Experimental Research Designs

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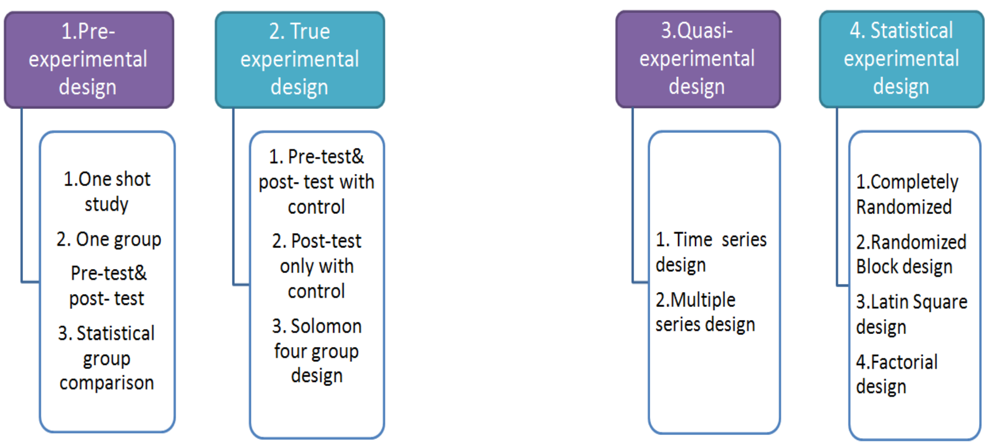


2.3.1 Experimental Research Designs.

What do you mean by experiment?

Experiments are studies involving intervention by the researcher beyond that required for measurement. The usual intervention is to manipulate some variable in a setting and observe how it affects the subjects being studied (e.g., people or physical entities). The researcher manipulates the independent or explanatory variable and then observes whether the hypothesized dependent variable is affected by the intervention.

Experimental research, often considered to be the "gold standard" in research designs, is one of the most rigorous of all research designs. In this design, one or more independent variables are manipulated by the researcher (as treatments), subjects are randomly assigned to different treatment levels (random assignment), and the results of the treatments on outcomes (dependent variables) are observed. The unique strength of experimental research is its internal validity (causality) due to its ability to link cause and effect through treatment manipulation, while controlling for the spurious effect of extraneous variable.

Experimental research is best suited for explanatory research (rather than for descriptive or exploratory research), where the goal of the study is to examine cause-effect relationships. It also works well for research that involves a relatively limited and well-defined set of independent variables that can either be manipulated or controlled. Experimental research can be conducted in laboratory or field settings. Laboratory experiments , conducted in laboratory (artificial) settings, tend to be high in internal validity, but this comes at the cost of low external validity (generalizability), because the artificial (laboratory) setting in which the study is conducted may not reflect the real world. Field experiments , conducted in field settings such as in a real organization, and high in both internal and external validity. But such experiments are relatively rare, because of the difficulties associated with manipulating treatments and controlling for extraneous effects in a field setting.

Experimentation Research is also known as causal research. **Descriptive research, will suggest the relationship if any between the variable, but it will not establish cause and effect relationship between the variable.**

Example: The data collected may show that the no. of people who own a car and their income has risen over a period of time. Despite this, we cannot say "No. of car increase is due to rise in the income". May be, improved road conditions or increase in number of banks offering car loans have caused in increase in the ownership of cars.

To find the causal relationship between the variables, the researcher has to do an experiment.

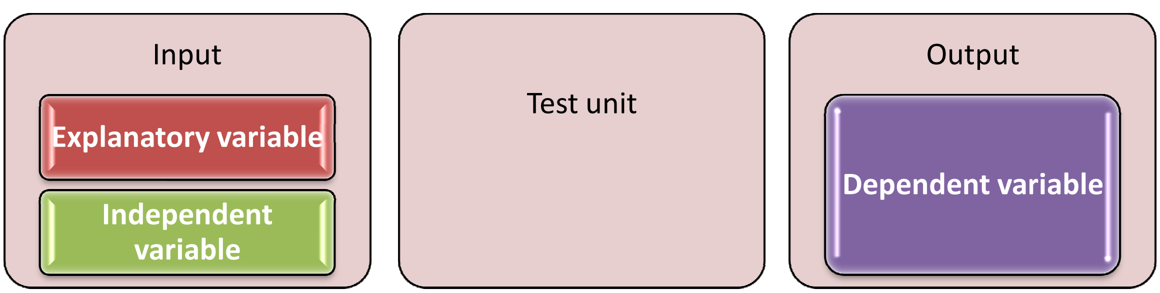
Example:

Which print advertisement is more effective? Is it front page, middle page or the last page?

Among several promotional measure, such as Advertisement, personal selling, "which one is more effective"?

Can we increase sales of our product by obtaining additional shelf space?

What is experimentation? It is research process in which one or more variables are manipulated, which shows the cause and effect relationship. Experimentation is done to find out the effect of one factor on the other.



