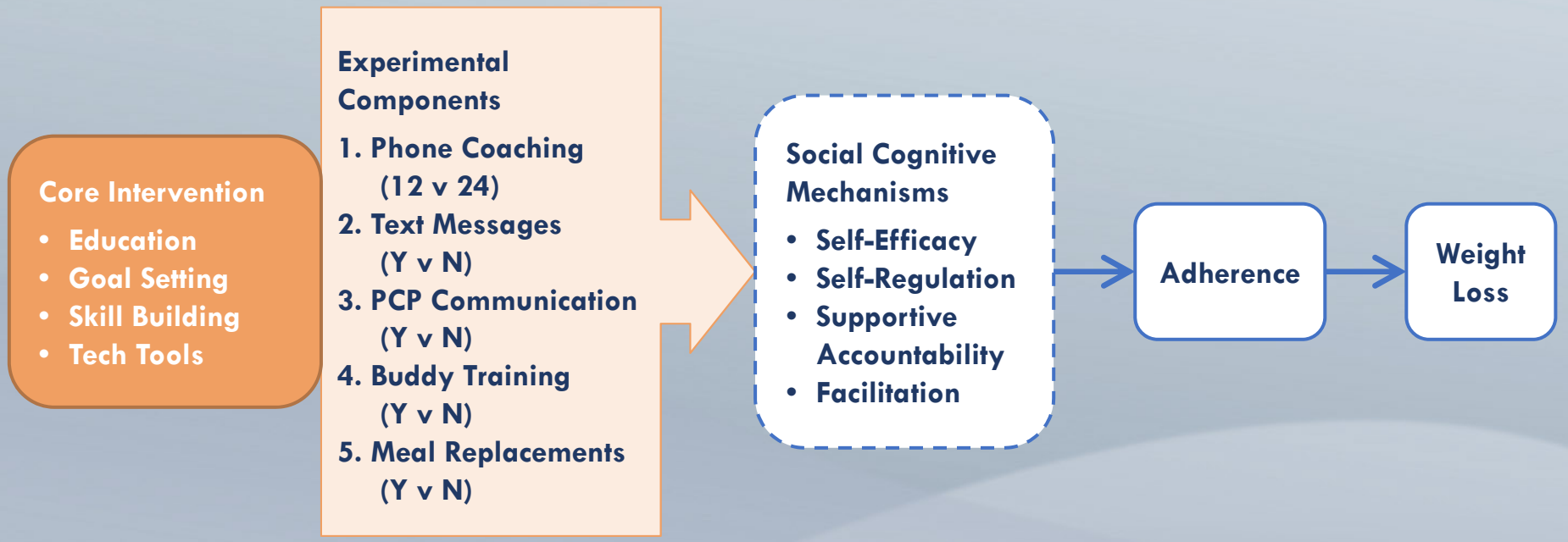
Principal Investigators (jointly):

Linda Collins (Penn State)

Bonnie Spring
(Northwestern University, Chicago, IL, USA)

Funded by the US National Institute of Diabetes and Digestive and Kidney Diseases

Opt-in theoretical model



The component selection 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 optimise the intervention

Choice of design for component selection experiment is critical

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

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

Experimental design possibility 1

- Conduct an experiment for each component

Experiment 1	**12 coaching sessions**	**24 coaching sessions**
Experiment 2	**No text messages**	**Text messages**
Experiment 3	**No PCP communication**	**PCP communication**
Experiment 4	**No buddy training**	**Buddy training**
Experiment 5	**No meal replacements**	**Meal replacements**

Experimental design possibility 2

- Comparative treatment experiment

24 coaching sessions All others set to low	**Text messages** All others set to low	**PCP communication** All others set to low	**Buddy training** All others set to low	**Meal replacements** All others set to low	**All set to low:** **12 coaching sessions** **No text mgs** **No PCP** **No buddy training** **No meals**

Experimental design possibility 3

- Factorial experiment
- The Opt-In study would require a 2X2X2X2X2, or 2^5, factorial experiment
- This would involve 32 experimental conditions.

Factorial experiments are not new

Sir Ronald A. Fisher invented the Analysis of Variance. His first book on this topic was published in 1925.

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

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***

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

What are we trying to estimate with a factorial experiment?

- 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))**

$$1/2((\mu_{A1,B=1} - \mu_{A2,B=1}) - (\mu_{A1,B=2} - \mu_{A2,B=2}))$$

What are we trying to estimate with a factorial experiment?

- **NOTE:** We are talking about EFFECT CODED effects, NOT dummy coded effects

Comparison of experimental design possibilities 1-3

Design	N to achieve power ≥ .8	Number of experimental conditions	Can interactions be examined?
Option 1: Five individual experiments	2,800	10	No
Option 2: Comparative treatment	1,680	6	No
Option 3: Factorial experiment	560	32	Yes, all

Why a factorial experiment?

- We decided to conduct a factorial experiment. Why?
- Enables examination of individual component effects AND
- Requires **smaller** sample sizes than alternative designs
- BUT they also usually require more experimental conditions than we may be accustomed to

Comparison of experimental design possibilities 1-3

Design	N to achieve power ≥ .8	Number of experimental conditions	Can interactions be examined?
Option 1: Five individual experiments	2,800	10	No
Option 2: Comparative treatment	1,680	6	No
Option 3: Factorial experiment	560	32	Yes, all

We liked the economy of a factorial experiment BUT we felt we could not handle more than 16 conditions.

Experimental design possibility 4

- Fractional factorial experiment
- Special type of factorial experiment
  - Used commonly in engineering research
  - A fraction of the experimental conditions are run
  - Powered exactly the same as an ordinary factorial experiment
  - Important trade-offs that we will discuss shortly

Comparison of experimental design possibilities 1-4

Design	N to achieve power ≥ .8	Number of experimental conditions	Can interactions be examined?
Option 1: Five individual experiments	2,800	10	No
Option 2: Comparative treatment	1,680	6	No
Option 3: Factorial experiment	560	32	Yes, all
Option 4: Fractional factorial experiment	560	16	Yes, selected

Design for Opt-In Component Screening Experiment

Experimental Condition	Core Intervention	# Phone Coaching Sessions	PCP Commun-ication	Text Messages	Meal Replace-ments	Buddy Training
1	Yes	12	Yes	No	No	No
2	Yes	12	Yes	No	Yes	Yes
3	Yes	12	Yes	Yes	No	Yes
4	Yes	12	Yes	Yes	Yes	No
5	Yes	12	No	No	No	Yes
6	Yes	12	No	No	Yes	No
7	Yes	12	No	Yes	No	No
8	Yes	12	No	Yes	Yes	Yes
9	Yes	24	Yes	No	No	No
10	Yes	24	Yes	No	Yes	Yes
11	Yes	24	Yes	Yes	No	Yes
12	Yes	24	Yes	Yes	Yes	No
13	Yes	24	No	No	No	Yes
14	Yes	24	No	No	Yes	No
15	Yes	24	No	Yes	No	No
16	Yes	24	No	Yes	Yes	Yes

Overall N=560, per-condition n=35.

How can 35 per condition be enough?

Design for Opt-In Component Screening Experiment

Experimental Condition	Core Intervention	# Phone Coaching Sessions	PCP Commun-ication	Text Messages	Meal Replace-ments	Buddy Training
1	Yes	12	Yes	No	No	No
2	Yes	12	Yes	No	Yes	Yes
3	Yes	12	Yes	Yes	No	Yes
4	Yes	12	Yes	Yes	Yes	No
5	Yes	12	No	No	No	Yes
6	Yes	12	No	No	Yes	No
7	Yes	12	No	Yes	No	No
8	Yes	12	No	Yes	Yes	Yes
9	Yes	24	Yes	No	No	No
10	Yes	24	Yes	No	Yes	Yes
11	Yes	24	Yes	Yes	No	Yes
12	Yes	24	Yes	Yes	Yes	No
13	Yes	24	No	No	No	Yes
14	Yes	24	No	No	Yes	No
15	Yes	24	No	Yes	No	No
16	Yes	24	No	Yes	Yes	Yes

Main effect of # Phone Coaching Sessions *based on overall N of 560*

Design for Opt-In Component Screening Experiment

Experimental Condition	Core Intervention	# Phone Coaching Sessions	PCP Commun-ication	Text Messages	Meal Replace-ments	Buddy Training
1	Yes	12	Yes	No	No	No
2	Yes	12	Yes	No	Yes	Yes
3	Yes	12	Yes	Yes	No	Yes
4	Yes	12	Yes	Yes	Yes	No
5	Yes	12	No	No	No	Yes
6	Yes	12	No	No	Yes	No
7	Yes	12	No	Yes	No	No
8	Yes	12	No	Yes	Yes	Yes
9	Yes	24	Yes	No	No	No
10	Yes	24	Yes	No	Yes	Yes
11	Yes	24	Yes	Yes	No	Yes
12	Yes	24	Yes	Yes	Yes	No
13	Yes	24	No	No	No	Yes
14	Yes	24	No	No	Yes	No
15	Yes	24	No	Yes	No	No
16	Yes	24	No	Yes	Yes	Yes

