UNIT 4 TWO WAY ANALYSIS OF VARIANCE

Structure

4.0 INTRODUCTION

In the preceding unit 3 we have learned about the one way analysis of variance. In this technique, the effect of one independent or one type of treatment was studied on single dependent variable, by taking number of groups from a population or from different population heaving different characteristics. Generally, in one way analysis of variance simple random design is used.

Now, suppose we want to study the effect of two independent variables on a single dependent variable. Further suppose our aim is to study the independent effects of the independent variables as well as their combined or joint effect on the dependent variable. For example a medicine company has developed two types of drugs to get relief from smoking habit. The company wants to know:

1) The independent effect of drug A on smoking behaviour,

2) The independent effect of drug B on smoking behaviour, and

3) The joint or interactional effect of drug A and B i.e. A x B on the smoking behaviour.

Take another example, in a field experiment, a psychologist wants to study effect of type of families on the cognitive development of the children of the age group 3 to 5+ years of age in relation to their sex.

In this field experiment there are two independent variables viz. Type of Family and gender of the Children. The dependent variable is Cognitive Development.

Further the type of family variable has two levels i.e. joint families and nuclear families.

Similarly the gender variable has also two levels viz. boys and girls.

The experimenter wants to study the independent effects of type of family (Joint vs Nuclear) gender (Boys vs Girls) and the interactional effect i.e. joint effect of type of family and gender on the dependent variable viz. Cognitive Development.

Such type of studies related to field experiments or real experiments are known as factorial design of 2 × 2 which indicates there are two independent variables each having two levels.

Like wise there are several situations in which the effect of two or more than two independent variable is studied on a single dependent variable.

In such experimental studies, the one way analysis of variance is not applicable. We have to use two, three or four way of analysis of variance, which depends upon the number of independent variables and their number of levels.

4.1 OBJECTIVES

After completing this unit, you will be able to:

- Define two way analysis of variance;
- Use analysis of variance vertically or column wise and horizontally or row wise;
- Explain the independent effects of two or more than two variables having each two or more than two levels;
- Explain the term interaction effect;
- Analyse the interaction effect of two or more than two variables;
- Differentiate between one way analysis of variance and two way analysis of variance;
- Analyse problems related to field experiments and true experiments where factorial designs are used;
- Explain the interactional effect of two variables on dependent variables; and
- Explain variables graphically.

4.2 TWO WAY ANALYSIS OF VARIANCE

In two way analysis of variance, usually the two independent variables are taken simultaneously. It has two main effects and one interactional or joint effect on dependent variable. In such condition we have to use analysis of variance in two way i.e. vertically as well as horizontally or we have to use ANOVA, column and row wise. To give an example , suppose you are interested to study the intelligence i.e. I.Q. level of boys and girls studying in VIII class in relation to their level of socio economic status (S.E.S.). in such condition you have the following 3 x 2 design.(Refer to table 4.2.1)

Table 4.2.1: SES, Intelligence and Gender factors

Groups	Levels of S.E.S.			
	High	Average	Low	Total
Boys	M_{HB}	M_{AB}	M_{LB}	M_B
Girls	M_{HG}	M_{AG}	M_{LG}	M_G
Total	M_H	M_A	M_L	M

In the table above,

M : Mean of intelligence scores.

M_{HB}, M_{AB}, & M_{LB} : Mean of intelligence scores of boys belonging to different levels of S.E.S. i.e. High, Average & Low respectively.

M_{HG}, M_{AG}, & M_{LG} : Mean of intelligence scores of girls belonging to different levels of S.E.S. respectively.

M_H, M_A, & M_L : Mean of the intelligence scores of students belonging to different levels of S.E.S. respectively.

M_B, M_G : Mean of the intelligence scores of boys and girls respectively.

From the above 3 x 2 contingency table, it is clear, first you have to study the significant difference in the means column wise or vertically, i.e. to compare the intelligence level of the students belonging to different categories of socio-economic status (High, Average and Low).

Second you have to study the significant difference in the means row wise or horizontally, i.e. to compose the intelligence level of the boys and girls.

Then you have to study the interactional or joint effect of sex and socio-economic status on intelligence level i.e. we have to compare the significant difference in the cell means of columns and rows.

Obviously, you have more than two groups, and to study the independent as well as interaction effect of the two variables viz. socio-economic status and sex on dependent variable viz. intelligence in terms of I.Q., you have to use two way analysis of variance i.e. to apply analysis of variance column and row wise.

