PERSILA Workshop:
Experimental Research

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Experimental Research

- In experimental research, the researcher manipulates at least one independent variable, controls other relevant variables, and observes the effect on one or more dependent variables.

- The independent variable (IV) (also known as treatment, causal, or experimental variable) is the treatment or characteristic believed to make a difference.

- E.g. of IVs:
  - method of instruction
  - type of reinforcement
  - arrangement of learning environment
  - type of learning materials
  - length of treatment
Experimental Research

- The dependent variable (DV) (also known as criterion, effect, or posttest variable) is the outcome of the study, the change or difference in groups that occurs as a result of the independent variable (IV).

- The DV can be measured by a test or some other quantitative measure (e.g., attendance, time on task).
Manipulation and Control

- Manipulation of an independent variable (IV). What does it mean? It means that the researcher chooses the treatments and determines which group will receive which treatment.

- Control refers to the researcher’s efforts to remove the influence of any variable (extraneous variables), other than the independent variable (IV), that may affect performance on dependent variable (DV).

- In other words, in an experimental design, the groups should differ only on the independent variable (IV). E.g., time of tutoring must be controlled (must be the same) in order to make a fair comparison of the effectiveness of tutoring of peer tutors and parent tutors.
Manipulation and Control

- Two types of extraneous variables need to be controlled:

1. Participant variables (e.g., gender, ability, anxiety)

2. Environmental variables (e.g., duration, learning materials, meeting place and time)
Threats to Experimental Validity

- “The validity of an experiment is a direct function of the degree to which extraneous variables are controlled” (Gay, Mills, & Airasian, 2014, p. 274).

- “Any uncontrolled extraneous variables affecting performance on the dependent variable are threats to the validity of an experiment” (Gay, Mills, & Airasian, 2014, p. 265).

- Two types of threats:
  1. Threats to internal validity
  2. Threats to external validity
Threats to Internal Validity

“Internal validity is the degree to which observed differences on the dependent variable are a direct result of manipulation of the independent variable, not some other variable” (Gay, Mills, & Airasian, 2014, p. 265).

Eight main threats to internal validity:

1. history
2. maturation
3. testing
4. instrumentation
5. statistical regression
6. differential selection of participants
7. mortality
8. selection-maturation interaction
# Threats to Internal Validity

**TABLE 10.1** Threats to internal validity

<table>
<thead>
<tr>
<th>Threat</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>History</td>
<td>Unexpected events occur between the pre- and posttest, affecting the dependent variable.</td>
</tr>
<tr>
<td>Maturation</td>
<td>Changes occur in the participants, from growing older, wiser, more experienced, etc., during the study.</td>
</tr>
<tr>
<td>Testing</td>
<td>Taking a pretest alters the result of the posttest.</td>
</tr>
<tr>
<td>Instrumentation</td>
<td>The measuring instrument is changed between pre- and posttesting, or a single measuring instrument is unreliable.</td>
</tr>
<tr>
<td>Statistical regression</td>
<td>Extremely high or extremely low scorers tend to regress to the mean on retesting.</td>
</tr>
<tr>
<td>Differential selection of participants</td>
<td>Participants in the experimental and control groups have different characteristics that affect the dependent variable differently.</td>
</tr>
<tr>
<td>Mortality</td>
<td>Different participants drop out of the study in different numbers, altering the composition of the treatment groups.</td>
</tr>
<tr>
<td>Selection-maturation interaction</td>
<td>The participants selected into treatment groups have different maturation rates. Selection interactions also occur with history and Instrumentation.</td>
</tr>
</tbody>
</table>

Source: Gay, Mills, & Airasian, 2009, p. 244.

Note: Also available in Gay, Mills, & Airasian, 2014, p. 267.
Threats to External Validity

“External validity is the degree to which study results are generalizable, or applicable, to groups and environments outside the experimental setting” (Gay, Mills, & Airasian, 2014, p. 265).

