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Effect of Using Parametric Multiple Comparison Tests After Non-Parametric Tests on Type I Error Rate and Power of Test

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Abstract: This study was conducted to investigate the effect of using parametric multiple comparison tests (e.g. Duncan test) after Kruskal-Wallis test on type I error rate and test power. Results of simulation study showed that Kruskal-Wallis tests are nonparametric alternative of one-way analysis of variance especially when normality assumption is not satisfied. Research showed that parametric multiple comparison tests can be used then the non-parametric tests. For this propose; Duncan Method (DUNNR) is used instead of Nonparametric Dunn's method (DUNN) after Kruskal-Wallis (H) test. Random numbers from N (0,1), χ^2 (3), β (5,3) distributions were generated; with the various sample sizes (n=3, 5, 7, 10, 15, 30), group numbers (k=3, 4, 5) and the different variance ratios (σ^2=1:1:1, 1:1:4, 1:1:10) in this study, The aim of study was determination of the possibility of use parametric pair wise multiple comparison; by determination of type I error and power of tests instead of no-parametric pair wise multiple comparison tests can be used.

Keywords: Pairwise multiple comparision tests, Dunn .test, Duncan test, Type I error rate, Similation.

INTRODUCTION

Analysis of Variance (ANOVA, F test) known as a statistical method, which using in practice commonly and simply.

ANOVA were used for two or more factors in model. ANOVA can be determined by the statically significant between the group means ($H_0 : \mu_1 = \mu_2 = ... = \mu_k$). Which means were statically significant, we need to use multiple comparison tests.

When the some assumptions of ANOVA (normality and variance homogeneity) executed, ANOVA could be used. These were important for the results reliability and type I error rate **(** α **).** If the assumptions were violated, we used transformation or other non-parametric methods (Kruskal-Wallis, Man-Whitney U Test etc.). Like these methods, we can be used Welch, Brown-Forsyth, Bootstrap, Permutation tests or Resembling methods [1, 2].
Group medians were used for comparisions in non parametric methods. If difference between the group medians were statisticly important, non-parametric multiple comparison tests can be used. Parametric multiple comparison tests can be using after the non-parametric tests.

Type I Error Rate (α)

After the hypothesis control, when H_0 is rejected and actually true that caused type I error (α). Possibilty of α must have been as small as possible for increasing the validity of obtained results. Furthermore sample size, variance and effect size were so important for results of hypothesis control. α is estimated at the beginning of the experiment or calculated at the end particularly simulations [3-5]. There is a balance between the α and power of test. When All other effects are fixed, α decreasing power of test is reduced [5, 6].

Power of Tests (1-β)

After the hypothesis control, when H_0 is not rejected but actually false that caused type II error rate (β). $(1-\beta)$ is named Power of Test. When H_0 is actually false, H_0 was rejected.

In literature when power of test is bigger than 0.80, this could be said strong. For this reason β is 0.20 (1-0.80) [5, 6].

Parametric and Non-Parametric Multiple Comparison Tests

Duncan Method

Multiple range test was submitted by Duncan [7], for comparing all possible pair wise comparison. This method considered size of means and ranks [8-11].

Duncan Method (D),

$D = Q.(s_{\bar{X}})$ can be calculated this equation.

$s_{\bar{X}}$: Standard error and equal to $\sqrt{\frac{MSE}{n}}$. MSE; mean square error which calculated with ANOVA table, n; number of observations and Q : Duncan table value with degrees of freedom MSE (Duncan 1955). This value considered the size of groups.

The whole procedure of testing differences is as follows:

- F test (H_0 : $\mu_1 = ... = \mu_k$, H_1 : $\mu_i \neq \mu_j$ for at least one pair i and j)
- If H_0 is rejected then the D_i' is calculated.
- All means ranked for all pairs i and j. Conclude $\mu_i \neq \mu_j$ if $\left|\bar{X}_i - \bar{X}_j\right| \geq D_i$

Nonparametric Bonferroni Method (Nonparametric Dunn's Method)

Nonparametric Dunn's Method can be used after the Kruskal Wallis H test and H_0 is rejected. After that, which group medians were different from each other, can be calculated. Means of group ranks compared. If the sample sizes are small, this method is powerfull [3].

Bonferroni Method,

$$z'_{ij} = \frac{\frac{R_i}{n_i} - \frac{R_j}{n_j}}{\sqrt{\frac{N(N+1)}{12}\left(\frac{1}{n_i} + \frac{1}{n_j}\right)}} = \frac{\bar{R}_i - \bar{R}_j}{\sqrt{\frac{N(N+1)}{12}\left(\frac{1}{n_i} + \frac{1}{n_j}\right)}}, \quad N = \sum_{i=1}^{k} n_i$$

In this equation;

$\bar{R}_i$; rank means of i . group, , $\bar{R}_j$; rank means of j . group, n_j ; obsevation in group j , N ; all observation and ($N = \sum_{i=1}^{k} n_i$, $i = 1, 2, ..., k$), z_{ij} is calculated for α_F (family eror rate) from group number k .