Therefore, in two way analysis of variance technique, the following type of effects are to be tested:

- Significance of the effect of A variable on D.V.
- Significance of the effect of B variable on A.V.
- Significance of the interaction effect of A x B variables on D.V.

In two way analysis of variance, the format of summary table after applying the analysis of variance is as under-

Table 4.2.2: Summary of two way ANOVA

Source of variance	**df**	**SS**	**MSS**	**F Ratio**
Among the groups				
Between the group A	$k_a - 1$	SS_A	MSS_A	$F_1 = \frac{MSS_A}{MSS_W}$
Between the Group B	$k_b - 1$	SS_B	MSS_B	$F_2 = \frac{MSS_B}{MSS_W}$
Interrelation A x B	$(k_a - 1)(k_b - 1)$	SS_{AxB}	MSS_{AxB}	$F_3 = \frac{MSS_{A\times B}}{MSS_W}$
Within the Groups (Error variance)	$N - k_a - k_b$			
Total	N – 1			

For interpretation of the obtained F ratios, we have to evaluate each F ratio value with the F ratio given in F table (refer to statistics book) keeping in view the corresponding grater and smaller df and the level of confidence. There may be two possibilities.

All the obtained F ratios may be found insignificant even at .05 level. This shows that there is no independent (i.e. individual) as well as interaction (i.e. joint) effect of the two independent variables on dependent variable. Hence null hypothesis will retain. There is no need to do further calculations.

All the three obtained F ratio's may be found significant either at .05 level of significance or at .01 level of significance. This shows that there is a significant independent (i.e. individual) as well as interactional (i.e. joint) effect of the independent variables on the dependent variable. Therefore the null hypothesis is rejected. In such condition if the two independent variables have more than two levels i.e. three or four, we have to go for further calculations and use post-hoc comparisons by finding out various 't' values by pairing the groups.

Similarly the significant interactional effect will also be studied further by applying 't' test of significance or by applying graphical method.

At least one or two obtained F ratio will be found significant either at .05 level of significance or at .01 level of significance. Thus the null hypothesis may partially be retained. In such condition too we have to do further calculations, by making post-hoc comparisons and use 't' test of significance, if the independent variables have more than two levels.

For more clarification, go through the following illustration carefully.

Example 1

A researcher wanted to study the effect of anxiety and types of personality (Extroverts and Introverts) on the academic achievement of the undergraduate students. For the purpose, he has taken a sample of 20 undergraduates by using random method of sample selection. He administered related test and found following observations in relation to the academic achievement of the students.

Level of Anxiety

	Groups	High anxiety	Low anxiety
Type of Personality	Extroverts	12 13 14 15 14	14 14 13 15 15
	Introverts	14 16 16 16 15	11 10 12 12 16

Determine the independent as well as interactional effect of anxiety and types of personality on the academic achievement of the undergraduates.

Solutions:

Given

Two independent variables

a) type of personality having two levels viz. extroverts and introverts

b) Anxiety it has also two level viz. high anxiety and low anxiety.

Dependent variable scores

Academic achievement scores.

Number of groups i.e. k = 4.

Number of units in each cell i.e. n = 5.

Total no. of units i.e. N = 20.

To find out :

Independent effect of type of personality and anxiety on the academic achievement of the students.

Interactional i.e. joint effect of anxiety and type of personality on academic achievement of the students.

Therefore

H_0 : "There is no significant effect of types of personality and level of anxiety on academic achievement."

For convenience, the given 2 x 2 table is rearranged as under:

Table 4.2.3

S.N.	Extroverts				Introverts			
	High Anxiety		Low Anxiety		High Anxiety		Low Anxiety	
	X_1	X_1^2	X_2	X_2^2	X_3	X_3^2	X_4	X_4^2
1	12	144	14	196	14	196	11	121
2	13	169	14	196	16	256	10	100
3	14	196	13	169	16	256	12	144
4	15	225	15	225	16	256	12	144
5	14	196	15	225	15	225	16	256
Sums	68	930	71	1011	77	1189	61	765
N	5		5		5		5	
M	13.60		14.20		15.40		12.20	

