Unit II
Research Design

Research Design

- Task of defining the research problem is the preparation of the research project, popularly known as the "research design".
- Decisions regarding what, where, when, how much, by what means concerning an inquiry or a research study constitute a research design.
- A plan or strategy for conducting the research.
- A research design is one that minimizes bias and maximizes the reliability of the data.
- It also yields maximum information, gives minimum experimental error, and provides different aspects of a single problem.
- A research design depends on the purpose and nature of the research problem. Thus, one single design cannot be used to solve all types of research problem, i.e., a particular design is suitable for a particular problem.

Need of research design

- Smooth sailing of research operations.
- Stands for advance planning of the methods.
- Great bearing on reliability of the results.
- Helps to give directions.
- Helps in decision making.
- Research design prevent blind searching.
- Helps researchers to anticipate potential problems in collecting data etc.

Features of a Good Design

- The means of obtaining information
- The availability and skills of the researcher and his staff, if any;
- The availability of time and money for the research work.
- It should be flexible enough to consider different aspects of the study in case of exploratory.
- The design should be accurate with minimum bias in case of accurate description
- Control of extraneous variables
- Statistical correctness for testing hypothesis

Concepts relating to research design

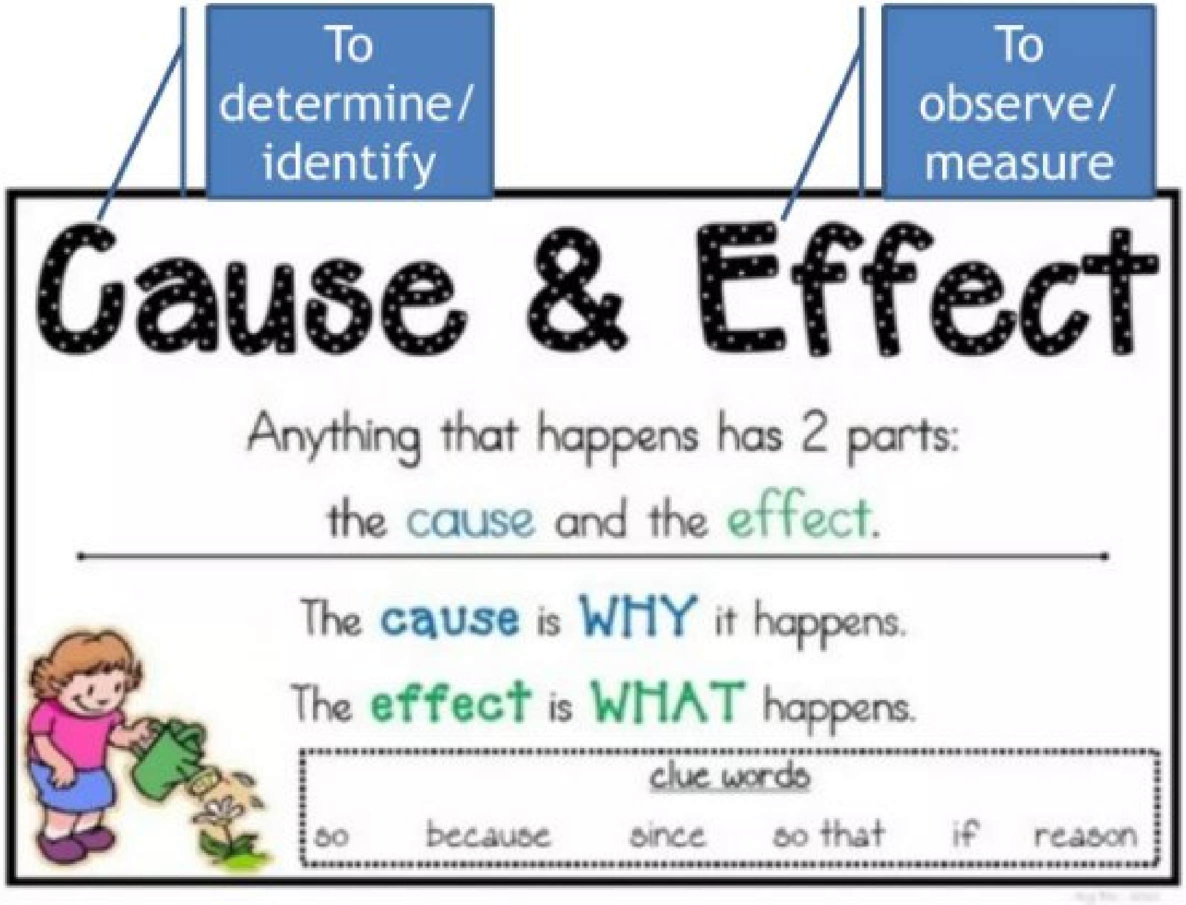
- ❑ Variables
  - Dependent variables and independent variables
  - Extraneous variables and confounded variables
- ❑ Research Hypothesis
  - Null and Alternate hypothesis
  - Directional and Non directional hypothesis
- ❑ Experimental and Control groups
- ❑ Treatments

