Series of notes on Randomization – Part I

What is randomization?

Randomization ia a process by which each sample drawn from a population has the same chance of being assigned to either intervention or control. It is perhaps the most important statistical tool for reducing unwanted effects. A successful randomization ensures that the treatment assignment outcome cannot be predicted.

Why randomize?

When coming to the end of an experiment, a difference in results occurs between two treatment assignments, the possible explanations for the difference would include:

a. There is indeed a real difference between the two treatments
b. The outcome difference is solely due to chance
c. There is a systematic difference (or bias) between the treatment groups due to factors other than the nature of the treatments

In fact, the main advantage of randomization is in its ability to reduce unknown or unmeasured sources of possible bias or systematic error. Such bias can be caused during both within-run and between-run. Randomization does help to validate of the assumptions needed to apply certain statistical techniques.

Consider an experiment to assess whether two metal digestion methods (A and B), using same analytical instrument ICP-AES on a single homogeneous reference material, are providing the same analysis result. We shall use a simple Student's t-test for significant between-digestion effects.

If we were to analyze the concentration of this reference material in each of the 12 digestion treatments (six digestions each for methods A and B) in a single analytical run, we can have the following convenient systematic ordering for analysis on the extracts:

A A A A A A B B B B B B

However such ordering runs a risk of having biased results because we know that analytical instruments tend to drift steadily over time. Clearly, if the instrument drifts steadily by 10% (not unusual in trace analysis), the results near the beginning can end up to 10% higher (or lower) than results near the end.

In other words, comparisons of the digestion methods will be biased by the instrument drift and will not provide a true measure of the effect of the digestion treatment.

Hence, placing the digested extracts systematically for analysis as above would risk creating an entirely spurious difference between the mean results for treatment A and the mean result for treatment B.

What would be the situation if we were to arrange the order of analysis in the following systematic alternation manner?

A B A B A B A B A B A B

This order might work out well if the instrument drift were known to be smooth and linear. This is because we can expect the systematic alternation to reverse the results at the midpoint, leading to the same change in mean value for both treatments.

In practice, this may not be the case because instrument drift and other uncontrollable effects, in particular are rarely so obliging; uncontrolled effects need not be monotonic and may change more or less randomly, making almost any systematic ordering unsafe.

Therefore, the best solution is to randomize the run order.

Such arrangement will have two effects. Firstly, if the run order is randomized, the A and B samples all have the same chance of encountering every level of drift, so in the long term, we expect the difference due to drift will disappear.

Secondly, the effect on the standard deviation for each treatment cannot be neglected. Because the observations are spread over the full range of the drift, we expect an increase of the standard deviation for each treatment. We have a better chance to compare the means of the two treatment correctly with the full standard deviation including drift effects as well, instead of only considering a smaller standard deviation that fails to take account of the entire effect of the drift.

Hence, randomizing the run order during experimentation provides a more realistic estimate of the standard deviation for the experiment.

We shall discuss some common methods in generating random numbers for random sampling from a population in the next few articles.