Step 1 : Correction Term Cx = $\frac{\left(\sum x^2\right)}{N}$

$$= \frac{(68+71+77+61)^2}{20} = \frac{(277)^2}{20}$$

= 3836.45

Step 2 : Sum of Squares of Total $SS_T = \sum x^2 - Cx$

= 930+1011+1189+765 – 3836.45

= 58.55

Step 3 : Sum of Squares Among the Groups

$$SS_A = \sum \frac{\left(\sum x\right)^2}{n} - Cx$$

$$= \frac{(68)^2}{5} + \frac{(71)^2}{5} + \frac{(77)^2}{5} + \frac{(61)^2}{5} = 3836.45$$

= 26.55

Step 4 : Sum of squares Between the A Groups (i.e. between types of personality)

$$SS_{BTP} = \frac{(\sum x_1 + \sum x_2)^2}{n_1 + n_2} + \frac{(\sum x_3 + \sum x_4)^2}{n_3 + n_4} - Cx$$

= 3836.50 – 3836.45

= .05

Step 5 : Sum of squares Between the B Groups (i.e. Between level of Anxiety)

$$SS_{Anx} = \frac{(\sum x_1 + \sum x_2)^2}{n_1 + n_2} + \frac{(\sum x_3 + \sum x_4)^2}{n_3 + n_4} - Cx$$

$$= \frac{(68+77)^2}{5+5} + \frac{(71+61)^2}{5+5} - 3836.45$$

= 8.45

Step 6 : Sum of squares of Interaction

$$SS_{AxB} = SS_A - SS_{BTP} - SS_{BAnx}$$

i.e. SS_{AxB} = Sum of squares Among the Groups – Sum of Squares Between Type of Personality – Sum of Squares Between Anxiety Levels.

$$SS_{AxB} = 26.55 - 0.05 - 8.45$$

$$= 18.05$$

Step 7 : Sum of Squares Within the Groups

$$SS_W = SS_T - SS_A - SS_B$$

$$= 58.55 - 26.55$$

$$= 32.00$$

Step 8 : Preparation of Result of Summary Table

Table 4.2.4 : Summary of Two-way ANOVA

Source of variance	df	Sum of Squares (SS)	Mean SS (MSS)	F Ratio
Among the Groups	(k-1) (4-1=3)	(26.55)	$\frac{SS_A}{df} = \frac{26.55}{3} = 8.85$	$\frac{8.85}{2} = 4.425$
Between the Groups- SS_{B_1} (Types of personality)	(k_1-1) 2 – 1 = 1	0.05	$\frac{SS_{B_1}}{df} = \frac{.05}{1} = .05$	$\frac{.05}{2} = .025$
SS_{B_2} (Anxiety levels)	(k_2-1) 2 – 1 = 1	8.45	$\frac{SS_{B_2}}{df} = \frac{8.45}{1} = 8.45$	$\frac{8.45}{2} = 4.225$
SS_{AxB}	$(k_1-1)(k_2-1)$ 1 x 1 = 1	18.05	$\frac{SS_{B_1} \times SS_{B_2}}{df} = \frac{18.05}{1} = 18.05$	$\frac{18.05}{2} = 9.025$
Within the Groups	(N-k) 20 – 4 = 16	32.00	$\frac{SS_W}{df} = \frac{32}{16} = 2$	
Total	19			

In the F table (refer to statistics book) for 1 and 6 df, the F value at .01 and .05 level are 8.86 and 4.60 respectively.

Our calculated F values for type of personality and anxiety are smaller than the table F value 4.60.

Therefore the obtained F ratio values are not significant even at .05 level of significance. Hence the null hypotheses is in relation to Type of Personality and Anxiety are retained.

In case of interaction effect the obtained F ratio value 9.025 is found higher than the F value given in table at .01 level of significance. Thus the F for interaction effect is significant at .01 level. Hence, null hypothesis for interaction effect is rejected.

Interpretation of the Results

Since our null hypotheses are accepted at .05 and .01 level of significance, for type of personality, therefore it can be said that there is no independent as well as interactional effect of Types of Personality and levels of Anxiety on the academic achievement of the students. In other words it can be said that the students who are either Extroverts or Introverts are equally good in their academic performance.

Similarly, the anxiety level of the students do not cause any significant variation in the academic achievement of the students.

But the students having different type of personality and have different level of anxiety, their academic achievement varies in 99% cases. From the mean values in the table 4.2.3 it is evident that the students who are Extroverts and have low level of anxiety are comparatively good in their academic achievement (M = 14.20).

In the case of Introverts those who have high level of anxiety are better in their academic achievement (M = 15.40) in comparison to others.

