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**Project Report**

**Design of Experiment—ISE 410**

**The analysis of factors affecting the running game**

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**ABSTRACT**

Usain Bolt, the fastest man alive, had many champions in the running games. He also is keeping the many World and Olympic records of running. 100 meter. His speed is fascinating to every man on this world. Then, how could we practice to get close to him? It’s a problem needed to discover. In this project, we all do our best to uncover the secrets by the analysis of experiments.

Everyone can run, but how to improve the speed is also an important question. In other words, there are some elements affecting the record of game. We design a special experiment to test which element has the most powerful influence. We invite a volunteer to join our experiment at first. Then we use software “Minitab” to analyze the results. This report concludes the original data, choices of factors and levels, response, and the conclusion.

**INTRODUCTION**

The time can be a tool to measure the achievement of a runner in a given distance. Our goal is to find out which factors affect the performance of this runner. We also try to find the levels of factors when the runner spends the least time. In this time, we select 50 meter. The reason we choose this because it’s convenient to process. And the time is so short that our experiment can do more times.

First of all, the preliminary analysis needs to be done before we start the experiment. We need to raise our problems, and select the factors, levels and ranges. It would be discussed as follows:

**Objective**: To find which factor could affect the time of 50m most, then according to the results got from the analysis, make a conclusion.

**HOW TO DESGIN EXPERIMENT**

Our teammates use brain-storm to find a few factors which would give impacts on the time.

**Factors**

1. **Food--carbohydrate**

The food can provide energy to runner, hence it may be important. So two levels of this factor are:

1. Running after eating food--low
2. Running without eating food--high
3. **Equipment**

The equipment like shoes is also a crucial factor. So two levels of this factor are:

1. Running with athletic shoes--low
2. Running with casual shoes--high
3. **The time of one day**

Certainly, the time of one day also decides the something. According to the scientific survey, the muscle of body would give a little more energy and power in the evening. It’s the reason why our sports game like NBA or athletics. So two levels of this factor are:

1. Evening--low
2. Morning—high
3. **Place of running**

Which place to run, it is quite subtle to the record. Based on the investigation on the records of outside and inside, we find when the athletes play games outside they probably get a beautiful grade. However, we are not interested in this factor. This is a nuisance factor. Fortunately, this factor iscontrollable. The two levels of this factor are:

1. Running outside--low
2. Running inside--high

**Choice of Design**

This design has three main factors, each at only two levels. So we choose to use the factorial design. And it seems factorial full design is most suitable for us.

**Number of Replicates**

In order to avoid the influence of the physique of people, this is a nuisance factor, so we decide to block it. We arrange 3 different people to participant in experiment. Thus, there are 3 replicates in this design.

**RUN THE EXPERIMENT**

The experiment is processed in the gym and the normal street. The time is measured by a stopwatch.

The experiment was conducted in the morning at 8.30 A.M and afternoon evening at 8:30 P.M. The food is provided with same calorie at every time, and it guarantees the enough energy for experimenter. After completing running one time, he would get a rest for 30 minutes to avoid the next potential influence.

**ANALYSIS OF DATA**

The analysis of the collected data was done using “Minitab” analysis software. Our hypothesis was as follows:

H0: There is no significant difference in the main/interaction effects.

H1: There is significant difference in the main/interaction effects.

