# PROJECT 3 ON RANDOMIZATION TESTS

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# Contents

## 1.1: Problem Statement:

We are given 3 treatment of size respectively 2,3 and 4. Our goal is to compare the treatments by using randomization tests. We will be performing both systematic and random permutation to compare the treatments.

## 1.2: Test Description and Methodology:

For both systematic and random permutation, our alternatives are:

$$H_0: \mu_{A=}\mu_{B=}\mu_C (Treatments\ are\ equal)$$

$$H_a: At\ least\ One\ of\ the\ \mu\ is\ not\ the\ same$$

Given treatment values are below:

| Treatments | Treatment Values |
|------------|------------------|
| A          | 6,8              |
| B          | 9,11,9           |
| C          | 17,15,16,16      |

We now denote $n_A, n_B$ and $n_c$ to be the number of treatment values of treatment A, B and C respectively. Let $r$ =total number of treatments. In this case, $n_A$=2, $n_B$=3 and $n_C$=4 and r=3. Our test statistic is given below:

$$t^* = \frac{\sum_{i=1}^2 T_{Ai}{}^2}{n_A} + \frac{\sum_{i=1}^3 T_{Bi}{}^2}{n_B} + \frac{\sum_{i=1}^4 T_{Ci}{}^2}{n_C} \qquad (1)$$

Where $T_{Ai}, T_{Bi}, T_{Ci}$ are treatment values for Treatment A, B and C respectively for case $i = 1,2, ..$ etc. After performing systematic and random permutation, our probability value for the test will be:

p-value= $\dfrac{Total\ number\ of\ test\ statistic\ values\ which\ are\ at\ least\ as\ large\ as\ the\ original\ test\ statistic}{N}$

Original test statistic is calculated from (1) keeping the same order as the original treatment values. N or total Number of permutations are different for systematic and random permutations.

We select $\alpha$=0.05 to be our significance value. Here are the decision rules:

If p-value<0.05, Assume $H_a$. If p-value >=0.05, Assume $H_0$.
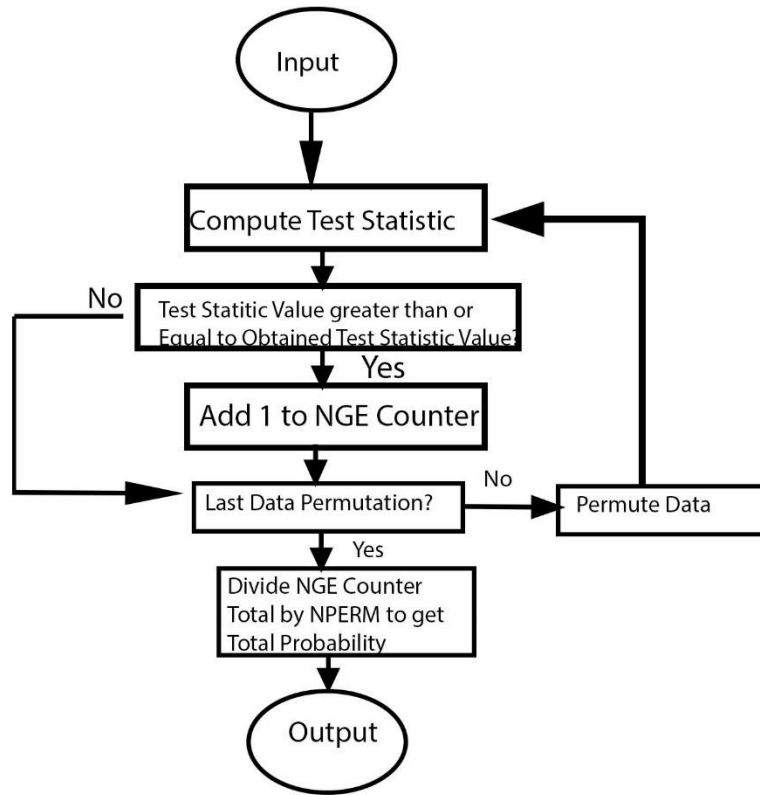


Figure: Flowchart for Randomization tests

We will conduct our tests with both systematic and random permutation of data. Here are the steps for systematic permutation:

1.  Arrange the data in a tabular form and group the measurements according to the treatments and assign index numbers 1 to N to the measurements, beginning with treatment A.
2.  Generate a systematic sequence of permutations of the index numbers associated with measurements, so that there are $n_A$ index numbers for A, $n_B$ index numbers for B and $n_C$ index numbers for C. For each of these permutations we perform steps 3 and 4. The 1st permutation is the obtained test result, so steps 3 and 4 associated with the 1st permutation is the original test statistic value. There will be $\frac{N!}{n_A! n_B! n_C!}$ total permutations of the N measurements for k groups. .
3.  Compute $T_A, T_B, T_C$, the totals for all treatment groups.
4.  Sum $\frac{T_A{}^2}{n_A}, \frac{T_B{}^2}{n_B}, \frac{T_C{}^2}{n_C}$ to obtain test statistic value

5. Compute the probability for F as the proportion of the $\frac{N!}{n_A! n_B! n_C!}$ (1260 total in this case)permutations that provide as large a value of the obtained test statistic, the value computed from the 1st permutation.