Example 2

In a study, effect of intelligence and sex on the mathematical creativity a group of 40 students (20 boys and 20 girls) was selected from a population of high school going students by using random method of sample selection. A test of intelligence and mathematics creativity was administrated to them. The observations obtained are given below. Determine the independent as well as interactional effect of sex and Intelligence on the mathematical creativity of the high school going students.

Table 4.2.5: Observations obtained on the mathematical creativity test

Groups	Boys	Girls
High Intelligent	15 15 15 12 13 15 16 16 16 20	14 13 13 15 15 13 13 14 15 14
Low Intelligent	15 14 12 13 15 14 15 14 13 12	10 12 10 13 13 10 11 12 10 10
Total units	20	20

Solution:

Given :

Two independent variables A- Sex, B- Intelligence. Each having 2 levels.

Dependent variable : Mathematical Creativity

Number of Groups k = 4

Number of cases in each group n = 10

Total number of units in the group N = 40

To find out : i) Independent effect of intelligence and sex on mathematical creativity.

ii) Interactional effect of intelligence and sex on mathematical creativity.

H_0 : There is no significant independent as well as interactional effect of Intelligence and Sex on the mathematical creativity of the students.

Therefore.

Table 4.2.6

Groups	Boys (A1)				Girls (A2)			
S.No.	High Intelligence (B1)		Low Intelligence (B2)		High Intelligence (B1)		Low Intelligence (B2)	
	X1	X2	X1	X2	X1	X2	X1	X2
1	15	225	15	225	14	196	10	100
2	15	225	14	196	13	169	12	144
3	15	225	12	144	13	169	10	100
4	12	144	13	169	15	225	13	169
5	13	169	15	225	15	225	13	169
6	15	225	14	196	13	169	10	100
7	16	256	15	225	13	169	11	121
8	16	256	14	196	14	196	12	144
9	16	256	13	169	15	225	10	100
10	20	400	12	144	14	196	10	100
Sum	153	2381	137	1889	139	1939	111	1247
n	10		10		10		10	
Mean	15.30		13.70		13.90		11.10	

Step 1 : Correction Term = Cx = $\frac{\Sigma(x)^2}{N} = \frac{(153+137+139+111)^2}{40}$

= 7290.00

Step 2 : Sum of Squares of total SS_T = $\sum x^2 - Cx$

= (2381+1889+1939+1247) – 7290

= 166.00

Step 3 : Sum of Squares Among groups SS_A = $\Sigma\frac{\Sigma(x)^2}{N} - Cx$

$$= \left(\frac{(153)^2}{10} + \frac{(137)^2}{10} + \frac{(139)^2}{10} + \frac{(111)^2}{10}\right) - 7290.00$$

= 92

Step 4 : Sum of squares Between the Groups (Sex)

$$SS_{BSex} = \frac{(\Sigma x_1 + \Sigma x_2)^2}{n_1 + n_2} + \frac{(\Sigma x_3 + \Sigma x_4)^2}{n_3 + n_4} - Cx$$

$$= \frac{(153+137)^2}{20} + \frac{(139+111)^2}{20} - 7290$$

= 40.00

Step 5 : Sum of squares Between the Groups (Intelligence)

$$SS_{BInt} = \frac{(\Sigma x_1 + \Sigma x_2)^2}{n_1 + n_2} + \frac{(\Sigma x_3 + \Sigma x_4)^2}{n_3 + n_4} - Cx$$

$$= \frac{(153+139)^2}{10+10} + \frac{(137+111)^2}{10+10} - 7290.00$$

= 48.40

Step 6 : Sum of squares Between the Interactions (Sex x Intelligence)

$$SS_{BSex \times Int} = SS_A - SS_{BSex} - SS_{BInt}$$

$= 3.60$

Step 7 : Sum of Squares within the Groups

$$SS_W = SS_T - SS_A$$

$= 166 - 92$

$= 74.00$

Step 8 : Preparation of Summary Table / Result table

Table 4.2.7 : Summary of Analysis of Variance

Source of variance	df	Sum of Squares SS	Mean SS MSS	F Ratio
1) Among the Groups	(k-1) 4-1=3	(92)	(30.67)	(14.88)
2) Between the Groups i) $SS_{B_{Sex}}$	(k_1-1) 2-1=1	40.00	40.00	19.42
ii) $SS_{B_{Int.}}$	(k_2-1) 2-1=1	48.40	48.40	23.49
iii) $SS_{B_{Sex \times Int.}}$	1x1=1	3.60	3.60	1.75
3.Within the Groups (Error variance)	(N-k) 40-4=36	74.00	2.06	
Total	39			

