Assessing Student Time Management to Obtain Insights for Academic Struggles

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Stat 530

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ABSTRACT

This paper discusses the application of a 2^4-1 fractional factorial model to analyze a group of struggling first-year students enrolled in a community college calculus class. The sample of students under interest are all students that have similar grades in the class and demonstrate a similar understanding of the material presented in the class. The reason for the concern in this particular group of students are their poor exam performances. In spite of attending class and review sessions, these students are still struggling on their calculus exams. In order to understand why these students are struggling, factors such as average hours of sleep, time spent on social media, time spent studying for the test, and commute time will be assessed to determine if whether or not, students are using their time to effectively prepare for exams. In doing so, the various factors and their interactions can be studied in order to determine if any of these factors and interactions are significant in affecting exam performance. Upon running the 2^4-1 experiment, the results showed that average time of sleep, commute time to school, and the interaction of the two factors were significant.

INTRODUCTION

The students enrolled in this calculus class are first-year students, many of whom are in fact first-generation college students. Needless to say, these students come from difficult economic and personal circumstances. The students examined in this study are all first-generation college students and are struggling with the class. This is a cause for concern in part because these students attend weekly review sessions and meet with an advisor on a weekly basis to discuss their progress. Despite such help, they are struggling with calculus and so their professor is interested in studying how these students use their time In order to gain a better understanding of how they are performing and using their time. By having students fill out a survey, the intention of this experiment is for the professor and advisor to gain a deeper understanding of how their students are using their time and if these factors are impacting their exam performance in any way. By performing the experiment, the hopes are to help students out and guide them toward helping better manage their time.

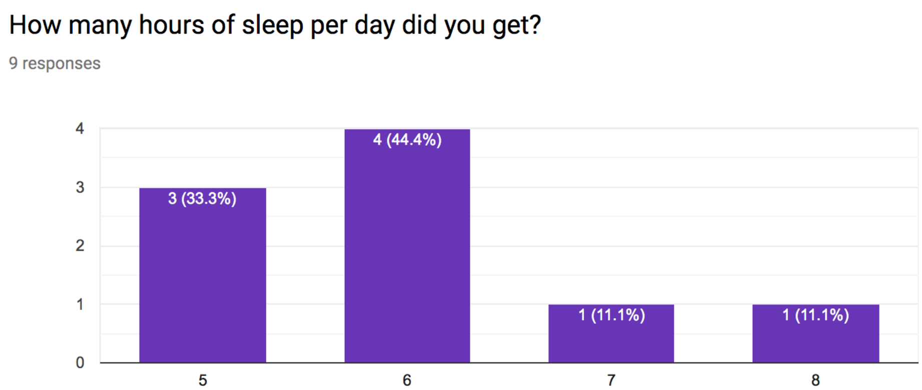
As stated previously, there are four factors that will be studied to assess why students are struggling with calculus. These factors include average minutes of sleep per night, average minutes spent on social media per day, average time spent commuting to school, and the average time in minutes these students spend studying for calculus each week. These factors are denoted A, B, C, and D respectively. The response variable, denoted by Y, is the scores these students received on their last exam out of 50 points.

Factors A and B are thought to be factors that may have to do with the student's personal characteristics and self-discipline. Factor A, average sleep per night is of interest because it is possible that if they go to class fatigued, they may not retain information very well regardless of how hard they try. This is measured at the high-level if they slept for 360 minutes of more per night, and low if not. Factor B, time spent on social media is believed to have a significant effect on these student's performance because it could cause their minds to be elsewhere when they are in class, doing homework, or studying the material. This is measured to be set at high for those who spent 120 minutes or more on social media per day, and low otherwise.

Factors C and D are thought to be factors regarding student's motivation. Factor C, commute time is a factor of interest because it is possible that if it takes the students a long time to get to and from school, their motivation to show up might be slim if they are not doing well. Commute is measured high for more than 22 minutes, and low otherwise. Lastly, factor D, time studying mathematics per week is thought to play a role because regardless of how much time they spend at review sessions or getting help, they need to be able to spend time studying the material on their own. Study time is measured high for those who studied more than 180 minutes, and low otherwise.

METHODS

The experiment was carried out on the eight students mentioned. These students were identified by the professor as being of concern. In order to measure their time management, a survey was conducted via google forms. The survey asked questions that pertained to the amount of time designated for studying, social media, sleep, and commute time. We had the students track their hours by keeping tabs for the week before their exam.



Responses from students with regards to a question on the survey

In order to examine the data garnered from the students, we must assume that the factors are independent of each other in order to base assumptions. This is so, when we examine the interaction between factors, there is no inherent prior influence.

STATISTICAL METHODOLOGY

Design

The 2^{4-1} Fractional Factorial Design is a commonly used design for screening experiments to explore which factors may influence the response variable. Another beneficial use of this design is when there is not enough time, or resources to complete all 16 treatment combinations in a single replicate. This design allows for statistical analysis to be completed in 8 runs rather than 16.

