Semester II

Unit II

Paper VII

Topic - Experimentation under controlled condition

By

Rani Singh

Asst professor

The GSCW(B.Ed.)

Experimentation Under Controlled Condition

A controlled experiment is a scientific test that is directly manipulated by a scientist, in order to test a single variable at a time. The variable being tested is the *independent variable*, and is adjusted to see the effects on the system being studied. The *controlled variables* are held constant to minimize or stabilize their effects on the subject. In biology, a controlled experiment often includes restricting the environment of the organism being studied. This is necessary to minimize the random effects of the environment and the many variables that exist in the wild.

In a controlled experiment, the study population is often divided into two groups. One group receives a change in a certain variable, while the other group receives a standard environment and conditions. This group is referred to as the *control group*, and allows for comparison with the other group, known as the *experimental group*. Many types of controls exist in various experiments, which are designed to ensure that the experiment worked, and to have a basis for comparison. In science, results are only accepted if it can be shown that they are *statistically significant*. Statisticians can use the difference between the control group and experimental group and the expected difference to determine if the experiment supports the *hypothesis*, or if the data was simply created by chance.

Anyone who has used a cellular phone knows that certain situations require a bit of research: If you suddenly find yourself in an area with poor phone reception, you might move a bit to the left or right, walk a few steps forward or back, or even hold the phone over your head to get a better signal. While the actions of a cell phone user might seem obvious, the person seeking cell phone reception is actually performing a scientific experiment: consciously manipulating one component (the location of the cell phone) and observing the effect of that action on another component (the phone's reception). Scientific experiments are obviously a bit more complicated, and generally involve more rigorous use of controls, but they draw on the same type of reasoning that we use in many everyday situations. In fact, the earliest documented scientific experiments were devised to answer a very common everyday question: how vision works.

Experimentation as a scientific research method

Experimentation is one scientific research method, perhaps the most recognizable, in a spectrum of methods that also includes description, comparison, and modelling. While all of these methods share in common a scientific approach, experimentation is unique in that it involves the conscious manipulation of certain aspects of a real system and the observation of the effects of that manipulation. You could solve a cell phone reception problem by walking around a neighbourhood until you see a cell phone tower, observing other cell phone users to see where those people who get the best reception are standing, or looking on the web for a map of cell phone signal coverage. All of these methods could also provide answers, but by moving around and testing reception yourself, you are experimenting.

Variables: Independent and dependent

In the experimental method, a condition or a parameter, generally referred to as a variable, is consciously manipulated (often referred to as a treatment) and the outcome or effect of that manipulation is observed on other variables. Variables are given different names depending on whether they are the ones manipulated or the ones observed:

- **Independent variable** refers to a condition within an experiment that is manipulated by the scientist.
- **Dependent variable** refers to an event or outcome of an experiment that might be affected by the manipulation of the independent variable.

Scientific experimentation helps to determine the nature of the relationship between independent and dependent variables. While it is often difficult, or sometimes impossible, to manipulate a single variable in an experiment, scientists often work to minimize the number of variables being manipulated. For example, as we move from one location to another to get better cell reception, we likely change the orientation of our body, perhaps from south-facing to east-facing, or we hold the cell phone at a different angle. Which variable affected reception: location, orientation, or angle of the phone? It is critical that scientists understand which aspects of their experiment they are manipulating so that they can accurately determine the impacts of that manipulation. In order to constrain the possible outcomes of an experimental procedure, most scientific experiments use a system of controls.

Controls:

Negative, positive, and placebos

In a controlled study, a scientist essentially runs two (or more) parallel and simultaneous experiments: a treatment group, in which the effect of an experimental manipulation is observed on a dependent variable, and a control group, which uses all of the same conditions as the first with the exception of the actual treatment.
Controls can fall into one of two groups: negative controls and positive controls.
In a negative control, the control group is exposed to all of the experimental conditions except for the actual treatment. The need to match all experimental conditions exactly is so great that, for example, in a trial for a new drug, the negative control group will be given a pill or liquid that looks exactly like the drug, except that it will not contain the drug itself, a control often referred to as a *placebo*. Negative controls allow scientists to measure the natural variability of the dependent variable(s), provide a means of measuring error in the experiment, and also provide a baseline to measure against the experimental treatment.
Some experimental designs also make use of positive controls. A positive control is run as a parallel experiment and generally involves the use of an alternative treatment that the researcher knows will have an effect on the dependent variable. For example, when testing the effectiveness of a new drug for pain relief, a scientist might administer treatment placebo to one group of patients as a negative control, and a known treatment like aspirin to a separate group of individuals as a

positive control since the pain-relieving aspects of aspirin are well documented. In both cases, the controls allow scientists to quantify background variability and reject alternative hypotheses that might otherwise explain the effect of the treatment on the dependent variable.

Experimentation in practice: The case of Louis Pasteur

Well-controlled experiments generally provide strong evidence of causality, demonstrating whether the manipulation of one variable causes a response in another variable. For example, as early as the 6th century BCE, Anaximander, a Greek philosopher, speculated that life could be formed from a mixture of sea water, mud, and sunlight. The idea probably stemmed from the observation of worms, mosquitoes, and other insects "magically" appearing in mudflats and other shallow areas. While the suggestion was challenged on a number of occasions, the idea that living microorganisms could be spontaneously generated from air persisted until the middle of the 18th century.

In the 1750s, John Needham, a Scottish clergyman and naturalist, claimed to have proved that spontaneous generation does occur when he showed that microorganisms flourished in certain foods such as soup broth, even after they had been briefly boiled and covered. Several years later, the Italian abbot and biologist Lazzaro Spallanzani, boiled soup broth for over an hour and then placed bowls of this soup in different conditions, sealing some and leaving others exposed to air. Spallanzani found that microorganisms grew in the soup exposed to air but were absent from the sealed soup. He therefore challenged Needham's conclusions and hypothesized that microorganisms suspended in air settled onto the exposed soup but not the sealed soup, and rejected the idea of spontaneous generation.