2.3.2 The different elements of experiment are explained below.		
	Test Units	These are units, on which the experiment is carried out. It is done, with one or more independent variables controlled by a person to find out its effect, on a dependent variable.
1	**Explanatory Variable**	These are the variables whose effects, researcher wishes to examine. For example, explanatory variables may be **advertising, pricing, packaging etc.**
2	**Dependent Variable**	This is a variable which is under study. **For example, sales, consumer attitude, brand loyalty etc.**
	Example:	Suppose a particular colour TV manufacturer reduces the price of the TV by 20%. Assume that his reduction is passed on to the consumer and expect the sales will go up by 15% in next 1 year. These types of experiments are done by leading TV companies during festival season. The causal research finds out, **whether the price reduction causes an increase in sales.**
3	**Extraneous Variables**	These are also called as **blocking variables** or **undesirable variables** Extraneous variables affects, the result of the experiments.

2.3.3 Types of Extraneous Variables

The following are the various types:

1. History

2. Maturation

3. Testing

4. Instrument variation

5. Selection bias

6. Experimental mortality

1. History: History refers to those events, external to the experiment, but occurs at the same time, as the experiment is being conducted. This may affect the result. *Example: Let us say that, a manufacture makes a 20% cut in the price of a product and monitors sales in the coming weeks.* ***The purpose of the research is to find the impact of price on sales****. Mean while if the production of the product declines due to shortage of raw materials, then the sales will not increase. Therefore, we cannot conclude that the price cut, did not have any influence on sales because the history of external events have occurred during the period and we cannot control the event. The event can only be identified.*

2. Maturation: Maturation is similar to history. Maturation specifically refers to changes occurring within the test units and not due to the effect of experiment. ***Maturation takes place due to passage of time. Maturation refers to the effect of people growing older. People may be using a product. They may discontinue the product usage or switch over to alternate product.***

Example:

(a) Pepsi is consumed when you are young. Due to passage of time the consumer becoming older, might prefer to consume Diet pepsi or even avoid it.

(b) Assume that training programme is conducted for sales man, the company wants to measure the impact of sales programme. If the company finds that, the sales have improved, it may not be due to training programme. It may be because, sales man have more experience now and know the customer better. Better understanding between sales man and customer may be the cause for increased sales.

Maturation effect is not just limited to test unit, composed of people alone. Organizations also changes, dealers grow, become more successful, diversify, etc.

3. Testing: Pre-testing effect occurs, when the same respondents ***are measured more than once. Responses given at a later part will have a direct bearing on the responses given during earlier measurement.***

Example: Consider a respondent, who is given an initial questionnaire, intended to measure brand awareness. After exposing him, if a second questionnaire similar to the initial questionnaire is given to the respondent, he will respond quiet differently, because of respondent's familiarity the earlier questionnaire.

Pretest suffers from internal validity. This can be understood through an example. Assume that a respondent's opinion is measured before and after the exposure to a TV commercial of Hyundai car with Shahrukh Khan as brand ambassador. When the respondent is replying the second time, He may remember, how he rated Hyundai during the first measurement.

He may give the same rating to prove that, he is consistent. In that case, the difference between the two measurements will reveal nothing about the real impact. Alternately some of respondents might give a different rating during second measurement. This may not be due to the fact that the respondent has changed his opinion about Hyundai and the brand ambassador. He has given different rating because; he does not want to be identified as a person with no change of opinion to the said commercial.

In both the cases of above, internal validity suffers.

4. Instrument Variation: Instrument variation effect is a threat to internal validity when human respondents are involved. For example, an equipment such as a vacuum cleaner is left behind, for the customer to use for two weeks. After two weeks the respondents are given a questionnaire to answer. The reply may be quite different from what was given by the respondent before the trail of the product. This may be because of two reasons:

(a) Some of the questions have been changed

(b) Change in the interviewer for pre-testing and post testing are different

The measurement in experiments will depend upon the instrument used to measure. Also results may vary due to application of instruments, where there are several interviewers. Thus, it is very difficult to ensure that all the interviewers will ask the same questions with the same tone and develop the same rapport. There may be difference in response, because each *interviewer conducts the interview differently.*

5. Selection Bias: Selection bias occurs because 2 groups selected for experiment may not be identical. If the 2 groups are asked various questions, they will respond differently. If multiple groups are participating, this error will occur.

There are two promotional advertisement A & B for "Ready to eat food". The idea is to find effectiveness of the two advertisements. Assume that the respondent exposed to 'A' are dominant users of the product. Now suppose 50% of those who saw 'Advertisement A' bought the product and only 10% of those who saw 'Advertisement B' bought the product. From the above, one should not conclude that advertisement 'A' is more effective than advertisement 'B'. ***The main difference may be due to food preference habits between the groups, even in this case, internal validity might suffer but to a lesser degree.***

6. Experimental Mortality: Some members may leave the original group and some new members join the old group. This is because some members might migrate to another geographical area. This change in the members will alter the composition of the group.