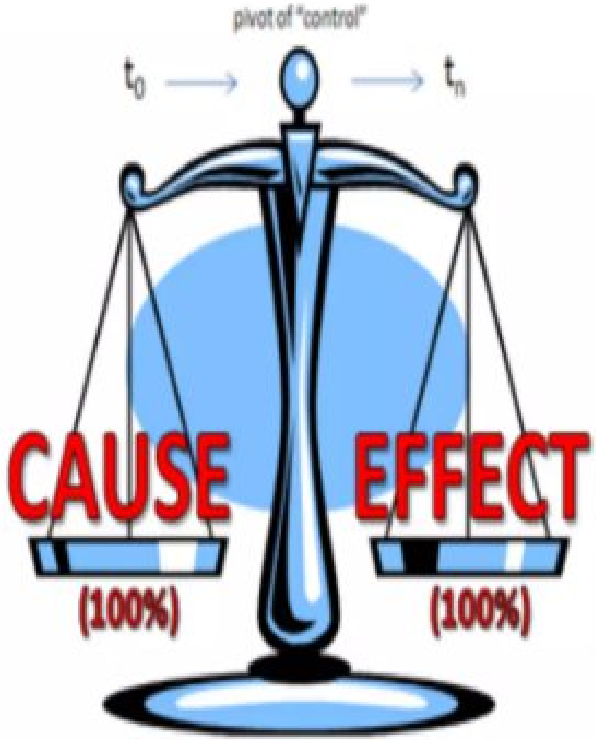
Variables

Any characteristics which is subject to change and can have more than one value. They play a crucial role in formulating hypotheses, designing experiments, and interpreting results.

Example: intelligence, motivation, age, gender

Concept of cause and effect





Types of Variables

Independent Variables

Independent variables are the factors that researchers manipulate or control in an experiment to observe their effect on the dependent variable. They are considered the "cause" in a cause-and-effect relationship.

Types:

1.Experimental Independent Variables: These are directly manipulated by the researcher (e.g., dosage of a drug).

2.Subject Variables: These are characteristics of the subjects that cannot be manipulated but can categorize participants (e.g., age, gender)

Dependent Variables

Dependent variables are the outcomes or effects that researchers measure in response to changes in the independent variable. They are considered the "effect" in a cause-and-effect relationship.

Characteristics: The values of dependent variables depend on the variations of independent variables.

Extraneous Variables

Extraneous variables are any variables other than the independent variable that could influence the dependent variable. These can introduce noise into the experiment and potentially confound results if not controlled.

Examples: Environmental factors (temperature, lighting)

- Participant characteristics (mood, fatigue)
- Experimental conditions (time of day when measurements are taken)

Confounded Variables

Confounded variables occur when two or more variables are intertwined in such a way that their individual effects on the dependent variable cannot be separated. This can lead to misleading conclusions about relationships between variables.

Characteristics: Confounding occurs when an extraneous variable correlates with both the independent and dependent variables.

Importance of Variables in Research

Understanding variables is essential for several reasons:

- **Hypothesis Development:** Clearly defined variables help in formulating testable hypotheses.
- **Experimental Design:** Knowledge of how to manipulate and measure variables is crucial for designing effective experiments.
- **Data Analysis:** Identifying variable types informs appropriate statistical analyses and interpretation of results.

Research Hypothesis

- The research hypothesis is a predictive statement that relates an independent variable to dependent variable.
- A hypothesis may be defined as a proposition or set of proposition set forth as an explanation for occurrence of some specified group of phenomena either asserted merely as a provisional conjucture to guide some investigation or accepted as highly probable in the light of established facts

Purpose of hypothesis

- Guides/gives direction to the study/investigation
- Defines Facts that are relevant and not relevant
- Suggests which form of research design is likely to be the most appropriate
- Provides a framework for organizing the conclusions of the findings
- Limits the research to specific area
- Offers explanations for the relationships between those variables that can be empirically tested
- Furnishes proof that the researcher has sufficient background knowledge to enable her/him to make suggestions in order to extend existing knowledge
- Structures the next phase in the investigation and therefore furnishes continuity to the examination of the problem

Types of hypothesis

- **Based on formulation:** Null and Alternate hypothesis
- **Based on direction:** Directional and non directional hypothesis

Null and Alternative Hypotheses

- **Null Hypothesis (H_0):** The null hypothesis is a statement asserting that there is no effect, no difference, or no relationship between variables in a population. It serves as a default position that researchers aim to test against.
- **Example:** In a study examining the effect of a new drug on blood pressure, the null hypothesis might state that the mean blood pressure of patients taking the drug is equal to that of those not taking it (H_0: $\mu_1 = \mu_2$).
- **Alternative Hypothesis (H_1 or H_a):** The alternative hypothesis is a statement that contradicts the null hypothesis, suggesting that there is an effect, a difference, or a relationship present. It represents what the researcher aims to support through evidence.
- **Example:** Continuing with the drug study, the alternative hypothesis could state that the mean blood pressure of patients taking the drug is different from that of those not taking it (H_1: $\mu_1 \neq \mu_2$).

