**Randomization**

Randomization provides a mechanism for assigning treatmentsto experimental units that is free from intentional or unintentionalbiases that can be introduced by a researcher wishing to findevidence that a treatment causes changes in a response. Furthermore,the use of random assignment justifies the formal probabilitystatements that play a central role in statistical inference.Perhaps the best way to grasp the importance of randomizationis to understand a method of inference due to Fisher known asa randomization test.

Suppose, for example, that two treatments(A and B) are randomly assigned to eight plants, with four plantsper treatment. Suppose that a quantitative response of interestis measured for each of the eight plants following treatmentand that the resulting data are **3,4 3,6 3,9 4,3** for treatment A (average 3,8) and

**4,6 5,9 6,0 6,7** for treatment B (average 5,8) as in the first line of the table 1.

Note that the average response for plants receiving treatment B is 2.0 units greater than the average response for plantsreceiving treatment A.

A researcher might wish to conclude fromthis difference between averages that treatment B caused anincrease in the response of interest relative to treatment A.There is, however, another explanation that must be consideredbefore this conclusion can be drawn. There is clearly variationin the response of interest even among experimental units (plants)treated identically. Perhaps treatments A and B had no effectwhatsoever on the response and the responses associated withthese eight plants would have been exactly the same regardlessof which treatment each received. The difference in averagescould be simply a consequence of the random assignment of treatmentsto the eight experimental units; that is, it is possible thatby chance the four plants that ultimately had the lowest fourresponses happened to be chosen to receive treatment A, whilethe four with the highest responses happened to be chosen toreceive treatment B. Because treatments were randomly assignedto experimental units initially, we can compute the probabilityof such a coincidence.

Accepting for the moment the hypothesis,

**H0 : the treatmentshad no effect on the responses,**

there are 70 different datasets that could have resulted from our experiment.

Each of thesedata sets corresponds to one of the 70 different ways that theeight experimental units could have been divided into two groupsof four for treatments A and B. = = 70

The 70 possibilitiesare presented explicitly in table 1 along with the differencein treatment averages that would have resulted.