Example: Assume that a vacuum cleaner manufacturer wants to introduce a new version. He interviews hundred respondents who are currently using the older version. Let us assume that, these 100 respondents have rated the existing vacuum cleaner on a 10 point scale (1 for lowest and 10 for highest). Let the mean rating of the respondents be 7.

Now the newer version is demonstrated to the same hundred respondents and equipment is left with them for 2 months. At the end of two months only 80 participant respond, since the remaining 20 refused to answer. Now if the mean score of 80 respondents is 8 on the same 10 point scale. From this can we conclude that the new vacuum cleaner is better?

The answer to the above question depends on the composition of 20 respondents who dropped out. Suppose the 20 respondents who dropped out had negative reaction to the product, then the mean score would not have been 8. It may even be lower than 7. The difference in mean rating does not give true picture. It does not indicate that the new product is better than the old product.

One might wonder, why not we leave the 20 respondent from the original group and calculate the mean rating of the remaining 80 and compare. But this method also will not solve the mortality effect. Mortality effect will occur in an experiment irrespective of whether the human beings or involved or not.

Concomitant Variable

Concomitant variable is the extent to which a cause "X" and the effect "Y" vary together in a predicted manner.

Example:

1. Electrical car is new to India. People may or may not hold positive attitude about electrical cars. ***Assume that, the company has undertaken a new advertising campaign "To change the attitude of the people towards this car", so that the sale of this car can increase. Suppose, in testing the result of this campaign, the company finds that both aims have been achieved i.e., the attitude of the people towards electrical car has become positive and also the sales have increased. Then we can say that there is a concomitant variation between attitude and sales. Both variables move in the same direction.***

2. Assume that an education institute introduces a new elective (Audit Course) which it claims is Job oriented. The college authorities advertise this course in leading news paper. They would like to know the perception of students to this course, and how many are willing to enroll. Now if on testing, it is found the perception towards this course is positive and majority of the respondent are willing to enroll, then we can say that, there is a concomitant variation between perception and enrolment. Both variables move in the same direction.

Goal of experimental research design	
Internal Validity	**To draw valid conclusions about the effect of independent variables on dependent variables**
External Validity	**To make valid generalizations to a larger population of interest**

In order to maintain the internal and external validity in experimental research design is to decrease or control the influence of extraneous variable as much as possible. Unless controlled adequately they are the source of error in an experiment. It also affects the validity of experimental results. If we want to get accurate and true results from our experiments we need to try to remove or minimize the effects of extraneous variable. Removing the effects of extraneous variable is called **controlling**.

Controlling of extraneous variable (How to control extraneous variable?)	
1	**To Hold extraneous variable as constant**
2	**Randomization: random assignment of test units to experimental group. So extraneous variables are equally distributed. but it is not effective if the group consists of small numbers**
3	**Researcher should conduct an experiment in an artificial environment for controlling the extraneous variable.**

It is important to control the extraneous variables to ensure the validity of results. There are three ways of controlling the extraneous variable.

1. **Randomization**. This involves random assignment of test units to experiment and control unit, along with random allocation of treatments to the two groups. This ensures that every member has equal chance of being assigned to a group. e.g., if a group of students is to be tested for teaching method effectiveness then it involves randomly choosing and assigning the students to two groups. By doing this, extraneous variables like IQ, sex, age, etc. are randomly distributed. In words of Rosenbaum, Randomization is preferred procedure for ensuring the prior equality of experimental groups.

2. **Matching**. Another method of reducing the contamination caused by extraneous variables is to match the various groups. This involves a prior identification of characteristics that may confound the experiment and then deliberately assigning them to groups e.g. the student's are assigned to experimental and control groups taking care that factors like gender, age and IQ are equally distributed. Since the effect of extraneous variables is equally distributed the researcher can confidently claim that the independent variable (X) alone is responsible for changes in dependent variable(Y).
3. **Statistical Control**. This is a more specific method of controlling the effect of extraneous variables. It involves measuring the effect of extraneous variables and making adjustments for their effect by using statistical analysis tools. Methods like two way ANOVA (Analysis of Variance), ANCOVA) Analysis of Co-variance) are some examples.

2.3.4 Principles of Experimental Design

Prof.R.A.Fisher, used experimental designs while he was conducting agricultural research at Rothamsted Experimental station, which is an agricultural research central in England. He has enumerated three principles for controlling extraneous variables (i) the Principle of Replication (ii) Principle of Randomization (iii) Principle of Local Control.