For the steps above N=9, $n_A = 2, n_B = 3 \ and \ n_C = 4$, k=3.

So according to systematic permutation, our 1st permutation will look like below:

| Permutation Sequence | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Data | 6 | 8 | 9 | 11 | 9 | 17 | 15 | 16 | 16 |

Random permutations can be used in place of systematic permutation if the number of systematic permutations is too large. In this project, we are going to use 800 random permutations. Here are the steps for random permutation:

1. Arrange the data in the form of a table, where the measurements are grouped by treatment and assign 1 to N to the measurements, beginning with the measurements for treatment 1.
2. Perform step 5 and 6 for the observed data to compute the test statistic value.
3. Using a random number generation algorithm, select $n_A(n_A = 2$ in this case) index numbers without replacement from N (N=9 in this case) index. From the remaining N-$n_A$ (7) index numbers, randomly select $n_B = 3$ index numbers to treatment B the remaining N-$n_A$-$n_C$ (4) treatments to treatment C. Each assignment of index numbers to every treatment constitutes a permutation of the data. We will perform 799 permutations (Considering the original statistic as 1 permutation)
4. Compute $T_A, T_B, T_C$, the totals for all treatment groups.
5. Sum $\frac{T_A^2}{n_A}, \frac{T_B^2}{n_B}, \frac{T_C^2}{n_C}$ to obtain test statistic value.
6. Compute the probability for F as the proportion of 800 permutations which gives at least as large test statistic as the original test statistic.

## 1.3 Test Results

**Systematic Permutation**

There are total 1260 permutations for systematic permutations. The p-value obtained is 1/1260 or 0.0007936507936507937. Here are all the test statistics calculated from python (1$^{st}$ one is the original test statistic):

| Permutation Sequence | | | | | | | | | Test Statistic(rounded) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 1402 |
| 1 | 2 | 3 | 4 | 6 | 5 | 7 | 8 | 9 | 1338 |
| 1 | 2 | 3 | 4 | 7 | 5 | 6 | 8 | 9 | 1347 |
| 1 | 2 | 3 | 4 | 8 | 5 | 6 | 7 | 9 | 1342 |
| 1 | 2 | 3 | 4 | 9 | 5 | 6 | 7 | 8 | 1342 |
| 1 | 2 | 3 | 5 | 6 | 4 | 7 | 8 | 9 | 1347 |
| 1 | 2 | 3 | 5 | 7 | 4 | 6 | 8 | 9 | 1361 |
| 1 | 2 | 3 | 5 | 8 | 4 | 6 | 7 | 9 | 1353 |
| 1 | 2 | 3 | 5 | 9 | 4 | 6 | 7 | 8 | 1353 |
| 1 | 2 | 3 | 6 | 7 | 4 | 5 | 8 | 9 | 1334 |
| 1 | 2 | 3 | 6 | 8 | 4 | 5 | 7 | 9 | 1336 |
| 1 | 2 | 3 | 6 | 9 | 4 | 5 | 7 | 8 | 1336 |
| 1 | 2 | 3 | 7 | 8 | 4 | 5 | 6 | 9 | 1333 |
| 1 | 2 | 3 | 7 | 9 | 4 | 5 | 6 | 8 | 1333 |
| 1 | 2 | 3 | 8 | 9 | 4 | 5 | 6 | 7 | 1334 |
| 1 | 2 | 4 | 5 | 6 | 3 | 7 | 8 | 9 | 1338 |
| 1 | 2 | 4 | 5 | 7 | 3 | 6 | 8 | 9 | 1347 |
| 1 | 2 | 4 | 5 | 8 | 3 | 6 | 7 | 9 | 1342 |
| 1 | 2 | 4 | 5 | 9 | 3 | 6 | 7 | 8 | 1342 |
| 1 | 2 | 4 | 6 | 7 | 3 | 5 | 8 | 9 | 1339 |
| 1 | 2 | 4 | 6 | 8 | 3 | 5 | 7 | 9 | 1343 |

