**MA4605 Experimental Design ( Intro )**

In an experiment study, various treatments are applied to test subjects and the response data is gathered for analysis. A critical tool for carrying out the analysis is the Analysis of Variance (ANOVA). It enables a researcher to differentiate treatment results based on easily computed statistical quantities from the treatment outcome.

The statistical process is derived from estimates of the [population variances](http://www.r-tutor.com/node/42) via two separate approaches. The first approach is based on the variance of the [sample means](http://www.r-tutor.com/node/35), and the second one is based on the mean of the sample variances.

Under the ANOVA assumptions as stated below, the ratio of the two statistical estimates follows the [F distribution](http://www.r-tutor.com/node/141). Hence we can test the null hypothesis on the equality of various response data from different treatments via estimates of critical regions.

* The treatment responses are independent of each other.
* The response data follow the [normal distribution](http://www.r-tutor.com/node/58).
* The variances of the response data are identical.

## Experimentation

An experiment deliberately imposes a treatment on a group of objects or subjects in the interest of observing the response. This differs from an observational study, which involves collecting and analyzing data without changing existing conditions. Because the validity of a experiment is directly affected by its construction and execution, attention to experimental design is extremely important.

## Treatment

In experiments, a treatment is something that researchers administer to experimental units. For example, a corn field is divided into four, each part is 'treated' with a different fertiliser to see which produces the most corn; a teacher practices different teaching methods on different groups in her class to see which yields the best results; a doctor treats a patient with a skin condition with different creams to see which is most effective.

Treatments are administered to experimental units by 'level', where level implies amount or magnitude. For example, if the experimental units were given 5mg, 10mg, 15mg of a medication, those amounts would be three levels of the treatment.

## Factor

A factor of an experiment is a controlled independent variable; a variable whose levels are set by the experimenter.

A factor is a general type or category of treatments. Different treatments constitute different levels of a factor. For example, three different groups of runners are subjected to different training methods. The runners are the experimental units, the training methods, the treatments, where the three types of training methods constitute three levels of the factor 'type of training'.

## Types of Effects

An effect is a change in the response due to a change in a factor level. There are different types of effects. One objective of an experiment is to determine if there are significant differences in the responses across levels of a treatment (a fixed effect) or any interaction between the treatment levels. If this is always the case, the analysis is usually easily manageable, given that the anomalies in the data are minimal (outliers, missing data, homogeneous variances, unbalanced sample sizes, and so on).

A random effect exists when the levels that are chosen represent a random selection from a much larger population of equally usable levels. This is often thought of as a sample of interchangeable individuals or conditions. The chosen levels represent arbitrary realisations from a much larger set of other equally acceptable levels. Elements of the design structure (for example, the blocks) are usually treated as ***random effects***. Blocks are a sub-set of the larger set of blocks over which inference is to be made. It is helpful to assume that there is no interaction among elements of the design structure and elements of the treatment structure if blocks are considered a fixed effect. If blocks are treated as random effects, you can determine interaction among elements of treatment structure and design structure.

The number of potential human subjects that are available is often very large compared to the actual number of subjects that are used. Subjects who are chosen are likely to be just as reasonable to collect data from as potential subjects who were not chosen, and inferences for how individual subjects respond is usually not of primary importance, whereas a measure of the variation in responses is important to know.

One additional consideration that is essential in the evaluation of the treatment and design structure with two or more treatment/design factors is to differentiate whether the levels of the factors are either crossed or nested with each other. Two factors that are crossed with one another means that all levels of the first factor appear in combination with all levels of the second factor, which produces all possible combinations. For example, in an education program, male and female students receive the same educational tests, thus, gender is crossed with test.

One factor that is nested in a second factor implies a ***hierarchy***. This means that a given level of the nested factor appears in one level of the nesting factor. For example, in a study of educational programs, teachers are usually nested within schools because, usually, teachers teach only at one school.

#### 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. This may also be accomplished using a computer.

#### Randomized Block Design

If an experimenter is aware of specific differences among groups of subjects or objects within an experimental group, he or she may prefer a randomized block design to a completely randomized design. In a block design, experimental subjects are first divided into homogeneous blocks before they are randomly assigned to a treatment group. If, for instance, an experimenter had reason to believe that age might be a significant factor in the effect of a given medication, he might choose to first divide the experimental subjects into age groups, such as under 30 years old, 30-60 years old, and over 60 years old.

Then, within each age level, individuals would be assigned to treatment groups using a completely randomized design.

In a block design, both ***control*** and ***randomization*** are considered.

***Example***

A researcher is carrying out a study of the effectiveness of four different skin creams for the treatment of a certain skin disease. He has eighty subjects and plans to divide them into 4 treatment groups of twenty subjects each.

Using a randomized block design, the subjects are assessed and put in blocks of four according to how severe their skin condition is; the four most severe cases are the first block, the next four most severe cases are the second block, and so on to the twentieth block. The four members of each block are then randomly assigned, one to each of the four treatment groups. 