MATERİALS AND METHODS

Material

Random numbers, were generated from Z (0,1), χ^2 (3) ve β (5,3) populations, compose the material of this study. In producing random numbers, Fortran Power Station Developer Studio's IMSL library used [12]. For this purpose, RNNOA, RNCHI and RNBET functions of IMSL library were used. In the study, programs written by different programming language; among the populations which have different variance and distributions, groups are composed by taking random samples in various sample width and F statistics was reckoned. As a result of variance analysis made according to this, if the difference between the group averages seems important, multiple comparison test is made concerning Duncan method. H statistics is estimated by giving sequence values to the same observation values. If it is determined that there is a difference between median values (median) multiple comparison test is made concerning nonparametric Bonferroni Method (Nonparametric Dunn's method. Afterwards, among the parametric multiple comparison tests Duncan multiple comparison method is introduced by being used of rank averages. We considered both homogeneity, for each group (1:1:1) and heterogeneity (1:1:4 and 1:1:10) of the variances on type-I error rates. After necessary standardizations are made, type 1 error (α) and the power of the test $(1-\beta)$ are estimated empirically [12]. In Table 3.1, group numbers (k), observation numbers (n), related distributions (σ^2) and test numbers are shown.

Table-3.1: Considered Test Conditions

Group	Distribution Type	Sample Size	Effect Size(Δ)	Homogeneity
3	N (0,1), χ^2 (3), β(5,3)	3, 5, 7, 10, 15, 30	0.50, 1.00	1:1:1, 1:1:4, 1:1:10
4	N (0,1), χ^2 (3), β(5,3)	3, 5, 7, 10, 15, 30	0.50, 1.00	1:1:1:1, 1:1:1:4, 1:1:1:10
5	N (0,1), χ^2 (3), β(5,3)	3, 5, 7, 10, 15, 30	0.50, 1.00	1:1:1:1:1, 1:1:1:1:4, 1:1:1:1:10

In the study, samples are taken from the populations Z (0,1), and (β (5,2), χ^2 (3)) which doesn't show normal distribution. These distributions are shown in the figure 3.1.-3.3.

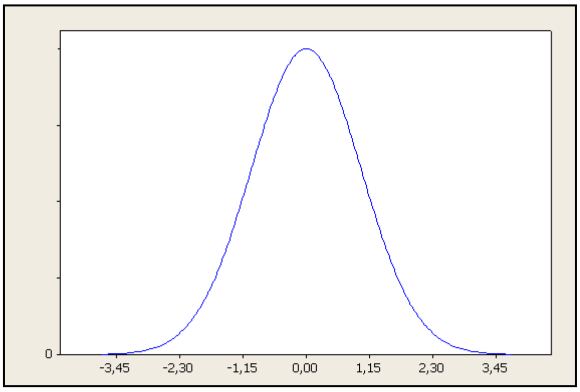

Fig-3.1: Standart Normal Distribution (Z (0, 1)

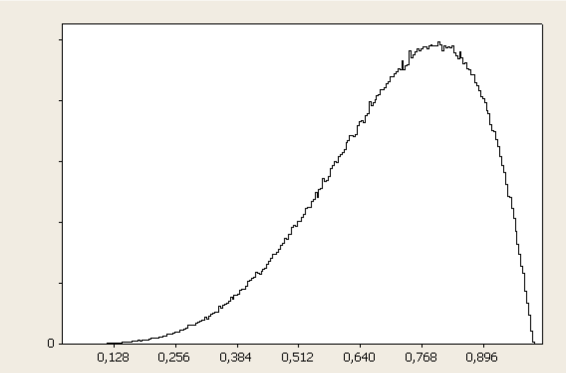

Fig-3.2: Beta Distribution (β (5, 3)

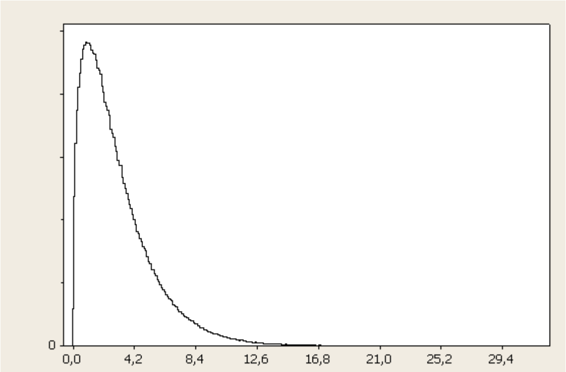

Fig-3.3: Chi-Square Distribution(χ^2 (3))

By standardizing random numbers which are produced concerning the related parameters and belonged to different distributions by $X_i = \frac{y_i - \mu_y}{\sigma_y}$ their means are provided (0) and their variances (1).