Directional and Non-Directional Hypotheses

- **Directional Hypothesis:** A directional hypothesis specifies the expected direction of the relationship or effect between variables. It indicates whether one variable is expected to be greater than or less than another.
- **Example:** In the context of the drug study, a directional hypothesis might state that patients taking the new drug will have lower blood pressure than those not taking it ($H_1: \mu_1 < \mu_2$).

- **Non-Directional Hypothesis:** A non-directional hypothesis does not specify a direction; it simply states that there is a difference or effect without indicating whether it is positive or negative.
- **Example:** Using the same drug study, a non-directional hypothesis would assert that there is a difference in mean blood pressure between patients taking the drug and those not taking it ($H_1: \mu_1 \neq \mu_2$).

Importance of hypothesis in Research

Understanding these hypotheses is crucial for conducting statistical tests and interpreting research findings effectively.

- **Null Hypothesis (H_0):** Assumes no effect or relationship exists.
- **Alternative Hypothesis (H_1):** Suggests an effect or relationship exists.
- **Directional Hypothesis:** Predicts the direction of the effect (greater than or less than).
- **Non-Directional Hypothesis:** Indicates there is a difference but does not specify direction.

Treatment

Treatment is what is administered to participants or experimental units in an experiment. It can take various forms, such as a drug, therapy, educational program, or any other intervention that is hypothesized to have an effect.

Types of Treatments

- **Experimental Treatments:** These are the new or modified interventions being tested (e.g., a new medication).
- **Control Treatments:** These may include standard treatments, placebos, or no treatment at all, used for comparison against the experimental treatments.

Purpose

The primary goal of applying treatments is to determine their effect on the outcome of interest (the dependent variable). By comparing the results from treatment groups to control groups, researchers can assess whether the treatment has a significant impact.

Design Considerations:

- Researchers must carefully design the treatment conditions, including dosage, duration, and delivery method, to ensure valid and reliable results.
- Random assignment of treatments helps minimize bias and confounding variables, enhancing the internal validity of the study.

Measurement:

- Outcomes are typically measured before and after treatment application (pretest and posttest) to evaluate changes attributable to the treatment.

Example of Treatment in Research

In a clinical trial evaluating the effectiveness of a new drug for hypertension:

- **Treatment Group:** Participants receive the new drug.
- **Control Group:** Participants receive a placebo.

Researchers compare blood pressure readings before and after treatment in both groups to determine if the new drug is effective.

Experimental and Control Groups

Experimental and control groups are foundational elements in research design. The experimental group allows researchers to test hypotheses by applying treatments, while the control group provides a reference point for evaluating those effects.

Together, they enable rigorous testing of theories and contribute to reliable scientific conclusions.

Experimental Group

The experimental group is the group of subjects that receives the treatment or intervention being tested. This group is exposed to the independent variable to observe its effects on the dependent variable.

Characteristics:

- **Treatment Application:** Members of the experimental group experience changes or interventions that are hypothesized to affect outcomes.
- **Comparison Basis:** The results from this group are compared against those from the control group to determine the effectiveness of the treatment.

Example: In a clinical trial testing a new medication, the experimental group would receive the actual drug being studied.

Control Group

The control group is a separate group that does not receive the treatment or intervention. Instead, it serves as a baseline to compare against the experimental group.

Characteristics:

- **No Treatment or Placebo:** Members of the control group may receive a placebo or standard treatment, allowing researchers to isolate the effects of the independent variable.
- **Similarity to Experimental Group:** Ideally, control and experimental groups should be identical in every way except for the treatment being tested. This ensures that any differences in outcomes can be attributed to the treatment.

Example: In clinical trial, the control group might receive a placebo pill that has no therapeutic effect.

Importance of Experimental and Control Groups

- Establishing Causality: By comparing outcomes between groups, researchers can determine whether changes in the dependent variable are due to the independent variable.
- Reducing Bias and Variability: Control groups help mitigate confounding variables and biases, enhancing the validity of findings.
- Benchmarking Results: The control group provides a standard against which researchers can measure changes observed in the experimental group.