Seven main threats to external validity:
1. pretest-treatment interaction
2. selection-treatment interaction
3. multiple-treatment interference
4. specificity of variables
5. treatment diffusion
6. experimenter effects
7. reactive arrangements
# Threats to External Validity

## Table 10.2: Threats to external validity

<table>
<thead>
<tr>
<th>Threat</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest-treatment interaction</td>
<td>The pretest sensitizes participants to aspects of the treatment and thus influences posttest scores.</td>
</tr>
<tr>
<td>Selection-treatment interaction</td>
<td>The nonrandom or volunteer selection of participants limits the generalizability of the study.</td>
</tr>
<tr>
<td>Multiple-treatment interference</td>
<td>When participants receive more than one treatment, the effect of prior treatment can affect or interact with later treatment, limiting generalizability.</td>
</tr>
<tr>
<td>Specificity of variables</td>
<td>Poorly operationalized variables make it difficult to identify the setting and procedures to which the variables can be generalized.</td>
</tr>
<tr>
<td>Treatment diffusion</td>
<td>Treatment groups communicate and adopt pieces of each other’s treatment, altering the initial status of the treatment’s comparison.</td>
</tr>
<tr>
<td>Experimenter effects</td>
<td>Conscious or unconscious actions of the researchers affect participants’ performance and responses.</td>
</tr>
<tr>
<td>Reactive arrangements</td>
<td>The fact of being in a study affects participants so that they act in ways different from their normal behavior. The Hawthorne and John Henry effects are reactive responses to being in a study.</td>
</tr>
</tbody>
</table>


Note: Also available in Gay, Mills, & Airasian, 2014, p. 270.
Control of Extraneous Variables

• Five ways to control extraneous variables:

  1. Randomization

  2. Matching

  3. Comparing homogeneous groups or subgroups

  4. Participants as their own controls

  5. Analysis of covariance
Randomization

- A procedure used to create representative and equivalent groups.

- The best way to control most of the extraneous variables.

- Random selection: Participants are randomly selected from a population.

- Random assignment: Participants are randomly assigned to treatment groups.

- Use tool such as table of random numbers.

- If groups cannot be randomly formed, use other techniques (2 to 5 in the previous slide) to equate groups.
Matching

- Pair-wise matching is the most commonly used approach to matching.

- Involve random assignment of pairs: one participant to each group.

- Matching based on extraneous variable(s) to be controlled. E.g.: (a) gender (the matched pairs must be of the same gender) (b) pretest scores (the matched pairs must be of the similar scores) (c) ability scores (the matched pairs must be of the similar scores)
Comparing Homogeneous Groups or Subgroups

1. Comparing groups that are homogeneous with respect to the extraneous variable (e.g., IQ) to be controlled:
   (a) select participants with IQ between 85 and 115 (i.e., average IQ)
   (b) randomly assign half of the selected participants to the experimental group and the other half to the control group

2. Comparing subgroups that are homogeneous with respect to the extraneous variable (e.g., IQ) to be controlled:
   (a) divide participants into subgroups with high (i.e., 116 and above), average (i.e., 85 to 115), and low (i.e., 84 and below).
   (b) randomly assign half of the participants from each subgroups to the experimental group and the other half to the control group (stratified sampling)
Participants as Their Own Controls

- The research design involve a single group of participants who received multiple treatments, one at a time.

- Control for participant differences because the same participants received both treatments.
Analysis of Covariance

- A statistical method for equating randomly formed groups on one or more variables.
- It adjusts scores on a dependent variable for initial differences on other variable (such as IQ, pretest scores).
Design of Experiment

- Two major classes of experimental designs:
  1. Single-variable designs
  2. Factorial designs
Single-Variable Designs

- A single-variable design is any design that involves one manipulated independent variable (IV).

- Classified as:
  1. Pre-experimental designs
  2. True experimental designs
  3. Quasi-experimental designs
Single-Variable Designs

- Pre-experimental designs provide a very low degree of control of threats to (internal and external) validity and should be avoided.

- True experimental designs provide a very high degree of control of threats to validity and are the preferred designs.

- Quasi-experimental designs are in between.
Pre-Experimental Designs

- Do not do a very good job of controlling extraneous variables that threaten validity.

- Three types of designs:
  
  (a) One-Shot Case Study Design.

  (b) One-Group Pretest-Posttest Design.

  (c) Static-Group Comparison Design.
One-Shot Case Study Design

- Involves a single group that is exposed to a treatment (X) and then posttested (O).