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|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 4 | 6 | 9 | 3 | 5 | 7 | 8 | 1343 |
| 1 | 2 | 4 | 7 | 8 | 3 | 5 | 6 | 9 | 1336 |
| 1 | 2 | 4 | 7 | 9 | 3 | 5 | 6 | 8 | 1336 |
| 1 | 2 | 4 | 8 | 9 | 3 | 5 | 6 | 7 | 1339 |
| 1 | 2 | 5 | 6 | 7 | 3 | 4 | 8 | 9 | 1334 |
| 1 | 2 | 5 | 6 | 8 | 3 | 4 | 7 | 9 | 1336 |
| 1 | 2 | 5 | 6 | 9 | 3 | 4 | 7 | 8 | 1336 |
| 1 | 2 | 5 | 7 | 8 | 3 | 4 | 6 | 9 | 1333 |
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| 1 | 2 | 5 | 8 | 9 | 3 | 4 | 6 | 7 | 1334 |
| 1 | 2 | 6 | 7 | 8 | 3 | 4 | 5 | 9 | 1372 |
| 1 | 2 | 6 | 7 | 9 | 3 | 4 | 5 | 8 | 1372 |
| 1 | 2 | 6 | 8 | 9 | 3 | 4 | 5 | 7 | 1382 |
| 1 | 2 | 7 | 8 | 9 | 3 | 4 | 5 | 6 | 1363 |
| 1 | 3 | 2 | 4 | 5 | 6 | 7 | 8 | 9 | 1397 |
| 1 | 3 | 2 | 4 | 6 | 5 | 7 | 8 | 9 | 1328 |
| 1 | 3 | 2 | 4 | 7 | 5 | 6 | 8 | 9 | 1338 |
| 1 | 3 | 2 | 4 | 8 | 5 | 6 | 7 | 9 | 1333 |
| 1 | 3 | 2 | 4 | 9 | 5 | 6 | 7 | 8 | 1333 |
| 1 | 3 | 2 | 5 | 6 | 4 | 7 | 8 | 9 | 1338 |
| 1 | 3 | 2 | 5 | 7 | 4 | 6 | 8 | 9 | 1353 |
| 1 | 3 | 2 | 5 | 8 | 4 | 6 | 7 | 9 | 1345 |
| 1 | 3 | 2 | 5 | 9 | 4 | 6 | 7 | 8 | 1345 |
| 1 | 3 | 2 | 6 | 7 | 4 | 5 | 8 | 9 | 1321 |
| 1 | 3 | 2 | 6 | 8 | 4 | 5 | 7 | 9 | 1323 |
| 1 | 3 | 2 | 6 | 9 | 4 | 5 | 7 | 8 | 1323 |
| 1 | 3 | 2 | 7 | 8 | 4 | 5 | 6 | 9 | 1321 |

| 1 | 3 | 2 | 7 | 9 | 4 | 5 | 6 | 8 | 1321 |
|---|---|---|---|---|---|---|---|---|------|
| 1 | 3 | 2 | 8 | 9 | 4 | 5 | 6 | 7 | 1321 |
| 1 | 3 | 4 | 5 | 6 | 2 | 7 | 8 | 9 | 1325 |
| 1 | 3 | 4 | 5 | 7 | 2 | 6 | 8 | 9 | 1333 |
| 1 | 3 | 4 | 5 | 8 | 2 | 6 | 7 | 9 | 1328 |
| 1 | 3 | 4 | 5 | 9 | 2 | 6 | 7 | 8 | 1328 |
| 1 | 3 | 4 | 6 | 7 | 2 | 5 | 8 | 9 | 1329 |
| 1 | 3 | 4 | 6 | 8 | 2 | 5 | 7 | 9 | 1333 |
| 1 | 3 | 4 | 6 | 9 | 2 | 5 | 7 | 8 | 1333 |
| 1 | 3 | 4 | 7 | 8 | 2 | 5 | 6 | 9 | 1325 |
| 1 | 3 | 4 | 7 | 9 | 2 | 5 | 6 | 8 | 1325 |
| 1 | 3 | 4 | 8 | 9 | 2 | 5 | 6 | 7 | 1329 |
| 1 | 3 | 5 | 6 | 7 | 2 | 4 | 8 | 9 | 1323 |
| 1 | 3 | 5 | 6 | 8 | 2 | 4 | 7 | 9 | 1325 |
| 1 | 3 | 5 | 6 | 9 | 2 | 4 | 7 | 8 | 1325 |
| 1 | 3 | 5 | 7 | 8 | 2 | 4 | 6 | 9 | 1321 |
| 1 | 3 | 5 | 7 | 9 | 2 | 4 | 6 | 8 | 1321 |
| 1 | 3 | 5 | 8 | 9 | 2 | 4 | 6 | 7 | 1323 |
| 1 | 3 | 6 | 7 | 8 | 2 | 4 | 5 | 9 | 1364 |
| 1 | 3 | 6 | 7 | 9 | 2 | 4 | 5 | 8 | 1364 |
| 1 | 3 | 6 | 8 | 9 | 2 | 4 | 5 | 7 | 1375 |
| 1 | 3 | 7 | 8 | 9 | 2 | 4 | 5 | 6 | 1355 |
| 1 | 4 | 2 | 3 | 5 | 6 | 7 | 8 | 9 | 1393 |
| 1 | 4 | 2 | 3 | 6 | 5 | 7 | 8 | 9 | 1313 |
| 1 | 4 | 2 | 3 | 7 | 5 | 6 | 8 | 9 | 1326 |
| 1 | 4 | 2 | 3 | 8 | 5 | 6 | 7 | 9 | 1319 |
| 1 | 4 | 2 | 3 | 9 | 5 | 6 | 7 | 8 | 1319 |