Method

After necessary standardizations are made by producing necessary numbers, by following process steps above type I error rate and the power of the test are tried to be estimated [13, 14].

1) $F = \frac{GAKO}{G\dot{I}KO}$ statistic is estimated,

2) If the difference is important,

$$S_{\bar{X}} = \sqrt{\frac{G\dot{I}KO}{n}} \text{ and } \left|\bar{X}_i - \bar{X}_j\right| = D_{(0,05;k,HSD)}.S_{\bar{X}}$$

By using these formulas, comparisons are made regarding Duncan method (D); type I error and the power of the test are estimated,

3) Same observation values are ordered and ranks and rank averages are reached,

4) H statistics is estimated by means of equivalent below.

$$H = \frac{12}{N(N+1)} \sum_{i=1}^{k} X_i^2 \left[\frac{(\sum R_i)^2}{n_i} \right] - 3(N+1)$$

5) If the difference between the median values of the groups are considerable

$$z_{adj} = \frac{0,05}{k(k-1)} \text{ and } z_{adj} \le \frac{\left|\bar{R}_i - \bar{R}_j\right|}{\sqrt{\frac{N(N+1)}{12}.\left(\frac{1}{n_i} + \frac{1}{n_j}\right)}}$$

By being used these formulas comparisons are made by means of Nonparametric Bonferroni Method (Nonparametric Dunn's method; DUNN) Type I error and the power of the test are estimated [13, 15].

6) By the same way, If the difference between the median values of the groups are considerable comparisons are made by being used formula below. In other words, Duncan multiple comparison method is used while rank averages are compared. Type I error and the power of the test are estimated.

(BONFERRONI-DUNN=DUNNR)

$$\left|\bar{R}_i - \bar{R}_j\right| = D_{(0,05;k,HSD)}.S_{\bar{X}}$$

RESULTS

Results related with Type I error rates

Type I error rate which happens empirically related with DUNN, DUNNR and D tests, are given procession ally in Table 4.1. – Table 4.9.

Type I Error Rate While k=3

It is observed that in all equal volume groups the variances of which are withdrawn from homogeneous populations, whatever the distribution types of populations are DUNN, DUNNR and D have type I error rate close to each other. Besides the more sample width increases the more type I error rate close to 0.05. At the same time, type I error rates which are obtained as a result of DUNNR is much more close to 0.05 compared with DUNN and D. For example, in the event of a condition in which sample width is 30, distribution is β(5,3), type I error rate obtained from the result of DUNN as %4.98.

In the case of being heterogeneous of variances whatever the distribution type is the possibility of Type I Error increases [16]. If it is necessary to be careful, in the event of being curve of the population distribution type it is observed that possibility of Type I Error becomes distant from 0,05 remarkably. Possibility of Type I Error which is observed empirically in the result of DUNN is estimated fairly more bigger than compared with the results of DUNN and D.

Type I Error Rate While k=4

In the aspect of each three comparison tests which are introduced while variances are homogeneous, increasing the number of groups from 3 to 4 does not affect the possibility of Type I Error. In the case that the group number is four, type I error rate resulted from DUNNR is estimated more close to 0.05 compared to DUNN and D tests. This condition becomes more noticeable by being increased of the sample widths [16, 17].

In the event that the group variances become heterogeneous, type I error rate which happen in each three tests increase. In this situation, Test D compared with DUNN and DUNNR tests, it is observed that more close values to 0.05 are obtained while sample width increases.

Type I Error Rate While k=5

In the event that the group number is five, as long as the variances are homogeneous Type I Error Rate which happens as a result of DUNN, DUNNR and D tests are more close to 0.05 compared with four groups. This condition becomes more remarkable (n=15, n=30) by increasing the sample width [16, 17]. For example, in the case that variances are homogeneous, distribution; β (5,3) and the sample width; n=30 Type I Error Rate which happens for DUNN, DUNNR and D are estimated %3.39, %5.05 and %5.00 respectively. Variances are homogeneous, whatever the distribution type it is observed that while Type I Error Rate which happens as a result of DUNNR and D tests become more close to 0.05 Type I Error Rate which happens as a result of DUNN test become lower.