- A diagram of this design is as follow:

\[
\begin{array}{c}
X \\
O
\end{array}
\]

- No pretest. Even if the research participants score high on the posttest, we cannot attribute their performance to the treatment as we do not know what they knew (their prior knowledge) before we administered the treatment.
One-Shot Case Study Design

- Suppose a researcher wants to determine if a new textbook increases student interest in philosophy. He uses the textbook (X) for a semester and then measures student interest (O) with an attitude scale. A diagram of this example is as follow:

  X
  New textbook

  O
  Attitude scale to measure interest

The researcher concluded that the new textbook had increased student interest in philosophy. What is your comment?
One-Group Pretest-Posttest Design

- Involves a single group that is pretested (O), exposed to a treatment (X) and then posttested (O).

- A diagram of this design is as follow:

  \[ O \quad X \quad O \]
One-Group Pretest-Posttest Design

- Suppose a professor teaches a statistics course. She is concerned that the high anxiety level of students interferes with their learning. The professor prepares a booklet to explain the course and tries to convince students that they will have no problems, and promises all the help they need to successfully complete the course. At the beginning of the semester, she administers an anxiety test and then give each student a copy of the booklet. Four weeks later, she administers the anxiety scale again. A diagram of this example is as follow:

  O   X   O
  Anxiety scale  The booklet  Anxiety scale

- The students’ scores indicate much less anxiety than at the beginning of the semester. What is your conclusion? What is your comment?
Static-Group Comparison Design

- Involves at least two nonrandomly formed groups, one group receives a new or unusual treatment (i.e., the experimental treatment) and another group receives a traditional treatment or no treatment at all (i.e., the control treatment). Both groups are posttested. A diagram of this design is as follow:

```
X_1  O
X_2  O
```
Static-Group Comparison Design

- Reconsider the example used in the One-Shot Case Study Design: The researcher finds two intact groups (two classes), assign the new textbook ($X_1$) to one of the classes but the regular textbook ($X_2$) to the other class, and then measure the degree of interest of all students in both classes at the end of the semester. A diagram of this example is as follow:

  $X_1$          O
  New textbook   Attitude scale to measure interest

  $X_2$          O
  Regular textbook   Attitude scale to measure interest

- The researcher concluded that the new textbook had increased student interest in philosophy in comparison with the regular textbook. What is your comment?
### FIGURE 10.1 - Sources of Invalidity for Pre-Experimental Designs

<table>
<thead>
<tr>
<th>Designs</th>
<th>Sources of Invalidity</th>
<th>Sources of Invalidity</th>
<th>External</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>History</td>
<td>Maturaion</td>
<td>Testing</td>
</tr>
<tr>
<td>One-Shot Case Study</td>
<td></td>
<td></td>
<td>(+)</td>
</tr>
<tr>
<td>X O</td>
<td></td>
<td></td>
<td>(+)</td>
</tr>
<tr>
<td>One-Group Pretest-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Posttest Design</td>
<td>O X O</td>
<td></td>
<td>(+)</td>
</tr>
<tr>
<td>Static-Group</td>
<td></td>
<td></td>
<td>(+)</td>
</tr>
<tr>
<td>Comparison</td>
<td>X1 O</td>
<td></td>
<td>(+)</td>
</tr>
<tr>
<td></td>
<td>X2 O</td>
<td></td>
<td>(+)</td>
</tr>
</tbody>
</table>

Each line of Xs and Os represents a group.

*Note: Symbols: X or X1 = unusual treatment; X2 = control treatment; O = test, pretest, or posttest; + = factor controlled for; (+) factor controlled for because not relevant; and − = factor not controlled for.*

Note: Also available in Gay, Mills, & Airasian, 2014, p. 277.
True Experimental Designs

- These designs control for almost all threats to internal and external validity.

- A common characteristic in true experimental designs: random assignment of participants to treatment groups. Other designs do not have this characteristic.

- All true experimental designs have a control group ($X_2$).
True Experimental Designs

- Three types of designs:
  
  (a) Pretest-Posttest Control Group Design.

  (b) Posttest-Only Control Group Design.

  (c) Solomon Four-Group Design.
Pretest-Posttest Control Group Design

- Involves at least two randomly formed groups.

- Both groups are administered a pretest. Each group receives a different treatment. Both groups are posttested. Scores are compared to determine the effectiveness of the treatment.