| 1 | 4 | 2 | 5 | 6 | 3 | 7 | 8 | 9 | 1313 |
|---|---|---|---|---|---|---|---|---|------|
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| 1 | 4 | 2 | 5 | 8 | 3 | 6 | 7 | 9 | 1319 |
| 1 | 4 | 2 | 5 | 9 | 3 | 6 | 7 | 8 | 1319 |
| 1 | 4 | 2 | 6 | 7 | 3 | 5 | 8 | 9 | 1302 |
| 1 | 4 | 2 | 6 | 8 | 3 | 5 | 7 | 9 | 1305 |
| 1 | 4 | 2 | 6 | 9 | 3 | 5 | 7 | 8 | 1305 |
| 1 | 4 | 2 | 7 | 8 | 3 | 5 | 6 | 9 | 1301 |
| 1 | 4 | 2 | 7 | 9 | 3 | 5 | 6 | 8 | 1301 |
| 1 | 4 | 2 | 8 | 9 | 3 | 5 | 6 | 7 | 1302 |
| 1 | 4 | 3 | 5 | 6 | 2 | 7 | 8 | 9 | 1309 |
| 1 | 4 | 3 | 5 | 7 | 2 | 6 | 8 | 9 | 1319 |
| 1 | 4 | 3 | 5 | 8 | 2 | 6 | 7 | 9 | 1313 |
| 1 | 4 | 3 | 5 | 9 | 2 | 6 | 7 | 8 | 1313 |
| 1 | 4 | 3 | 6 | 7 | 2 | 5 | 8 | 9 | 1305 |
| 1 | 4 | 3 | 6 | 8 | 2 | 5 | 7 | 9 | 1308 |
| 1 | 4 | 3 | 6 | 9 | 2 | 5 | 7 | 8 | 1308 |
| 1 | 4 | 3 | 7 | 8 | 2 | 5 | 6 | 9 | 1302 |
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| 1 | 4 | 5 | 6 | 9 | 2 | 3 | 7 | 8 | 1308 |
| 1 | 4 | 5 | 7 | 8 | 2 | 3 | 6 | 9 | 1302 |
| 1 | 4 | 5 | 7 | 9 | 2 | 3 | 6 | 8 | 1302 |
| 1 | 4 | 5 | 8 | 9 | 2 | 3 | 6 | 7 | 1305 |
| 1 | 4 | 6 | 7 | 8 | 2 | 3 | 5 | 9 | 1353 |

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| 1 | 5 | 2 | 3 | 7 | 4 | 6 | 8 | 9 | 1353 |
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| 1 | 5 | 2 | 3 | 9 | 4 | 6 | 7 | 8 | 1345 |
| 1 | 5 | 2 | 4 | 6 | 3 | 7 | 8 | 9 | 1328 |
| 1 | 5 | 2 | 4 | 7 | 3 | 6 | 8 | 9 | 1338 |
| 1 | 5 | 2 | 4 | 8 | 3 | 6 | 7 | 9 | 1333 |
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| 1 | 5 | 2 | 6 | 7 | 3 | 4 | 8 | 9 | 1321 |
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| 1 | 5 | 3 | 6 | 7 | 2 | 4 | 8 | 9 | 1323 |
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| 1 | 5 | 3 | 7 | 8 | 2 | 4 | 6 | 9 | 1321 |
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|---|---|---|---|---|---|---|---|---|------|
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| 1 | 5 | 4 | 6 | 8 | 2 | 3 | 7 | 9 | 1333 |
| 1 | 5 | 4 | 6 | 9 | 2 | 3 | 7 | 8 | 1333 |
| 1 | 5 | 4 | 7 | 8 | 2 | 3 | 6 | 9 | 1325 |
| 1 | 5 | 4 | 7 | 9 | 2 | 3 | 6 | 8 | 1325 |
| 1 | 5 | 4 | 8 | 9 | 2 | 3 | 6 | 7 | 1329 |
| 1 | 5 | 6 | 7 | 8 | 2 | 3 | 4 | 9 | 1364 |
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| 1 | 5 | 6 | 8 | 9 | 2 | 3 | 4 | 7 | 1375 |
| 1 | 5 | 7 | 8 | 9 | 2 | 3 | 4 | 6 | 1355 |
| 1 | 6 | 2 | 3 | 4 | 5 | 7 | 8 | 9 | 1309 |
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| 1 | 6 | 2 | 3 | 8 | 4 | 5 | 7 | 9 | 1277 |
| 1 | 6 | 2 | 3 | 9 | 4 | 5 | 7 | 8 | 1277 |
| 1 | 6 | 2 | 4 | 5 | 3 | 7 | 8 | 9 | 1309 |
| 1 | 6 | 2 | 4 | 7 | 3 | 5 | 8 | 9 | 1274 |
| 1 | 6 | 2 | 4 | 8 | 3 | 5 | 7 | 9 | 1273 |
| 1 | 6 | 2 | 4 | 9 | 3 | 5 | 7 | 8 | 1273 |
| 1 | 6 | 2 | 5 | 7 | 3 | 4 | 8 | 9 | 1281 |
| 1 | 6 | 2 | 5 | 8 | 3 | 4 | 7 | 9 | 1277 |
| 1 | 6 | 2 | 5 | 9 | 3 | 4 | 7 | 8 | 1277 |
| 1 | 6 | 2 | 7 | 8 | 3 | 4 | 5 | 9 | 1277 |
| 1 | 6 | 2 | 7 | 9 | 3 | 4 | 5 | 8 | 1277 |
| 1 | 6 | 2 | 8 | 9 | 3 | 4 | 5 | 7 | 1281 |
| 1 | 6 | 3 | 4 | 5 | 2 | 7 | 8 | 9 | 1301 |

