Design Analysis of Experiments

Getting a Better Night’s Sleep – as a College Student

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**Introduction:**

A good night’s sleep is often the key to having a successful and productive day. Those that achieve a the optimal amount of sleep are more attentive and alert, retain more information throughout the course of the day, and are better decision makers. However, in the busy lives of today’s college students, sleep is often the first thing that gets sacrificed and neglected. In a recent study done by the Journal of Adolescent Health, less than a third of its participants got the recommended eight hours of sleep every night. Long term sleep deprivation effects are more severe, and many issues begin to arise regarding physical and mental health.

To combat this issue, I wanted to determine what factors played an important role in influencing the amount of sleep students receive every night. When it came to choosing the factors that I wanted to analyze, I decided on coffee intake, exercise, and reading before bed. These were all factors that I had learned from a young age effected sleep in various degrees, and I wanted to see how accurate and significant their effects on sleep really were. Furthermore, many college students, including myself, have developed habits around at least one of the three factors in their daily routines.

To run the experiment, I used myself as the main and only participant and recorded the number of hours of sleep I received for each factor combination for a period of 24 days. I am a 21 year old, Asian male in good health, and I believe that my lifestyle is a good representation of the average student. The ultimate goal of this experiment is to see if I can discover and isolate the optimum combination of these three factors to achieve the most sleep. Furthermore, by understanding how these factors affect the hours of sleep that one gets every night, I can build a schedule that revolves around obtaining the recommended hours of sleep every night.

The experiment followed a 2^3, full factorial design with three replicates for each level, with the response being number of hours slept. Below is a list of the factors and its corresponding levels used:

Table 1.

|  |  |  |  |
| --- | --- | --- | --- |
| **Factor** | **Variable** | **High ( + )** | **Low ( - )** |
| Coffee (>8 oz) | A | Yes (drank 8oz of coffee) | No |
| Read Before Bed  (>30 min) | B | Yes (read for at least 30 min before bed) | No |
| Exercise (> 30 min) | C | Yes (exercised for at least 30 min during day) | No |

**Data Collection:**

Each factor that was tested required a minimum threshold to count as completed. For example, coffee intake was measured as a ‘yes’ for the day if I drank at least 8 oz of coffee, which is equivalent to a small Starbucks coffee. I did not adjust for type – i.e. a cold brew was viewed the same as a hot coffee. For the exercise factor, I determined this by the act of going to the gym and staying there for more than 30 minutes. Again it did not matter if I was playing basketball (a more cardio-intensive workout) or just lifting weights. To record the hours of sleep every night, I recorded the time that I would turn off the lights in my room as the start time. Although most of the time I would not fall asleep immediately, I believe that it would have been impossible to know exactly when I fall asleep and to start recording then. Because this was the case for every night, I did not believe an adjustment was needed. For the mornings, I recorded the end as when I got up to get changed.

Furthermore, the order at which I would complete these daily routines was randomized at the beginning of the experiment. Using Excel, each design was listed three times to correspond to the three replicates and assigned a random number between 0 and 1 using the function “rand().” The assignments were then ranked from smallest to largest (1-24) and that was the order which the design took. For the experiment, blocking effects between days were assumed to be not significant, and the experiment took place between 11/3/19 and 11/26/19. Table 2 below shows the planning matrix for the experimental design.

Table 2. Planning Matrix

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Planning Matrix** | | | | |
| Day | Run Order | Coffee | Read | Exercise |
| 11/3/19 | 1 | 0 | 0 | 1 |
| 11/4/19 | 2 | 0 | 1 | 1 |
| 11/5/19 | 3 | 1 | 0 | 0 |
| 11/6/19 | 4 | 1 | 0 | 1 |
| 11/7/19 | 5 | 1 | 0 | 0 |
| 11/8/19 | 6 | 1 | 1 | 0 |
| 11/9/19 | 7 | 0 | 0 | 1 |
| 11/10/19 | 8 | 1 | 1 | 0 |
| 11/11/19 | 9 | 1 | 1 | 1 |
| 11/12/19 | 10 | 1 | 0 | 0 |
| 11/13/19 | 11 | 0 | 0 | 0 |
| 11/14/19 | 12 | 0 | 0 | 1 |
| 11/15/19 | 13 | 1 | 1 | 1 |
| 11/16/19 | 14 | 0 | 1 | 0 |
| 11/17/19 | 15 | 0 | 1 | 1 |
| 11/18/19 | 16 | 0 | 1 | 0 |
| 11/19/19 | 17 | 1 | 1 | 0 |
| 11/20/19 | 18 | 0 | 1 | 1 |
| 11/21/19 | 19 | 1 | 0 | 1 |
| 11/22/19 | 20 | 1 | 0 | 1 |
| 11/23/19 | 21 | 0 | 0 | 0 |
| 11/24/19 | 22 | 1 | 1 | 1 |
| 11/25/19 | 23 | 0 | 0 | 0 |
| 11/26/19 | 24 | 0 | 1 | 0 |

Table 3. Recorded Data

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Factors (Yes/No)** | | | **Replicates / Response (Hours Slept)** | | | |
| Coffee (A) | Read (B) | Exercise (C) | 1 | 2 | 3 | Average (Y Bar) |
| + | + | + | 7.5 | 9 | 6 | 7.50 |
| + | + | - | 8.75 | 8.5 | 7 | 8.08 |
| + | - | + | 8 | 8.5 | 7 | 7.83 |
| + | - | - | 8 | 8.25 | 8 | 8.08 |
| - | + | + | 9 | 9.5 | 8.5 | 9.00 |
| - | + | - | 10 | 8.5 | 8.5 | 9.00 |
| - | - | + | 10 | 9.5 | 8.5 | 9.33 |
| - | - | - | 8 | 8 | 9 | 8.33 |

**Modeling Summary:**

The following data analysis was performed using R. Along with the generic packages provided, we also utilized “DoE.base” and “gplots” to create the graphs provided below. The generic fitted model is:

The factors A,B,C and its levels correspond to the three factors described in Table 1. After performing an initial ANOVA analysis, the only significant main effect is A, with the interaction effect between AC being the second most significant effect with a p-value of .20. This follows the Effect Heredity Principal, as although C has a insignificant effect by itself, when combined with A, creates a relatively important effect.

