Global mHealth Research Training Institute

June 6-9, 2016

Center for Global Health Studies
Experimental Designs for Optimizing Interventions
Inbal (Billie) Nahum-Shani

How do you evaluate?
Global mHealth Research Training
May 2016
Key Definition

- Multi-Component Interventions
  - Component:
    - The content of the intervention (e.g., topics in prevention program)
    - The intervention modality (e.g., phone calls/emails)
    - Features to promote compliance or adherence (e.g., reminder emails)

- Example:
  - Optimizing a technology supported intervention for weight loss:
    - Telephone Caching
    - Report to Primary Care Provider
    - Text Messages
    - Meal Replacements
    - Buddy Training

Bonnie Spring, PI. DK097364
How do We Typically Develop Interventions?

1. Scientific Model
2. Intervention Components
3. Intervention Package
4. Confirm Effectiveness
How do We Typically Develop Interventions?

1. Theoretical Model
2. Intervention Components
3. Intervention Package
4. Confirm Effectiveness
Open Questions

- Efficacy of Individual components
  - Which components are effective?
  - Which level is more appropriate?
  - Which components work well together?

- Sequencing of components
  - Which component to offer first?
  - Which to offer subsequently?
  - How should I tailor components over time?
Open Questions

- Efficacy of Individual components
  – Which components are effective?
  – Which level is more appropriate?
  – Which components work well together?

- Sequencing of components
  – Which component to offer first?
  – Which to offer subsequently?
  – How should I tailor components over time?
Factorial Designs
Factorial Designs

- Factorials: More than 1 factor; levels of each factor crossed with levels of other factors.

  Should I include Text Messages?
  - Factor 1: Text (On/Off)

  Should I include Meal Replacement?
  - Factor 2: Meal (On/Off)
Factorial Designs

- Factorials: More than 1 factor; levels of each factor crossed with levels of other factors.

- Should I include *Text Messages*?
  - Factor 1: Text *(On/Off)*

- Should I include *Meal Replacement*?
  - Factor 2: Meal *(On/Off)*

<table>
<thead>
<tr>
<th>Experiment Condition</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Text</td>
</tr>
<tr>
<td>1 (N=100)</td>
<td>On</td>
</tr>
<tr>
<td>2 (N=100)</td>
<td>On</td>
</tr>
<tr>
<td>3 (N=100)</td>
<td>Off</td>
</tr>
<tr>
<td>4 (N=100)</td>
<td>Off</td>
</tr>
</tbody>
</table>
Factorial Designs

- Factorials: More than 1 factor; levels of each factor crossed with levels of other factors.

- Should I include *Text Messages*?
  - Factor 1: Text (On/Off)
  - Main effect: On (N=200) vs. Off (N=200)

- Should I include *Meal Replacement*?
  - Factor 2: Meal (On/Off)

<table>
<thead>
<tr>
<th>Experiment Condition</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Text</td>
</tr>
<tr>
<td>1 (N=100)</td>
<td>On</td>
</tr>
<tr>
<td>2 (N=100)</td>
<td>On</td>
</tr>
<tr>
<td>3 (N=100)</td>
<td>Off</td>
</tr>
<tr>
<td>4 (N=100)</td>
<td>Off</td>
</tr>
</tbody>
</table>
Factorial Designs

- Factorials: More than 1 factor; levels of each factor crossed with levels of other factors.

Q1. Should I include Text Messages?
- Factor 1: Text (On/Off)
- Main effect: On (N=200) vs. Off (N=200)

Q2. Should I include Meal Replacement?
- Factor 2: Meal (On/Off)
- Main effect: On (N=200) vs. Off (N=200)

Experimental conditions 2X2 factorial N=400

<table>
<thead>
<tr>
<th>Experiment Condition</th>
<th>Text</th>
<th>Meal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (N=100)</td>
<td>On</td>
<td>On</td>
</tr>
<tr>
<td>2 (N=100)</td>
<td>On</td>
<td>Off</td>
</tr>
<tr>
<td>3 (N=100)</td>
<td>Off</td>
<td>On</td>
</tr>
<tr>
<td>4 (N=100)</td>
<td>Off</td>
<td>Off</td>
</tr>
</tbody>
</table>
Factorial Designs

- Factorials: More than 1 factor; levels of each factor crossed with levels of other factors.