From F table, the value of $F_{.05}$ for 1 and 36 df = 4.12 and $F_{.01}$ for 1 and 36 df = 7.42

Interpretation of the Results:

Independent Effects

Sex : From the ANOVA summary table the F ratio value for Sex is found 19.42, which is high in comparison to the F value given in F table for 1 and 36 df. Therefore F ratio for Sex variable is found significant at .01 level. Hence null hypothesis is rejected. In conclusion it can be said that in 99% cases, the boys are high in mathematical creativity in comparison to the girls. There are only 1% chance that the girls are better in mathematical creativity than the boys.

Intelligence: From the ANOVA summary table the F ratio value for intelligence is found 23.49, which is also significant at .01 level for 1 and 36 df. Thus the null hypothesis is rejected at .01 level of confidence.

Therefore, in 99% cases the high intelligent high school going students are high in their mathematical creativity in comparison to the low intelligent students. Only in 1 case out of 100, the low intelligent high school going students are high in mathematical creativity.

Interactional Effect

From the ANOVA summary table it is evident that the F ratio for interactional effect is found insignificant even at .05 level of significance for 1 and 36 df. Thus the null hypothesis is accepted.

Therefore, the joint effect of sex and intelligence do not cause any significant variation in the scores of mathematical creativity. In other words both boys and girls who are high in their intelligence are equally good in their mathematical creativity.

Similarly the low intelligent boys and girls also do not differ in their mathematical creativity. In the group of boys the high intelligent and low intelligent high school going students also do not differ in their mathematical creativity. Similarly in the group of girls, the high intelligent and low intelligent girls are also do not differ significantly in their mathematical creativity. This fact is also confirmed from the following Figure A and B.

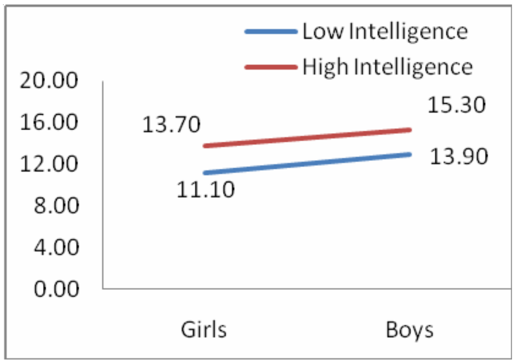

Fig. 4.2.1(A)

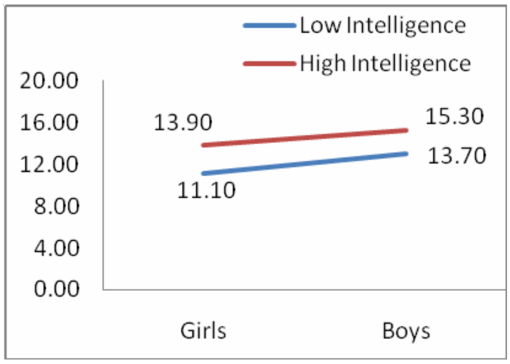

Fig. 4.2.1(B)

The two figures 4.2.1 (A) and 4.2.1 (B) both are showing two parallel lines. Which indicates that there is no interaction effect of sex and intelligence on the mathematical creativity of the high school going students.

Self Assessment Questions

1) What is the difference between one way analysis of variance and two way analysis of variance?

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2) When we use two way analysis of variance?

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3) In two way analysis of variance how many effects are tested.

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4) What indicates $K_{(a)}$, $K_{(b)}$ and $K_{(c)}$

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5) What is meant by df_1 and df_2?

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6) In what way we decide the significance of F ratio obtained in relation to various effects?

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7) What do you mean by

2 x 2 Level design

3 x 3 Level design

2 x 4 Level design

3 x 3 Level design

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4.3 INTERACTIONAL EFFECT

In the foregoing discussion we have frequently used the term "interaction" or "interactional effect" therefore it is essential to clarify the same.

In the two way analysis of variance, the consideration and interpretation of the interaction of variables or factors become important. Without considering the interaction between the different variables in a study, there is no use of two way or three way analysis of variance.