1. **Principle of Replication**. According to this principle, the experiment should be conducted more than once i.e. it should be repeated again and again. For example, in the experiment being conducted to test the effectiveness of teaching methods, there should be more than one experiment group and control group. The data would then be collected from all the groups and significant comparisons can be made to test the effectiveness. Another way of implementing the principle is that the experiment can be repeated more than once. Principle of replication increases the accuracy of the study.
2. **Principle of Randomization**. As discussed earlier, randomization is used to control the effect of extraneous variables. The units and treatments are randomly assigned so that the variations caused by extraneous variables can be controlled and can be clubbed under a general factor 'chance'. Principle of randomization helps us to obtain a better estimate of the experimental error. The effect of extraneous variables are randomly distributed among the groups.
3. **Principle of Local Control**. Using this principle, it becomes possible for the researcher to measure and eliminate the effect of extraneous variables. The known source of variability i.e. the extraneous factor is made to vary deliberately over a wide range in a manner that its effect can be measured e.g. IQ is an extraneous factor which, may influence the study on Effect of teaching methods on student performance. To control its effect, students with similar IQ can be clubbed in one group . Hence the difference in performance among groups caused due to IQ variations can be extracted and then eliminated from the results of the study. The group are called as 'blocks' and they are homogeneous with respect to the extraneous variables i.e. the IQ level within a group is same. Two way ANOVA can then be used to statistically measure the effect of extraneous variables.

2.3.5 Types of Experiments	Strengths	Limitations
1. Laboratory Experiments These are conducted under controlled conditions, in which the researcher deliberately changes something (I.V.) to see the effect of this on something else (D.V.).	**Control** – lab experiments have a high degree of control over the environment & other extraneous variables which means that the researcher can accurately assess the effects of the I.V, so it has higher internal validity. **Replicable** – due to the researcher's high levels of control, research procedures can be repeated so that the reliability of results can be checked.	**Lacks ecological validity** – due to the involvement of the researcher in manipulating and controlling variables, findings cannot be easily generalised to other (real life) settings, resulting in poor external validity.
2. Field Experiments These are carried out in a natural setting, in which the researcher manipulates something (I.V.) to see the effect of this on something else (D.V.).	**Validity** – field experiments have some degree of control but also are conducted in a natural environment, so can be seen to have reasonable internal and external validity.	**Less control** than lab experiments and therefore extraneous variables are more likely to distort findings and so internal validity is likely to be lower.
3. Natural / Quasi Experiments These are typically carried out in a natural setting, in which the researcher measures the effect of something which is	**High ecological validity** – due to the lack of involvement of the researcher; variables are naturally occurring so findings can be easily generalised to other (real life) settings,	**Lack of control** – natural experiments have no control over the environment & other extraneous variables which means that the researcher cannot always accurately

to see the effect of this on something else (D.V.). Note that in this case there is no deliberate manipulation of a variable; this already naturally changing, which means the research is merely measuring the effect of something that is already happening.	resulting in high external validity.	assess the effects of the I.V, so it has low internal validity. **Not replicable** – due to the researcher's lack of control, research procedures cannot be repeated so that the reliability of results cannot be checked.

4. **Simulation**

A **simulation** is an approximate imitation of the operation of a process or system; that represents its operation over time.

Simulation is used in many contexts, such as simulation of technology for performance tuning or optimizing, safety engineering, testing, training, education, and video games. Often, computer experiments are used to study simulation models. Simulation is also used with scientific modelling of natural systems or human systems to gain insight into their functioning, as in economics. Simulation can be used to show the eventual real effects of alternative conditions and courses of action. Simulation is also used when the real system cannot be engaged, because it may not be accessible, or it may be dangerous or unacceptable to engage, or it is being designed but not yet built, or it may simply not exist. **A simulation involves representing a situation by creating an artificial setting in which individual or group behavior can be observed.**

In a sense, **simulation is similar to a laboratory experiment**, except that it does not seek to control participants' activities as much as in an experimental research design. Simulations can thus give participants much greater freedom to act according to their judgment and to make decisions and their actions become the focus of observation.

Eg) Simulations can be conducted in a university laboratory or college classroom. Then the laboratory looks like an organizational conference room. The students are asked to dress as business professionals. They are observed and their management skills are rated according to

a behavioural checklist. After the simulation, students complete a self-rating checklist to rate their own managerial skills. Each student is also assessed by a peer.

A model constructs a conceptual framework that describes a system. The behavior of a system that evolves over time is studied by developing a simulation model. The model takes a set of expressed assumptions: ... Mathematical, logical ... Symbolic relationship between the entities.

Types of Simulation

There are three types of simulation, viz.., (a) man simulations (b) computer simulations and (c) man-computer simulations.

Man Simulation: This is a game played by people in a laboratory setting to simulate people in real world. For example, number of individuals are divided into groups that are placed in a laboratory room. Each group is instructed to imagine that it represents the government of a particular nation. Simulated international situations involving treaties, alliances, threats, wars and the like are then played out by the groups.

No gaming model can serve as a universal model for all games. Each model is unique. The size of the group is important factor. The size may be two persons, three persons or more than three persons. Others important dimensions are information level (whether individuals have perfect information or not), and perceived goal motivation –no common interest and purely competitive or partly competitive and partly cooperative.

Computer simulation: This is an operational model programmed to generate a sequence of interactions. This requires precise definitions, storing of large amounts of data on the system to be analysed and programming of the analysis. For example, two or more sets of ratios relating to liquidity, profitability and operational efficiency may be fed into a discriminant function analysis in order to find out which set of variables has a better power to predict the financial health of an enterprise.