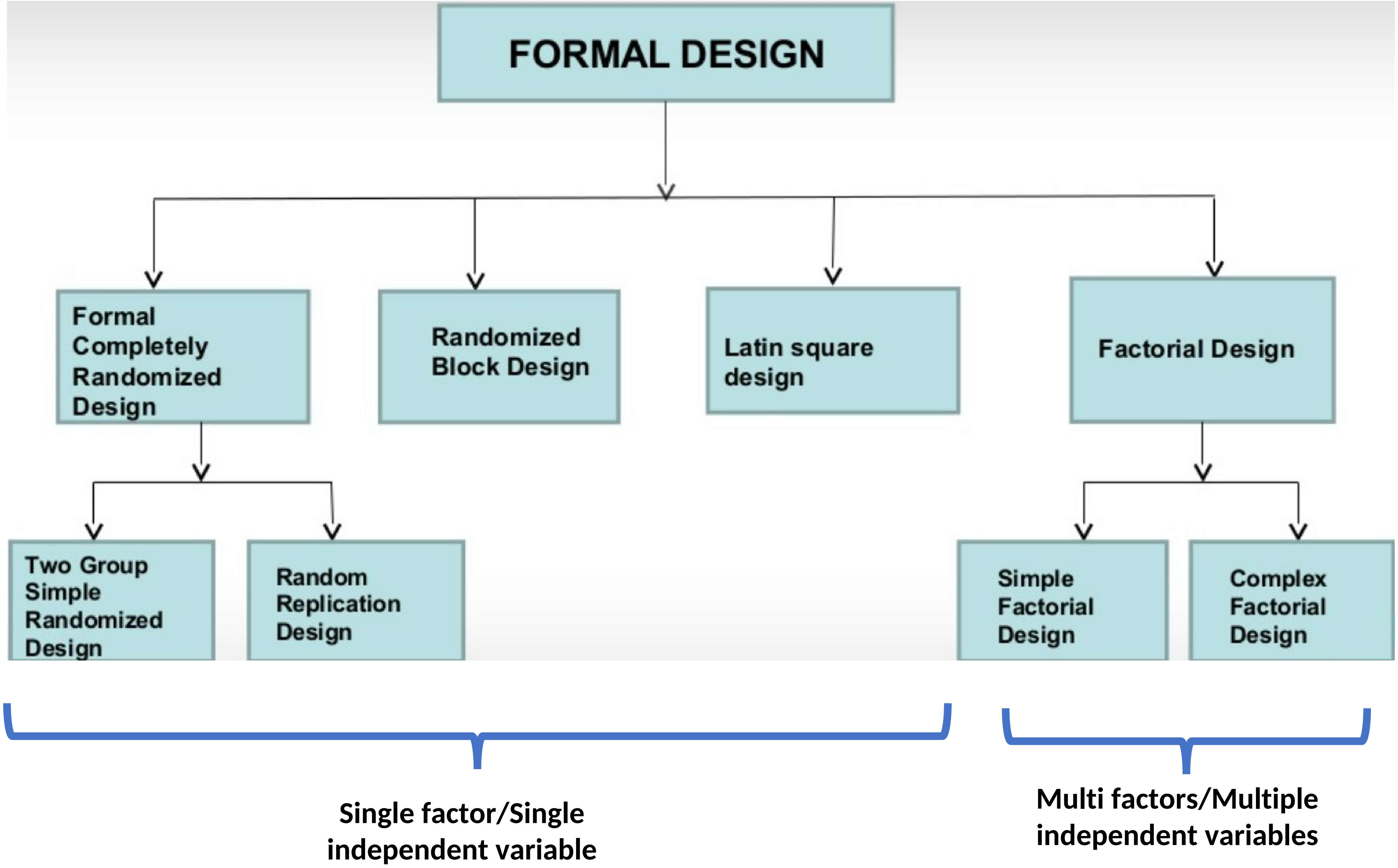
Experimental Design

Experimental design methods allow the experimenter to understand better and evaluate the factors that influence a particular system by means of statistical approaches.

Such approaches combine theoretical knowledge of experimental designs and a working knowledge of the particular factors to be studied.

Principles of Experimental Design

- **Control** – make conditions as similar as possible for all treatment groups (aside from the actual treatments).
  - *If we observe a difference between groups, we want to know that it is a result of the treatment(s)!*
- **Randomization** – the use of chance to assign subjects/units to treatments
  - *This helps create roughly equivalent groups of experimental units by balancing the effects of lurking variables that aren't controlled on the treatment groups.*
- **Replication** of the experiment on many subjects/in different locations/etc.