**Analysis of Variance (ANOVA):**

**Factorial Regression: C9 versus Blocks, Carbohydrate, Shoes, Daytime, Place**

Analysis of Variance

Source DF Adj SS Adj MS F-Value P-Value

Model 17 4.74670 0.27922 84.80 0.000

Blocks 2 0.00549 0.00274 0.83 0.444

Linear 4 4.68773 1.17193 355.92 0.000

Carbohydrate 1 0.87750 0.87750 266.50 0.000

Shoes 1 2.46160 2.46160 747.61 0.000

Daytime 1 0.25960 0.25960 78.84 0.000

Place 1 1.08902 1.08902 330.74 0.000

2-Way Interactions 6 0.01868 0.00311 0.95 0.478

Carbohydrate\*Shoes 1 0.00350 0.00350 1.06 0.311

Carbohydrate\*Daytime 1 0.00200 0.00200 0.61 0.442

Carbohydrate\*Place 1 0.00047 0.00047 0.14 0.709

Shoes\*Daytime 1 0.00385 0.00385 1.17 0.288

Shoes\*Place 1 0.00500 0.00500 1.52 0.227

Daytime\*Place 1 0.00385 0.00385 1.17 0.288

3-Way Interactions 4 0.01006 0.00251 0.76 0.557

Carbohydrate\*Shoes\*Daytime 1 0.00010 0.00010 0.03 0.861

Carbohydrate\*Shoes\*Place 1 0.00000 0.00000 0.00 0.980

Carbohydrate\*Daytime\*Place 1 0.00935 0.00935 2.84 0.102

Shoes\*Daytime\*Place 1 0.00060 0.00060 0.18 0.672

4-Way Interactions 1 0.02475 0.02475 7.52 0.010

Carbohydrate\*Shoes\*Daytime\*Place 1 0.02475 0.02475 7.52 0.010

Error 30 0.09878 0.00329

Total 47 4.84548

Model Summary

S R-sq R-sq(adj) R-sq(pred)

0.0573815 97.96% 96.81% 94.78%

Coded Coefficients

Term Effect Coef SE Coef T-Value P-Value VIF

Constant 7.35063 0.00828 887.51 0.000

Blocks

1 -0.0031 0.0117 -0.27 0.791 1.33

2 -0.0112 0.0117 -0.96 0.344 1.33

Carbohydrate 0.27042 0.13521 0.00828 16.32 0.000 1.00

Shoes 0.45292 0.22646 0.00828 27.34 0.000 1.00

Daytime 0.14708 0.07354 0.00828 8.88 0.000 1.00

Place 0.30125 0.15063 0.00828 18.19 0.000 1.00

Carbohydrate\*Shoes 0.01708 0.00854 0.00828 1.03 0.311 1.00

Carbohydrate\*Daytime 0.01292 0.00646 0.00828 0.78 0.442 1.00

Carbohydrate\*Place -0.00625 -0.00312 0.00828 -0.38 0.709 1.00

Shoes\*Daytime -0.01792 -0.00896 0.00828 -1.08 0.288 1.00

Shoes\*Place -0.02042 -0.01021 0.00828 -1.23 0.227 1.00

Daytime\*Place -0.01792 -0.00896 0.00828 -1.08 0.288 1.00

Carbohydrate\*Shoes\*Daytime 0.00292 0.00146 0.00828 0.18 0.861 1.00

Carbohydrate\*Shoes\*Place 0.00042 0.00021 0.00828 0.03 0.980 1.00

Carbohydrate\*Daytime\*Place 0.02792 0.01396 0.00828 1.69 0.102 1.00

Shoes\*Daytime\*Place 0.00708 0.00354 0.00828 0.43 0.672 1.00

Carbohydrate\*Shoes\*Daytime\*Place -0.04542 -0.02271 0.00828 -2.74 0.010 1.00

After realizing the “Normal plot” and the “half Normal plot”, we continue to do the analysis of variance. The ANOVA is obtained from “Minitab” software. The model had seventeen degrees of freedom. The block had two degrees of freedom and the residuals had twelve degrees of freedom, total 47 degrees of freedom.

From this ANOVA table, we found the P-Values of all factors are 0.000, which are less than 0.01. These extremely low P-Values mean that all of them are significant. What’s more, the P-Value of the model is 0.000 that is less than 0.01, which proves that the model is quite significant. The F-Value of model also implies that the model is significant. So, we reject the null hypothesis and admit that there is at least one factor affecting the performance of the runners. There is only a 0.000 % chance that a “Model F-Value” this large could occur due to noise.