Man-computer simulation: In this type of simulation, persons play the role of decision-makers, while the computer is responsive to the players' activities. In this game, the computer must be provided with a script. "The script lists the messages conveyed to the player. Two kinds of messages are involved. One is simple response to the players' actions. The other is instruction to the player as to the appropriate way he can respond to the computer".

The successive runs of a simulation should give similar results. Then it is said to be reliable. This is rarely a problem in computer simulation, but it may be a problem in games, the reliability in games requires that the physical equipment should not be cumbersome, the rules should be clear, simple and complete and the game should not overtax the player's span of attention.

Validity refers to the generalization of the findings of the simulation. This depends on the degree of correspondence between the operating model and its reference system.

Usage of simulation

- **Analysis tool for predicating the effect of changes**
- **Design tool to predicate the performance of new system**
- **It is better to do simulation before Implementation.**

Types of simulation

Automobiles

- An automobile simulator provides an opportunity to reproduce the characteristics of real vehicles in a virtual environment. It replicates the external factors and conditions with which a vehicle interacts enabling a driver to feel as if they are sitting in the cab of their own vehicle. Scenarios and events are replicated with sufficient reality to ensure that drivers become fully immersed in the experience rather than simply viewing it as an educational experience. For companies, it provides an opportunity to educate staff in the driving skills that achieve reduced maintenance costs, improved productivity and, most importantly, to ensure the safety of their actions in all possible situations.
- **Finance**

Monte Carlo methods in finance and Mathematical finance

In finance, computer simulations are often used for scenario planning. Risk-adjusted net present value, for example, is computed from well-defined but not always known (or fixed) inputs. By imitating the performance of the project under evaluation, simulation can provide a distribution of

NPV over a range of discount rates and other variables. Simulations are also often used to test a financial theory or the ability of a financial model.

Simulations are frequently used in financial training to engage participants in experiencing various historical as well as fictional situations. There are stock market simulations, portfolio simulations, risk management simulations or models and forex simulations. Such simulations are typically based on **stochastic asset models**. Using these simulations in a training program allows for the application of theory into a something akin to real life. As with other industries, the use of simulations can be technology or case-study driven.

2.3.6Types of Experimental research Design

The types of experimental research design are determined by the way the researcher assigns subjects to different conditions and groups. They are of 4 types, namely; pre-experimental, quasi-experimental, and true experimental and statistical experimental research design.

The way you classify research subjects, based on conditions or groups, determines the type of design.

Following are the common symbols used in the experimental research

X = exposure of a group to an experimental treatment or independent variable

O = observation or measurement of the dependent variable on the test units.

O1,O2 and O3… are the various observations or measurements of the dependent variable taken during the course of the experiment

R = random assignment of test units to experimental groups

EG = experimental group, which is exposed to the experimental treatment

CG = control group of test units involved in the experiment.

1.**Pre-experimental designs** lack proper control mechanisms to deal with the influence of extraneous variables on experimental results. There are three prominent pre-experimental designs used by business researchers. They are

Pre-experimental design		
One-shot design (after only design)	**One-group pre-test–post-test design**	**Static group design.**

1. **One shot study** - one group is exposed to the treatment, and only a post test is given to observe or measure the effect of the treatment on the dependent variable within the experimental group. The chosen group is exposed to the treatment, and then it is tested only once for the purpose of measuring the degree of change on the dependent variable after the treatment. ***There is no control group in this design.***

One-shot design involves exposing the experimental group to treatment X after which the measurement (O) of the dependent variable is taken. This can be shown symbolically as follows:

EG : X O1

For example, a company may launch a sales promotion initiative in the selected supermarkets in a city for a month to ascertain the impact of sales promotion on sales. Then, it might measure the sales registered in that particular month. The higher sales may prompt the company to extend the sales promotion offers to other cities where it has a presence. There are some drawbacks associated with this study. The test units are not selected randomly. Instead, their selection is based on the researcher's judgment. The results might not reflect the experimental treatment's impact completely as various extraneous variables influence the dependent variable including history, maturation and mortality. As this study lacks proper control mechanisms to deal with extraneous variables, the internal validity of the experiment is affected. Moreover, we cannot infer results based on the measurement O1, as there is no other measurement against which O1 can be compared with. Due to these limitations, ***one-shot design is not used for conclusive research. It is used more for exploratory research.***

2. **One-Group Pre-test/Post-test Design**

This type of design involves exposing an experimental group of test units to experimental treatment (X). Measurements are taken before and after experimental treatment. This can be symbolically expressed as:

EG: O1 X O2
TE= O2-O1

O1 represents the measurement of the dependent variable before the experimental group is exposed to the treatment. O2 represents the measurement of the dependent variable after the experimental group is exposed to the treatment. So the difference between O2 and O1 will be the impact of treatment on the dependent variable.

For example, an HR manager may plan a training programme for employees and measure the productivity change. First, he may measure the productivity of employees. Then, the training programme will be conducted. After the training, employee productivity is again measured. However, just like the one-shot design, this experimental design too lacks proper control mechanisms to limit the influence of extraneous variables. These include history, maturation, testing effect, statistical regression effect, selection bias and mortality effect.

