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Two-Way ANOVA

A Two-Way ANOVA is useful when we desire to compare the effect of multiple levels of two factors and we have multiple observations at each level.

One-Way ANOVA compares three or more levels of **one factor**. But some experiments involve **two factors** each with multiple levels in which case it is appropriate to use Two-Way ANOVA.

Let us discuss the concepts of factors, levels and observation through an example.

Factors and Levels - An Example

Let us suppose that the Human Resources Department of a company desires to know if occupational stress varies according to age and gender.

A Two-Way ANOVA is a design with two factors.

The variable of interest is therefore **occupational stress** as measured by a scale.

There are two **factors** being studied - age and gender.

Further suppose that the employees have been classified into three groups or **levels**:

- age less than 40,

- 40 to 55
- above 55

In addition employees have been labeled into gender classification **(levels)**:

- male
- female

In this design [1], factor age has three levels and gender two. In all, there are 3 x 2 = 6 groups or cells. With this layout, we obtain scores on occupational stress from employee(s) belonging to the six cells.

Testing for Interaction

There are two versions of the Two-Way ANOVA.

The basic version has one observation in each cell - one occupational stress score from one employee in each of the six cells.

The second version has more than one observation per cell but the number of observations in each cell must be equal. The advantage of the second version is it also helps us to test if there is any interaction between the two factors.

For instance, in the example above, we may be interested to know if there is any interaction between age and gender.

This helps us to know if age and gender are independent of each other - they are independent if the effect of age on stress remains the same irrespective of whether we take gender into consideration.

Hypothesis Testing

In the basic version there are two null hypotheses [2] to be tested [3].

- H_{01}: All the age groups have equal stress on the average
- H_{02}: Both the gender groups have equal stress on the average.

In the second version, a third hypothesis is also tested:

- H_{03}: The two factors are independent or that interaction effect is not present.

The computational aspect involves computing F-statistic for each hypothesis.

Assumption

The assumptions in both versions remain the same - normality, independence and equality of variance [4].

Advantages

- An important advantage of this design is it is more efficient than its one-way counterpart. There are two assignable sources of variation - age and gender in our example - and this helps to reduce error variation thereby making this design more efficient.
- Unlike One-Way ANOVA, it enables us to test the effect of two factors at the same time.
- One can also test for independence of the factors provided there are more than one observation in each cell. The only restriction is that the number of observations in each cell has to be equal (there is no such restriction in case of one-way ANOVA).

Replication, Randomization and Local Control

An Two-Way ANOVA satisfies all three principles of design of experiments [5] namely replication, randomization and local control [6].

Principles of replication and randomization need to be satisfied in a manner similar to One-Way ANOVA.

The principle of local control means to make the observations as homogeneous as possible so that error due to one or more assignable causes may be removed from the experimental error [7].

In our example if we divided the employees only according to their age, then we would have ignored the effect of gender on stress which would then accumulate with the experimental error.

But we divided them not only according to age but also according to gender which would help in reducing the error - this is application of the principle of local control for reducing error variation and making the design more efficient.

Links
[1] https://explorable.com/factorial-design
[2] https://explorable.com/null-hypothesis
[3] https://explorable.com/hypothesis-testing
[4] https://explorable.com/statistical-variance
[5] https://explorable.com/design-of-experiment
[6] https://explorable.com/controlled-variables
[7] https://explorable.com/experimental-error