In the event that the variances become heterogeneous D test gives much more close results to 0.05 compared with DUNNR and D tests. This situation becomes more remarkable in the case of increasing the sample width and the variance rates being 1:1:10.

Increase in variance rates, scaling the group number to 5, affect Type I Error Possibility more positively compared to the situation that the groups are three and four and more close values to 0.05 are obtained.

Comparisons of the obtained results in the aspect of Power of Test

Power of test of DUNN, DUNNR and D tests which happen empirically regarding testing conditions are presented in Table 4.1. – Table 4.9. While the topic is evaluated, among the influence quantities only (Δ=0.50, 1.00 and 1.50) becomes Δ=1.00 is regarded. Because in practice the situation being Δ=1.00 is encountered more.

Power of Test While k=3

It is observed that DUNN, DUNNR and D tests have much close power ratings with each other when three groups and variances being homogeneous are compared. In the event of increasing sample width, remarkably good power ratings for each test are estimated. For example, In the case that the sample width=30 and variance rates 1:1:1, power ratings reach ratings such as %97.00-%99.00.Under these circumstances, becoming distant of distribution type balancing does not affect power ratings. At the same time it is observed that power of test resulted from DUNNR test become bigger compared with DUNN and D tests.

Being heterogeneous of variances; especially in the case that variance rates are 1:1:10 affects the power ratings of each three tests negatively. However, in the event that the distribution is symmetrical N (0,1), increasing the sample width n=30 obtained power ratings give better results compared with other results. It is observed that in $\chi 2$ (3) distribution it becomes %8.69-9.91, β(5,3) %21.39-23.72 in the event that it becomes N(0,1) higher power of test such as %32.18-35.04 are observed.

In the case of scaling of the group numbers, observation numbers also increase naturally. In the case that group numbers are four and five, power tests are are higher compared with three groups [16, 17].

Table-4.1: Estimated Type I Error Rate and Power of Test by Samples Obtained from k=3 and χ2 (3) Distribution

		Δ=0			Δ= 0.50			Δ= 1.00		
	Test	1:1:1	1:1:4	1:1:10	1:1:1	1:1:4	1:1:10	1:1:1	1:1:4	1:1:10
n=3	DUNN	1.12	2.24	3.26	1.87	1.54	2.50	4.23	2.20	2.42
	DUNNR	1.12	2.23	3.20	1.87	1.52	2.40	4.23	2.17	2.27
	D	1.03	2.11	3.14	1.76	1.42	2.33	4.08	1.35	2.17
n=5	DUNN	3.37	6.03	7.65	9.76	4.55	5.75	29.03	9.22	5.46
	DUNNR	4.21	7.09	8.64	11.96	5.48	6.64	33.76	11.06	6.48
	D	3.59	6.54	8.28	10.70	4.90	6.21	31.37	10.13	5.91
n=7	DUNN	3.66	6.59	8.95	14.05	4.59	5.85	46.76	12.64	5.96
	DUNNR	4.72	7.90	10.71	16.46	5.45	7.12	51.93	14.60	7.08
	D	3.85	6.45	8.34	14.62	4.82	5.65	47.82	13.86	6.23
n=10	DUNN	3.78	8.00	10.70	21.35	4.75	5.93	68.83	17.33	6.35
	DUNNR	4.59	9.42	12.40	24.55	5.70	7.00	73.43	19.97	7.51
	D	3.91	6.87	8.42	20.94	4.94	4.93	66.95	19.34	6.62
n=15	DUNN	3.99	9.80	14.07	35.28	5.56	6.45	89.35	26.15	7.21
	DUNNR	4.72	11.11	15.89	38.64	6.40	7.45	91.45	28.90	8.35
	D	3.99	6.72	8.57	31.93	5.55	4.22	85.50	28.39	7.28
n=30	DUNN	4.15	15.93	22.49	67.91	6.55	7.44	98.80	50.37	8.69
	DUNNR	4.89	17.74	24.82	71.53	7.59	8.51	99.89	53.90	9.91
	D	3.92	7.33	8.26	59.24	6.81	2.90	99.08	53.75	9.05

Table-4.2: Estimated Type I Error Rate and Power of Test by Samples Obtained from k=3 ve N (0,1) Distribution