The interactions may be between two or more than two independent variables and its effect is measured on the dependent variable or the criterion variable. The need to know interaction effect on criterion variable or dependent variable is to know the combined effect of two or more than two independent variables on the criterion variable.

The reason, suppose there are two independent variables A & B and each has their own significance to create high variations in the criterion or dependent variable, but their joint or combined effect may cause very high, or low or their nullified effect on the dependent variable or criterion variable.

To have more clear idea let us suppose we have two types of fertilizers e.g. Urea and Phosphate. These have their own importance in the growth of the corps independently. But when we use the two chemical fertilizers in combined way with proper ratio, it might be possible, the growth of crops may be increased tremendously. Or it might be possible, the growth of crops may go down.

In the field of psychology and education suppose a treatment or a method of teaching A has its own significance to increase the level of achievement in a school subject, similarly the treatment B or a teaching method B is also good for encouraging results in academic achievement. But when we use the two methods of teaching jointly or give two treatments in combination we may get more encouraging results in academic achievement, or we do not have any significant effect on the achievement of the learners.

In the illustration-2, presented in this unit, compare the mean values, which we have shown in each cell in table 4.2.6. for convenience we are taking the same values here and presenting in the following 2 x 2 table.

Table 4.3.1

Intelligence	Boys M_1	Girls M_2	Total Mean
High	15.30	13.90	14.60
Low	13.70	11.10	12.40
Total Mean	14.50	12.50	13.50

In the above table, if we compare the total mean of first and second column, it is quite clear that there is a difference in the mean values of boys and girls and the higher mean is in the favour of boys. This is an independent effect of sex on mathematical creativity.

Similarly if we compare the total means of two rows we find, there is a difference in the means of high intelligent and low intelligent students and higher mean is in favour of the high intelligent group. It is actually the independent effect of intelligence on mathematical creativity.

Further in the above table 4.3.1, sex effects for boys and girls are

(14.50-13.50) = 1 and (12.50 – 13.50) = -1 respectively. If we subtract the first effect 1, from all averages in the first row and add 1 to all the averages in the second row, we have the following table:

Table 4.3.2: Sex factor

Groups	Boys	Girls	Total M
High Intelligence	14.30	12.90	13.60
Low Intelligence	14.70	12.10	13.40
Total Mean	14.50	12.50	13.50

Similarly in table 4.3.1 we subtract 1 from first column and add to the second column we have the following table:

Table 4.3.3: Sex factor

Groups	Boys	Girls	Total M
High Intelligence	14.30	12.90	14.60
Low Intelligence	14.70	12.10	12.40
Total M	13.50	13.50	13.50

Table 4.3.2 and table 4.3.3 give the intersectional resultant average, which show the direction of interaction and also indicates that there is no interaction effect of the A and B independent variable on dependent variable. In such condition if we plot the graph between the two independent variables we have approximately two parallel lines, as we have seen in the graphical presentation (see fig. 4.2.1 A and 4.2.1 B) respectively.

If there is a significant interactional effect of the two or more independent variables on the dependent variables; in such condition the graphical representation of the interactional effect will show two lines which are interacting at a point. For example, in example 1 the interactional effect of type of personality and anxiety is found significant at .01 level. If we draw the graph for interaction effect of Type of Personality and Level of Anxiety by considering the mean values of academic achievement, the obtained graph will be as under. (table 4.3.4. and graphs figures 4.3.1. A and B)

Table 4.3.4: the mean values of Extroverts and Introverts having high and low level of anxiety

Groups	Extroverts M1	Introverts M2	Total Mean
High Anxiety	13.60	15.40	14.50
Low Anxiety	14.20	12.20	13.20
Total Mean	13.90	13.80	13.85

(Mean values from table 4.2.3)

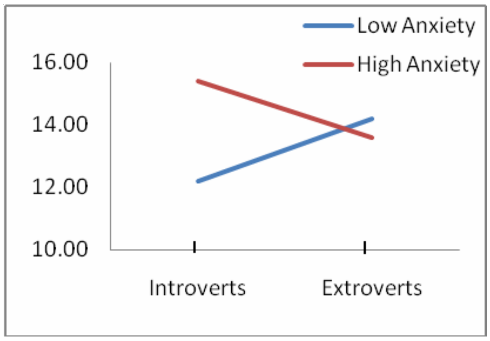

Fig. 4.3.1 (A)