- A diagram of this design is as follow:

```
R O X₁ O
R O X₂ O
```
Suppose a researcher examines the effects of a series of sensitivity training workshops on teachers in a large state. The researcher (a) randomly selects a sample of 120 teachers from all the teachers in the state, (b) randomly assigns the teachers into two groups, (c) measures the morale of each group using a questionnaire, (d) expose one group to the sensitivity training workshops, but not the other group, (e) measures the morale of each group using a questionnaire.
Pretest-Posttest Control Group Design

A diagram of this example is as follow:

- **R** Random assignment of 60 teachers to exp. group
- **O** Teachers morale questionnaire
- **X₁** Sensitivity training workshops
- **O** Teachers morale questionnaire

- **R** Random assignment of 60 teachers to control group
- **O** Teachers morale questionnaire
- **X₂** Workshops that do not include sensitivity training
- **O** Teachers morale questionnaire
Posttest-Only Control Group Design

- Same as the Pretest-posttest Control Group Design except there is no pretest.

- Involves at least two randomly formed groups.

- Each group receives a different treatment. Both groups are posttested. Scores are compared to determine the effectiveness of the treatment.

- A diagram of this design is as follow:

```
R X1 O
R X2 O
```
Posttest-Only Control Group Design

- Reconsider the example used in the Pretest-posttest Control Group Design:

- Suppose a researcher examines the effects of a series of sensitivity training workshops on teachers in a large state. The researcher (a) randomly selects a sample of 120 teachers from all the teachers in the state, (b) randomly assigns the teachers into two groups, (c) expose one group to the sensitivity training workshops, but not the other group, (d) measures the morale of each group using a questionnaire.
Posttest-Only Control Group Design

- A diagram of this example is as follow:

  - **R**
    - Random assignment of 60 teachers to exp. group

  - **R**
    - Random assignment of 60 teachers to control group

  - **X_1**
    - Sensitivity training workshops

  - **X_2**
    - Workshops that do not include sensitivity training

  - **O**
    - Teachers morale questionnaire
    - Teachers morale questionnaire
Solomon Four-Group Design

- Combination of the Pretest-posttest Control Group Design and the Posttest-Only Control Group Design:
  (a) Involves random assignment of participants into four groups.
  (b) Two groups are pretested and two are not.
  (c) One of the pretested groups and one of the groups not pretested receive the experimental treatment.
  (d) All four groups are posttested.

- A diagram of this design is as follow:
Solomon Four-Group Design

R
Random assignment of 30 teachers to exp. group

O
Teachers morale questionnaire

X_1
Sensitivity training workshops

O
Teachers morale questionnaire

R
Random assignment of 30 teachers to control group

O
Teachers morale questionnaire

X_2
Workshops that do not include sensitivity training

O
Teachers morale questionnaire

R
Random assignment of 30 teachers to exp. group

O
Teachers morale questionnaire

X_1
Sensitivity training workshops

O
Teachers morale questionnaire

R
Random assignment of 30 teachers to control group

O
Teachers morale questionnaire

X_2
Workshops that do not include sensitivity training

O
Teachers morale questionnaire
Quasi-Experimental Designs

- These designs do not use random assignment of individual participants.

- Sometimes it is impossible to assign individual participants into groups randomly. E.g., research that involves pupils. The researcher usually has to agree to the existing classrooms intact. Specifically, the entire classrooms, not individual pupils, are assigned to treatments.

- Quasi-Experimental Designs provide adequate controls.

- Quasi-Experimental Designs are to be used only when it is not possible use a true experimental design.
Quasi-Experimental Designs

- Three types of designs:

  (a) Nonequivalent Control Group Design.

  (b) Time-Series Design.

  (c) Counterbalanced Design.
Nonequivalent Control Group Design

- Two (or more) groups are pretested, administered a treatment, and posttested.
- Involves random assignment of intact groups to treatments, not random assignment of individuals.
- A diagram of this design is as follow:

```
O   X_1   O
O   X_2   O
```
Nonequivalent Control Group Design

- E.g., suppose that a secondary school volunteered four intact classrooms for a study. Two of the classrooms may be randomly assigned to the experimental group ($X_1$) and the other two assigned to the control group ($X_2$).

- The researcher measures the mathematics achievement of the students from the four classroom using a test.

- Expose the experimental group ($X_1$) to constructivist teaching method the control group ($X_2$) to traditional teaching method.

