FACTORIAL DESIGN

INTRODUCTION

Research problems are stated in the form of hypothesis. They are stated so that they can be empirically tested. There is a wide range of possibilities of testing hypothesis. There are as many designs of research that exist as there are possibilities. Designs are carefully worked out to yield dependable and valid answers to the hypothesis. The results of the research depends on how the observation and the inferences are made. How dependable our observation and inferences will be, depends on how adequately we plan the research design. The planning of research design depends on the number of independent variables, the number of levels of each independent variable, the kinds of independent variable. If we have one independent variable then we use single factor experimental design. When we have more than one independent variable with more than one level than we use the factorial design. Factorial design may be two factor, three factor, four factor etc. In this unit we will discuss two factor design.

OBJECTIVES

After reading this unit, you will be able to:

- Define factorial design;
- Describe the terms related to factorial design

Formulate factorial design;

- Describe graphically the results of factorial experiment; and
- Identify the advantages and limitations of factorial design.

Traditional research method generally study the effect of one variable at a time because it is statistically easy to manipulate. However in many cases, two factors may be interdependent. One of the most significant developments in modern research design and statistics is, planning and analysis of simultaneous operation and interaction of two or more variables. Variables do not act independently. Rather they often act in concert. There is one design i.e. factorial design by which we can study the effect of more than one independent variable on dependent variable. The factorial designs have the advantage over the single factor design in that interaction of two or more variables can also be studied along with the main effect. In a single factor design the levels of only one factor is varied and the levels of other relevant variable are held constant. Thus the information provided by factorial design is far more complete than provided by single factor design.

2.0 MEANING OF FACTORIAL DESIGN

A factorial design is one in which two or more variable or factors are employed in such a way that all the possible combinations of selected values of each variable are used (Mcburney & White, 2007). According to Singh (1998), Factorial design is a design in which selected values of two or more independent variables are manipulated in all possible combinations so that their independent as well as interactive effect upon the dependent variable may be studied. On the basis of the above definition it can be said that the factorial design is one in which two or more independent variables are manipulated in all possible combinations and thus the factorial design enables the experimenter to study the independent effect as well as interactive effect of two or more independent variables.

2.1 TERMS RELATED TO FACTORIAL DESIGN

Factors : The term factor is broadly used to include the independent variable that is manipulated by the investigator in the experiment or that is manipulated through selection. In the research some time it is possible to manipulate the independent variable directly, for example in a study researcher wants to study the effect of different drugs on the recovery of the patient. The researcher may select three dosages 2 mg, 4 mg. and 6 mg. and administer the drug to the subjects. Further researcher may find that age is another important variable that may influence the rate of recovery from the diseases. The second independent variable that is age cannot be directly manipulated by the researcher. The manipulation of the variable 'age' is achieved through selection of the sample. The researcher then may divide the subjects into three age groups.

Main Effect

This is the simplest effect of a factor on a dependent variable. It is the effect of the factor alone averaged across the level of other factors.

According to Mcburney & White (2007) main effect in a factorial experiment, the effect of one independent variable, averaged over all levels of another independent variable.

Interaction : The conclusion based on the main effects of two independent variables may be at times misleading, unless we take into consideration the interaction effect of the two variables also.

According to Mcburney & White (2007) Interaction means when the effect of one independent variable depends on the level of another independent variable. An interaction is the variation among the difference between mean for different levels of one factor over different levels of the other factor. For example a cholestrol reduction clinic has two diets and one exercise regime. It was found that exercise alone was effective and diet alone was effective in reducing cholestrol levels (main effect of exercise and main effect of diet). Also for those patients who didn't exercise, the two diets worked equally well (the main effect of diet); those who follow diet A and exercised got the benefits of both (main effect of diet A & main effect of exercise). However it was found that those patients who followed diet B and exercised got the benefit of both plus a bonus, an interaction effect (main effect of diet B, main effect of exercise plus an interaction effect of diet and exercise).

Types of Interaction

1) **Antagonistic interaction :** When main effect is non-significant and interaction is significant. In this situation the two independent variables tend to reverse each others effect.

2) **Synergistic interaction :** When higher level of one independent variable enhances the effect of another independent variable.

3) **Celling effect interaction :** When the higher level of one independent variable reduces the differential effect of another variable. that is one variable has a smaller effect when paired with higher level of a second variable (Mcburney & White, 2007).

All of these types of interaction are common in psychological research.

Randomisation : Randomisation is the process by which experimental units are allocated to treatment; that is by a random process and not by any subjective process. The treatment should be allocated to units in such a way that each treatment is equally likely to be applied to each unit.

