**Principles of experiment design**

We cannot eliminate experimental error. But there are certain *principles of experiment design* that we can employ to minimize the **effect of experimental error on our conclusions about the effects of the factors on the response** (not necessarily on the value of the response). These are

1.  
2.  
3.  
4.  

**1. About control:**

- **Controlled variable**: a variable whose value is kept constant throughout the experiment
- Why control? We control a variable to keep its value from affecting our conclusions about the effects of the factors on the response.
- In general, controlling a variable does not prevent that variable from affecting the response. But by keeping the variable constant, it will affect the response in the same way for all experimental units.
- Controlling a variable reduces experimental error (variability in the response due to causes other than the treatments being different).
- **In the example,**
  - the students could have controlled wind speed and direction by performing the experiment indoors while the A/C was off
  - The students could explicitly state the plane-making protocol to ensure that the planes are as similar as possible
  - The students could explicitly state a plane-throwing protocol to ensure that the throws are as similar as possible
  - The students could have controlled the value of the variable thrower to keep the effect of the thrower from affecting conclusions about the effects of paper weight and model
  - Controlling the value of thrower does not prevent the value of thrower from affecting the hang time. If the stronger person always throws, all the values of the response will be higher.
2. **About replication:**

- **Replication:** is the application of each treatment to more than one experimental unit
- **Number of replicates** ($r$): means number of experimental units *per treatment*
- In the example, there were three replicates ($r=3$)
- **Why replicate:**

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3. **About randomization:**

- **What do we randomize?**
  - The assignment of experimental units to treatments (where applicable)
  - The order of applying the treatment or of running the experiment

- **Why randomize?**
  - To protect against a systematic influence of lurking variables (the lurking variables you weren’t aware of and thus couldn’t control for)
  - Randomization *does not* keep lv’s from affecting the response, but it hopefully prevents them from affecting our conclusions about the effects of the factors on the response.
  - Randomization *does not reduce* experimental error.

- **Two named types of randomization** (actually, there are many more, but we’ll cover these)

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    - From the EU’s, randomly select $r$ units to receive treatment 1.
    - From what’s left, randomly select $r$ units to receive treatment 2.
    - Continue until all treatments have been assigned $r$ experimental units.
  
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We’ll discuss this when we discuss blocking.
• **How do we randomize?---Use paper airplane example**
  Your calculator should allow you to generate $n$ random integers between $a$ and $b$, where $a$ and $b$ are also integers.

  **For example, on a TI83 do the following:**
  MATH, PRB, randInt(a,b,n)

  **On a TI89, do the following:**
  HOME, CATALOG, rand(a,b)

  - The students could not randomly assign the weight of the paper, because the paper came as a certain weight.
  - The students should take 6 pieces of notebook paper and randomly assign each piece of paper to a value of model. Then they should do the same for the 6 pieces of printer paper, and then for the 6 pieces of construction paper.
  - The students should randomly choose the order in which to make the airplanes. Or do this in a systematic manner.
  - After the creation of the paper airplanes, the students should arbitrarily assign a unique number between 1 and 18 to each plane, and then randomly select the first plane to throw, the second, etc. Or they should perform the throws in a systematic manner.

• **How to write about randomization**
  - You will have one, two, or three paragraphs like these in your project.
  - Things to avoid: misuse of the word “random”
  - If a random number generator wasn’t used, use the word “arbitrary” instead of the word random.
4. About blocking

Example:

Imagine that a farmer wants to perform a field experiment to determine the effect of Variety and Fertilizer on the yield of corn. He has two varieties of corn: normal and pest-resistant. He has two types of fertilizer: A and B. He will measure yield in units of bushels per acre. He has a large field, bordered by a stream, that he can use for this experiment. He wants four reps/trt, so he divides the field into 16 plots.

If this were a CRD

If this were a RCBD,

What is a block?  

- **Within a block:** homogeneity of conditions (other than treatments being applied)
- **Between blocks:** heterogeneity of conditions

- Multiple blocks will be used in the experiment:
  - Experiment run over several days: day = block
  - Experiment run at several locations: location = block
  - Planes are thrown by different people: thrower = block

- **Why block?**
  - There is inherent variability in experimental units that cannot be avoided, but units/runs can be grouped into homogeneous subgroups.
  - That is, there may be a lurking variable that cannot be controlled (kept constant), but we can “manage” it by blocking.
  - Cannot have same person make all airplanes because it takes too long. So have each group member make one from each treatment so that EVERY treatment gets the “Bob” effect and the “Sue” effect and the “Joe” effect.
  - Cannot have exact same conditions in all 16 plots of land.
  - Want results to apply to a “population of blocks”—like all people who might make these airplanes. All plots of land to which we might apply this fertilizer and this variety of seed.