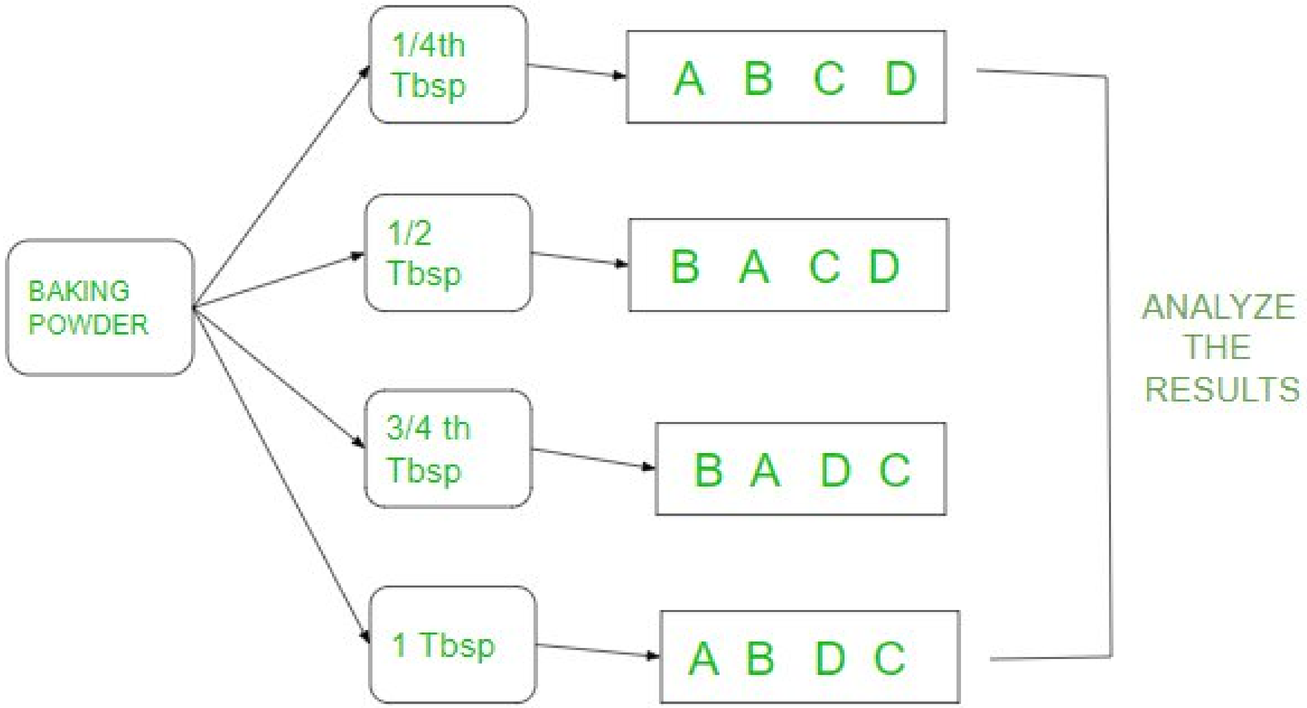

FORMAL DESIGN
Formal Completely Randomized Design
Randomized Block Design
Latin square design
Factorial Design
Two Group Simple Randomized Design
Random Replication Design
Simple Factorial Design
Complex Factorial Design
Single factor/Single independent variable
Multi factors/Multiple independent variables

Completely Randomised Design

Completely Randomized Design (CRD) is a basic experimental design in which treatments are assigned to experimental units completely at random. This means that each unit has an equal chance of receiving any treatment, ensuring that the effects of the treatments can be assessed without bias.

❑Example

- Adding more baking powder to cakes increases the heights of the cake



- **Key Characteristics**

1. **Random Assignment:** Treatments are allocated randomly to experimental units, which minimizes the influence of uncontrolled variables and helps in achieving homogeneity among groups.
2. **Single Factor Focus:** CRD is typically used when studying the effects of one primary factor (treatment) on a response variable.
3. **Homogeneity Requirement:** It is most effective when the experimental units are homogeneous, meaning they are similar in all respects except for the treatment being tested.
4. **Flexibility:** The design allows for any number of treatments and replications, making it adaptable to various experimental conditions.

Statistical Model

The statistical model for CRD can be expressed as:

$$Y_{ij} = \mu + T_i + e_{ij}$$

Where:

- Y_{ij} = observation for treatment i and replication j
- μ = overall mean
- T_i = effect of treatment i
- e_{ij} = random error associated with the observation

- **Advantages**
- Simplicity: The layout and analysis of CRD are straightforward, making it easy to implement.
- Statistical Efficiency: It provides maximum degrees of freedom for error, which enhances the sensitivity of statistical tests.
- Flexibility in Design: Researchers can easily modify treatment levels and replications as needed.
- **Limitations**
- Homogeneity Requirement: CRD is less effective if the experimental units are not homogeneous, as this can lead to increased variability and reduced precision.
- Less Accurate in Field Experiments: Due to environmental variations, CRD may not be suitable for field experiments where conditions are not controlled.
- Inability to Detect Interactions: It does not account for interactions between factors, which may limit its applicability in more complex experiments.

❑Applications

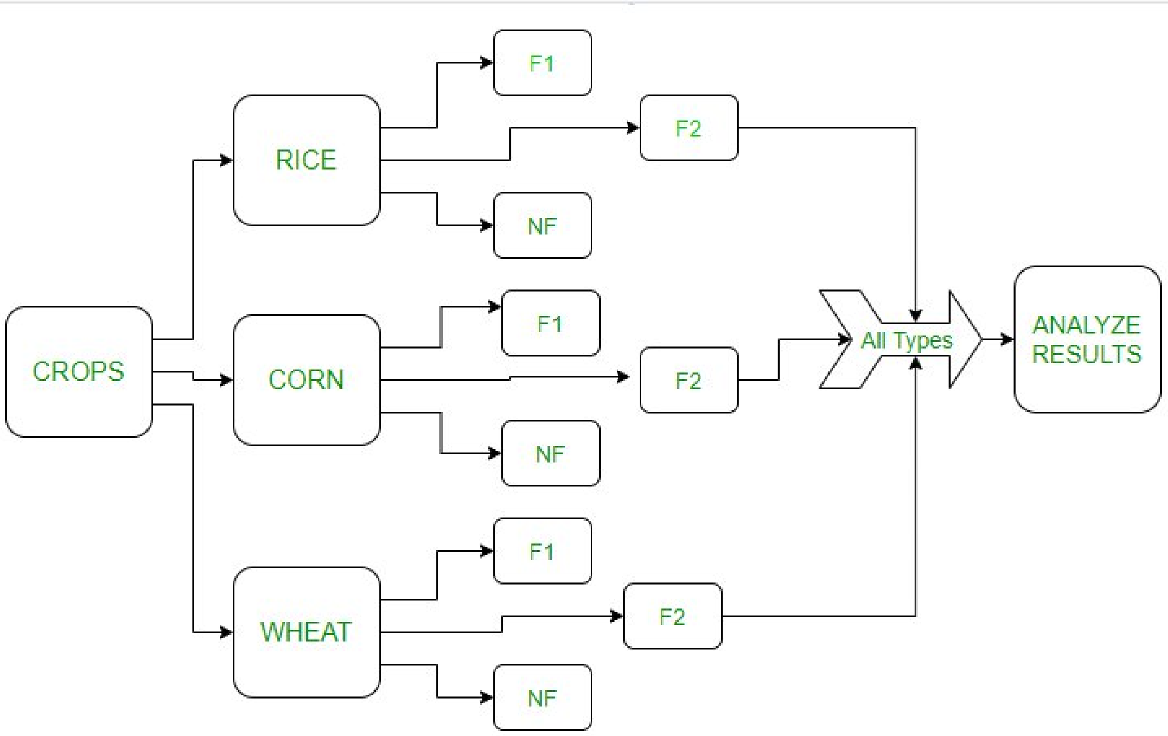
- CRD is widely used in laboratory experiments where conditions can be tightly controlled, such as: Agricultural research to test different treatments on crops.
- Clinical trials to assess the effectiveness of new drugs.
- Basic research in biology and chemistry where randomization is crucial for unbiased results.