Blocking: This is the procedure by which experimental units are grouped into homogenous cluster in an attempt to improve the comparison of treatment by randomly allocating the treatment within each cluster or block.

2.2 SIMPLE TWO FACTOR DESIGN

In the two factor design we have two independent variables, each of which has two values or levels. This is known as two by two (2x2) factorial design because of the two levels of each variables.

2.4.1 Layout of Factorial Design

2 × 2 Factorial Design

	Factor A	
Factor B	A_1	A_2
B_1	A_1B_1	A_2B_1
B_2	A_1B_2	A_2B_2

If we have two levels of one variable and three of another variable we would have two by three (2 × 3) factorial design.

2 × 3 Factorial Design

	Factor A		
Factors B	A_1	A_2	A_3
B_1	A_1B_1	A_2B_1	A_3B_1
B_2	A_1B_2	A_2B_2	A_3B_2

We may have as many factors and level as we desire but with increasing complexity we will require more time and data become complicated to interpret. Most experiment use two or three factors, with two to six levels on the various factors.

2.4.2 Example of Factorial Design

In an experiment Tulving and Pearlstone (1965) subjects were asked to learn a list of 12, 24 or 48 words (factor A with three levels). These words can be put in pairs by categories (for example apple and banana can be grouped as 'fruits'). Subjects were asked to learn these words and they were shown the category name at the same time as the words were presented. Subjects were told that they did not have to learn the category names. After a very short time, subjects were asked to recall the words. At that time half of the subjects were given the list of the category names, and the other half had to recall the words without the list of categories (factor B with two levels). The dependent variable is the number of words recalled by each subjects is given in the table below:

Table 2.1

Level of A

	A_1	A_2	A_3	**Total**
Levels of B	12 words	24 words	48 words	
B_1 Cued recall	A_1B_1 (10)	A_2B_1 (13)	A_3B_1 (19)	**42**
B_2 Free recall	A_1B_2 (10)	A_2B_2 (15)	A_3B_2 (29)	**54**
Total	**20**	**28**	**48**	**96**

Here we have two independent variables number of words and presence and absence of cues and one dependent variable, that is the number of words recalled by each subject. We could do two separate experiments, one which varied the number of words and the other which varied the presence or absence of cues.

The first experiment could be as in Table 2. This table shows the independent effect of number of words. The second experiments could be as in Table 3.

Table 2.2

Cued Recall

12 Words	24 Words	48 Words
A_1	A_2	A_3

Table 2.3

Free recall

12 Words	24 Words	48 Words
A_1	A_2	A_3

In the above example (Table 2.1) there are six cells into which the sample is divided. Each of the six combination would receive one treatment or experimental condition. Subjects are assigned at random to each treatment in same manner as in a randomised group design. The mean (shown in bracket) for different cells may be obtained along with the means for different rows and columns. Means of different cells represent the mean scores for the dependent variable and the column mean in the given design are termed the main effect for number of words without taking into account any differential effect that is due to the presence or absence cues. Similarly the row mean in the above design are termed the main effect for presence or absence of cues without regard to number of words. Thus through this design we can study not only the main effect of number of words and presence or absence of cues, but we can also study the interactive effect of number of words and presence or absence of cues, on the number of words recalled by the subject.

In this design we have two independent variables, we are able to examine two possible main effects. We found the main effect of number of words by averaging effect of number of words over the two levels of presence and absence of cues when we looked at the column mean. Similarly we found the main effect of presence or absence of categories by averaging the effect of presence or absence of categories over the three levels of number of words when we looked at the row mean.

By these results we can find out the interactive effect. Two variables interact if the effect of one variable depends on the level of the other. We have an interaction here. Because the effect of presence or absence of cues depends on the number of words. Similarly the retention is influence by the length of the test.

Interaction can be presented in a tabular form as well as in graphical form.

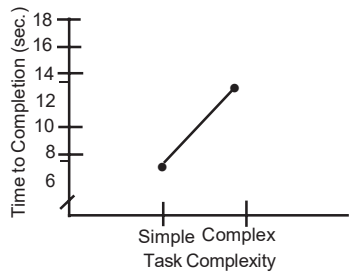
2.4.3 Representing Interaction in Graphic Form

We take the fictitious ons data to present the results in graphic form. One independent variable is task complexity with two levels and second independent variable is level of arousal, that is low arousal and high arousal and the dependent variable is average time (in second) to completion of a task. Result are shown in the Table 2.4.