**Q1. Should I include *Text Messages*?**
- Factor 1: Text *(On/Off)*

**Q2. Should I include *Meal Replacement*?**
- Factor 2: Meal *(On/Off)*

**Q3. Should I include *Buddy Training*?**
- Factor 3: Buddy *(On/Off)*
Factorial Designs

- Factorials: More than 1 factor; levels of each factor crossed with levels of other factors.

**Q1.** Should I include *Text Messages*?
- Factor 1: Text (On/Off)

**Q2.** Should I include *Meal Replacement*?
- Factor 2: Meal (On/Off)

**Q3.** Should I include *Buddy Training*?
- Factor 3: Buddy (On/Off)

### Experimental conditions 2X2X2 factorial N=400

<table>
<thead>
<tr>
<th>Condition</th>
<th>Text</th>
<th>Meal</th>
<th>Buddy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (N=50)</td>
<td>On</td>
<td>On</td>
<td>On</td>
</tr>
<tr>
<td>2 (N=50)</td>
<td>On</td>
<td>On</td>
<td>Off</td>
</tr>
<tr>
<td>3 (N=50)</td>
<td>On</td>
<td>Off</td>
<td>On</td>
</tr>
<tr>
<td>4 (N=50)</td>
<td>On</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>5 (N=50)</td>
<td>Off</td>
<td>On</td>
<td>On</td>
</tr>
<tr>
<td>6 (N=50)</td>
<td>Off</td>
<td>On</td>
<td>Off</td>
</tr>
<tr>
<td>7 (N=50)</td>
<td>Off</td>
<td>Off</td>
<td>On</td>
</tr>
<tr>
<td>8 (N=50)</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
</tr>
</tbody>
</table>
Factorial Designs

- Factorials: More than 1 factor; levels of each factor crossed with levels of other factors.

Q1. Should I include *Text Messages*?
   - Factor 1: Text *(On/Off)*
   - Main effect: **On (N=200)** vs. **Off (N=200)**

Q2. Should I include *Meal Replacement*?
   - Factor 2: Meal *(On/Off)*

Q3. Should I include *Buddy Training*?
   - Factor 3: Buddy *(On/Off)*

### Experimental conditions 2X2X2 factorial N=400

<table>
<thead>
<tr>
<th>Condition</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Text</td>
</tr>
<tr>
<td>1 (N=50)</td>
<td>On</td>
</tr>
<tr>
<td>2 (N=50)</td>
<td>On</td>
</tr>
<tr>
<td>3 (N=50)</td>
<td>On</td>
</tr>
<tr>
<td>4 (N=50)</td>
<td>On</td>
</tr>
<tr>
<td>5 (N=50)</td>
<td>Off</td>
</tr>
<tr>
<td>6 (N=50)</td>
<td>Off</td>
</tr>
<tr>
<td>7 (N=50)</td>
<td>Off</td>
</tr>
<tr>
<td>8 (N=50)</td>
<td>Off</td>
</tr>
</tbody>
</table>
Factorial Designs

- Factorials: More than 1 factor; levels of each factor crossed with levels of other factors.

Q1. Should I include Text Messages?
  - Factor 1: Text (On/Off)

Q2. Should I include Meal Replacement?
  - Factor 2: Meal (On/Off)
  - Main effect: On (N=200) vs. Off (N=200)

Q3. Should I include Buddy Training?
  - Factor 3: Buddy (On/Off)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Text</td>
</tr>
<tr>
<td>1 (N=50)</td>
<td>On</td>
</tr>
<tr>
<td>2 (N=50)</td>
<td>On</td>
</tr>
<tr>
<td>3 (N=50)</td>
<td>On</td>
</tr>
<tr>
<td>4 (N=50)</td>
<td>On</td>
</tr>
<tr>
<td>5 (N=50)</td>
<td>Off</td>
</tr>
<tr>
<td>6 (N=50)</td>
<td>Off</td>
</tr>
<tr>
<td>7 (N=50)</td>
<td>Off</td>
</tr>
<tr>
<td>8 (N=50)</td>
<td>Off</td>
</tr>
</tbody>
</table>

Experimental conditions 2X2X2 factorial N=400
Factorial Designs

- Factorials: More than 1 factor; levels of each factor crossed with levels of other factors.