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|---|---|---|---|---|---|---|---|---|---|
| 1 | 6 | 3 | 4 | 7 | 2 | 5 | 8 | 9 | 1273 |
| 1 | 6 | 3 | 4 | 8 | 2 | 5 | 7 | 9 | 1272 |
| 1 | 6 | 3 | 4 | 9 | 2 | 5 | 7 | 8 | 1272 |
| 1 | 6 | 3 | 5 | 7 | 2 | 4 | 8 | 9 | 1277 |
| 1 | 6 | 3 | 5 | 8 | 2 | 4 | 7 | 9 | 1274 |
| 1 | 6 | 3 | 5 | 9 | 2 | 4 | 7 | 8 | 1274 |
| 1 | 6 | 3 | 7 | 8 | 2 | 4 | 5 | 9 | 1281 |
| 1 | 6 | 3 | 7 | 9 | 2 | 4 | 5 | 8 | 1281 |
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| 1 | 6 | 4 | 5 | 8 | 2 | 3 | 7 | 9 | 1272 |
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| 1 | 6 | 4 | 8 | 9 | 2 | 3 | 5 | 7 | 1301 |
| 1 | 6 | 5 | 7 | 8 | 2 | 3 | 4 | 9 | 1281 |
| 1 | 6 | 5 | 7 | 9 | 2 | 3 | 4 | 8 | 1281 |
| 1 | 6 | 5 | 8 | 9 | 2 | 3 | 4 | 7 | 1287 |
| 1 | 6 | 7 | 8 | 9 | 2 | 3 | 4 | 5 | 1343 |
| 1 | 7 | 2 | 3 | 4 | 5 | 6 | 8 | 9 | 1322 |
| 1 | 7 | 2 | 3 | 5 | 4 | 6 | 8 | 9 | 1345 |
| 1 | 7 | 2 | 3 | 6 | 4 | 5 | 8 | 9 | 1281 |
| 1 | 7 | 2 | 3 | 8 | 4 | 5 | 6 | 9 | 1285 |
| 1 | 7 | 2 | 3 | 9 | 4 | 5 | 6 | 8 | 1285 |
| 1 | 7 | 2 | 4 | 5 | 3 | 6 | 8 | 9 | 1322 |
| 1 | 7 | 2 | 4 | 6 | 3 | 5 | 8 | 9 | 1277 |
| 1 | 7 | 2 | 4 | 8 | 3 | 5 | 6 | 9 | 1279 |