3. **Static Group Design**

In static group design, two groups of test units, the experimental group and the control group, are involved in the experiment. The experimental group is exposed to the experimental treatment. The control group is not exposed to the experimental treatment. The measurements are taken for both groups after the experiment.

This can be symbolically expressed as follows:

EG:	X	O1
CG:		O2
TE= O1-O2		

We may note that O1is the measurement of the dependent variable of the experimental group after exposing it to the treatment and O2 is the measurement of the dependent variable of the control group, which is not exposed to the treatment. The difference between these two measurements, that is, O1- O2 will be the effect of treatment.

Example, A study wants to assess the relationship of 'family support' (measur5ed by the presence of domestic help or spouse/ family's help in carrying out domestic chores) with the work life balance of BPO women employees. Here, the presence or absence of help is ascertained and then we can measure the work life balance. Thus the design is essentially ***ex -post facto*** and any segregation into experimental or control group is not made by the researcher. The treatment effect could be measured by O1-O2. So the difference could be attributed due to various extraneous variables like selection bias. The non-random selection of test units may result in differences between the units assigned to the experimental group and the control group. Another extraneous variable that will influence the results is the mortality effect. Some test units may drop out from the experiment. This is more so for the experimental group if the treatment is strenuous. Demerit is that no pre test is to be conducted. These are also lead to make the design invalid for drawing any casual inferences.

2. True experimental research design: True experimental research relies on statistical analysis to prove or disprove a hypothesis, making it the most accurate form of research. Of the types of experimental design, only true design can establish a cause-effect relationship within a group. In a true experiment, three factors need to be satisfied:

- There is a Control Group, which won't be subject to changes, and an Experimental Group, which will experience the changed variables.
- A variable which can be manipulated by the researcher
- Random distribution

This experimental research method commonly occurs in the **physical sciences.**

As discussed earlier, true experimental designs use the principle of randomization to control the influence of extraneous variables. Randomization refers to the assignment of test units to either experimental groups or control groups at random. Such selection of test units will reduce the differences between the groups on whom the experiment is being conducted. Apart from the use of the randomization technique, true experimental designs also use one or more than one control groups to reduce the effect of extraneous variables. Following are prominent true experimental designs widely used in business research:

True experimental research design		
Pre-test/post-test control group design	**Post-test only control group design**	**Solomon four group design.**

1. Pre-test/post-test control group design

In this design, two groups of test units, that is, experimental group and control group are considered for the experiment. The test units are assigned to these two groups randomly. Pre-test measurements of dependent variable are taken for the two groups. Then, the experimental group is exposed to the treatment. The posttest measurements of the dependent variable are taken for the two groups. It can be shown symbolically as below:

EG: R O1	X		O2
CG: R O3			O4
TE= (O2-O1)-(O4-O3)			

O1 and O2 are the pre-test measurement and post-test measurement of dependent variable of the experimental group. R represents that the assignment of testing units to each group is done on a random basis.

O3 and O4 are the pre-test and post-test measurement of dependent variable of the control group. We know that the control group is not exposed to experimental treatment.

The treatment effect (TE) can be calculated as follows: let A= (O2-O1) and B= (O4-O3) therefore TE = A-B

A= (O2-O1)	EG: includes both treatment and Extraneous Variable
B= (O4-O3)	CG: includes no treatment only Extraneous Variable
TE = A-B	

The extraneous variables like history, maturation, Testing, Instrument variation, Selection bias and Experimental mortality all are influence the experimental group while in the control group the interactive testing effect is absent subjected to no treatment. Therefore, it is doubtful to generalize the result of experiment.

For example, a fertilizer company is launching a new fertilizer. To test its efficacy, the company has decided to conduct an experiment. For this, it has divided an agricultural field into a few parts. These parts are randomly assigned to the experimental group and the control group. Then, the pre-test measurements (productivity) of the fields are taken. The parts in the experimental group are treated with fertilizer and the parts in the control group are not exposed to the fertilizer treatment.

The post-test measurements are taken. The differences between the pre-test and post-test measurements are analyzed.

This design addresses most of the extraneous variables. Hence, it provides accurate results. However, this design may not control the testing effect. This is because pre-test measurements are taken, and such measurements will sensitize test units. This may have an impact on post-test measurements. This design avoids extraneous variation resulting from extraneous variable.

2. Post-test only with control Group Design

In this design, both the experimental and control groups participate in the experiment. The test is exposed to the experimental treatment and the second is kept unexposed. The post-test measurement of the dependent variables is taken for both groups. This can be shown symbolically:

EG:	R	X	O1
CG:	R		O2
TE=O1-O2			

EG: includes both treatment and Extraneous Variable
CG: includes no treatment only Extraneous Variable

To illustrate, a personal product company has claimed that the use of its new hair oil formulation will reduce hair fall by 50 % compared with other hair oils. To support this claim, the company has conducted an experiment by randomly assigning consumers who use a competing coconut oil brand to both the experimental group and the control group. The experimental group consumers are provided with the company's hair-oil formulation for 6 months, while the control group continues to use the competing hair-oil brand. Measurements are taken after 6 months.