		Δ=0			Δ= 0.50			Δ= 1.00		
	Test	1:1:1	1:1:4	1:1:10	1:1:1	1:1:4	1:1:10	1:1:1	1:1:4	1:1:10
n=3	DUNN	1.10	1.70	2.33	1.63	1.84	2.63	3.66	3.08	3.02
	DUNNR	1.10	1.71	2.32	1.63	1.85	2.62	3.66	3.09	2.99
	D	1.09	1.66	2.24	1.63	1.80	2.52	3.65	3.06	2.87
n=5	DUNN	3.64	4.64	5.39	7.36	6.13	6.20	21.15	11.85	9.02
	DUNNR	4.50	5.59	6.26	8.80	7.30	7.17	24.71	13.82	10.23
	D	4.28	5.32	5.95	8.54	7.10	6.89	24.33	13.59	9.99
n=7	DUNN	3.59	4.37	5.35	10.16	6.71	6.74	32.89	15.54	10.51
	DUNNR	4.39	5.29	6.54	11.89	8.04	8.19	37.12	18.01	12.52
	D	4.21	4.91	5.66	11.63	7.49	7.25	36.81	17.53	11.59
n=10	DUNN	3.77	4.48	5.43	14.37	8.60	7.41	49.47	22.02	13.39
	DUNNR	4.63	5.36	6.41	16.45	9.98	8.70	54.11	25.00	15.45
	D	4.44	4.77	5.28	16.16	9.40	7.47	53.78	24.30	14.06
n=15	DUNN	4.03	4.88	5.66	21.54	11.58	8.68	72.02	33.02	18.32
	DUNNR	4.78	5.68	6.54	23.94	13.05	9.87	75.44	36.06	20.35
	D	4.55	4.99	5.22	23.56	12.24	8.45	75.24	35.30	18.73
n=30	DUNN	4.09	4.58	5.64	42.95	19.26	12.34	96.83	60.57	32.18
	DUNNR	4.87	5.46	6.56	46.59	21.50	13.84	97.67	63.96	35.04
	D	4.69	4.70	5.06	46.24	20.52	12.14	97.64	63.50	33.37

Table-4.3: Estimated Type I Error Rate and Power of Test by Samples Obtained from k=3 ve β(5,3) Distribution

		Δ=0			Δ= 0.50			Δ= 1.00		
	Test	1:1:1	1:1:4	1:1:10	1:1:1	1:1:4	1:1:10	1:1:1	1:1:4	1:1:10
n=3	DUNN	1.01	1.73	2.46	1.61	1.85	2.57	3.35	2.57	2.73
	DUNNR	1.01	1.73	2.46	1.61	1.84	2.56	3.36	2.55	2.71
	D	1.01	1.71	2.40	1.59	1.80	2.51	3.33	2.52	2.63
n=5	DUNN	3.58	4.49	5.58	6.82	5.66	5.77	20.06	10.16	7.45
	DUNNR	4.45	5.39	6.32	8.42	6.85	6.74	23.61	11.99	8.58
	D	4.29	5.19	6.09	8.21	6.61	6.48	23.32	11.79	8.34
n=7	DUNN	3.68	4.67	5.51	9.57	6.09	5.88	31.18	13.00	8.65
	DUNNR	4.49	5.62	6.71	11.33	7.22	7.15	35.23	15.16	10.40
	D	4.33	5.21	5.83	11.14	6.90	6.41	34.98	14.93	9.71
n=10	DUNN	3.82	4.89	5.84	13.33	6.97	6.21	48.13	17.96	10.07
	DUNNR	4.71	5.85	7.05	15.56	8.18	7.24	52.94	20.46	11.78
	D	4.57	5.23	5.76	15.34	7.82	6.35	52.75	20.28	11.13
n=15	DUNN	3.98	4.95	6.09	20.43	8.65	6.85	71.46	26.92	13.19
	DUNNR	4.78	5.83	7.06	22.80	9.86	7.87	74.95	29.58	14.75
	D	4.64	5.03	5.48	22.57	9.57	6.82	74.84	29.46	14.14
n=30	DUNN	4.18	5.33	6.71	41.60	13.43	8.01	96.63	50.39	21.39
	DUNNR	4.98	6.26	7.64	45.13	15.24	9.20	97.42	53.92	23.72
	D	4.88	5.23	5.64	44.96	14.99	8.30	97.42	53.89	23.44

Table-4.4: Estimated Type I Error Rate and Power of Test by Samples Obtained from k=4 ve χ2 (3) Distribution