Main effect of PCP Communication *based on overall N of 560*

Design for Opt-In Component Screening Experiment

Experimental Condition	Core Intervention	# Phone Coaching Sessions	PCP Commun-ication	Text Messages	Meal Replace-ments	Buddy Training
1	Yes	12	Yes	No	No	No
2	Yes	12	Yes	No	Yes	Yes
3	Yes	12	Yes	Yes	No	Yes
4	Yes	12	Yes	Yes	Yes	No
5	Yes	12	No	No	No	Yes
6	Yes	12	No	No	Yes	No
7	Yes	12	No	Yes	No	No
8	Yes	12	No	Yes	Yes	Yes
9	Yes	24	Yes	No	No	No
10	Yes	24	Yes	No	Yes	Yes
11	Yes	24	Yes	Yes	No	Yes
12	Yes	24	Yes	Yes	Yes	No
13	Yes	24	No	No	No	Yes
14	Yes	24	No	No	Yes	No
15	Yes	24	No	Yes	No	No
16	Yes	24	No	Yes	Yes	Yes

Main effect of Text Messages *based on overall N of 560*

Design for Opt-In Component Screening Experiment

Experimental Condition	Core Intervention	# Phone Coaching Sessions	PCP Commun-ication	Text Messages	Meal Replace-ments	Buddy Training
1	Yes	12	Yes	No	No	No
2	Yes	12	Yes	No	Yes	Yes
3	Yes	12	Yes	Yes	No	Yes
4	Yes	12	Yes	Yes	Yes	No
5	Yes	12	No	No	No	Yes
6	Yes	12	No	No	Yes	No
7	Yes	12	No	Yes	No	No
8	Yes	12	No	Yes	Yes	Yes
9	Yes	24	Yes	No	No	No
10	Yes	24	Yes	No	Yes	Yes
11	Yes	24	Yes	Yes	No	Yes
12	Yes	24	Yes	Yes	Yes	No
13	Yes	24	No	No	No	Yes
14	Yes	24	No	No	Yes	No
15	Yes	24	No	Yes	No	No
16	Yes	24	No	Yes	Yes	Yes

Main effect of Meal Replacements *based on overall N of 560*

Design for Opt-In Component Screening Experiment

Experimental Condition	Core Intervention	# Phone Coaching Sessions	PCP Commun-ication	Text Messages	Meal Replace-ments	Buddy Training
1	Yes	12	Yes	No	No	No
2	Yes	12	Yes	No	Yes	Yes
3	Yes	12	Yes	Yes	No	Yes
4	Yes	12	Yes	Yes	Yes	No
5	Yes	12	No	No	No	Yes
6	Yes	12	No	No	Yes	No
7	Yes	12	No	Yes	No	No
8	Yes	12	No	Yes	Yes	Yes
9	Yes	24	Yes	No	No	No
10	Yes	24	Yes	No	Yes	Yes
11	Yes	24	Yes	Yes	No	Yes
12	Yes	24	Yes	Yes	Yes	No
13	Yes	24	No	No	No	Yes
14	Yes	24	No	No	Yes	No
15	Yes	24	No	Yes	No	No
16	Yes	24	No	Yes	Yes	Yes

Main effect of Buddy Training *based on overall N of 560*

Some common misconceptions about factorial experiments

- Misconception 1: Factorial experimental designs require larger numbers of subjects than available alternative designs.

- Reality: When used to address suitable research questions, balanced factorial experimental designs often require many FEWER subjects than alternative designs.

Some common misconceptions about factorial experiments

- Misconception 2: If you want to add a factor to a balanced factorial experiment, you will have to increase the number of subjects dramatically to maintain power.
- Reality: This depends on the effect size of the factor to be added. If this effect size is no smaller than the smallest factor already in the experiment, power will be about the same WITHOUT ANY INCREASE IN THE NUMBER OF SUBJECTS.

Some common misconceptions about factorial experiments

- Misconception 3: The primary motivation for conducting a factorial experiment is always to test for interactions between factors.
- Reality: Even if you somehow knew that there were no interactions between factors, you still might want to conduct a factorial experiment to make economical use of subjects.

Some common misconceptions about factorial experiments

- Misconception 4: Any interaction between factors necessarily makes interpretation of main effects impossible.
- Reality:
  - Interactions definitely require thought. However, they do not necessarily render main effects uninterpretable.
  - To an extent this misconception may stem from use of dummy coding.
  - We recommend use of effect coding for component selection experiments. When effect coding is used and there are equal *n*'s per condition, all main effects and interactions are uncorrelated.

Some reasons you might want to consider a factorial experimental design… they

- SAVE TIME by enabling experimentation on many components simultaneously
- REQUIRE MANY FEWER SUBJECTS than other design approaches
- ENABLE STRONGER INFERENCE when random assignment used
- ENABLE EXAMINATION OF INTERACTIONS

Some reasons you might not want to use a factorial experimental design

- Intervention composed of many components with tiny effects, overall effect is cumulative
  - If so, may be tough to power experiment to examine individual components
  - However, may be able to sort components into thematic bundles and examine bundles
- Factorial experiments REQUIRE MORE EXPERIMENTAL CONDITIONS
  - but fractional factorial designs a possibility – we will discuss further shortly

Powering factorial experiments

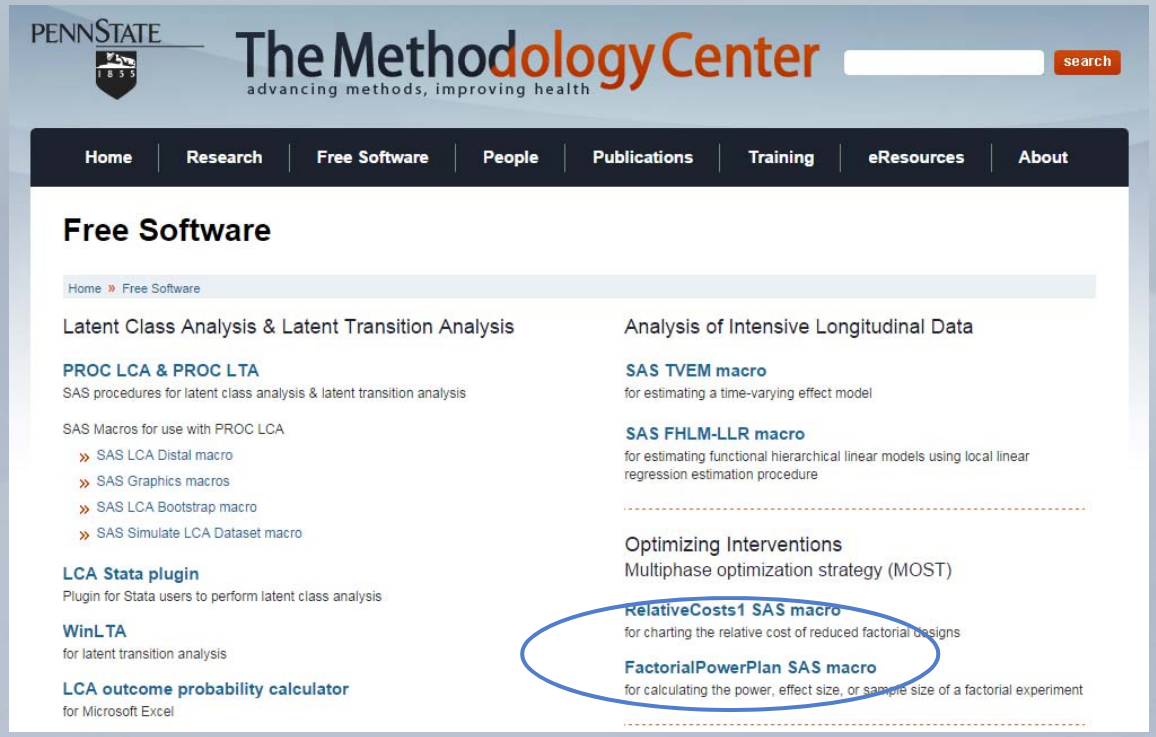
- Power for main effects: sample size requirements for a *k*-factor experiment about the same as for a *t*-test
- Power the experiment for the smallest effect size
- Adding a factor generally does not increase sample size requirements, unless that factor is expected to have a smaller effect size
- For component selection (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



INTRODUCTION TO FRACTIONAL FACTORIAL DESIGNS

Comparison of experimental design possibilities 1-4

Design	N to achieve power ≥ .8	Number of experimental conditions	Can interactions be examined?
Option 1: Five individual experiments	2,800	10	No
Option 2: Comparative treatment	1,680	6	No
Option 3: Factorial experiment	560	32	Yes, all
Option 4: Fractional factorial experiment	560	16	Yes, selected