Output 1. ANOVA Summary

A screenshot of a cell phone

Description automatically generated

I used a regression model to estimate the main effects and interaction effects. Because the baseline constraint for each of the factored main effects was set to the value corresponding to -1, to get the actual main effects for each factor, the formula along with a table of the effects is given below:

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Factor | A | B | C | AB | AC | BC | ABC |
| Effect | -1.04 | 0 | 0.04 | -0.17 | -0.45 | -0.33 | 0.17 |

The regression output along with the coefficient estimates are given in Output 2 below. Again, the output for the regression analysis gave the same conclusions as the ANOVA table about the significance of different effects. The adjusted R^2 for the model was only .19, meaning that the model did not do a good job at predicting the actual data points.

Output 2. Regression Output

A screenshot of text

Description automatically generated

When analyzing the residuals for the given model, Output 3 shows some of the graphical checks that were performed. We believed that the model did not violate the normality of errors or linear relationship assumptions for linear regression, however, based on the Scale-Location graph, there may be a homoscedasticity issue with our model. Furthermore, we did not find any outliers based on the leverage for each value.

Output 3. Residual Analysis

A close up of a map

Description automatically generated

The following Outputs 4-7 show the main and interaction effects. The half-normal plot and main effects plot confirm that A is the only significant main effect. From the box-plots of the three main effects, it can be seen that factor C has clear difference in variance between its two levels. The interaction plots show an antagonistic relationship between B and C, and a synergistic relationship between the AB and AC factors.

Output 4. Half-Normal Plot for Main and Interaction Effects

A close up of a map

Description automatically generated

Output 5. Main Effects Plot

A screenshot of a cell phone

Description automatically generated

Output 6. Box-plot for Main Effects

A screenshot of a cell phone

Description automatically generated

Output 7. Interaction Effects

A close up of a map

Description automatically generated

**Data Analysis:**

Based on the results of the ANOVA along with the accompanying graphs, the most important factors are A and AC. Performing an additional regression analysis on just these factors produces the following output:

Output 8. Regression Output 2 – A, C, AC

A screenshot of text

Description automatically generated

This regression model produces the best Adjusted R-squared of .2949, and follows the Effect Sparsity Principal with only two relatively important effects in the model. The average amount a sleep on a given day that I should receive is about 8.40. By setting A to -1 and C to +1, the most sleep is achieved.

**Conclusion/Inference:**

The objective for this project was to examine important factors and their interactions and discover their effects on the total hours of sleep one receives a night. In the final model, the only significant effect was the main effect for Coffee, which effected sleep by 1 hour. The second most significant effect was the interaction effect between Coffee and Exercise, with a p-value of .168, and demonstrate a synergistic relationship. The main effect and corresponding interaction effects associated with reading before bed were not found to be significant in this experiment. The interaction effect between coffee and exercise lead to an interesting conclusion. My working assumption is that days where I drank coffee and exercised would result in increased sleep, however it leads to the opposite effect, causing me to lose about 30 minutes of sleep. This may be due to the fact that I didn’t distinguish between the types of different workouts. For example, on days where I played basketball (i.e. a cardio workout) I found myself significantly more exhausted than when I lifted weights.

According to William Dement, a researcher and professor at Stanford that specializes in the diagnosis and treatment of sleep disorders, an average college student requires at least 8 hours of sleep to be productive with their social and school life. To obtain the ideal day for sleep, (focusing on the significant effects) the final model would recommend to not drink coffee and to exercise, which would result in around 9.9 hours of sleep for the night. In terms of practicality, due to how long our daily schedules are, most college students consume at least one cup of coffee every day. In fact, according to a recent study published in Clinical Nutrition, approximately 93% of students use coffee as their daily source of caffeine. For a given day where coffee is consumed, to obtain the most sleep, the model would suggest not working out for the day to obtain about 7.8 hours of sleep.

As I was performing the experiment over the course of the month, I discovered a potential major flaw in the design of my project. In my experiment, I assumed that the blocking effects to be not significant. However, a huge factor that determines when I go to bed every night and when I wake up is the time of my morning class. On days where I had a later starting class, I found myself waking up later and thus getting more hours of sleep. Furthermore, the amount of work I had to do also greatly influenced the time I would go to bed every night. If I had an exam or a major project due the next day, I would get less sleep. Although this could be seen as a random variable that contributed to the variance of the overall model, future studies could attempt to quantify the amount of work that you have for the day or for the week and see how that influences overall sleep.

In conclusion, this experiment attempted to examine the effects of coffee, reading, and exercise on the hours of sleep one receives every night. This experiment took a very simplistic view on sleep. It only focused on the total number of hours spent in bed., and did not address the quality of sleep, which would require more advanced measuring devices. In reality, there were some nights where I wouldn’t be able to fall asleep for another hour after turning off the lights, or nights where I would wake up in the middle of the night and not be able to fall asleep. Obviously, there are many other factors that go into sleep. For example, I was going through a break-up in the latter half of the experiment, and found it hard to sleep regardless of what I did during the day. Furthermore, because the sample size of this experiment was only one, this study may not be replicable to an entire population. However, I believe that I was able to identify a few major influential effects, and hopefully encourage others to think about patterns in their daily routines.

References

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