Randomized Block Design

Randomized Block Design (RBD) is an experimental design that involves grouping experimental units into blocks based on certain characteristics or factors that are expected to affect the outcome of the experiment. Within each block, treatments are assigned randomly to minimize the impact of variability between blocks.

❑Example

- Testing new fertilizers in different types of crops. Crops are divided into 3 different types(blocks).Thes … that are used on those crops



- **Key Features**

1. **Blocking:** Experimental units are grouped into blocks that share similar characteristics (e.g., age, gender, location). This helps control for variability and reduces the experimental error associated with those nuisance factors.
2. **Random Assignment:** Treatments are randomly assigned within each block, ensuring that each treatment has an equal chance of being applied to any experimental unit in the block.
3. **Complete Treatment Application:** Each treatment is applied to all blocks, allowing for a comprehensive comparison across different conditions.

Statistical Model

The statistical model for RBD can be expressed as:

$$Y_{ij} = \mu + T_j + B_i + E_{ij}$$

Where:

- Y_{ij} = observation for treatment j in block i
- μ = overall mean
- T_j = effect of treatment j
- B_i = effect of block i
- E_{ij} = random error associated with the observation

- **Advantages**

1. Reduction of Variability: By accounting for known sources of variability, RBD increases the precision of the experiment and enhances the reliability of results.
2. Increased Statistical Power: The design allows for more accurate estimates of treatment effects by reducing the error variance, leading to more powerful statistical tests.
3. Flexibility: RBD can accommodate various types of experimental conditions and is adaptable to many fields, including agriculture, medicine, and social sciences.

- **Limitations**

1. Complexity in Design: Designing an experiment with appropriate blocking factors can be complex and requires prior knowledge about potential sources of variability.
2. Assumption of Homogeneity: The effectiveness of blocking relies on the assumption that variability within blocks is less than between blocks. If this assumption is violated, it may lead to misleading results.

❑Applications

- Agricultural Experiments: Used to test different fertilizers or treatments across fields with varying soil types or environmental conditions.
- Clinical Trials: Employed to assess treatment effects while controlling for patient demographics or baseline characteristics.
- Industrial Testing: Applied in quality control processes where variations in production conditions need to be accounted for.

Latin Square Design

Latin Square Design (LSD) is an experimental design used to control for two blocking factors while studying the effects of one treatment factor. It is structured as an n×n grid where each treatment appears exactly once in each row and once in each column, effectively controlling for variability due to the two blocking factors.