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|---|---|---|---|---|---|---|---|---|---|
| 1 | 7 | 2 | 4 | 9 | 3 | 5 | 6 | 8 | 1279 |
| 1 | 7 | 2 | 5 | 6 | 3 | 4 | 8 | 9 | 1281 |
| 1 | 7 | 2 | 5 | 8 | 3 | 4 | 6 | 9 | 1285 |
| 1 | 7 | 2 | 5 | 9 | 3 | 4 | 6 | 8 | 1285 |
| 1 | 7 | 2 | 6 | 8 | 3 | 4 | 5 | 9 | 1287 |
| 1 | 7 | 2 | 6 | 9 | 3 | 4 | 5 | 8 | 1287 |
| 1 | 7 | 2 | 8 | 9 | 3 | 4 | 5 | 6 | 1282 |
| 1 | 7 | 3 | 4 | 5 | 2 | 6 | 8 | 9 | 1313 |
| 1 | 7 | 3 | 4 | 6 | 2 | 5 | 8 | 9 | 1277 |
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| 1 | 7 | 3 | 5 | 6 | 2 | 4 | 8 | 9 | 1279 |
| 1 | 7 | 3 | 5 | 8 | 2 | 4 | 6 | 9 | 1281 |
| 1 | 7 | 3 | 5 | 9 | 2 | 4 | 6 | 8 | 1281 |
| 1 | 7 | 3 | 6 | 8 | 2 | 4 | 5 | 9 | 1292 |
| 1 | 7 | 3 | 6 | 9 | 2 | 4 | 5 | 8 | 1292 |
| 1 | 7 | 3 | 8 | 9 | 2 | 4 | 5 | 6 | 1287 |
| 1 | 7 | 4 | 5 | 6 | 2 | 3 | 8 | 9 | 1277 |
| 1 | 7 | 4 | 5 | 8 | 2 | 3 | 6 | 9 | 1277 |
| 1 | 7 | 4 | 5 | 9 | 2 | 3 | 6 | 8 | 1277 |
| 1 | 7 | 4 | 6 | 8 | 2 | 3 | 5 | 9 | 1306 |
| 1 | 7 | 4 | 6 | 9 | 2 | 3 | 5 | 8 | 1306 |
| 1 | 7 | 4 | 8 | 9 | 2 | 3 | 5 | 6 | 1299 |
| 1 | 7 | 5 | 6 | 8 | 2 | 3 | 4 | 9 | 1292 |
| 1 | 7 | 5 | 6 | 9 | 2 | 3 | 4 | 8 | 1292 |
| 1 | 7 | 5 | 8 | 9 | 2 | 3 | 4 | 6 | 1287 |
| 1 | 7 | 6 | 8 | 9 | 2 | 3 | 4 | 5 | 1363 |

| 1 | 8 | 2 | 3 | 4 | 5 | 6 | 7 | 9 | 1315 |
|---|---|---|---|---|---|---|---|---|------|
| 1 | 8 | 2 | 3 | 5 | 4 | 6 | 7 | 9 | 1337 |
| 1 | 8 | 2 | 3 | 6 | 4 | 5 | 7 | 9 | 1277 |
| 1 | 8 | 2 | 3 | 7 | 4 | 5 | 6 | 9 | 1285 |
| 1 | 8 | 2 | 3 | 9 | 4 | 5 | 6 | 7 | 1281 |
| 1 | 8 | 2 | 4 | 5 | 3 | 6 | 7 | 9 | 1315 |
| 1 | 8 | 2 | 4 | 6 | 3 | 5 | 7 | 9 | 1274 |
| 1 | 8 | 2 | 4 | 7 | 3 | 5 | 6 | 9 | 1277 |
| 1 | 8 | 2 | 4 | 9 | 3 | 5 | 6 | 7 | 1275 |
| 1 | 8 | 2 | 5 | 6 | 3 | 4 | 7 | 9 | 1277 |
| 1 | 8 | 2 | 5 | 7 | 3 | 4 | 6 | 9 | 1285 |
| 1 | 8 | 2 | 5 | 9 | 3 | 4 | 6 | 7 | 1281 |
| 1 | 8 | 2 | 6 | 7 | 3 | 4 | 5 | 9 | 1281 |
| 1 | 8 | 2 | 6 | 9 | 3 | 4 | 5 | 7 | 1286 |
| 1 | 8 | 2 | 7 | 9 | 3 | 4 | 5 | 6 | 1278 |
| 1 | 8 | 3 | 4 | 5 | 2 | 6 | 7 | 9 | 1306 |
| 1 | 8 | 3 | 4 | 6 | 2 | 5 | 7 | 9 | 1274 |
| 1 | 8 | 3 | 4 | 7 | 2 | 5 | 6 | 9 | 1275 |
| 1 | 8 | 3 | 4 | 9 | 2 | 5 | 6 | 7 | 1274 |
| 1 | 8 | 3 | 5 | 6 | 2 | 4 | 7 | 9 | 1275 |
| 1 | 8 | 3 | 5 | 7 | 2 | 4 | 6 | 9 | 1281 |
| 1 | 8 | 3 | 5 | 9 | 2 | 4 | 6 | 7 | 1277 |
| 1 | 8 | 3 | 6 | 7 | 2 | 4 | 5 | 9 | 1286 |
| 1 | 8 | 3 | 6 | 9 | 2 | 4 | 5 | 7 | 1292 |
| 1 | 8 | 3 | 7 | 9 | 2 | 4 | 5 | 6 | 1281 |
| 1 | 8 | 4 | 5 | 6 | 2 | 3 | 7 | 9 | 1274 |
| 1 | 8 | 4 | 5 | 7 | 2 | 3 | 6 | 9 | 1275 |

