Field and Lab Experimental Designs

The term experimental design is fairly generic and is best defined within the field of research in which it is used. Most of the designs illustrated here are statistical layouts used in agricultural, environmental, and other biological research.

Field Experiment Design

A field experiment applies the scientific method to experimentally examine an intervention in the real world (or as many experimentalists like to say, naturally occurring environments) rather than in the laboratory.

Completely Randomized Design

In a completely randomized design, objects or subjects are assigned to groups completely at random. One standard method for assigning subjects to treatment groups is to label each subject, then use a table of random numbers to select from the labelled subjects.

Randomized Block Design

In a block design, experimental subjects are first divided into homogeneous blocks before they are randomly assigned to a treatment group.

Factorial Designs

When only one factor is of interest, the resulting statistical analysis is simple. But typically ecologists need to worry about several factors at the same time.

Split-Unit Designs

When the treatment structure of an experiment involves two or more factors, the best treatment design is a factorial one. But there are a class of designs that have been called *split-plot designs* because they originated in agriculture but are better labelled split-unit designs because not all treatment structures involve physical plots.

Control of local variability - Blocking

Blocking is the arrangement of experimental units into groups that are similar to one another. Within blocks, it is possible to assess the effect of different levels of the factor of interest without having to worry about variations which are accounted for in the analysis.

Functions of replication

- To provide evidence of the repeatability of the results of the experiment.
- To improve precision of the experiment by reducing the standard error of estimates.
- To facilitate extension of the results to a wider range of conditions.
- To permit control of error variance.

Functions of randomization

- To insure applicability of results to the entire population of inference.
- To validate the use of probability theory as a tool of inference based on experiment.

- To reduce the chance of systematic bias affecting the accuracy of the estimates of the parameters of interest.

Completely Randomised Designs

A total of *n* experimental units (EU) are available for use in the experiment. These EU are as homogeneous as possible; that is no source of variation can be recognized among them under any grouping or arrangement.

a. CR Design

One of the requirements for using a CR design is that the experimental units EU must be homogeneous. In some experiments, there may be so many design factors involved that non homogeneity would not be anticipated, the researcher must consider experimental designs other than the CR. In most of the field experiments conducted by **Agronomists and Plant breeders**, non-homogeneity of EU is guaranteed due to soil variability.

b. RCB Design

Advantages

i. **Straightforward analysis:** Even with missing observations in some of the block, a meaningful analysis may be possible.

ii. **More accurate results:** When significant blocking can be achieved, differences due to EU are eliminated from treatment contrasts.

iii. **Flexibility:** Subject to conditions for a balanced design and available resources, there is no limitation on the number of treatments and/or blocks.

Disadvantages

i. The more EU per block, the greater the chance of them being heterogeneous.

ii. If block and treatment effects interact (that is, they are not additive). The RCB analysis is not appropriate.

Incomplete Block Designs

These designs are arranged in blocks that are smaller than a complete replication, in order to eliminate heterogeneity to a greater extent than is possible with randomized blocks. They may be ‘balanced or partially balanced’.

i. Balanced incomplete block designs

The balanced designs will be illustrated first by simple examples of the experimental plans. Every pair of treatments will be found to occur once, and only once, in the same block.

ii. Partially balanced designs

Partially balanced designs are less suitable than balanced designs as the statistical analysis is more complicated. When the variation among blocks (or rows and columns) is large, some pairs of treatments are more precisely compared than others, and several different standard errors may have to be computed for tests of significance.

Lab Experimental Designs

Segregated Designs

The simple segregated designs are rarely found in ecological field studies but may occur in laboratory experiments. Even if laboratory or greenhouse experiments are set up with the same initial conditions, subsequent chance events may have uneven effects if the treatments are isolated.

Replication

To improve the significance of an experimental result, replication, the repetition of an experiment on a large group of treatments, is required. Replication reduces variability in experimental results, increasing their significance and the confidence level with which a researcher can draw conclusions about an experimental factor.

Statistical terms

Variable: A variable is an attribute that describes a person, place, thing, or idea. The value of the variable can "vary" from one entity to another.
Example: in $x + 2 = 6$, x is the variable.
Dependent variable: The "output" value of a function is known as dependent variable.

In $y = x^2$

x is an Independent Variable

y is the Dependent Variable

Independent Variable: An "input" value of a function:

In $y = x^2$

x is an Independent Variable

y is the Dependent Variable

In an experimental design, the independent variable is the variable that is manipulated by the experimenter to determine its relationship to an observed phenomenon, called the dependent variable. More generally, the independent variable is the “cause,” while dependent variable is the “effect” of the independent variable.

Standars Deviation: The standard deviation is a numerical value used to indicate how widely individuals in a group vary. If individual observations vary greatly from the group mean, the standard deviation is big; and vice versa.

This is the formula for Standard Deviation:

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2}$$

Standard Error: The standard error is a measure of the variability of a statistic. It is an estimate of the standard deviation of a sampling distribution. The standard error depends on three factors:

- N: The number of observations in the population.
- n: The number of observations in the sample.
- The way that the random sample is chosen.

Normality Test: A normality test is a statistical process used to determine if a sample or any group of data fits a standard normal distribution. A normality test can be performed mathematically or graphically.

Data Transformation: In data analysis transformation is the replacement of a variable by a function of that variable: for example, replacing a variable x by the square root of x or the logarithm of x. In a stronger sense, a transformation is a replacement that changes the shape of a distribution or relationship.
Equation: $Y = a + bX$
Meaning: A unit increase in X is associated with an average of b units increase in Y.

ANOVA: The analysis of variance (ANOVA) is a test of hypothesis that is appropriate to compare means of a continuous variable in two or more independent comparison groups.

For example, in some clinical trials there are more than two comparison groups.

Types of Tests:

There are two main types: one-way and two-way. Two-way tests can be with or without replication.

1. One-way ANOVA between groups: used when you want to test two groups to see if there’s a difference between them.
2. Two way ANOVA without replication: used when you have one group and you’re double-testing that same group. For example, you’re testing one set of individuals before and after they take a medication to see if it works or not.
3. Two way ANOVA with replication: Two groups, and the members of those groups are doing more than one thing. For example, two groups of patients from different hospitals trying two different therapies.