Approaches to examining individual intervention components

- Strategy 4: 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 FRACTION (e.g. ½, ¼) of experimental conditions are run
- But not just any conditions! Carefully chosen to preserve balance properties
- FF designs require at most ½ the experimental conditions of a complete factorial, often many fewer
- They require the SAME *N* as complete factorial

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

Design for Opt-In Component Screening Experiment

Experimental Condition	Core Intervention	# Phone Coaching Sessions	PCP Commun-ication	Text Messages	Meal Replace-ments	Buddy Training
1	Yes	12	Yes	No	No	No
2	Yes	12	Yes	No	Yes	Yes
3	Yes	12	Yes	Yes	No	Yes
4	Yes	12	Yes	Yes	Yes	No
5	Yes	12	No	No	No	Yes
6	Yes	12	No	No	Yes	No
7	Yes	12	No	Yes	No	No
8	Yes	12	No	Yes	Yes	Yes
9	Yes	24	Yes	No	No	No
10	Yes	24	Yes	No	Yes	Yes
11	Yes	24	Yes	Yes	No	Yes
12	Yes	24	Yes	Yes	Yes	No
13	Yes	24	No	No	No	Yes
14	Yes	24	No	No	Yes	No
15	Yes	24	No	Yes	No	No
16	Yes	24	No	Yes	Yes	Yes

This is a ½ fraction; complete factorial would have 32 conditions.

Hey, where is the control group????

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:

- 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

- Suppose 4 factors, A, B, C, and D.
- Each factor has 2 levels: Off and On.
- Complete factorial: 2^4 (i.e. 16 experimental conditions)

Complete 2^4 (2X2X2X2) Factorial Design				
Experimental condition	A	B	C	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

The logic behind FF designs

- In this (or any) complete 2^4 factorial design
  - 16 experimental conditions
  - Effects estimated:
    - 1 intercept
    - 4 main effects
    - 6 two-way interactions
    - 4 three-way interactions
    - 1 four-way interaction
    - TOTAL=16

The logic behind FF designs

- Complete factorial: 2^4 (i.e. 16 experimental conditions)
- What if we included only 8 experimental conditions in the design?
- This would be a half-fraction, represented as 2^{4-1}. This notation tells you
  - The number of conditions in the "original" complete factorial (2^4)
  - The number of conditions in the FF ($2^{4-1}=2^3=8$)
  - The fraction by which the FF reduces the original ($2^{-1}=1/2$)

The logic behind FF designs

- OK, what would happen if we removed half of the experimental conditions from a 2^4 factorial design, making it a 2^{4-1}?
- 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 24 there are 16 experimental conditions, so you can estimate 16 effects
  - Once you remove half of the experimental conditions, you can estimate only 8 effects
  - As a result, each of these 8 effects is a combination of two of the effects from the complete factorial
- THIS IS NOT NECESSARILY ALL BAD

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 strategicially
  - As it is in fractional factorial experiments

The logic behind FF designs

- Statisticians have figured out what happens when you remove different conditions
- SO it follows that it is possible to select a FF design with conditions that produce characteristics we like!
- Consider the following 2^{4-1} FF

A 2^{4-1} Fractional Factorial Design				
Experimental condition	A	B	C	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

Aliasing in 4-factor example.**

THIS EFFECT	IS MADE UP OF THESE ALIASED EFFECTS
I	Main effect of A + BCD interaction
II	Main effect of B + ACD interaction
III	Main effect of C + ABD interaction
IV	Main effect of D + ABC interaction
V	AB interaction + CD interaction
VI	AC interaction + BD interaction
VII	AD interaction + BC interaction
VIII	Intercept +ABCD interaction

**NOTE: Effects are numbered arbitrarily. 4-factor example chosen for didactic purposes; in general fractional factorial designs used with ≥ 5 factors

Aliasing of effects

- In a ½ fraction design, each effect is aliased with ONE other effect (i.e. "bundles" of two)
- In a ¼ fraction design, each effect is aliased with THREE other effects (i.e. "bundles" of four)
- Because it is known which effects are aliased with which, **it is possible to choose a design that aliases effects strategically**

Strategic aliasing

- Suppose you are comfortable assuming that the three-way interactions are negligible

THIS EFFECT	MADE UP OF THESE ALIASED EFFECTS	CAN BE INTERPRETED AS APPROXIMATELY
I	Main effect of A + BCD interaction	Main effect of A
II	Main effect of B + ACD interaction	Main effect of B
III	Main effect of C + ABD interaction	Main effect of C
IV	Main effect of D + ABC interaction	Main effect of D
V	AB interaction + CD interaction	
VI	AC interaction + BD interaction	
VII	AD interaction + BC interaction	
VIII	Intercept +ABCD interaction	

Strategic aliasing

- Suppose you are also comfortable assuming that SOME of the two-way interactions are negligible

THIS EFFECT	MADE UP OF THESE ALIASED EFFECTS	CAN BE INTERPRETED AS APPROXIMATELY
I	Main effect of A + BCD interaction	Main effect of A
II	Main effect of B + ACD interaction	Main effect of B
III	Main effect of C + ABD interaction	Main effect of C
IV	Main effect of D + ABC interaction	Main effect of D
V	AB interaction + CD interaction	CD interaction
VI	AC interaction + BD interaction	AC interaction
VII	AD interaction + BC interaction	BC interaction
VIII	Intercept +ABCD interaction	

Strategic aliasing

- If you are comfortable assuming that the three-way interactions are negligible, and that some of the two-way interactions are negligible, this 2^{4-1} FF design could be great for you!
- Why?
  - Note that the sample size requirements would be the same – no savings there
  - BUT YOU WOULD HAVE TO DEAL WITH THE LOGISTICS OF ONLY HALF OF THE EXPERIMENTAL CONDITIONS.

Strategic aliasing

- For four factors there is only one FF design
- However, as the number of factors increases there many be MANY designs to choose from
  - Different designs alias different effects
- One aliasing structure may be great for a particular study, another might be inappropriate
- The experimenter must choose the design that best meets the needs of the study

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

- You don't (unless you are a GENIUS)
- 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

Design for Opt-In Component Screening Experiment

Experimental Condition	Core Intervention	# Phone Coaching Sessions	PCP Commun-ication	Text Messages	Meal Replace-ments	Buddy Training
1	Yes	12	Yes	No	No	No
2	Yes	12	Yes	No	Yes	Yes
3	Yes	12	Yes	Yes	No	Yes
4	Yes	12	Yes	Yes	Yes	No
5	Yes	12	No	No	No	Yes
6	Yes	12	No	No	Yes	No
7	Yes	12	No	Yes	No	No
8	Yes	12	No	Yes	Yes	Yes
9	Yes	24	Yes	No	No	No
10	Yes	24	Yes	No	Yes	Yes
11	Yes	24	Yes	Yes	No	Yes
12	Yes	24	Yes	Yes	Yes	No
13	Yes	24	No	No	No	Yes
14	Yes	24	No	No	Yes	No
15	Yes	24	No	Yes	No	No
16	Yes	24	No	Yes	Yes	Yes

This is a 2^{5-1}; each main effect is aliased with one 4-way interaction, each two-way aliased with one three-way

Experimental design used to examine components of smoking cessation intervention

- This is a 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

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

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

1. When considering a FF design for the component selection 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 selection 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.

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)
  - You MUST power your experiment to detect the interactions.
  - You will have to devote resources to detecting even small interactions
  - This will limit the amount of research you can do
    - This perspective has already limited the progress of intervention science

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
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)

Making decisions based on experimental results

The idea

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

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 optimisation criteria

- No inactive components
- Most effective that can be delivered for ≤ some $$$
- Most cost-effective
- Most effective that can be delivered for ≤ some amount of time
- Most time-effective
- Or…?