		Δ=0			Δ= 0.50			Δ= 1.00		
	Test	1:1:1:1	1:1:1:4	1:1:1:10	1:1:1:1	1:1:1:4	1:1:1:10	1:1:1:1	1:1:1:4	1:1:1:10
n=3	DUNN	1.55	3.18	4.46	2.88	2.29	3.72	5.53	3.16	3.50
	DUNNR	2.02	3.59	4.74	3.65	2.72	3.98	7.09	3.68	3.83
	D	1.64	2.90	4.17	2.99	2.18	3.38	6.19	3.05	3.17
n=5	DUNN	3.61	6.11	7.98	8.85	4.55	5.89	27.24	9.33	5.83
	DUNNR	3.81	6.27	8.10	9.33	4.70	6.01	27.84	9.57	5.97
	D	2.73	5.02	7.35	6.84	3.63	5.26	23.41	8.09	5.23
n=7	DUNN	4.07	7.08	9.72	13.39	5.15	6.32	47.77	12.87	6.03
	DUNNR	4.26	7.28	9.85	13.96	5.32	6.44	48.31	13.19	6.18
	D	2.78	5.07	7.33	9.85	3.91	4.68	39.16	11.39	5.03
n=10	DUNN	4.17	8.56	11.64	21.82	5.50	6.47	72.55	17.91	6.86
	DUNNR	4.36	8.75	11.81	22.39	5.70	6.59	72.83	18.17	7.02
	D	2.69	5.13	7.30	15.06	4.17	4.11	58.71	16.18	5.71
n=15	DUNN	4.43	10.46	14.58	35.52	6.08	7.06	92.72	27.11	7.47
	DUNNR	4.65	10.64	14.73	36.14	6.31	7.22	92.84	27.50	7.64
	D	2.70	5.11	7.51	23.35	4.67	3.63	79.37	25.61	6.26
n=30	DUNN	4.46	16.20	23.89	71.15	6.92	7.82	94.94	51.96	9.26
	DUNNR	4.62	16.48	24.11	71.41	7.11	7.95	96.82	52.27	9.46
	D	2.66	5.02	7.67	47.80	5.81	2.24	86.90	51.39	8.53

Table-4.5: Estimated Type I Error Rate and Power of Test by Samples Obtained from k=4 ve N (0,1) Distribution

		Δ=0			Δ= 0.50			Δ= 1.00		
	Test	1:1:1:1	1:1:1:4	1:1:1:10	1:1:1:1	1:1:1:4	1:1:1:10	1:1:1:1	1:1:1:4	1:1:1:10
n=3	DUNN	1.59	2.33	3.48	2.37	2.84	3.64	5.02	4.29	4.49
	DUNNR	2.07	2.69	3.73	2.97	3.22	3.96	5.94	4.77	4.83
	D	1.83	2.43	3.40	2.73	2.96	3.67	5.49	4.42	4.45
n=5	DUNN	3.55	4.59	5.50	7.18	6.35	6.54	20.80	12.14	9.37
	DUNNR	3.73	4.75	5.67	7.53	6.53	6.68	21.27	12.36	9.56
	D	3.13	4.11	5.19	6.53	5.92	6.18	19.49	11.49	9.05
n=7	DUNN	3.93	4.98	5.78	10.04	7.59	7.19	33.80	16.87	11.32
	DUNNR	4.12	5.14	5.93	10.41	7.79	7.36	34.27	17.13	11.51
	D	3.34	4.11	4.76	8.85	6.67	6.20	31.25	15.78	10.12
n=10	DUNN	4.29	4.99	5.94	14.65	9.39	7.99	46.22	23.23	14.38
	DUNNR	4.47	5.18	6.09	15.02	9.56	8.12	52.40	23.50	14.52
	D	3.50	3.86	4.54	12.64	8.16	6.57	49.01	21.70	12.85
n=15	DUNN	4.45	5.25	6.12	22.01	12.06	9.31	74.11	34.97	19.07
	DUNNR	4.65	5.40	6.27	22.42	12.27	9.46	74.39	35.29	19.31
	D	3.53	3.90	4.49	19.03	10.36	7.49	71.22	33.18	17.25
n=30	DUNN	4.78	5.33	6.18	44.11	20.19	12.85	97.70	62.45	33.27
	DUNNR	4.98	5.50	6.31	44.59	20.49	13.02	97.74	62.66	33.49
	D	3.55	3.70	4.18	39.91	18.06	10.80	97.27	61.19	31.37

Table-4.6: Estimated Type I Error Rate and Power of Test by Samples Obtained from k=4 ve β(5,3) Distribution