**Analysis of the Normal Plot**

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We use Minitab to obtain the normal plot of the standardized effects. From it, we find factor A,B,C,D are significantly away from the straight line. Thus, we deduce that these factors were not distributed with a mean zero and a constant variance, and they are significant. The factor B“shoes” is the largest effect, then next largest effects are factor D“place”, factor A“carbohydrate” and factor C“daytime”.

In addition, the ABCD interaction is the least effect. Its P-value is 0.010, it is less than 0.05. It is also significant. Also according to the graph, we can find it obviously and consider it in our model.

**Analysis of the Half Normal Plot**



Also, we can receive the same conclusion from data of the half normal plot of standardized effect. The effects of factor A, B, C, D and ABCD interaction are significant.

**Analysis of Perato Chart**



This graph also tells us the factors B,D,A,C and ABCD are significant.

**Analysis of Residual**

We have had the analysis of variance and regression model, and then we proceed to analyze the residual plots. The primary objective of analysis of residual is to judge if the model is fitting with statistics based on the situation of residual. If the fitting is good, the residuals should be normal.

**The Residual plots for response“time”**

First of all, we need to analyze these graphs. For the graph “Versus Order”, it is a scatter diagram whose abscissa axis is observation order. We find that each point fluctuate in the horizontal axis randomly and irregularly. For the graph “Versus Fits”, it also is a scatter diagram whose abscissa axis is fitted value. We find that each point is distributed randomly and irregularly. For the histogram, we find the residuals meet the normal distribution.

Hence, the residuals are normally distributed.

**The** **Residuals VS Shoes**



**The** **Residuals VS Carbohydrate**



**The** **Residuals Vs Daytime**



**The** **Residuals VS** **Place**

These four residual plots prove that the residuals versus factors are distributed normally.

**Regression Model:**

**Final Equation in Terms of Actual Factors:**

Time Taken = 7.35063

+ 0.13521 Carbohydrate

+ 0.22646 Shoes

+ 0.07354 Daytime

+ 0.15063 Place

+ 0.00854 Carbohydrate\*Shoes + 0.00646 Carbohydrate\*Daytime

- 0.00312 Carbohydrate\*Place - 0.00896 Shoes\*Daytime

- 0.01021 Shoes\*Place

- 0.00896 Daytime\*Place + 0.00146 Carbohydrate\*Shoes\*Daytime

+ 0.00021 Carbohydrate\*Shoes\*Place + 0.01396 Carbohydrate\*Daytime\*Place

+ 0.00354 Shoes\*Daytime\*Place - 0.02271 Carbohydrate\*Shoes\*Daytime\*Place

**CONFIRMATION SIGNIFICANT OF MAIN EFFECTS AND INTERACTIONS**

We could judge the significant by main effects plot and interactions





According to the main effects plot, we can see the regression lines of shoes, place, carbohydrate and daytime are oblique, especially the lines of shoes is the most slant. In other words, for improving the performance of running which means the record should be as small as possible, four factors should be inclined to be small, that is running inside, with shoes, after eating, and in the evening.



The cube plot also tells us the result of the optimal solution.

**CONCLUSIONS**

From ANOVA, we know that the model F-Value of 84 and its small P-Value of 0.000 implies that the model is significant. There is only a 0.00 % chance that the model F-Value so large could have occurred due to noise.

From the analysis of the “Normal Plot” and the “Half Normal Plot”, we know that the factors “shoes”, “place”, “daytime” and “carbohydrate” are significant. Their P-Values are far less than 0.1, which prove this conclusion is right. In addition, the interaction of all factors is also significant.

From the analysis of residuals, we notice that the residuals are distributed normally, which means the model is reliable.

Thus, we demonstrate the four factors, “shoes” “place” “daytime” and “carbohydrate”, all determine the performance of running. And in the evening at an outside track, runners would run more quickly with perfect athletic shoes.

**SUGGESTIONS:**

According to the data we collect and the conclusions, we find if runners comply with these suggestions, the results of 50m would be improved. Now there are our advices.

1. The runner should wear athletic shoes instead of casual shoes.
2. The runner should run outside rather than inside.
3. The runner should take little foods to eat before running.
4. The runner should make the competition in the evening.