This type of design will address most of the extraneous variables. ***This design is widely used in marketing research.***

3. **Solomon four group design**

This type of design involves conducting an experiment with four groups, two experimental groups and two control groups. Six measurements are taken, two pretest and four post-test. This study is also known as the four-group, six-study design. This is also referred to as 'ideal controlled Experiment'. This design helps the researcher to remove the influence of extraneous variables and also the interactive testing effect. The design can be symbolically represented as follows:

Group 1 1	EG: R O1 X O2
2	CG: R O3 O4
Group 2 **3**	EG: R X O5
4	CG: R O6

In the above design test units are selected at random in all the four groups. It is seen that group 1 are under pre test measurement but the Group 2 are not given pre test measurement. The researcher assumes that all the groups are equal before experiment. Therefore the treatment effect can be calculated as follows:

EG: 1 Pre–test measurement	TE= O2-O1	EG: includes both treatment and Extraneous Variable	There is an interactive testing effect
CG:1 Pre–test measurement	TE= O4-O3	CG: includes no treatment **only Extraneous Variable**	No interactive testing effect
EG:2 No Pre–test measurement	TE=O5-O1 TE=O5-O3	TE= O5 - ($\frac{O1+O3}{2}$)	No Pre-test measurement therefore No interactive testing effect will occur
CG:2 No Pre–test measurement	TE=O6-O1 TE=O6-O3	TE= O6 - ($\frac{O1+O3}{2}$)	

TE= O5–O6

	TE= O5-O3		
	TE=(O2-O1)-(O4-O3)		

As the Group 2 was not subjected to any treatment, the difference in measurement would only indicate the effect of extraneous variables without interactive testing effect. Therefore the researcher by taking the average of both ($\frac{O1+O3}{2}$).Though the design addresses all extraneous variables, it is expensive and consumes time and effort. The design provides various measures, which can be analysed. Thus this design is not commonly used in research. This design is an extension of the pre -test and post –test control group design. This helps not only in measuring the effect of treatment, but also in obtaining magnitude of the interacting testing effect and extraneous factors. ***This design is frequently used by industries like pharmaceuticals where cause and effect relationship is equivalent to life and death situations and thus critical for the survival of the business.***

3.Quasi Experimental Designs

In quasi experimental designs the researcher can control when measurements are taken and on whom they are taken. They do not involve randomization so the experimental control is lacking to treatments. Therefore there is a possibility of getting confounded results is very high. Then the researcher should be aware of what variables are not controlled and the effects of such variables should be incorporated into the findings.

Quasi Experimental Designs	
Time series design	**Multiple time series design**

Time series design:

It involves pre-testing and post testing of subjects at different intervals. The aim is to determine the long term effect of the treatment; hence measurement is taken over a period of time. Eg) the effect of advertisement on consumer's buying behaviour. It requires that the treatment (ad) or commercial is broadcast a number of times and the subsequent behavior recorded to arrive at any conclusive result.

EG	O1	O2	O3	O4	X	O5	O6	O7	O8

The result of time series design may be affected by an interactive testing effect because multiple measurements are made on these test units.

Multiple time series design

In this design, the researcher use of the principle of replication that means the treatments are given to all groups in a different order, and the number of groups should be equal to the number of treatments. Then multiple post treatment test scores are taken from both the group (may be EG and CG). This is also termed as counter balanced design.

EG	O1	O2	O3	O4	X	O5	O6	O7	O8
CG	O1	O2	O3	O4		O5	O6	O7	O8

Example: In deciding which medicine is superior, the physician has to administer the various medicines not only to one group but many different groups over a period of time.

4. **Statistical Design**			
1. Completely Randomized Design (CRD)	2. Randomized Block Design (RBD)	3. Latin Square Design (LSD)	4. Factorial Design

1. Completely Randomized Design (CRD)		
Principle of randomization	**Merits** 1. **Flexible** 2. **No. of times treatments are repeated**	**Demerits** 1. **Assumes homogeneity of**

and Principle of replication are applied.	**3. Statistical analysis (One way ANOVA is used to find out the significance of differences among the treatments) so it is easy and straight forward.** **4. Degree of freedom used for estimating the experimental error**	**experimental units** **2. When the no. of treatment is fairly large it may not be efficient**

1. Completely Randomized Design

A completely randomized design is probably the simplest experimental design, in terms of data analysis and convenience. With this design, subjects are randomly assigned to treatments. In this design the two principles of experimental design ie, Principle of randomization and principle of replication are applied.