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 theoretical 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

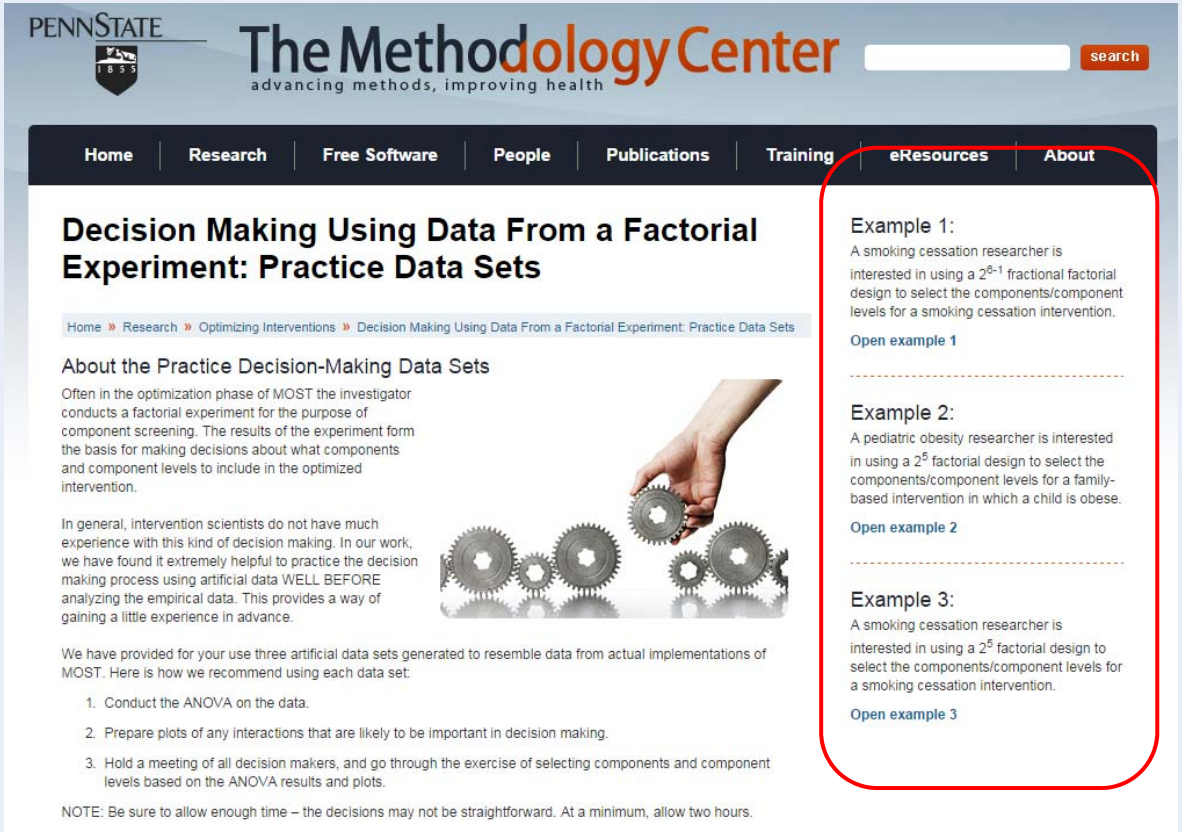
- **Important considerations that are not outcomes per se:**
  - Attrition
  - Compliance
  - Practicality
  - Etc.

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



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 selection 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 selection 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))

$$1/2((\mu_{A1,B=1} - \mu_{A2,B=1}) - (\mu_{A1,B=2} - \mu_{A2,B=2}))$$

Slightly different way to think of interaction

- Extent to which the combined effect of two or more the factors cannot be represented completely by their main effects
- The combined effect of A and B = $ME_A + ME_B + INT_{AXB} + INT_{AXBXC} + \ldots$
- If $INT_{AXB} = 0$ and $INT_{AXBXC} = 0$ and… , then the combined effect of A and B is $ME_A + ME_B$
- Even if some of the interactions are not exactly 0, the sum of the main effects may be a reasonable approximation

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!

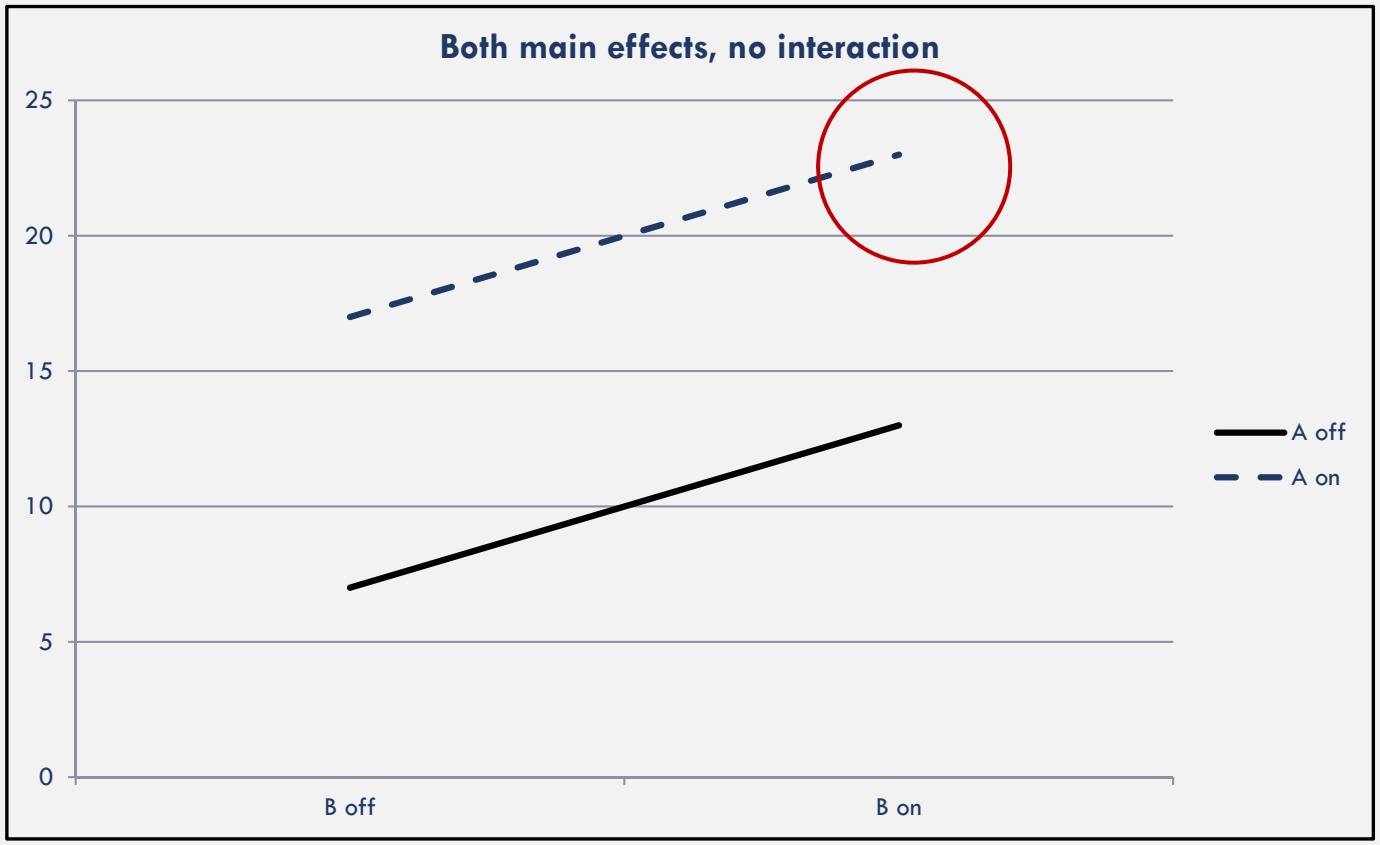
Interactions and selecting components/levels

- 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

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

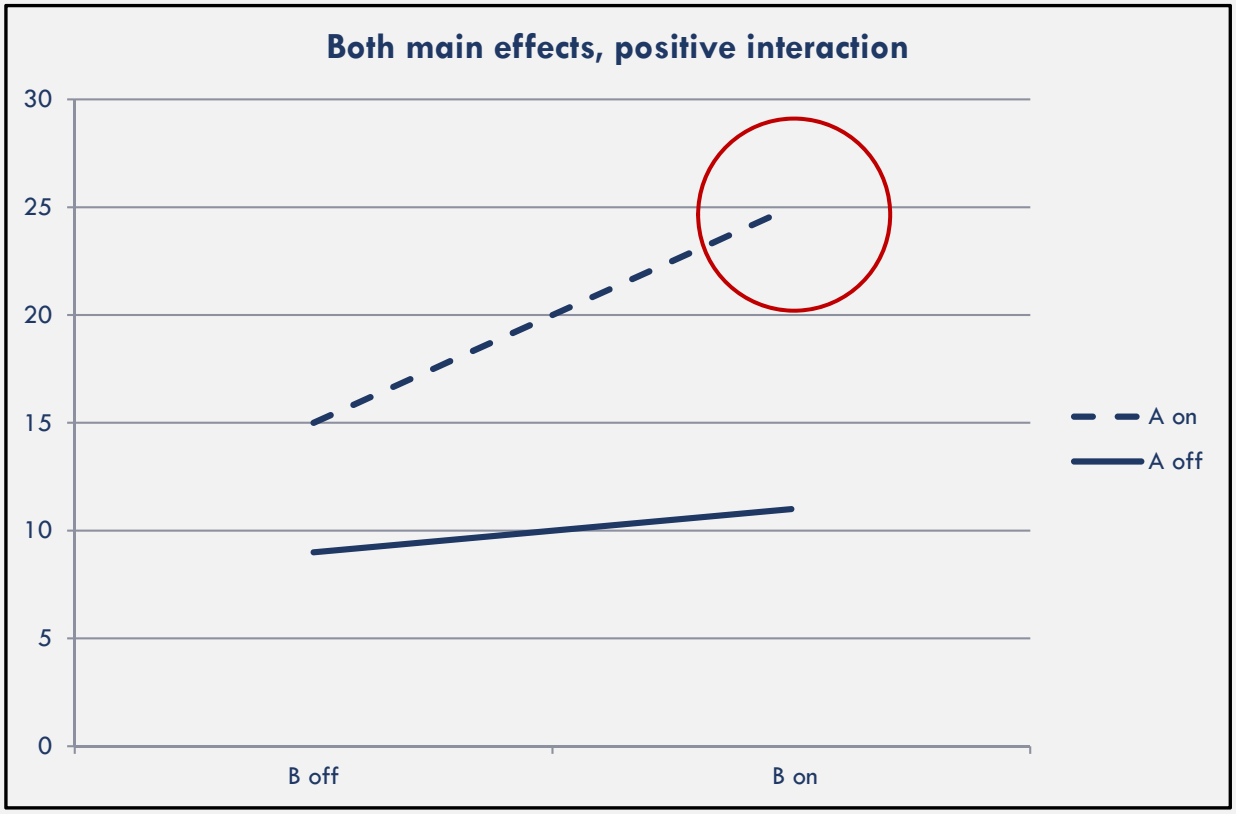
- Effect sparsity (Pareto) principle
  - Only a small subset of the effects important
- Hierarchical ordering principle
  - Look at lower-order effects first, and only if these are significant, examine interaction
  - So if of *A* and *B* only one main effect significant, an engineer does not usually care about the *AXB* interaction (unless there is a compelling reason to think otherwise)
  - Wu & Hamada, 2009