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|---|---|---|---|---|---|---|---|---|---|
| 1 | 8 | 4 | 5 | 9 | 2 | 3 | 6 | 7 | 1274 |
| 1 | 8 | 4 | 6 | 7 | 2 | 3 | 5 | 9 | 1299 |
| 1 | 8 | 4 | 6 | 9 | 2 | 3 | 5 | 7 | 1307 |
| 1 | 8 | 4 | 7 | 9 | 2 | 3 | 5 | 6 | 1292 |
| 1 | 8 | 5 | 6 | 7 | 2 | 3 | 4 | 9 | 1286 |
| 1 | 8 | 5 | 6 | 9 | 2 | 3 | 4 | 7 | 1292 |
| 1 | 8 | 5 | 7 | 9 | 2 | 3 | 4 | 6 | 1281 |
| 1 | 8 | 6 | 7 | 9 | 2 | 3 | 4 | 5 | 1352 |
| 1 | 9 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 1315 |
| 1 | 9 | 2 | 3 | 5 | 4 | 6 | 7 | 8 | 1337 |
| 1 | 9 | 2 | 3 | 6 | 4 | 5 | 7 | 8 | 1277 |
| 1 | 9 | 2 | 3 | 7 | 4 | 5 | 6 | 8 | 1285 |
| 1 | 9 | 2 | 3 | 8 | 4 | 5 | 6 | 7 | 1281 |
| 1 | 9 | 2 | 4 | 5 | 3 | 6 | 7 | 8 | 1315 |
| 1 | 9 | 2 | 4 | 6 | 3 | 5 | 7 | 8 | 1274 |
| 1 | 9 | 2 | 4 | 7 | 3 | 5 | 6 | 8 | 1277 |
| 1 | 9 | 2 | 4 | 8 | 3 | 5 | 6 | 7 | 1275 |
| 1 | 9 | 2 | 5 | 6 | 3 | 4 | 7 | 8 | 1277 |
| 1 | 9 | 2 | 5 | 7 | 3 | 4 | 6 | 8 | 1285 |
| 1 | 9 | 2 | 5 | 8 | 3 | 4 | 6 | 7 | 1281 |
| 1 | 9 | 2 | 6 | 7 | 3 | 4 | 5 | 8 | 1281 |
| 1 | 9 | 2 | 6 | 8 | 3 | 4 | 5 | 7 | 1286 |
| 1 | 9 | 2 | 7 | 8 | 3 | 4 | 5 | 6 | 1278 |
| 1 | 9 | 3 | 4 | 5 | 2 | 6 | 7 | 8 | 1306 |
| 1 | 9 | 3 | 4 | 6 | 2 | 5 | 7 | 8 | 1274 |
| 1 | 9 | 3 | 4 | 7 | 2 | 5 | 6 | 8 | 1275 |
| 1 | 9 | 3 | 4 | 8 | 2 | 5 | 6 | 7 | 1274 |

| 1 | 9 | 3 | 5 | 6 | 2 | 4 | 7 | 8 | 1275 |
|---|---|---|---|---|---|---|---|---|------|
| 1 | 9 | 3 | 5 | 7 | 2 | 4 | 6 | 8 | 1281 |
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| 8 | 9 | 3 | 5 | 7 | 1 | 2 | 4 | 6 | 1316 |
| 8 | 9 | 3 | 6 | 7 | 1 | 2 | 4 | 5 | 1361 |
| 8 | 9 | 4 | 5 | 6 | 1 | 2 | 3 | 7 | 1329 |
| 8 | 9 | 4 | 5 | 7 | 1 | 2 | 3 | 6 | 1320 |
| 8 | 9 | 4 | 6 | 7 | 1 | 2 | 3 | 5 | 1384 |
| 8 | 9 | 5 | 6 | 7 | 1 | 2 | 3 | 4 | 1361 |

As p-value obtained is less than the significance value, we reject the null hypothesis. So, we conclude that at least 1 of the treatments are different ($H_a$).

**Random Permutation**

We get different p value in each simulation. Here are the p-values we got from 100 simulations:

| p-values |
| --- |
| 0.0025 |
| 0.0025 |
| 0.0013 |
| 0.0000 |
| 0.0013 |
| 0.0025 |
| 0.0013 |
| 0.0013 |
| 0.0000 |
| 0.0000 |
| 0.0025 |
| 0.0013 |
| 0.0013 |
| 0.0000 |
| 0.0000 |
| 0.0013 |
| 0.0000 |
| 0.0000 |
| 0.0000 |
| 0.0000 |
| 0.0000 |
| 0.0000 |
| 0.0000 |
| 0.0013 |

| |
|---|
| 0.0000 |
| 0.0013 |
| 0.0013 |
| 0.0000 |
| 0.0025 |
| 0.0037 |
| 0.0000 |
| 0.0000 |
| 0.0000 |
| 0.0000 |
| 0.0013 |
| 0.0000 |
| 0.0000 |
| 0.0000 |
| 0.0025 |
| 0.0000 |
| 0.0000 |
| 0.0000 |
| 0.0000 |
| 0.0000 |
| 0.0000 |
| 0.0025 |
| 0.0000 |
| 0.0025 |
| 0.0000 |
| 0.0000 |
| 0.0000 |