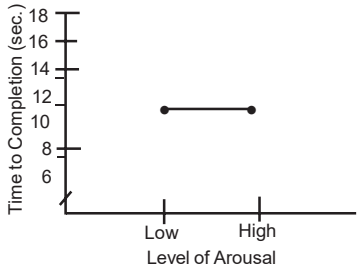
Table 2.4

Study 1	**Task Complexity**	
High arousal	Simple	Complex
	7.6	13.1
Study 2	**Level of arousal**	
	Low arousal	High arousal
	10.3	10.4
Study 3	**Task complexity x level of arousal**	
	Simple Task	Complex Task
Low arousal	9.0	11.8
High arousal	6.2	14.4

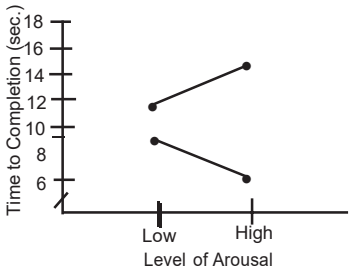
Graphs



a. Study I results



b. Study II results



c. Study III results

The concept of interaction can be understood clearly by looking at the graph rather than the table. The graph for study III shows the interaction between task complexity and arousal. The fact that the two lines on that graph for the simple and complex task groups, are not parallel to one another suggest that there is an interaction. Whether the lines diverge, converge or even cross whenever they are not parallel the variable interact. If they are parallel, then the relationship between the independent variables is an additive one.

Of course, in an actual research study the lines would rarely be perfectly parallel. There are statistical test that can tell us when they are close enough to parallel to indicate that there is no interaction, as well as when they deviate enough from parallel to indicate that there is an interaction.

2.4.4 Importance of Interaction

Main effect is an average effect. It can be misleading when an interaction is present. When interaction is present we should examine the effect of any factor of interest at each level of the interacting factor before making interpretation (Minimum et.al. 2001). The two factor design is really made up of several one factor experiments. In addition to main effect, the factorial design also allows us to test simple effect.

For example we have 2×2 design. One factor A has two levels A_1 and A_2 and other factor B has two levels B_1 and B_2. Main effects compare differences among the level of one factor averaged across all levels of the other. However, this particular design consists of four one way experiment and we may analyse each of them separately. We may be interested in effect of A (all two levels) specifically for condition B_2. Simple effects refer to the results of these one factor analysis. To make such comparison the interaction must first be significant.

Sometimes researcher is more interested in interaction than in a main effect. For example, a study involving two methods and learner of low and high intelligence. Research already established that individual with low intelligence learn more slowly than individuals with high intelligence. The researcher may not be interested in confirming the results, but may be interested to explore whether the relative difference in effectiveness of the two teaching methods is the same for slow learners and for fast learners, that is related to the question about the interaction between method and learning ability. It could be that method and learning ability interact to such a degree that one method is more effective with slow learner and the other is more effective with fast learner.

Self Assessment Questions

1) Given below are statement. Indicate whether they are true or false :

   i) Factorial design is used to study the effect of one independent variable.

   ii) Interaction effect can be study by single factor design.

   iii) The independent variables of an experiment is known as factors of the experiment.

   iv) In within subject factorial design each subject experience each condition.

   v) The 2×2 design means two independ variables with two levels.

2) Fill in the blanks :

   i) The interaction in which two independent variables tend to reverse each other's effect is known as .....

   ii) Interaction in which two independent variables reinforce each other's effect is known as .....

   iii) If graphical representation of a variables shows curves that are not parallel line it shows ..... between the variable.

   iv) The effect of one independent variable averaged over all levels of another independent variable is known as .....

2.3 TYPES OF FACTORIAL DESIGN

Factorial experiments may be conducted either within subject or between subject. A mixed factorial design is also used in psychology. A mixed factorial design is one that has at least one within subject variable and at least one between subject variable.

2.5.1 Within Subject Factorial Design

In an experiment by Godden & Baddeley (1975), researcher wants to study the effect of context on memory. They hypothesised that memory should be better when the condition at test are more similar to the conditions experienced during learning. To operationalise this idea Godden and Baddeley decided to use a very particular population : deepsea divers. The divers were asked to learn a list of 50 unrelated words either on the beach or under 10 feet of water. The divers were then tested either on beach or under sea. The divers were tested in both the environment in order to make sure that any effect observed could not be attributed to a global effect of one of the environment. The first independent variable is the place of learning. It has 2 levels (on the beach and under sea). The second independent variable is the place of testing. It has two levels (on the beach and under sea). These 2 independent variables gives 4 experimental conditions :

i) Learning on the beach and recalling on the beach.

ii) Learning on the beach and recalling under sea.

iii) Learning under sea and recalling on the beach.

iv) Learning under sea and recalling under sea.

Each subject in this experiment was tested in all four experimental condition. The list of words was randomly created and assigned to each subject. The order of testing was randomised in order to control the carry over effect. The layout of the within subject factorial design is presented below.