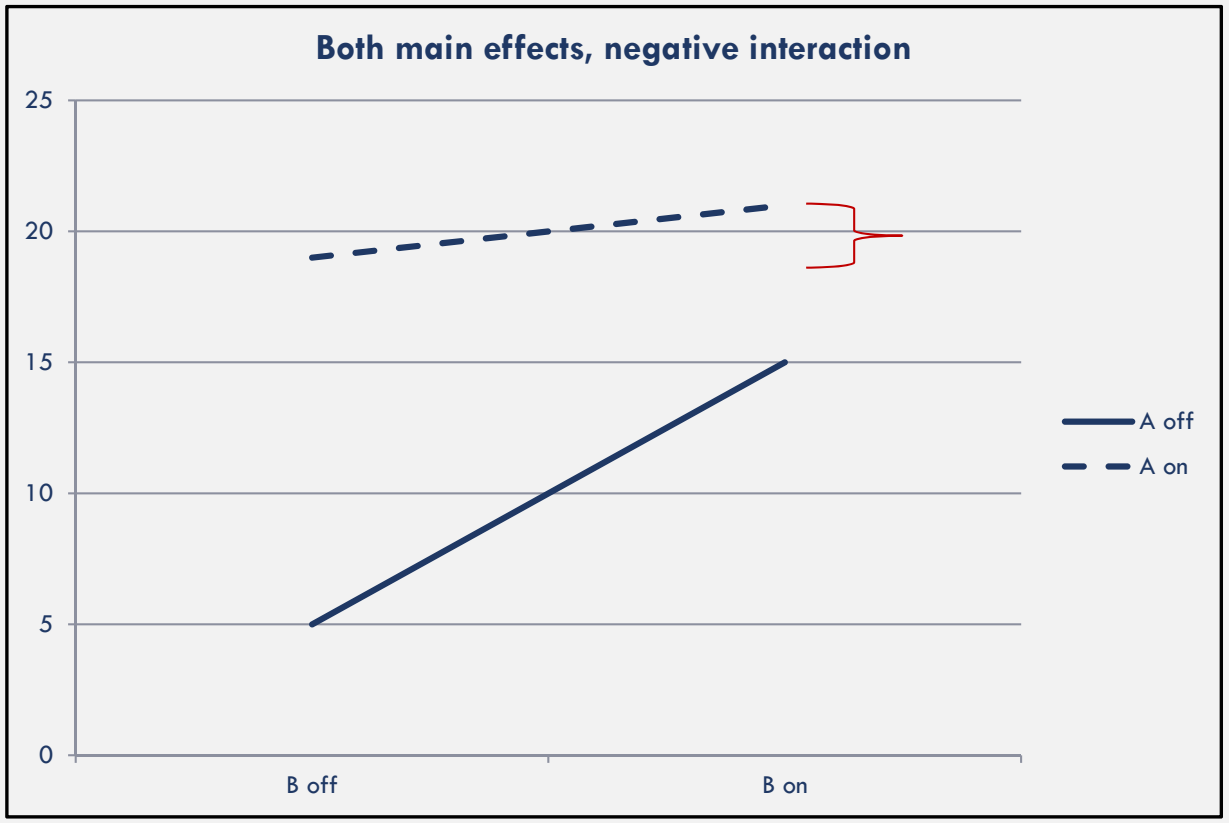
A suggested approach to decision making

- Any rational approach to decision making can be used! There isn't one single approach.
- But here is a suggestion:
  - When the main effect of Factor A is significant, examine all two-way interactions that involve A.
  - When the AXB interaction is significant, examine AXBXC (and all three-way interactions that involve A and B).
  - If both A and B nonsignificant, do not bother with AXB (unless a specific a priori reason to think otherwise)
    - Why? If A and B are separate components, it's unlikely that each alone would have no effect but together have a big effect
    - If this happened and you selected A and B, you would have to make sure that every participant got both, otherwise neither would work

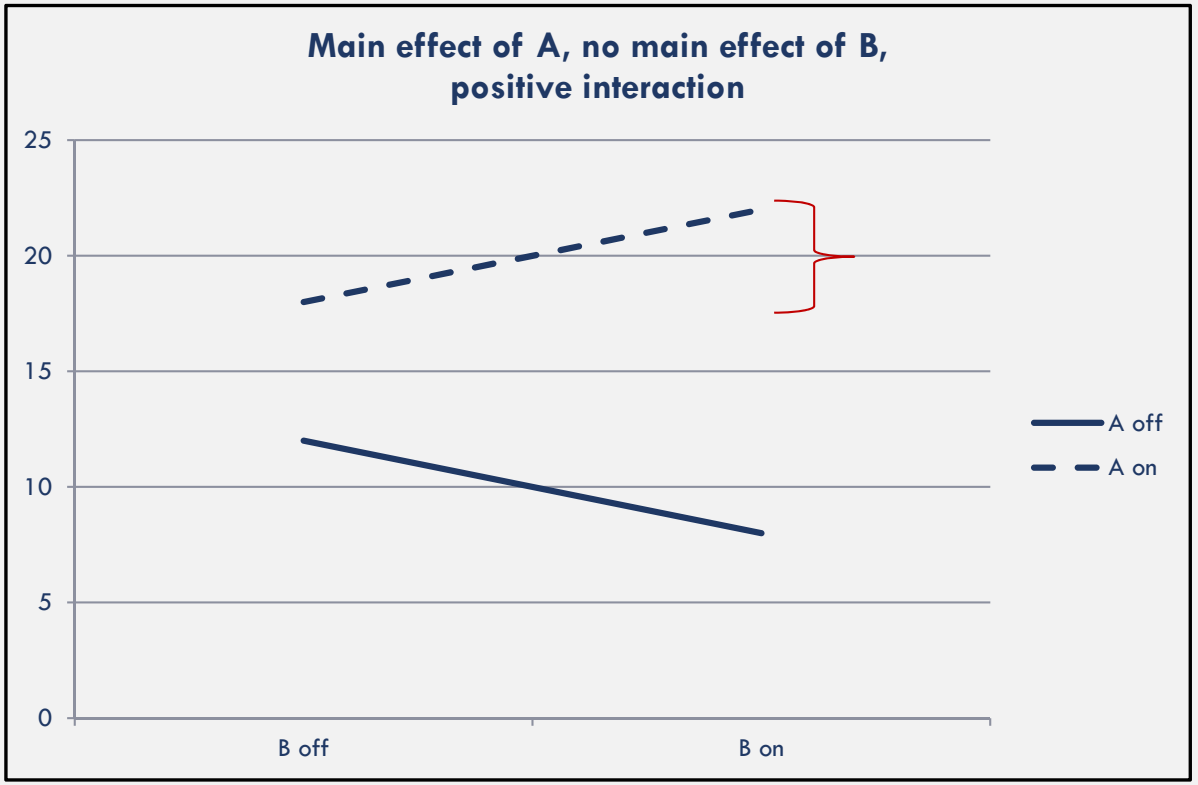
Suggested decision process for selecting components in presence of interactions Notes: (1) This assumes effect coding used. (2) These decision rules do not take cost or other factors into account. (3) We recommend examining a plot of any interaction of interest.				
Scenario	Main effect of A	Main effect 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.