- The researcher measures the mathematics achievement of the students using a test at the end of a semester.
Nonequivalent Control Group Design

A diagram of this example is as follow:

\[ O \quad X_1 \quad O \]
\[
\begin{align*}
O & \quad \text{Maths test} \\
& \quad \text{Constructivist teaching method}
\end{align*}
\[
X_1 & \quad O \\
& \quad \text{Maths test}
\]

\[ O \quad X_2 \quad O \]
\[
\begin{align*}
O & \quad \text{Maths test} \\
& \quad \text{Traditional teaching method}
\end{align*}
\[
X_2 & \quad O \\
& \quad \text{Maths test}
\]
Time-Series Design

- An elaboration of the One-Group Pretest-Posttest Design (O  X  O).

- One group is repeatedly pretested (O) until pretest scores are stable. Expose to a treatment (X). Repeated posttested (O).

- A diagram of this design is as follow:

```
O O O O X O O O O O
```
Reconsider the example used in the One-Group Pretest-Posttest Design (O  X  O).

Suppose the professor measures anxiety four times each before and after giving the students her booklet.

A diagram of this example is as follow:

```
O O O O   X   O O O O
Repeated anxiety scale The booklet Repeated anxiety scale
```
The following figure shows some of the possible patterns for the results of a study using a time-series design (Gay, Mills, & Airasian, 2009, p. 259). Note: Also available in Gay, Mills, & Airasian, 2014, p. 267.

Which patterns show a treatment effect?
Time-Series Design

- Pattern A: No treatment effect.
- Pattern B: Indicates a treatment effect.
- Pattern C: Indicates a treatment effect (more permanent).
- Pattern D: No treatment effect.
Counterbalanced Design

- In this design, all groups receive all treatments but in different order. The groups are posttested after each treatment.

- A diagram of this design is as follow:

\[
\begin{align*}
X_1 & \ O \ X_2 \ O \ X_3 \ O \\
X_3 & \ O \ X_1 \ O \ X_2 \ O \\
X_2 & \ O \ X_3 \ O \ X_1 \ O
\end{align*}
\]
Counterbalanced Design

- Involves at least two groups.

- What is the restriction? The number of groups must be equal to the number of treatments.

- The order of treatments receive by each group is randomly determined.

- Usually used with intact groups.

- The average performance of the groups on each treatment will be calculated and compared in order to determine the effectiveness of the treatments.
Consider the two sets of hypothetical data shown in the following figure.

<table>
<thead>
<tr>
<th>Study 1</th>
<th>Study 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Group 1</strong></td>
<td><strong>Group 2</strong></td>
</tr>
<tr>
<td>Method X = 12</td>
<td>Method Y = 8</td>
</tr>
<tr>
<td>Method Y = 8</td>
<td>Method X = 12</td>
</tr>
<tr>
<td><strong>Overall Means</strong>: Method X = 12; Method Y = 8</td>
<td>Method X = 12; Method Y = 8</td>
</tr>
</tbody>
</table>

Source: Figure 13.8 Results (means) from a study using a Counterbalanced Design, from Fraenkel & Wallen, 2010, p. 272.

What is your interpretation of results from Study 1? Study 2?
Counterbalanced Design

- Interpretation of results from Study 1: Method X is more effective for both groups regardless of sequence.

- Interpretation of results from Study 2:
  (a) When method X or Y was given first in the sequence, there was no difference in effectiveness (method X = 10, method Y = 10).
  (b) Group 1 performed worse on method Y (method Y = 6) when it was exposed to it after method X.
  (c) Group 2 performed better on method X (method X = 14) when it was exposed to it after method Y.

- Overall: Method X is more effective.
Note: Also available in Gay, Mills, & Airasian, 2014, p. 280.
Factorial Designs

- A factorial design refers to a design that has more than one *independent variable* (IV) (also known as a *factor*), at least one of which is manipulated.

- What is the purpose of a factorial design? To ascertain whether the effects of an independent variable (IV) are generalizable across all levels or specific to particular levels.

- E.g., one method of teaching science may be more effective for high aptitude (ability) students while another method may be more effective for low aptitude students.
Factorial Designs

- In this example, *method of teaching* is one factor and *student aptitude* is another factor. *Method of teaching* has two levels (e.g., constructivist teaching method and traditional teaching method). *Student aptitude* also has two levels, namely high aptitude and low aptitude.