Table 2.5: A within subject factorial design

learning place

A

Testing Place B	**Onland** A_1	**Under Sea** A_2
B_1	S_1	S_1
	S_2	S_2
	S_3	S_3
	S_4	S_4
	S_5	S_5
	S_6	S_6
B_2	S_1	S_1
	S_2	S_2
	S_3	S_3
	S_4	S_4
	S_5	S_5
	S_6	S_6

2.5.2 Between Subject Factorial Design

A between subject facotoria design is presented in the following table. The example is 2×2 design. Separate groups of six experience each condition, thus requiring 24 subjects to get six responses to each of four conditions.

Table 2.6: A between subject factorial design

Factor - A

Factor-B	A_1	A_2
B_1	S_1 S_2 S_3 S_4 S_5 S_6	S_{13} S_{14} S_{15} S_{16} S_{17} S_{18}
B_2	S_7 S_8 S_9 S_{10} S_{11} S_{12}	S_{19} S_{20} S_{21} S_{22} S_{23} S_{24}

2.5.3 Mixed Factorial Design

Some time the researcher uses mixed factorial design. Researcher has two independent variable A and B. Variable A is the within subject variable and variable B is the between subject variable. Subject either experiences B_1, once with A_1 and also with A_2; or they experience B_2 once with A_1 and also with A_2.

For example we want to study the effect of gender and alcohol on risk taking while driving. Here we have two independent variables gender (A) and alcohol level (B). Suppose we have decided to operationalise the independent variable 'alcohol level' by having four concentration levels. We decide to have each subject observed in each alcohol condition. The order of administration of each condition will be randomised for each subject. The measures are non repeated for the factor (A) gender and repeated for the factor (B) alcohol level.

Suppose we have 10 subjects 5 males and 5 females. The experimental lay out will be as follows :

Table 2.7

Between Subject Variables	Within Subject Variable			
A	B_1	B_2	B_3	B_4
A_1	S_1 S_2 S_3	S_1 S_2 S_3	S_1 S_2 S_3	S_1 S_2 S_3

	S_4 S_5	S_4 S_5	S_4 S_5	S_4 S_5
A_2	S_6 S_7 S_8 S_9 S_{10}	S_6 S_7 S_8 S_9 S_{10}	S_6 S_7 S_8 S_9 S_{10}	S_6 S_7 S_8 S_9 S_{10}

This example shows a situation in which you would have to use a mixed design.

2.4 ADVANTAGE OF FACTORIAL DESIGN

Factorial design enables the researcher to manipulate and control two or more independent variables simultaneously. By this design we can study the separate and combined effect of number of independent variables.

Factorial design is more precise than single factor design (Kerlinger, 2007).

By factorial design we can find out the independent or main effect of independent variables and interactive effect of two or more independent variables.

The experimental results of a factorial experiment are more comprehensive and can be generalised to a wider range due to the manipulation of several independent variables is one experiment.

2.5 LIMITATION OF FACTORIAL DESIGN

Sometime especially when we have more than three independent variables each with three or more levels are to be manipulated together, the experimental setup and statistical analysis become very complicated.

In factorial experiments when the number of treatment combinations or treatments become large, it becomes difficult for the experimenter to select a homogeneous group.

2.6 LET US SUM UP

Factorial designs are employed when one wants to study the independent and joint effect of two or more independent variables. There are different types of interaction such as antagonistic, synergistic and ceiling effect. Factorial designs may be conducted as within subject, between subject or they may be used in mixed experiments that have one within subject and one between subject variable.

2.7 UNIT END QUESTIONS

1) What do you mean by factorial design. Explain with example.
2) Differential with illustration the between group factorial design and within subject factorial design.
3) Discuss the advantage and limitation of factorial design.

4) What do you mean by interaction in factorial design. Discuss various types of interaction.

SAQ ANSWERS :

1) i) F ii) F iii) T iv) T v) T

2) i) antagonistic interaction ii) synergistic interaction
iii) interaction iv) main effect

2.8 GLOSSARY

Factorial design : Research design that involve all combination of at least two values of two or more independent variables.

Main effect : The effect of one independent variable averaged over all levels of another independent variable.

Interaction : When the effect of one independent variable depends on the level of another independent variable.

2.9 SUGGESTED READINGS

McBurney, D.H. & White, T.L. (2007), *"Research Method 7"* Delhi, Thomson Wadsworth.

Kerlinger, F.N. (2007), *"Foundation of Behavioural Research"* (10th reprint), Delhi, Surjeet publications.

Godden A., Baddeley A. (1980), When does context influence recognition memory ? *British Journal of Psychology,* 71, 99-104.

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