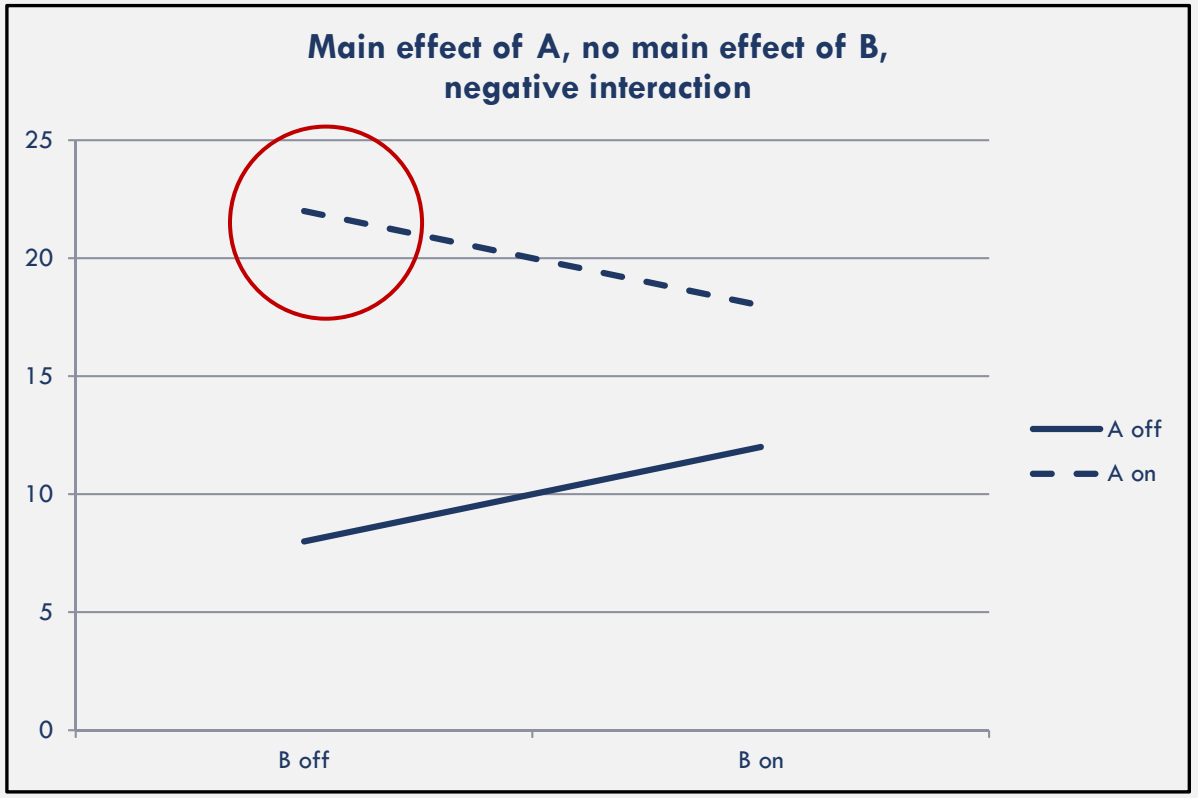
Suggested decision process for selecting components in presence of interactions Notes: (1) This assumes effect coding used. (2) These decision rules do not take cost or other factors into account. (3) We recommend examining a plot of any interaction of interest.				
Scenario	Main effect of A	Main effect 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.


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

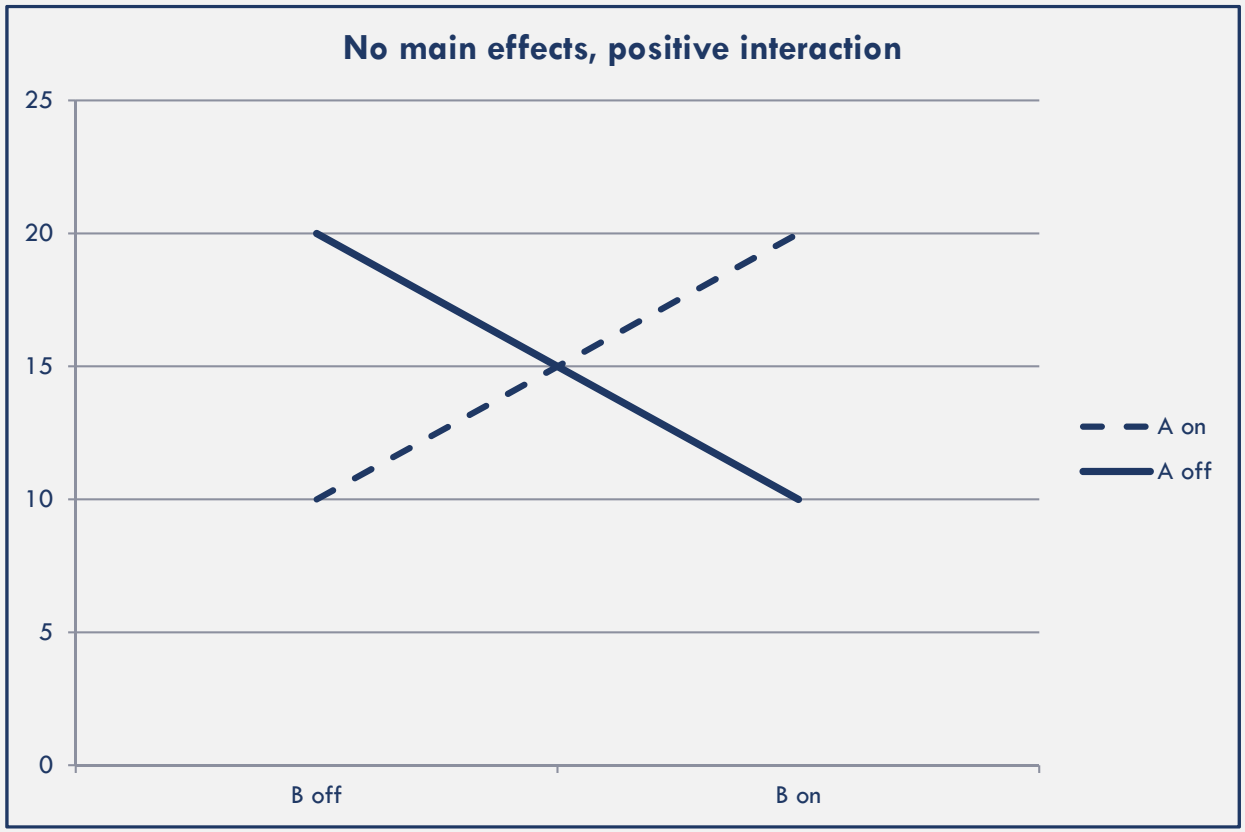

Both main effects, negative interaction
25
20
15
10
5
0
B off
B on
A off
A on

Suggested decision process for selecting components in presence of interactions 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.				
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.


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


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

Suggested decision process for selecting components in presence of interactions 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.				
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.


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

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. Here you can get the cost macro and the power macro

lmcollins@psu.edu

OPEN DISCUSSION

EXTRA SLIDES

Currently funded projects using MOST (that I know of)

- Wisconsin study on smoking cessation (funded by National Cancer Institute)
- Intervention to reduce anxiety related to fear of recurrence in cancer survivors (Lynne Wagner, Northwestern University; funded by the National Cancer Institute)
- Positive psychology intervention for cardiac patients to improve health behaviours (Jeff Huffman, Harvard U; funded by National Heart, Lung, and Blood Institute)

Currently funded projects using MOST (that I know of)

- Study on drug abuse and HIV prevention in South Africa (funded by National Institute on Drug Abuse)
- Project to develop an online intervention to prevent drug use/abuse in college athletes (David Wyrick at U North Carolina Greensboro; funded by NIDA)
- Project to develop a substance use prevention program aimed at American Indian families (Nancy Whitesell at University of Colorado; funded by NIDA)

Currently funded projects using MOST (that I know of)

- Project to develop a weight reduction program for adults (Bonnie Spring at Northwestern University and Linda Collins at Penn State; funded by National Institute on Diabetes and Digestive and Kidney Diseases)
- Adherence intervention to promote use of insulin pumps among adolescents (Kim Driscoll, U of Florida; funded by NIDDK)

Some common misconceptions about factorial experiments

- Misconception 2: If you want to add a factor to a balanced factorial experiment, you will have to increase the number of subjects dramatically to maintain power.
- Reality: This depends on the effect size of the factor to be added. If this effect size is no smaller than the smallest factor already in the experiment, power will be about the same WITHOUT ANY INCREASE IN THE NUMBER OF SUBJECTS.

Main effect of Enhanced school climate is mean of (2.4.6.8) vs. mean of (1,3,5,7).

Note that all 56 schools are used in estimating the main effect.