Selected Latin Squares

3 x 3

A	B	C
B	C	A
C	A	B

4 x 4

A	B	C	D
B	A	D	C
C	D	B	A
D	C	A	B

A	B	C	D
B	C	D	A
C	D	A	B
D	A	B	C

A	B	C	D
B	D	A	C
C	A	D	B
D	C	B	A

A	B	C	D
B	A	D	C
C	D	A	B
D	C	B	A

5 x 5

A	B	C	D	E
B	A	E	C	D
C	D	A	E	B
D	E	B	A	C
E	C	D	B	A

6 x 6

A	B	C	D	E	F
B	F	D	C	A	E
C	D	E	F	B	A
D	A	F	E	C	B
E	C	A	B	F	D
F	E	B	A	D	C

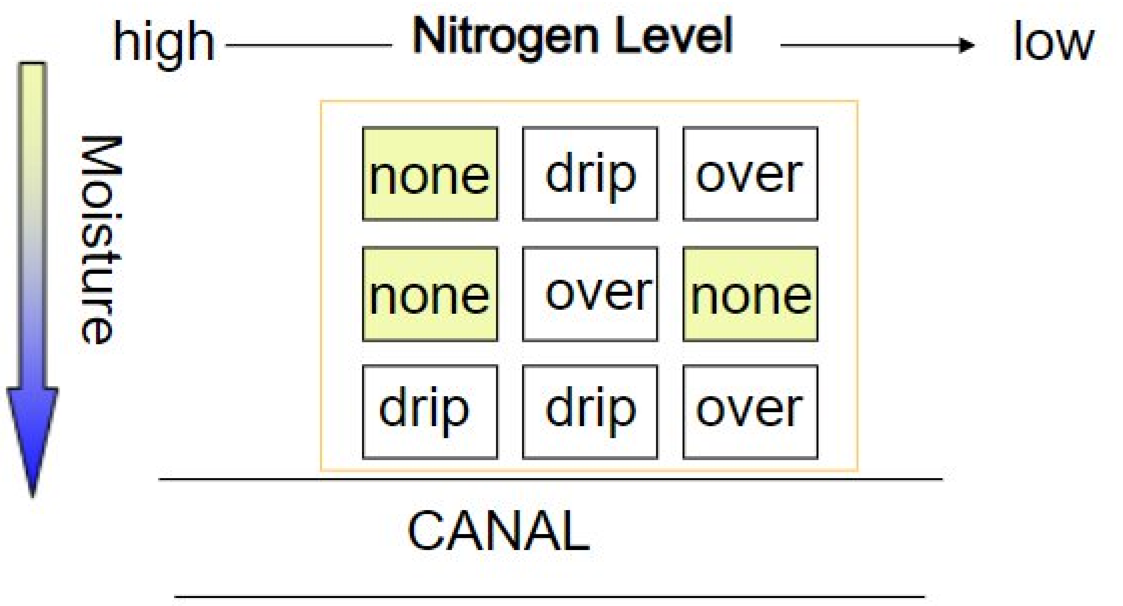
Example:

Cold Protection of Strawberries

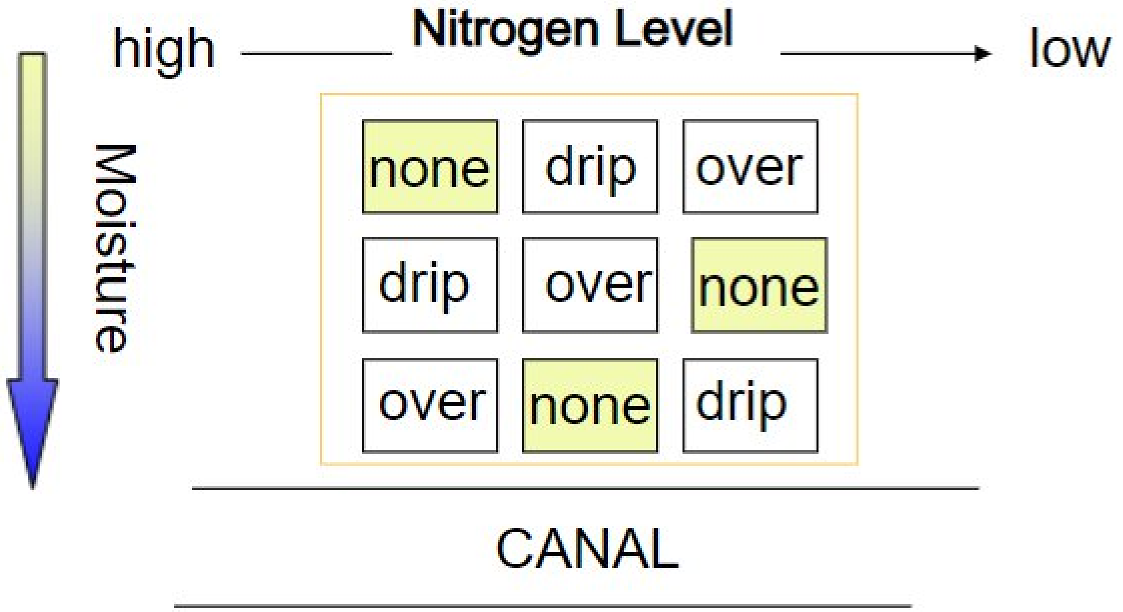
- Three different irrigation methods **(treatment levels)** are used on strawberries:
    1. drip,
    2. overhead sprinkler,
    3. no irrigation.
- We wish to determine which of these is most effective in protecting strawberries from extreme cold.
- All strawberries grown through plastic mulch.
- Measure weight of frozen fruit (lower values indicate more protection).

Field Layout

Moisture and Soil Nitrogen are two sources of extraneous variation that we wish to simultaneously control for.



Which design will best allow us to account for both soil moisture and nitrogen gradients?



- **Key Features**

1. **Structure:** The design consists of a square matrix where both rows and columns represent different blocking factors. Each cell in the matrix contains a treatment, ensuring that every treatment is tested under every combination of the blocking factors.
2. **Blocking Factors:** The two blocking factors are usually known nuisance variables that could affect the outcome of the experiment. By arranging treatments in this way, researchers can isolate the effects of the treatment from those of the blocking factors.
3. **Equal Treatment Replication:** Each treatment appears once in each row and column, allowing for balanced comparisons across all conditions.