Q1. Should I include *Text Messages*?
   - Factor 1: Text *(On/Off)*

Q2. Should I include *Meal Replacement*?
   - Factor 2: Meal *(On/Off)*

Q3. Should I include *Buddy Training*?
   - Factor 3: Buddy *(On/Off)*
   - Main effect: **On (N=200)** vs. **Off (N=200)**

### Experimental conditions 2X2X2 factorial N=400

<table>
<thead>
<tr>
<th>Condition</th>
<th>Text</th>
<th>Meal</th>
<th>Buddy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (N=50)</td>
<td>On</td>
<td>On</td>
<td>On</td>
</tr>
<tr>
<td>2 (N=50)</td>
<td>On</td>
<td>On</td>
<td>Off</td>
</tr>
<tr>
<td>3 (N=50)</td>
<td>On</td>
<td>Off</td>
<td>On</td>
</tr>
<tr>
<td>4 (N=50)</td>
<td>On</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>5 (N=50)</td>
<td>Off</td>
<td>On</td>
<td>On</td>
</tr>
<tr>
<td>6 (N=50)</td>
<td>Off</td>
<td>On</td>
<td>Off</td>
</tr>
<tr>
<td>7 (N=50)</td>
<td>Off</td>
<td>Off</td>
<td>On</td>
</tr>
<tr>
<td>8 (N=50)</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
</tr>
</tbody>
</table>
Factorial Designs

- Power for comparing package vs. control?

<table>
<thead>
<tr>
<th>Experimental conditions 2X2 factorial N=400</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experiment Condition</td>
</tr>
<tr>
<td>Text</td>
</tr>
<tr>
<td>1 (N=100)</td>
</tr>
<tr>
<td>2 (N=100)</td>
</tr>
<tr>
<td>3 (N=100)</td>
</tr>
<tr>
<td>4 (N=100)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Experimental conditions 2X2X2 factorial N=400</th>
</tr>
</thead>
<tbody>
<tr>
<td>Condition</td>
</tr>
<tr>
<td>Text</td>
</tr>
<tr>
<td>1 (N=50)</td>
</tr>
<tr>
<td>2 (N=50)</td>
</tr>
<tr>
<td>3 (N=50)</td>
</tr>
<tr>
<td>4 (N=50)</td>
</tr>
<tr>
<td>5 (N=50)</td>
</tr>
<tr>
<td>6 (N=50)</td>
</tr>
<tr>
<td>7 (N=50)</td>
</tr>
<tr>
<td>8 (N=50)</td>
</tr>
</tbody>
</table>
SMART Designs
SMART Designs

- Adaptive Intervention:
  - Intervention design that uses ongoing/dynamic information about the individual to decide which component to offer, when and how.

- Hypothetical Example: (NIH/NIDDK R01DK108678; Spring & Nahum-Shani)

![Diagram showing the flow of intervention stages based on responses.]

\[ \text{Stage 1} = \{\text{Text}\}, \]
\[ \text{Then} \]
\[ \text{IF response} = \{\text{NO}\} \]
\[ \text{THEN stage 2} = \{\text{Add Buddy}\} \]
\[ \text{ELSE IF response} = \{\text{YES}\} \]
\[ \text{THEN stage 2} = \{\text{Step-Down}\} \]
SMART Designs

- Motivation in the context of technology-supported interventions:

  - **Cost:** Some mHealth components are costly; resources are often limited.

  - **Boredom:** Lack of interest in and difficulty concentrating on the task.