Experi-mental condi-tion	*N* of schools	Health-Wise program	Training	Structure, support, & super-vision	Enhan-ced school climate
1	7	✓			
2	7	✓			✓
3	7	✓		✓	
4	7	✓		✓	✓
5	7	✓	✓		
6	7	✓	✓		✓
7	7	✓	✓	✓	
8	7	✓	✓	✓	✓

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

All 56 schools still used to estimate each main effect

Experi-mental condition	N of schools	Health wise	Train-ing	S, S, & S	Enhan-ced SC	New factor
1	3	✓				
2	4	✓				✓
3	3	✓			✓	
4	4	✓			✓	✓
5	4	✓		✓		
6	3	✓		✓		✓
7	4	✓		✓	✓	
8	3	✓		✓	✓	✓
9	3	✓	✓			
10	4	✓	✓			✓
11	4	✓	✓		✓	
12	4	✓	✓		✓	✓
13	3	✓	✓	✓		
14	3	✓	✓	✓		✓
15	3	✓	✓	✓	✓	
16	4	✓	✓	✓	✓	✓

Why (I think) so many people mistakenly think factorial experiments need massive sample sizes

- Suppose *N*=100 provides sufficient power for the treatment-control comparison in this RCT:

Treatment A *n*=50	Control *n*=50

- Now suppose you decide you want to compare an additional treatment, expecting the same effect size:

Treatment A *n*=50	Treatment B *n*=50	Control *n*=50

- **In an RCT you have to add subjects every time you add an experimental condition.**
- This is different from a factorial experiment.

SELECTING A FRACTIONAL FACTORIAL DESIGN

How do I go about selecting a fractional factorial design?

- Here is the idea:
  - In a FF design all of the effects are going to be aliased
  - Some of the effects are important, some are not
  - As the investigator, you have a choice among a variety of FF designs
  - Different designs alias different effects (i.e. have different aliasing structures)
  - You want to select a design that aliases scientifically important effects with effects that are both unimportant and small

How do I go about selecting a fractional factorial design?

- Start with the complete factorial, list all effects
- Categorize all effects as follows:
  - Scientifically important
  - Scientifically unimportant and negligible in size
  - Scientifically unimportant but may be sizeable
- Why? This is how you control aliasing.
- You want to choose a design that
  - Aliases important effects ONLY with unimportant/small effects
  - NEVER aliases important effects with other important effects or with large effects

Scientifically important effects

- In this category go
  - All main effects always
  - Often some 2-way interactions
  - Occasionally a 3-way interaction
- Important to remember: the more effects you put in this category, the less economical the design will be

Scientifically unimportant and negligible in size

- In this category go:
  - Higher-order interactions
  - Often all 3-way interactions go here
  - Some 2-way interactions
- Important to remember: the more effects you put in this category, the more economical the design will be
- These are effects you feel comfortable aliasing with the scientifically important effects

Scientifically unimportant but may be sizeable

- In this category go:
  - Any interactions that are not scientifically interesting but may be large
  - This is a "hedge your bets" category
- These are effects you do not feel comfortable aliasing with scientifically important events
- However, they can be aliased with each other
- Placing effects in this category reduces economy, but not as much as placing effects in the scientifically important category

When categorizing effects:

- Start with the premise that all main effects are important and all interactions are likely to be small.
- Then think carefully about which effects you want to move into the "scientifically important and sizeable" category.
  - You want to make sure all important effects are in this category.
  - You also want to make sure this category is as small as possible.
- Also keep the "unimportant but may be sizeable" category as small as possible.

Example: Clinic-based smoking cessation study funded by NCI

Tim Baker

Mike Fiore

University of Wisconsin

Center for Tobacco Research and Intervention

Overview of experimentation to examine individual intervention components

- For nicotine patch, gum, precessation counseling
  - Comparison of On vs. Off
  - Experiment will provide evidence of whether or not each has an effect on outcomes
  - If yes, consider including in intervention package

Overview of experimentation to examine individual intervention components

- For cessation counseling, cessation phone counseling
  - Comparison of Minimal vs. Intensive
  - Experiment will provide evidence of whether Intensive is doing more than Minimal
  - If Intensive NOT > Minimal, select Minimal
  - If Intensive > Minimal, consider selecting intensive

Overview of experimentation to examine individual intervention components

- For duration of cessation/maintenance NRT
  - Comparison of 8 weeks vs. 16 weeks
  - Experiment will 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 8 weeks

Independent variables in smoking cessation experiment

(pericessation=cessation)

1. Patch vs. no patch (PRE_PATCH)
2. Ad lib gum vs. no gum (PRE_ADLIB)
3. Precessation counseling vs. no precessation counseling (PRE_COUN)
4. Intensive pericessation in-person counseling vs. minimal (PERI_IN)
5. Intensive pericessation phone counseling vs. minimal (PERI_PH)
6. 16 weeks of NRT during pericessation/maintenance vs. 8 weeks (PERI_MD)

List of effects

- Main effects
- All 2-way interactions
- All 3-way interactions
- All 4-way interactions
- All 5-way interactions
- One 6-way interaction

Scientifically important effects

- All six main effects
- The following 2-way interactions:
  - PRE_PATCH by PRE_ADLIB
  - PRE_PATCH by PRE_COUN
  - PRE_ADLIB by PRE_COUN
  - PRE_COUN by PERI_IN
  - PRE_COUN by PERI_PH
- This 3-way interaction
  - PRE_PATCH by PRE_ADLIB by PRE_COUN

Unimportant but may be sizeable

- All remaining 2-way interactions

Unimportant and negligible

- All remaining effects
  - All 4-way, 5-way interactions
  - 6-way interaction

  All 3-way interactions except PRE_PATCH by PRE_ADLIB by PRE_COUN

SAS PROC FACTEX

```
PROC FACTEX;
TITLE MINIMUM NUMBER OF CONDITIONS PRESERVING THREE-WAY,
      PLUS DECLARING ALL TWO-WAYS NONNEG;
FACTORS PRE_PATCH PRE_ADLIB PRE_COUN PERI_IN PERI_PH PERI_MD;
SIZE DESIGN=MINIMUM;
MODEL ESTIMATE = (PRE_PATCH PRE_ADLIB PRE_COUN PERI_IN PERI_PH PERI_MD
     PRE_PATCH*PRE_ADLIB PRE_PATCH*PRE_COUN PRE_ADLIB*PRE_COUN
     PRE_COUN*PERI_IN PRE_COUN*PERI_PH PRE_PATCH*PRE_ADLIB*PRE_COUN)
NONNEGLIGIBLE = (PRE_PATCH|PRE_ADLIB|PRE_COUN|PERI_IN|PERI_PH|PERI_MD @2);
EXAMINE ALIASING(6) DESIGN;
```

You don't use any data!! Weird.

DESIGN=MINIMUM means we want the design with the smallest number of conditions that still meets the aliasing criteria

The result:

- A 2^{6-1} FF design (32 experimental conditions)
- This is a half-fraction (32 is half of 64)
- This means that effects are aliased in bundles of two
  - Or, each effect you are interested in will be aliased with ONE other effect
- A Resolution VI design
  - Each main effect aliased with a 5-way interaction (or higher)
  - Each 2-way interaction aliased with a 4-way (or higher)

The FACTEX Procedure

Design Points

Experiment Number	PRE_PATCH	PRE_ADLIB	PRE_COUN	PERI_IN	PERI_PH	PERI_MD
1	-1	-1	-1	-1	-1	-1
2	-1	-1	-1	-1	1	1
3	-1	-1	-1	1	-1	1
4	-1	-1	-1	1	1	-1
5	-1	-1	1	-1	-1	1
6	-1	-1	1	-1	1	-1
7	-1	-1	1	1	-1	-1
8	-1	-1	1	1	1	1
9	-1	1	-1	-1	-1	1
10	-1	1	-1	-1	1	-1
11	-1	1	-1	1	-1	-1
12	-1	1	-1	1	1	1
13	-1	1	1	-1	-1	-1
14	-1	1	1	-1	1	1
15	-1	1	1	1	-1	1
16	-1	1	1	1	1	-1
17	1	-1	-1	-1	-1	1
18	1	-1	-1	-1	1	-1
19	1	-1	-1	1	-1	-1
20	1	-1	-1	1	1	1
21	1	-1	1	-1	-1	-1
22	1	-1	1	-1	1	1
23	1	-1	1	1	-1	1
24	1	-1	1	1	1	-1
25	1	1	-1	-1	-1	-1
26	1	1	-1	-1	1	1
27	1	1	-1	1	-1	1
28	1	1	-1	1	1	-1
29	1	1	1	-1	-1	1
30	1	1	1	-1	1	-1
31	1	1	1	1	-1	-1
32	1	1	1	1	1	1

Experimental design used to examine components of smoking cessation intervention

- This is a factorial experiment with six factors.
- It is a 2^{6-1} fractional factorial.
- Resolution VI
- The design has 32 experimental conditions.
- Cool feature of this design: no "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

Aliasing structure in this design (note that = means “aliased with”)