**Table 1**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Treatment A** | | |  |  | **Treatment B** | | |  | **Difference between Averages** | | |
| **3,4** | **3,6** | **3,9** | **4,3** |  | **4,6** | **5,9** | **6,0** | **6,7** |  | -2 |  |  |
| 3,4 | 3,6 | 3,9 | 4,6 |  | 4,3 | 5,9 | 6,0 | 6,7 |  | -1,85 |  |  |
| 3,4 | 3,6 | 4,6 | 4,3 |  | 3,9 | 5,9 | 6,0 | 6,7 |  | -1,65 |  |  |
| 3,4 | 4,6 | 3,9 | 4,3 |  | 3,6 | 5,9 | 6,0 | 6,7 |  | -1,5 |  |  |
| 4,6 | 3,6 | 3,9 | 4,3 |  | 3,4 | 5,9 | 6,0 | 6,7 |  | -1,4 |  |  |
| 3,4 | 3,6 | 3,9 | 5,9 |  | 4,6 | 4,3 | 6,0 | 6,7 |  | -1,2 |  |  |
| 3,4 | 3,6 | 5,9 | 4,3 |  | 4,6 | 3,9 | 6,0 | 6,7 |  | -1 |  |  |
| 3,4 | 5,9 | 3,9 | 4,3 |  | 4,6 | 3,6 | 6,0 | 6,7 |  | -0,85 |  |  |
| 5,9 | 3,6 | 3,9 | 4,3 |  | 4,6 | 3,4 | 6,0 | 6,7 |  | -0,75 |  |  |
| 3,4 | 3,6 | 3,9 | 6,0 |  | 4,6 | 5,9 | 4,3 | 6,7 |  | -1,15 |  |  |
| 3,4 | 3,6 | 6,0 | 4,3 |  | 4,6 | 5,9 | 3,9 | 6,7 |  | -0,95 |  |  |
| 3,4 | 6,0 | 3,9 | 4,3 |  | 4,6 | 5,9 | 3,6 | 6,7 |  | -0,8 |  |  |
| 6,0 | 3,6 | 3,9 | 4,3 |  | 4,6 | 5,9 | 3,4 | 6,7 |  | -0,7 |  |  |
| 3,4 | 3,6 | 3,9 | 6,7 |  | 4,6 | 5,9 | 6,0 | 4,3 |  | -0,8 |  |  |
| 3,4 | 3,6 | 6,7 | 4,3 |  | 4,6 | 5,9 | 6,0 | 3,9 |  | -0,6 |  |  |
| 3,4 | 6,7 | 3,9 | 4,3 |  | 4,6 | 5,9 | 6,0 | 3,6 |  | -0,45 |  |  |
| 6,7 | 3,6 | 3,9 | 4,3 |  | 4,6 | 5,9 | 6,0 | 3,4 |  | -0,35 |  |  |
| 3,4 | 3,6 | 5,9 | 4,6 |  | 4,3 | 3,9 | 6,0 | 6,7 |  | -0,85 |  |  |
| 3,4 | 5,9 | 4,6 | 4,3 |  | 3,9 | 3,6 | 6,0 | 6,7 |  | -0,5 |  |  |
| 5,9 | 4,6 | 3,9 | 4,3 |  | 3,6 | 3,4 | 6,0 | 6,7 |  | -0,25 |  |  |
| 3,4 | 5,9 | 3,9 | 4,6 |  | 4,3 | 3,6 | 6,0 | 6,7 |  | -0,7 |  |  |
| 5,9 | 3,6 | 3,9 | 4,6 |  | 4,3 | 3,4 | 6,0 | 6,7 |  | -0,6 |  |  |
| 5,9 | 3,6 | 4,6 | 4,3 |  | 3,9 | 3,4 | 6,0 | 6,7 |  | -0,4 |  |  |
| 3,4 | 3,6 | 6,0 | 4,6 |  | 4,3 | 5,9 | 3,9 | 6,7 |  | -0,8 |  |  |
| 3,4 | 6,0 | 4,6 | 4,3 |  | 3,9 | 5,9 | 3,6 | 6,7 |  | -0,45 |  |  |
| 6,0 | 4,6 | 3,9 | 4,3 |  | 3,6 | 5,9 | 3,4 | 6,7 |  | -0,2 |  |  |
| 3,4 | 6,0 | 3,9 | 4,6 |  | 4,3 | 5,9 | 3,6 | 6,7 |  | -0,65 |  |  |
| 6,0 | 3,6 | 3,9 | 4,6 |  | 4,3 | 5,9 | 3,4 | 6,7 |  | -0,55 |  |  |
| 6,0 | 3,6 | 4,6 | 4,3 |  | 3,9 | 5,9 | 3,4 | 6,7 |  | -0,35 |  |  |
| 3,4 | 3,6 | 6,7 | 4,6 |  | 4,3 | 5,9 | 6,0 | 3,9 |  | -0,45 |  |  |
| 3,4 | 6,7 | 4,6 | 4,3 |  | 3,9 | 5,9 | 6,0 | 3,6 |  | -0,1 |  |  |
| 6,7 | 4,6 | 3,9 | 4,3 |  | 3,6 | 5,9 | 6,0 | 3,4 |  | 0,15 |  |  |
| 3,4 | 6,7 | 3,9 | 4,6 |  | 4,3 | 5,9 | 6,0 | 3,6 |  | -0,3 |  |  |
| 6,7 | 3,6 | 3,9 | 4,6 |  | 4,3 | 5,9 | 6,0 | 3,4 |  | -0,2 |  |  |
| 6,7 | 3,6 | 4,6 | 4,3 |  | 3,9 | 5,9 | 6,0 | 3,4 |  | 0 |  |  |
| 3,4 | 3,6 | 6,0 | 5,9 |  | 4,6 | 4,3 | 3,9 | 6,7 |  | -0,15 |  |  |
| 3,4 | 6,0 | 5,9 | 4,3 |  | 4,6 | 3,9 | 3,6 | 6,7 |  | 0,2 |  |  |
| 6,0 | 5,9 | 3,9 | 4,3 |  | 4,6 | 3,6 | 3,4 | 6,7 |  | 0,45 |  |  |
| 3,4 | 6,0 | 3,9 | 5,9 |  | 4,6 | 4,3 | 3,6 | 6,7 |  | 0 |  |  |
| 6,0 | 3,6 | 3,9 | 5,9 |  | 4,6 | 4,3 | 3,4 | 6,7 |  | 0,1 |  |  |
| 6,0 | 3,6 | 5,9 | 4,3 |  | 4,6 | 3,9 | 3,4 | 6,7 |  | 0,3 |  |  |
| 3,4 | 3,6 | 6,7 | 5,9 |  | 4,6 | 4,3 | 6,0 | 3,9 |  | 0,2 |  |  |
| 3,4 | 6,7 | 5,9 | 4,3 |  | 4,6 | 3,9 | 6,0 | 3,6 |  | 0,55 |  |  |
| 6,7 | 5,9 | 3,9 | 4,3 |  | 4,6 | 3,6 | 6,0 | 3,4 |  | 0,8 |  |  |
| 3,4 | 6,7 | 3,9 | 5,9 |  | 4,6 | 4,3 | 6,0 | 3,6 |  | 0,35 |  |  |
| 6,7 | 3,6 | 3,9 | 5,9 |  | 4,6 | 4,3 | 6,0 | 3,4 |  | 0,45 |  |  |