  - **Burden:** The “workload” required from participants and the impact on their well-being.
SMART Designs

- SMARTs can help us build empirically-based adaptive interventions:
  - Randomized Trials
  - Multiple stages of randomization
  - Each stage corresponds to a critical question concerning the sequencing and adaptation of intervention options over time
SMART Designs

- Hypothetical Example (NIH/NIDDK R01DK108678; Spring & Nahum-Shani)
  - Aim: Develop an adaptive technology-supported weight loss intervention
  - Open scientific questions
    - Q1. Which component to offer first: Text or Phone?
    - Q2. Which component to add for non-responders: Buddy or Phone?
Questions We Can Address with SMART

- First-stage intervention component:
  - Is it better to start with Phone Coaching or Text Messages?
  - (SG1+SG2+SG3) vs. (SG4+SG5+SG6)
  - Phone Coaching vs. Text Messages
    - Controlling for subsequent intervention component
Questions We Can Address with SMART

- Second-stage intervention component:
  - For non-responders: Is it better to add Phone or Buddy?
  - (SG2+SG5) vs. (SG3+SG6)
  - Phone Coaching vs. Buddy Training
Questions We Can Address with SMART

- Embedded adaptive interventions

Stage 1 = \{Text\},
Then
IF response = \{NO\}
THEN stage 2 = \{Add Buddy\}
ELSE IF response = \{YES\}
THEN stage 2 = \{Step-Down\}
Questions We Can Address with SMART

- Embedded adaptive interventions

Stage 1 = \{Text\},
Then

\textbf{IF} response = \{NO\}
\textbf{THEN} stage 2 = \{Add Phone\}

\textbf{ELSE IF} response = \{YES\}
\textbf{THEN} stage 2 = \{Step-Down\}
Questions We Can Address with SMART

- Embedded adaptive interventions

\[ \text{Stage 1} = \{\text{Phone}\}, \]
Then
\[ \text{IF } \text{response} = \{\text{NO}\} \]
\[ \text{THEN stage 2} = \{\text{Add Phone}\} \]
\[ \text{ELSE IF } \text{response} = \{\text{YES}\} \]
\[ \text{THEN stage 2} = \{\text{Step-Down}\} \]
Questions We Can Address with SMART

- Embedded adaptive interventions

Stage 1 = \{Phone\}

Then,

IF response = \{NO\} THEN stage 2 = \{Add Buddy\}

ELSE IF response = \{YES\} THEN stage 2 = \{Step-Down\}
Questions We Can Address with SMART

- Embedded adaptive interventions

Stage 1 = {Phone},

Then

IF response = {NO}

THEN stage 2 = {Add Phone}

ELSE IF response = {YES}

THEN stage 2 = {Step-Down}

Stage 1 = {Text},

Then

IF response = {NO}

THEN stage 2 = {Add Buddy}

ELSE IF response = {YES}

THEN stage 2 = {Step-Down}
Summary

Factorial Designs:

- Efficacy of Individual components
  - Which components are effective?
  - Which level is more appropriate?
  - Which components work well together?

SMART Designs:

- Sequencing and adaptation of components
  - Which component to offer first?
  - Which to offer subsequently?
  - How should I tailor components over time?
Experts + Resources

- Collaborators:
  - U of Michigan: Statistical Reinforcement Learning Lab
    - Susan Murphy: [http://dept.stat.lsa.umich.edu/~samurphy/](http://dept.stat.lsa.umich.edu/~samurphy/)
    - Danny Almirall: [http://www-personal.umich.edu/~dalmiral/](http://www-personal.umich.edu/~dalmiral/)
  - Penn State: Methodology Center
    - Linda Collins: [http://methodology.psu.edu/people/lcollins](http://methodology.psu.edu/people/lcollins)
    - John Dziak: [http://methodology.psu.edu/people/jdziak](http://methodology.psu.edu/people/jdziak)

- Resources:
  - SMART:
    - Projects using SMARTs: [https://methodology.psu.edu/ra/adap-inter](https://methodology.psu.edu/ra/adap-inter)
  - Factorials:
    - Q&A: [https://methodology.psu.edu/ra/most/fefaq](https://methodology.psu.edu/ra/most/fefaq)
Questions

Inbal (Billie) Nahum-Shani
University of Michigan
inbal@umich.edu