Example, 'To study the effect of teaching methods on the performance of students'.			
Test unit Students are taken at random	Treatments (Independent variable) Method of teaching	Performance of student (Dependent variable)	Principle of replication are applied. (repeated at 5 times
A Group of students	1) Lecture method 2) Seminars 3) Assignments 4) Case study		Total experiment is 20 (4*5) times

The 4 treatments are allotted to the experimental plots completely at random, so that every plot will have the same chance of any of the 4 treatments. This design permits partitioning of total variability present in the observations into 2 components.

1. One attributable to experimental error(chance factors)
2. Other due to treatment differences

One way NAOVA is used to find out the significance of differences among the treatments

2. **Randomized Block Design**

To overcome the limitation of CRD (Assumption of homogeneity of experimental units) RBD is being adopted. In this design the principle of local control is applied using blocks.

Subjects within each block are homogeneous with respect to the selected variable. This variable is often extraneous variable which influences the dependent variable.

Example, when an agricultural scientist experiment with different varieties they cannot make sure that all the plots are uniform in soil fertility. In this design, the researcher divides the experimental plots into separate homogeneous block viz, less soil fertility, medium soil fertility and high soil fertility. Within each block treatments are allocated at random. (RBD) Each treatment appears the same number of times in each block. Between blocks are heterogeneous in nature. Therefore, the researcher uses Two-way ANOVA under this design to control the extraneous factors. In this design , the researcher can study not only the effect of soil fertility on yield but also the variation in each block and in varieties of treatment.

3. **Latin square design**

The Latin square design is used where the researcher desires to control the variation in an experiment that is related to rows and columns in the field. (ie. 2 extraneous variables) With the Latin Square design you are able to control variation in two directions.

-Treatments are arranged in rows and columns

Example, to study the influence of price (treatment) on sales. Let 3 levels of price categories namely low, medium and high. The sales could be influenced by 2 extraneous variables viz, store size and type of packaging. For the application of LSD, the number of categories of 2 extraneous variables should be equal to the number of levels of treatments. This is the necessary condition for the use of LSD.

Store size	Packaging		
	I	II	III
Small	X1	X2	X3
Medium	X2	X3	X1
large	X3	X1	X2

This would result in 3*3 LSD. Each treatment occurs once and only once in each row and in each column. This design helps to measure statistically the effect of a treatment on dependent variable and also the measurement of an error resulting from extraneous variables. This design is highly complex and expensive to execute.

4. **Factorial design**

To measure the effect of more than one independent variable on the dependent variable. This design allow the interaction between variables. An interaction takes place when sum of effects of 2 or more variables taken together is different from the sum of effects

2 types of Factorial design

Simple Factorial design: In simple factorial design, the effect of not more than 2 factors are tested

Complex Factorial design: In Complex Factorial design, experiments with more than 2 factors at a time are involved.

If there are 3 treatments at 2 levels then it becomes 2*2*2 factorial design.

Example, the sales of a product may be influenced by 2 factors namely store size and price levels.

The store size could be categorized into small (B1) and big (B2)

The price levels are categorized into 3 namely, low(A1), medium (A2) and high (A3)

Price	Store size	
	Small (B1)	Big (B2)
A1 Low level	A1B1	A1B2
A2 Medium level	A2B1	A2B2
A3 High level	A3B1	A3B2

There are 3*2= 6 cells. Six different levels of treatment combinations would be produced each with specific price level and store size. It allows the researcher to save time and effort to study the effects of each other.

Summary

Experimental research is conducted to study the cause and effect relationship between variables under study. An attempt is made by the researcher to maintain control and manipulate the variables that affect his study. Following steps are involved in conducting an experimental study.

1. Identification and definition of problem
2. Formulation of hypothesis
3. Developing an experimental design. The design should discuss the following:
    - Select the sample subjects
    - Group or pair subjects
    - Identify and control non-experimental factors
    - Construct and validate an instrument to measure
    - Determine place, time and duration of experiment.
4. Conduct the experiment
5. Analyze the data and test the hypothesis
6. Report the findings

Experimental designs pay specific attention to controlling extraneous variables because if left unchecked they have the power of altering the results. The extraneous variables are also called as confounding variables.

Hypothesis-testing research studies (generally known as experimental studies) are those where the researcher tests the hypotheses of causal relationships between variables. Such studies require procedures that will not only reduce bias and increase reliability, but will permit drawing inferences about causality. Usually experiments meet this requirement. Hence, when we talk of research design in such studies, we often mean the design of experiments.

Professor R.A. Fisher's name is associated with experimental designs. Beginning of such designs

was made by him when he was working at Rothamsted Experimental Station (Centre for Agricultural Research in England). As such the study of experimental designs has its origin in agricultural research. Professor Fisher found that by dividing agricultural fields or plots into different blocks and then by conducting experiments in each of these blocks, whatever information is collected and inferences drawn from them, happens to be more reliable. This fact inspired him to develop certain experimental designs for testing hypotheses concerning scientific investigations. Today, the experimental designs are being used in researches relating to phenomena of several disciplines. Since experimental designs originated in the context of agricultural operations, we still use, though in a technical sense, several terms of agriculture (such as treatment, yield, plot, block etc.) in experimental designs.

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