PRE_PATCH = PRE_ADLIB*PRE_COUN*PERI_IN*PERI_PH*PERI_MD

PRE_ADLIB = PRE_PATCH*PRE_COUN*PERI_IN*PERI_PH*PERI_MD

PRE_COUN = PRE_PATCH*PRE_ADLIB*PERI_IN*PERI_PH*PERI_MD

PERI_IN = PRE_PATCH*PRE_ADLIB*PRE_COUN*PERI_PH*PERI_MD

PERI_PH = PRE_PATCH*PRE_ADLIB*PRE_COUN*PERI_IN*PERI_MD

PERI_MD = PRE_PATCH*PRE_ADLIB*PRE_COUN*PERI_IN*PERI_PH

Aliasing structure in this design (note that = means “aliased with”)

PRE_PATCH*PRE_ADLIB = PRE_COUN*PERI_IN*PERI_PH*PERI_MD

PRE_PATCH*PRE_COUN = PRE_ADLIB*PERI_IN*PERI_PH*PERI_MD

PRE_PATCH*PERI_IN = PRE_ADLIB*PRE_COUN*PERI_PH*PERI_MD

PRE_PATCH*PERI_PH = PRE_ADLIB*PRE_COUN*PERI_IN*PERI_MD

PRE_PATCH*PERI_MD = PRE_ADLIB*PRE_COUN*PERI_IN*PERI_PH

PRE_ADLIB*PRE_COUN = PRE_PATCH*PERI_IN*PERI_PH*PERI_MD

PRE_ADLIB*PERI_IN = PRE_PATCH*PRE_COUN*PERI_PH*PERI_MD

PRE_ADLIB*PERI_PH = PRE_PATCH*PRE_COUN*PERI_IN*PERI_MD

PRE_ADLIB*PERI_MD = PRE_PATCH*PRE_COUN*PERI_IN*PERI_PH

PRE_COUN*PERI_IN = PRE_PATCH*PRE_ADLIB*PERI_PH*PERI_MD

PRE_COUN*PERI_PH = PRE_PATCH*PRE_ADLIB*PERI_IN*PERI_MD

PRE_COUN*PERI_MD = PRE_PATCH*PRE_ADLIB*PERI_IN*PERI_PH

PERI_IN*PERI_PH = PRE_PATCH*PRE_ADLIB*PRE_COUN*PERI_MD

PERI_IN*PERI_MD = PRE_PATCH*PRE_ADLIB*PRE_COUN*PERI_PH

PERI_PH*PERI_MD = PRE_PATCH*PRE_ADLIB*PRE_COUN*PERI_IN

Aliasing structure in this design (note that = means “aliased with”)

PRE_PATCH*PRE_ADLIB*PRE_COUN = PERI_IN*PERI_PH*PERI_MD

PRE_PATCH*PRE_ADLIB*PERI_IN = PRE_COUN*PERI_PH*PERI_MD

PRE_PATCH*PRE_ADLIB*PERI_PH = PRE_COUN*PERI_IN*PERI_MD

PRE_PATCH*PRE_ADLIB*PERI_MD = PRE_COUN*PERI_IN*PERI_PH

PRE_PATCH*PRE_COUN*PERI_IN = PRE_ADLIB*PERI_PH*PERI_MD

PRE_PATCH*PRE_COUN*PERI_PH = PRE_ADLIB*PERI_IN*PERI_MD

PRE_PATCH*PRE_COUN*PERI_MD = PRE_ADLIB*PERI_IN*PERI_PH

PRE_PATCH*PERI_IN*PERI_PH = PRE_ADLIB*PRE_COUN*PERI_MD

PRE_PATCH*PERI_IN*PERI_MD = PRE_ADLIB*PRE_COUN*PERI_PH

PRE_PATCH*PERI_PH*PERI_MD = PRE_ADLIB*PRE_COUN*PERI_IN

Aliasing: The tradeoff

- In the chosen design, we don't really have an estimate of the main effect of PRE_PATCH
- Instead, we have an estimate of the combination of the main effect of PRE_PATCH and PRE_ADLIB*PRE_COUN*PERI_IN*PERI_PH*PERI_MD
- We have assumed that PRE_ADLIB*PRE_COUN*PERI_IN*PERI_PH*PERI_MD is negligible
- If this assumption is correct, then the combined estimate is essentially attributable to the main effect of PRE_PATCH.
- Similar logic applies to all the other effects of primary scientific interest.

Aliasing: The tradeoff

- More stringent assumptions would have allowed a more economical design, say a 16-cell Res IV
- There is a tradeoff between assumptions and economy
- In general, more assumptions=more economy=more risk of assumptions being incorrect

Aliasing: The tradeoff

- When you choose a FF you are trading aliasing, and accompanying assumptions, for economy
  - On the one hand: assuming effects are negligible buys economy; economy enables you to do more; doing more means moving science forward faster
  - On the other hand: assumptions can be wrong; if they are wrong, you may move science backward

Aliasing: The tradeoff

- When you choose an incomplete factorial (e.g. dismantling design) you ARE aliasing effects, and you may be making assumptions (perhaps implicitly) about interactions
- When you chose a complete factorial, you are assuming that all effects are sizeable and therefore resources must be devoted to estimating them
  - These are resources that you are not using on other research
  - Thus this assumption comes with a cost too

The cost of making incorrect assumptions: It works both ways

- What if you assume an effect is negligible and you are incorrect?
  - You may draw the wrong scientific conclusions
  - You may make the wrong decision about which components/levels to include in an intervention
- What if you assume an effect is sizeable and you are incorrect?
  - You have squandered resources that could have been used to move science forward
  - You may not be able to address some important scientific questions

Aliasing: The tradeoff

- The Resource Management Principle says:
  - FOCUS ON DECISION MAKING
  - TAKE CALCULATED RISKS
  - TAKE THE COURSE OF ACTION THAT IS EXPECTED TO MOVE SCIENCE FORWARD FASTEST GIVEN THE AVAILABLE RESOURCES

Different ways to approach selecting a FF design using software

- APPROACH 1: What we just discussed
  - Specify a particular aliasing structure by categorizing effects
  - You can specify that you want the design with the minimum number of experimental conditions
  - OR you can specify that you want a design with at least some specified resolution

Different ways to approach selecting a FF design using software

- APPROACH 2: Specify the DESIGN RESOLUTION you want, and request the design with smallest number of conditions

```
PROC FACTEX;
FACTORS PRE_PATCH PRE_ADLIB PRE_COUN PERI_IN PERI_PH PERI_MD;
SIZE DESIGN = MINIMUM;
MODEL RESOLUTION = 4;
RUN;
```

Different ways to approach selecting a FF design using software

- This asks for a Resolution IV design
- Main effects aliased with three-way interactions and up; two-way interactions aliased with each other
- If subject to those constraints ANY aliasing structure OK with you, then you are set
- But sometimes
  - You don't like the aliasing structure (EXAMINE command requests listing of aliasing)
  - Resulting design has more conditions than you can afford

```
PROC FACTEX;
FACTORS PRE_PATCH PRE_ADLIB PRE_COUN PERI_IN PERI_PH PERI_MD;
SIZE DESIGN = MINIMUM;
MODEL RESOLUTION = 4;
RUN;
```

Different ways to approach selecting a FF design using software

- APPROACH 3: Specify the maximum number of experimental conditions in the design

```
PROC FACTEX;
FACTORS PRE_PATCH PRE_ADLIB PRE_COUN PERI_IN PERI_PH PERI_MD;
SIZE DESIGN = 8;
MODEL RESOLUTION = MAXIMUM;
RUN;
```

Different ways to approach selecting a FF design using software

- This specifies that you want the highest resolution you can get with 8 experimental conditions
- You may or may not like what you can get for 8 experimental conditions
  - In this case, Res III

```
PROC FACTEX;
FACTORS PRE_PATCH PRE_ADLIB PRE_COUN PERI_IN PERI_PH PERI_MD;
SIZE DESIGN = 8;
MODEL RESOLUTION = MAXIMUM;
RUN;
```

–Do you see the Resource Management Principle in action here?

Summary of design alternatives

Design	**Most efficient when…**	**Enables estimation of…**	**Aliasing**
Randomized Controlled Trial (RCT)	Comparing a treatment package to a control group	A single bundle consisting of main effects and all interactions up to the *k*-way	All with each other
Individual experiments on each intervention component	Results of one experiment necessary before next can begin	Main effect bundled with numerous interactions	Main effect of A with all interactions involving A up to the *k*-way
Single factor experiment	Experimental condition expenses very high in relation to subject expenses	Main effect bundled with numerous interactions	Main effect of A with all interactions involving A up to the *k*-way
Complete factorial experiment	Subject expenses high in relation to experimental condition expenses	Main effects and all interactions	None
Fractional factorial experiment	Experimental condition expenses high in relation to subject expenses	Effects in bundles of 2 or more, depending on choice of design	Varies; experimenter can select best alternative aliasing structure