Needham countered, arguing that the growth of bacteria in the soup was not due to microbes settling onto the soup from the air, but rather because spontaneous generation required contact with an intangible "life force" in the air itself. He proposed that Spallanzani's extensive boiling destroyed the "life force" present in the soup, preventing spontaneous generation in the sealed bowls but allowing air to replenish the life force in the open bowls. For several decades, scientists continued to debate the spontaneous generation theory of life, with support for the theory coming from several notable scientists including Félix Pouchet and Henry Bastion. Pouchet, Director of the Rouen Museum of Natural History in France, and Bastion, a well-known British bacteriologist, argued that living organisms could spontaneously arise from chemical processes such as fermentation and putrefaction. The debate became so heated that in 1860, the French Academy of Sciences established the Alhumbert prize of 2,500 francs to the first person who could conclusively resolve the conflict. In 1864, Louis Pasteur achieved that result with a series of well-controlled experiments and in doing so claimed the Alhumbert prize.

After reviewing several articles of spontaneous generation of life by different scientists Pasteur prepared for his experiments by studying the work of others that came before him

. In these, he repeated Spallanzani's method of boiling soup broth, but he divided the broth into portions and exposed these portions to different controlled conditions. Some broth was placed in flasks that had straight necks that were open to the air, some broth was placed in sealed flasks that were not open to the air, and some broth was placed into a specially designed set of swan-necked flasks, in which the broth would be open to the air but the air would have to travel a curved path before reaching the broth, thus preventing anything that might be present in the air from simply settling onto the soup. Pasteur then observed the response of the dependent variable (the growth of microorganisms) in response to the independent variable (the design of the flask). Pasteur's experiments contained both positive controls (samples in the straight-necked flasks that he knew would become contaminated with microorganisms) and negative controls (samples in the sealed flasks that he knew would remain sterile). If spontaneous generation did indeed occur upon exposure to air, Pasteur hypothesized, microorganisms would be found in both the swan-neck flasks and the straight-necked flasks, but not in the sealed flasks. Instead, Pasteur found that microorganisms appeared in the straight-necked flasks, but not in the sealed flasks or the swan-necked flasks.

By using controls and replicating his experiment (he used more than one of each type of flask), Pasteur was able to answer many of the questions that still surrounded the issue of spontaneous generation. Pasteur said of his experimental design, "I affirm with the most perfect sincerity that I have never had a single experiment, arranged as I have just explained, which gave me a doubtful result" (Porter, 1961). Pasteur's work helped refute the theory of spontaneous generation – his experiments showed that air alone was not the cause of bacterial growth in the flask, and his research supported the hypothesis that live microorganisms suspended in air could settle onto the broth in open-necked flasks via gravity.

Experimentation across disciplines

Experiments are used across all scientific disciplines to investigate a multitude of questions. In some cases, scientific experiments are used for exploratory purposes in which the scientist does not know what the dependent variable is. In this type of experiment, the scientist will manipulate an independent variable and observe what the effect of the manipulation is in order to identify a dependent variable (or variables). Exploratory experiments are sometimes used in nutritional biology when scientists probe the function and purpose of dietary nutrients. In one approach, a scientist will expose one group of animals to a normal diet, and a second group to a similar diet except that it is lacking a specific vitamin or nutrient. The researcher will then observe the two groups to see what specific physiological changes or medical problems arise in the group lacking the nutrient being studied.

Scientific experiments are also commonly used to quantify the magnitude of a relationship between two or more variables. For example, in the fields of pharmacology and toxicology, scientific experiments are used to determine the dose-response relationship of a new drug or chemical. In these approaches, researchers perform a series of experiments in which a population of organisms, such as laboratory mice, is separated into groups and each group is exposed to a different amount of the drug or chemical of interest. The analysis of the data that result from these experiments involves comparing the degree of the organism's response to the dose of the substance administered. In this context, experiments can provide additional evidence to complement other research methods.

Sometimes experimental approaches and other research methods are not clearly distinct, or scientists may even use multiple research approaches in combination. For example, at 1:52 a.m. EDT on July 4, 2005, scientists with the National Aeronautics and Space Administration (NASA) conducted a study in which a 370 kg spacecraft named Deep Impact was purposely slammed into passing comet Tempel 1. A nearby spacecraft observed the impact and radioed data back to Earth. The research was partially descriptive in that it documented the chemical composition of the comet, but it was also partly experimental in that the effect of slamming the Deep Impact probe into the comet on the volatilization of previously undetected compounds, such as water, was assessed (A'Hearn et al., 2005). It is particularly common that experimentation and description overlap:

Limitations of experimental methods

While scientific experiments provide invaluable data regarding causal relationships, they do have limitations. One criticism of experiments is that they do not necessarily represent real-world situations. In order to clearly identify the relationship between an independent variable and a dependent variable, experiments are designed so that many other contributing variables are fixed or eliminated.

While this is an important aspect of making an experiment manageable and informative, it is often not representative of the real world, in which many variables may change at once, including the foods you eat. Still, experimental research is an excellent way of determining relationships between variables that can be later validated in real world settings through descriptive or comparative studies.

Design is critical to the success or failure of an experiment. Slight variations in the experimental set-up could strongly affect the outcome being measured.

Scientists also have an obligation to adhere to ethical limits in designing and conducting experiments of chemicals and drugs on human beings.

. As an alternative, comparative studies were initiated in humans, and experimental studies focused on animal subjects.