| 6,7 | 3,6 | 5,9 | 4,3 |  | 4,6 | 3,9 | 6,0 | 3,4 |  | 0,65 |  |  |
| 3,4 | 3,6 | 6,7 | 6,0 |  | 4,6 | 5,9 | 4,3 | 3,9 |  | 0,25 |  |  |
| 3,4 | 6,7 | 6,0 | 4,3 |  | 4,6 | 5,9 | 3,9 | 3,6 |  | 0,6 |  |  |
| 6,7 | 6,0 | 3,9 | 4,3 |  | 4,6 | 5,9 | 3,6 | 3,4 |  | 0,85 |  |  |
| 3,4 | 6,7 | 3,9 | 6,0 |  | 4,6 | 5,9 | 4,3 | 3,6 |  | 0,4 |  |  |
| 6,7 | 3,6 | 3,9 | 6,0 |  | 4,6 | 5,9 | 4,3 | 3,4 |  | 0,5 |  |  |
| 6,7 | 3,6 | 6,0 | 4,3 |  | 4,6 | 5,9 | 3,9 | 3,4 |  | 0,7 |  |  |
| 3,4 | 5,9 | 6,0 | 6,7 |  | 4,6 | 3,6 | 3,9 | 4,3 |  | 1,4 |  |  |
| 5,9 | 3,6 | 6,0 | 6,7 |  | 4,6 | 3,4 | 3,9 | 4,3 |  | 1,5 |  |  |
| 5,9 | 6,0 | 3,9 | 6,7 |  | 4,6 | 3,4 | 3,6 | 4,3 |  | 1,65 |  |  |
| 5,9 | 6,0 | 6,7 | 4,3 |  | 4,6 | 3,4 | 3,6 | 3,9 |  | 1,85 |  |  |
| 3,4 | 4,6 | 6,0 | 6,7 |  | 3,6 | 5,9 | 3,9 | 4,3 |  | 0,75 |  |  |
| 4,6 | 3,6 | 6,0 | 6,7 |  | 3,4 | 5,9 | 3,9 | 4,3 |  | 0,85 |  |  |
| 4,6 | 6,0 | 3,9 | 6,7 |  | 3,4 | 5,9 | 3,6 | 4,3 |  | 1 |  |  |
| 4,6 | 6,0 | 6,7 | 4,3 |  | 3,4 | 5,9 | 3,6 | 3,9 |  | 1,2 |  |  |
| 3,4 | 4,6 | 5,9 | 6,7 |  | 3,6 | 3,9 | 6,0 | 4,3 |  | 0,7 |  |  |
| 4,6 | 3,6 | 5,9 | 6,7 |  | 3,4 | 3,9 | 6,0 | 4,3 |  | 0,8 |  |  |
| 4,6 | 5,9 | 3,9 | 6,7 |  | 3,4 | 3,6 | 6,0 | 4,3 |  | 0,95 |  |  |
| 4,6 | 5,9 | 6,7 | 4,3 |  | 3,4 | 3,6 | 6,0 | 3,9 |  | 1,15 |  |  |
| 3,4 | 4,6 | 5,9 | 6,0 |  | 3,6 | 3,9 | 4,3 | 6,7 |  | 0,35 |  |  |
| 4,6 | 3,6 | 5,9 | 6,0 |  | 3,4 | 3,9 | 4,3 | 6,7 |  | 0,45 |  |  |
| 4,6 | 5,9 | 3,9 | 6,0 |  | 3,4 | 3,6 | 4,3 | 6,7 |  | 0,6 |  |  |
| 4,6 | 5,9 | 6,0 | 4,3 |  | 3,4 | 3,6 | 3,9 | 6,7 |  | 0,8 |  |  |
| 4,6 | 5,9 | 6,0 | 6,7 |  | 3,4 | 3,6 | 3,9 | 4,3 |  | 2 |  |  |

From this table, we can see that most of the random assignmentswould have resulted in a difference between averages closerto 0 than the difference we observed in the actual experiment.In fact only two of the 70 random assignments (the first and last in table 1) provide a difference in averages as far from 0 as thedifference we observed.

Thus, under the assumption of no treatmenteffect, the chance was 2/70 {approx} 0.0286 of seeing a difference inaverages as far from 0 as the difference we observed.

Becausea difference in averages so far from 0 would be unlikely tooccur if there were no treatment effect, we have good reasonto believe that the treatments did indeed affect the response. The quantity 2/70 is an example of a P- value.

Note that wewere able to compute a P value in this example without makingany distributional assumptions about the data. For example,we did not need to assume the data were normally distributed,as is done when conducting a standard two-sample t- test. Thekey point for computing the P value was that all 70 random assignmentswere equally likely to have occurred due to our initial randomassignment of treatments to the experimental units. Withoutthis random assignment, the argument for a treatment effectbreaks down, and in this way, randomization plays a crucialrole in establishing that a treatment causes changes in a response.

Note that replication was also essential in our argument. Hadthere been only one experimental unit (plant) for each treatment,any difference between the plants could have been attributedto natural variation between experimental units rather thana treatment effect.

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adapted by Wilma Groenewegen