		Δ=0			Δ= 0.50			Δ= 1.00		
	Test	1:1:1:1	1:1:1:4	1:1:1:10	1:1:1:1	1:1:1:4	1:1:1:10	1:1:1:1	1:1:1:4	1:1:1:10
n=3	DUNN	1.77	2.45	3.72	2.25	2.65	3.47	4.54	3.79	3.95
	DUNNR	2.19	2.88	3.98	2.84	3.07	3.75	5.46	4.31	4.29
	D	2.00	2.64	3.75	2.60	2.81	3.48	5.17	3.99	3.98
n=5	DUNN	3.70	4.71	5.72	6.82	5.62	5.69	18.90	10.20	7.79
	DUNNR	3.92	4.90	5.85	7.12	5.77	5.82	19.44	10.41	7.94
	D	3.35	4.37	5.33	6.26	5.21	5.38	17.96	9.80	7.43
n=7	DUNN	3.81	4.96	6.13	9.90	6.45	6.42	31.67	13.70	9.02
	DUNNR	4.01	5.11	6.28	10.23	6.64	6.59	32.21	13.96	9.14
	D	3.36	4.20	5.11	8.93	5.69	5.48	29.58	12.99	8.26
n=10	DUNN	4.28	5.11	6.37	13.68	7.75	6.78	50.18	19.05	11.04
	DUNNR	4.48	5.29	6.51	14.08	7.95	6.91	50.54	19.29	11.22
	D	3.59	4.05	4.86	12.11	6.92	5.97	47.13	18.26	10.13
n=15	DUNN	4.34	5.49	6.78	20.54	9.38	7.16	73.54	27.96	13.79
	DUNNR	4.56	5.66	6.96	21.02	9.58	7.31	73.84	28.22	14.00
	D	3.51	4.05	4.91	18.13	8.36	5.90	70.81	27.18	12.81
n=30	DUNN	4.82	6.05	7.22	42.98	14.25	8.60	96.91	47.31	19.91
	DUNNR	4.99	6.20	7.38	43.42	14.49	8.76	97.91	51.64	22.68
	D	3.89	4.10	4.81	39.10	13.37	7.24	97.45	51.11	21.87

Table-4.7: Estimated Type I Error Rate and Power of Test by Samples Obtained from k=5 ve χ2 (3) Distribution

		Δ=0			Δ= 0.50			Δ= 1.00		
	Test	1:1:1:1:1	1:1:1:1:4	1:1:1:1:10	1:1:1:1:1	1:1:1:1:4	1:1:1:1:10	1:1:1:1:1	1:1:1:1:4	1:1:1:1:10
n=3	DUNN	1.28	2.36	3.56	2.04	1.78	2.75	4.19	2.27	2.49
	DUNNR	1.96	3.19	4.54	3.16	2.62	3.54	6.28	3.32	3.30
	D	1.85	3.12	4.49	3.01	2.49	3.47	6.11	3.16	3.19
n=5	DUNN	2.21	4.26	6.30	4.99	3.18	4.36	17.15	6.11	4.38
	DUNNR	3.83	5.97	7.93	8.41	4.74	5.71	24.43	8.78	5.93
	D	3.54	5.73	7.63	7.91	4.50	5.46	23.71	8.57	5.71
n=7	DUNN	2.58	5.20	7.26	8.69	3.63	4.66	37.02	9.26	4.71
	DUNNR	4.08	6.89	9.08	12.83	5.11	6.05	44.79	12.29	6.17
	D	3.77	6.20	7.93	12.08	4.81	5.22	43.37	12.03	5.71
n=10	DUNN	2.96	6.32	8.99	14.83	3.69	4.85	63.35	15.23	5.24
	DUNNR	4.56	8.22	11.09	20.22	5.18	6.39	70.38	18.21	6.84
	D	4.22	6.87	8.72	18.84	4.82	4.99	67.80	18.22	5.43
n=15	DUNN	3.07	8.05	11.79	27.90	4.30	5.46	89.79	21.55	5.89
	DUNNR	4.67	10.06	14.01	34.16	5.99	7.00	92.78	25.85	7.47
	D	4.23	7.68	9.79	31.44	5.57	4.73	90.26	25.71	6.71
n=30	DUNN	3.13	13.33	19.74	64.60	5.22	6.21	99.94	45.01	7.35
	DUNNR	4.66	15.92	22.60	70.21	7.04	7.81	99.96	49.85	9.18
	D	4.27	9.71	11.82	64.37	6.55	3.59	99.81	49.83	8.47

Table-4.8: Estimated Type I Error Rate and Power of Test by Samples Obtained from k=5 ve N (0,1) Distribution