| |
|---|
| 0.0025 |
| 0.0025 |
| 0.0000 |
| 0.0000 |
| 0.0025 |
| 0.0000 |
| 0.0013 |
| 0.0037 |
| 0.0000 |
| 0.0000 |
| 0.0025 |
| 0.0025 |
| 0.0000 |
| 0.0000 |
| 0.0000 |
| 0.0000 |
| 0.0000 |
| 0.0000 |
| 0.0013 |
| 0.0013 |
| 0.0000 |
| 0.0013 |
| 0.0013 |
| 0.0000 |
| 0.0000 |
| 0.0000 |
| 0.0000 |

| |
|---|
| 0.0000 |
| 0.0000 |
| 0.0013 |
| 0.0025 |
| 0.0025 |
| 0.0013 |
| 0.0000 |
| 0.0000 |
| 0.0000 |
| 0.0013 |
| 0.0037 |
| 0.0000 |
| 0.0000 |
| 0.0000 |
| 0.0013 |
| 0.0013 |
| 0.0013 |
| 0.0000 |
| 0.0013 |
| 0.0000 |
| 0.0013 |
| 0.0000 |

We can see the maximum p-value we got is 0.0037 which is still less than the significance value 0.05. So according to random permutation we also reject the null hypotheses or alternatively we assume that at least 1 of the treatment is not the same.

## 1.4 Discussion:

Both systematic and random permutation rejects $H_0$. Here is the summary of the both systematic and random permutation results:

| | Systematic Permutation | Random Permutation |
|---|---|---|
| p-value | 0.0007936507936507937 | Changes in different simulations. Minimum=0, Maximum=0.00375(From 100 simulations) |
| Conclusion | Rejects $H_0$ | Rejects $H_0$ |
| Number of permutations | 1260 | 800 |

Appendix:

```
# -*- coding: utf-8 -*-
"""
Created on Tue Mar 10 22:05:39 2020

@author: Salehin
"""
from itertools import combinations
import math
import numpy as np
data=[6,8,9,11,9,17,15,16,16]
indexes=list(range(1,len(data)+1))
import random
sizea=2
sizeb=3
sizec=4
def removefroma(indexes,trta):
    b=[]
    for i in range(len(indexes)):
        k=indexes[i]
        if k not in trta:
            b.append(k)
    return b
def randomselection(size,array):
    current=[]
    new=array
    for i in range(size):
        a=random.choice(new)
```

```python
        if a not in current:

            current.append(a)

            new.remove(a)

    return current




def stats(index,data):

    summ=0

    for i in range(len(index)):

        summ+=data[index[i]-1]

    return summ**2/len(index)




def trta(indexes,sizea):

     return list(combinations(indexes,sizea))

removable=()

n=0

p=0

storage=np.zeros([1260,10])

original=stats((1,2),data)+stats((3,4,5),data)+stats((6,7,8,9),data)

for                                              i                                              in
range(int(math.factorial(len(indexes))/((math.factorial(sizea))*math.factorial(len(indexes)-
sizea)))):

    currenta=trta(indexes,sizea)[i]

    removable=currenta

    other=removefroma(indexes,removable)

    treatmentb=trta(other,sizeb)

    for j in range(len(treatmentb)):
```

```python
        currentb=treatmentb[j]

        removable=removable+currentb

        other=removefroma(indexes,removable)

        removable=currenta

        total=stats(currenta,data)+stats(currentb,data)+stats(other,data)


a=[currenta[0],currenta[1],currentb[0],currentb[1],currentb[2],other[0],other[1],other[2],other
[3],total]

        storage[n][0],storage[n][1]=currenta[0],currenta[1]

        storage[n][2],storage[n][3],storage[n][4]=currentb[0],currentb[1],currentb[2]

        storage[n][5],storage[n][6],storage[n][7],storage[n][8]=other[0],other[1],other[2],other[3]

        storage[n][9]=total

        if(total>=original):

            p+=1

        n+=1




np.savetxt('result.txt',storage,delimiter=',',fmt='%1d')

print("Result with Systematic Permutation: ",p/n)

n=800

p1=0

for i in range(n-1):

    currentarray=indexes.copy()

    trta=randomselection(sizea,currentarray)


    arraytoremove=trta

    currentarray=removefroma(indexes,arraytoremove)

    trtb=randomselection(sizeb,currentarray)

    arraytoremove=trta+trtb
```

```python
        currentarray=removefroma(indexes,arraytoremove)

        trtc=currentarray

        total=stats(trta,data)+stats(trtb,data)+stats(trtc,data)

        if(total>=original):

            p1+=1

        currentarray.clear()

        arraytoremove.clear()

np.savetxt('random.txt',pvalues,delimiter=',',fmt='%1.4f')

print('Result with random permutation: ',p1/n)
```