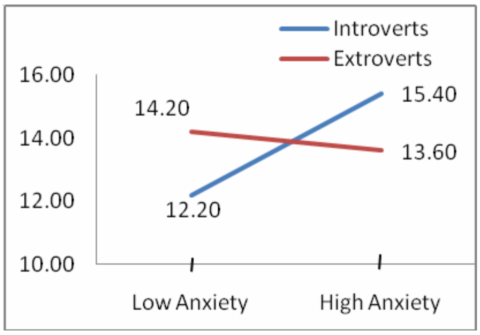

Fig. 4.3.1 (B)

4.4 MERITS AND DEMERITS OF TWO WAY ANOVA

4.4.1 Merits of Two Way Analysis of Variance

The following are the advantages of two way analysis of variance-

- This technique is used to analyse two types of effects viz. main effects and Interaction Effects.
- More than two factors effects are analysed by this technique.
- For analysing the data obtained on the basis of factorial designs, this technique is used.
- This technique is used to analyse the data for complex experimental studies.

4.4.2 Demerits or Limitations of Two Way ANOVA

The following limitations are found in this technique:

- When there are more than two classification of a factor or factors of study. F ratio value provides global picture of difference among the main treatment effects. The inference can be specified by using 't' test in case when F ratio is found significant for a treatment.
- This technique also follows the assumptions on which one way analysis of variance is based. If these assumptions are not fulfilled, the use of this technique may give us spurious results.
- This technique is difficult and time consuming.
- As the number of factors are increased in a study, the complexity of analysis in increased and interpretation of results become difficult.
- This technique requires high level arithmetical and calculative ability. Similarly it also requires high level of imaginative and logical ability to interpret the obtained results.

4.5 LET US SUM UP

The two way analysis of variance is a very important parametric technique of inferential statistics. It helps in taking concrete decisions about the effect of various treatments on criterion or dependent variable independently and jointly.

The independent effect of a variable on treatment means the direct or isolate effect of it on the dependent or criterion variable.

The interactional effect means joint effect of the two or more variables acting together on a dependent or criterion variables.

In case of insignificant interactional effect of the two or more predictors or independent variables on a criterion or dependable variable. The graphical representation will show the parallel lines, when the interactional effect is significant, its graphical representation will show the two crossed lines.

The two way analysis variance is a useful technique in experimental psychology as well as in experimental education especially in the field of teaching and learning. It is frequently used in field experiments or true experiments, when we use factorial designs specifically.

Interaction variance might be more reasonably expected in a combination of teacher and instruction method, of kind of task and method of attack by the learner, and of kind of reward when combined with a certain condition of motivation.

4.6 UNIT END QUESTIONS

1) What do you mean by Two-way Analysis of Variance.?
2) What is the difference between one way and two way ANOVA?
3) Indicate the graphical presentation of interaction effects?
4) Highlight the advantages and limitations of two way analysis of variance.
5) From the following hypothetical data, (Table below) determine-Which teaching method is effective than others. Also, Which teacher is contributing effectively in the learning outputs of the learners.
6) How far the joint effect of teaching method and the teacher is contributing in the learning performance of the students.

Teaching Methods

Teacher	A	B	C
T_1	10 7 6 10 4	3 3 3 3 3	10 11 10 5 6
T_2	3 1 8 9 2	3 3 3 3 3	8 9 12 9 10

Four groups of 8 students each having an equal number of boys and girls were selected randomly and assigned to different four conditions of an experiment. Test main effects due to conditions and sex and the interaction of the two conditions

Graphs	I	II	III	IV
Boys	7	9	12	12
	0	4	6	14
	5	5	10	9
	8	6	6	5
Girls	3	4	3	6
	3	7	7	7
	2	5	4	6
	0	2	6	5

7) In 4 × 3 factorial design 5 subjects are assigned randomly in each graph of 12 cells.

The following data obtained at the end of the experiment

Level of Intelligence	Method of Teaching			
	M1	M2	M3	M4
High (L_1)	6	8	7	9
	2	3	6	6
	4	7	9	8
	2	5	8	8
	6	2	5	9
Average (L_2)	4	6	9	7
	1	6	4	8
	5	2	8	4
	2	3	4	7
	3	6	8	4
Low (L_3)	4	3	6	6
	2	1	4	5
	1	1	3	7
	1	2	8	9
	2	3	4	8

Test the significance difference of difference of main effects and interaction effects.

4.7 SUGGESTED READINGS

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