- Thus, a \(2 \times 2\) (two by two) factorial design has two factors and each factor has two levels. It is the simplest factorial design (four-celled design).
Factorial Designs

- Other examples:

(a) a $2 \times 3$ factorial design has two factors. The first factor has two levels. The second factor has three levels (e.g., high, average, and low aptitude). This design has ___ cells.

(b) a $3 \times 3 \times 2$ factorial design has three factors—homework (compulsory homework, voluntary homework, no homework), aptitude (high, average, and low), and gender (male, female). This design has ___ cells.

Note: multiplying the factors produces the amount of cells (i.e., groups) in the factorial design.
Factorial Designs

- The following figure illustrates the simplest 2x2 factorial design.

<table>
<thead>
<tr>
<th>Types of Teaching Method</th>
<th>Constructivist</th>
<th>Traditional</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>Group 1</td>
<td>Group 2</td>
</tr>
<tr>
<td>Low</td>
<td>Group 3</td>
<td>Group 4</td>
</tr>
</tbody>
</table>

- This design has two factors. The first factor, *types of teaching method*, has two levels: constructivist and traditional. The second factor, *IQ*, also has two levels: high and low.
Factorial Designs

- Each group represents a combination of a level of the first factor and a level of the second factor:
  
  (a) Group 1 is composed of high-IQ students receiving constructivist teaching method.
  (b) Group 2 ___
  (c) Group 3 ___
  (d) Group 4 ___

- How to implement this design? High-IQ students would be randomly assigned to either Group 1 or Group 2. Low-IQ students would be randomly assigned to either Group 3 or Group 4.
Factorial Designs

- In a factorial design (e.g., a $2^2$ factorial design), at least one independent variable may be a manipulated variable. The other independent variable is a nonmanipulated variable. The nonmanipulated variable is referred to as a *control variable* (or *moderator variable*).

- Control variables refer to the physical or mental characteristics of the participants (e.g., gender, aptitude, IQ, anxiety, or years of experience). In the preceding example, IQ is a control variable.

- Conventionally (or traditionally), the manipulated variable is placed first when describing and symbolizing factorial designs. E.g., a study with two factors: types of homework (compulsory homework, voluntary homework, no homework) and aptitude (high, low), would be symbolized as $3^2$, not $2^3$. 
Factorial Designs

The following figure shows two possible outcomes for an experiment involving a 2 x 2 factorial design (Gay, Mills, & Airasian, 2009, p. 262). Note: Also available in Gay, Mills, & Airasian, 2014, p. 285.
Factorial Designs

- The number in each cell (or box) shows the average posttest score for that group. In the first example:

  (a) the high-IQ students under Method A had an average posttest score of 80.

  (b) the high-IQ students under Method B had an average posttest score of ___.

  (c) the low-IQ students under Method A had an average posttest score of ___.

  (d) the low-IQ students under Method B had an average posttest score of ___.
Factorial Designs

- The row and column numbers outside the cells show the average posttest score across cells. In the first example, the average posttest score for:

(a) high-IQ students was 60 (i.e., (80 + 40)/2 = 60).

(b) low-IQ students was ____.

(c) students under Method A was ____.

(d) students under Method B was ____.
Factorial Designs

- The cell averages indicate that Method A was more effective than Method B for high-IQ students (i.e., 80 vs 40) and also low-IQ students (i.e., 60 vs 20).

- What can we conclude? Method A was more effective, regardless of IQ level. There was no interaction between method and IQ:
  
  (a) the high-IQ students in each method performed better than the low-IQ students in each method.
  
  (b) the students in Method A performed better than the students in Method B.
  
  (c) the parallel lines show that there is no interaction between method and IQ.
Factorial Designs

- In the second example, the *crossed lines* or *intersection of the lines* show that there is interaction between method and IQ:

  (a) for high-IQ students, Method A was more effective (i.e., 80 vs 60).

  (b) for low-IQ students, Method B was more effective (i.e., 20 vs 40).

- What can we conclude? Method A was more effective for high-IQ students. Method B was more effective for low-IQ students.

- What is the advantage of using factorial design? It allowed the researcher to see the *interaction* between the independent variables (such as method and IQ in the second example).
Closure

- What is the most appropriate design?

- “… the design most appropriate for a given study is determined not only by the controls provided by the various designs but also by the nature of the study and the setting in which it is to be conducted.” (Gay, Mills, & Airasian, 2014, p. 277).
Thank You