Statistical Model

The statistical model for analyzing data from a Latin Square Design can be represented as:

$Y_{ijk} = \mu + T_j + R_i + C_k + E_{ijk}$

Where:

- Y_{ijk} = observation for treatment j in row i and column k
- μ = overall mean
- T_j = effect of treatment j
- R_i = effect of row i
- C_k = effect of column k
- E_{ijk} = random error associated with the observation

- **Advantages**

1. Control of Variability: By accounting for two sources of variability (rows and columns), LSD reduces experimental error and increases the precision of results.
2. Efficient Use of Resources: The design requires fewer experimental units compared to running separate experiments for each blocking factor.
3. Flexibility: It can accommodate various types of treatments and is applicable in multiple fields, including agriculture, psychology, and clinical studies.

- **Limitations**

1. Limited Number of Treatments: The number of treatments must equal the number of rows and columns, which can limit its applicability if there are too many treatments.
2. Complexity in Design: Designing a Latin square can be more complex than simpler designs, requiring careful planning to ensure that all treatments are adequately represented.
3. Assumption of Homogeneity: The effectiveness relies on the assumption that variations within rows and columns are minimal; significant differences may lead to

❑Applications

- Agricultural Experiments: Used to evaluate different fertilizers or crop treatments while controlling for soil type (rows) and environmental conditions (columns).
- Clinical Trials: Employed to study drug effects while accounting for patient demographics (rows) and treatment regimens (columns).
- Psychological Studies: Applied in experiments where subjects may differ based on characteristics like age or gender, ensuring balanced representation across treatments.

Factorial Design

Factorial design is a statistical experimental methodology used to evaluate the effects of two or more independent variables (factors) on a dependent variable. This design allows researchers to assess not only the main effects of each factor but also the interaction effects between factors, providing a comprehensive understanding of how these variables influence outcomes.

- **Key Features**

1. **Multiple Factors:** Factorial designs involve at least two independent variables, each with multiple levels. For example, a 2x2 factorial design includes two factors, each at two levels, resulting in four treatment combinations.
2. **Main and Interaction Effects:**

Main Effects: The individual impact of each factor on the dependent variable.

Interaction Effects: How the effect of one factor changes depending on the level of another factor.

3. **Comprehensive Analysis:** By manipulating multiple factors simultaneously, factorial designs allow for a nuanced analysis that can reveal complex relationships that might not be evident when studying factors in isolation.

Simple Factorial Design

A simple factorial design typically involves two or more factors, each with two levels. It is often represented in a format like 2x2, where the first number indicates the number of levels for the first factor and the second number indicates the levels for the second factor.

Example: In a 2x2 factorial design examining the effects of drug dosage (low vs. high) and treatment duration (short vs. long), there would be four treatment combinations:

- Low dosage, short duration
- Low dosage, long duration
- High dosage, short duration
- High dosage, long duration

Complex Factorial Design

Complex factorial designs involve more than two factors or factors with more than two levels. They can be represented as 2x3 or 3x2x2, indicating multiple factors and their respective levels.

Example: In a 3x2x2 factorial design examining the effects of three factors—type of therapy (Cognitive Behavioral Therapy, Psychodynamic Therapy, and Humanistic Therapy), duration (short vs. long), and therapist gender (male vs. female)—there would be 12 treatment combinations:

- CBT, short duration, male
- CBT, short duration, female
- CBT, long duration, male
- CBT, long duration, female
- Psychodynamic, short duration, male
- Psychodynamic, short duration, female
- Psychodynamic, long duration, male
- Psychodynamic, long duration, female
- Humanistic, short duration, male
- Humanistic, short duration, female

Advantages of factorial design

- There are many advantages of the factorial experiments:

1. Factorial experiments are advantageous to study the combined effect of two or more factors simultaneously and analyze their interrelationships. Such factorial experiments are economic in nature and provide a lot of relevant information about the phenomenon under study. It also increases the efficiency of the experiment.
2. It is an advantageous because a wide range of factor combination are used. This will give us an idea to predict about what will happen when two or more factors are used in combination.
3. The factorial approach will result in considerable saving of the time and the experimental materials. It is because the time required for the combined experiment is less than that required for the separate experiments.
4. In single factor experiments, the results may not be satisfactory because of the changes in environmental conditions. However, in factorial experiments such type of difficulties will not arise even after several factors are investigated simultaneously.
5. Information may obtained from factorial experiments is more complete than that obtained from a series of single factor experiments, in the sense that factorial experiments permit the evaluation of interaction effects.

Disadvantages of factorial design

➢ The disadvantages of the factorial experiments are:

- It is disadvantageous because the execution of the experiment and the statistical analysis becomes more complex when several treatments combinations or factors are involved simultaneously.
- It is also disadvantageous in cases where may not be interested in certain treatment combinations but we are forced to include them in the experiment. This will lead to wastage of time and also the experimental material.
- In factorial experiments, the number of treatment combinations will increase if the factors are increased. This will also lead to the increase in block size, which in turn will increase the heterogenicity in the experimental material. Because of this it will lead to the increased experimental error and will decrease the precision in the experiment. Appropriate block size must be maintained.

Thank You