		Δ=0			Δ= 0.50			Δ= 1.00		
	Test	1:1:1:1:1	1:1:1:1:4	1:1:1:1:10	1:1:1:1:1	1:1:1:1:4	1:1:1:1:10	1:1:1:1:1	1:1:1:1:4	1:1:1:1:10
n=3	DUNN	1.27	1.70	2.62	1.84	2.11	2.63	3.86	3.16	3.32
	DUNNR	2.04	2.50	3.41	2.86	2.98	3.55	5.57	4.31	4.34
	D	2.04	2.48	3.39	2.85	2.97	3.54	5.56	4.31	4.33
n=5	DUNN	2.03	2.87	4.09	4.34	4.15	4.81	13.78	8.70	7.08
	DUNNR	3.61	4.36	5.50	6.98	6.06	6.41	19.09	11.69	9.00
	D	3.58	4.26	5.35	6.95	5.98	6.24	19.05	11.62	8.80
n=7	DUNN	2.51	3.23	4.19	6.71	5.38	5.36	25.67	12.67	8.62
	DUNNR	4.02	4.69	5.55	9.60	7.37	6.91	31.46	15.98	10.72
	D	3.99	4.51	5.07	9.53	7.18	6.52	31.44	15.81	10.32
n=10	DUNN	2.78	3.45	4.32	9.97	7.08	6.13	43.05	18.38	11.50
	DUNNR	4.43	4.94	5.84	13.75	9.15	7.86	49.36	22.16	13.90
	D	4.38	4.69	5.20	13.69	8.93	7.25	49.34	21.99	13.28
n=15	DUNN	2.94	3.78	4.54	16.31	9.46	7.33	67.63	28.88	15.60
	DUNNR	4.45	5.10	6.09	20.68	11.82	9.12	72.63	33.01	18.39
	D	4.41	4.86	5.33	20.63	11.60	8.36	72.62	32.89	17.83
n=30	DUNN	3.27	3.90	4.75	37.27	16.16	10.31	96.67	56.09	28.37
	DUNNR	4.80	5.41	6.22	42.59	19.43	12.46	97.64	60.35	31.94
	D	4.75	5.17	5.36	44.25	19.23	11.71	97.65	60.28	31.49

Table-4.9: Estimated Type I Error Rate and Power of Test by Samples Obtained from k=5 ve β(5,3) Distribution

		Δ=0			Δ= 0.50			Δ= 1.00		
	Test	1:1:1:1:1	1:1:1:1:4	1:1:1:1:10	1:1:1:1:1	1:1:1:1:4	1:1:1:1:10	1:1:1:1:1	1:1:1:1:4	1:1:1:1:10
n=3	DUNN	1.28	1.88	2.69	1.72	1.92	2.57	3.31	2.74	2.91
	DUNNR	1.96	2.65	3.59	2.58	2.76	3.46	4.86	3.79	3.84
	D	1.96	2.64	3.57	2.58	2.75	3.44	4.85	3.77	3.83
n=5	DUNN	2.03	3.25	4.16	4.06	3.86	4.36	11.95	7.19	5.77
	DUNNR	3.60	4.74	5.56	6.65	5.51	5.84	17.14	9.83	7.40
	D	3.59	4.66	5.36	6.62	5.44	5.65	17.12	9.78	7.25
n=7	DUNN	2.48	3.38	4.46	6.24	4.40	4.49	23.94	10.37	6.70
	DUNNR	4.03	4.88	5.84	9.19	6.21	5.88	29.93	12.99	8.45
	D	4.00	4.68	5.40	9.16	6.08	5.48	29.90	12.91	8.16
n=10	DUNN	2.82	3.82	4.66	9.57	5.33	5.07	41.19	14.82	8.52
	DUNNR	4.35	5.37	6.29	13.15	7.25	6.63	48.02	18.31	10.59
	D	4.33	5.14	5.64	13.11	7.13	6.13	48.00	18.26	10.25
n=15	DUNN	2.96	3.93	5.11	15.53	6.98	5.47	66.53	22.93	11.03
	DUNNR	4.54	5.46	6.62	19.96	9.09	6.98	71.90	26.81	13.35
	D	4.52	5.22	5.90	19.93	8.98	6.43	71.89	26.77	13.00
n=30	DUNN	3.39	4.46	5.47	35.61	11.43	6.85	96.71	45.27	18.53
	DUNNR	5.05	6.03	6.91	41.32	13.94	8.52	97.68	49.74	21.51
	D	5.03	5.74	5.88	41.30	13.88	7.82	97.68	49.76	21.33

CONCLUSION

Being homogeneous or heterogeneous of group variances plays important role in determining which of the multiple comparison tests will be chosen. If group variances are homogeneous an done of these groups is chosen for control and other group averages are compared regarding this, Dunnet test is made use of. If it is necessary to control mainly the average of one group with the averages of some other groups, Scheffe test is made use of. If the averages are wanted to be compared regarding size order, Duncan test must be made use of. If the group number is eight or more than this Tukey test must be preferred. Usage of some of the parametrical multiple comparison test after nonparametric tests is seen important in the aspect of both ease of implementation and reliability; Besides,

If homogeneous of group variances which are one of the prerequisites variance analyses are not provided, It can be said that usage of one of the parametrical multiple comparisons tests may be more accurate. Also DUNN method is thought to be implemented after a nonparametrical test.

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