Design Construction

To effectively construct the 2^{4-1} Fractional Factorial Design, a generator must be chosen such that no effects of potential interest are aliased with each other. Choosing a generator as $I = ABCD$ gives the principal fraction since the chosen generator is positive and yields the following alias structure:

Alias Structure →	Defining Relation: $I = ABCD$
$A = BCD \rightarrow A + BCD$	$AB = CD \rightarrow AB + CD$
$B = ACD \rightarrow B + ACD$	$AC = BD \rightarrow AC + BD$

$C = ABD \rightarrow C + ABD$	$AD = BC \rightarrow AD + BC$
$D = ABC \rightarrow D + ABC$	

Note that the generator is also the defining relation for the design since it is a one-half fraction. The defining relation produces a design of resolution IV, since no main effects are aliased with any other main effect or two-factor interaction, but the two-factor interactions are aliased with each other.

Design Layout

To construct the 2^{4-1} fractional design, start by writing down the basic 2^3 design, and equate $D = ABC$ by multiplying it by the generator: $D = ABCD^2 = ABC$

Basic Design				
A	*B*	*C*	*D = ABC*	Treatment Combination
−	−	−	−	(1)
+	−	−	+	*ad*
−	+	−	+	*bd*
+	+	−	−	*ab*
−	−	+	+	*cd*
+	−	+	−	*ac*
−	+	+	−	*bc*
+	+	+	+	*abcd*

The treatment combinations change as well, where factor D is added to the treatment combinations set at its high and low level.

Statistical Analysis

1. ***Analysis of Variance***

Initial Statistical Model:

$$\hat{y} = \hat{\beta}_0 + \hat{\beta}_1 x_1 + \hat{\beta}_2 x_2 + \hat{\beta}_3 x_3 + \hat{\beta}_4 x_4 + \hat{\beta}_{12} x_1 x_2 + \hat{\beta}_{13} x_1 x_3 + \hat{\beta}_{14} x_1 x_4 + \epsilon$$

Where y is the response variable, $x_1, \dots, x_4$ are the factors, $\beta's$ are unknown parameters, and $\epsilon \sim N(0, \sigma^2)$ is the random error term.
ANOVA is testing whether is any statistically significant differences in the means of different treatment combinations at different levels.
Since there is only one replicate, the estimation of effects will leave there with zero mean square for the error term. To determine the mean square for error, the sum of squares of all treatment combinations is found and those pooled together those whose estimated effects seemed to be negligible as the error mean square.

2. ***Tukey's Multiple Comparison Procedures***

Tukey's method simultaneously compares all pairwise comparisons simultaneously. The statistic:

$$T_\alpha = q_\alpha(a, v)\sqrt{\frac{MS_E}{n}} = \frac{q_\alpha(a,v)}{\sqrt{2}}\sqrt{MS_E\left(\frac{1}{n^i} + \frac{1}{n^{i_\prime}}\right)}$$

Is called Tukey's Honest Significant Difference (HSD) where a = number of levels of the factor, n = number of observations per treatment, v = degrees of freedom for MS_E, and q_α is the upper α percentage point of q-distribution.

Simultaneous confidence intervals are given by:

$$\widehat{D} \pm T_{\alpha}$$

RESULTS

Design Layout

Construction of the 2^{4-1} fraction design of resolution IV with defining relation $I = ABCD$ yields the following design matrix:

A	B	C	D	AB	AC	AD	Run	y
-1	-1	-1	-1	1	1	1	(1)	45.0
1	-1	-1	1	-1	-1	1	ad	39.5
-1	1	-1	1	-1	1	-1	bd	42.5
1	1	-1	-1	1	-1	-1	ab	43.0
-1	-1	1	1	1	-1	-1	cd	31.0
1	-1	1	-1	-1	1	-1	ac	37.0
-1	1	1	-1	-1	-1	1	bc	25.0
1	1	1	1	1	1	1	abcd	40.0

Note that since the generator is $I = +ABCD$ this is the principal fraction.

Estimation of Effects

The estimation of the effects for the full model of this fraction are given below:

Treatment	Estimated Effect	Sum of Squares
A	4.00000000	32.0000000
B	-0.50000000	0.5000000
C	-9.25000000	171.1250000
D	0.75000000	1.1250000
AB	3.75000000	28.1250000
AC	6.50000000	84.5000000
AD	-1.00000000	2.0000000

In this experiment, since there is just a single replicate, there is no estimation of an error term. Consider the percentages that each main effect and interaction effect accounts for in the total sum of squares:

Source	Sum of Squares	% Contributed
A	32.000	10.02%
B	0.500	0.16%
C	171.125	53.58%
D	1.125	0.35%
AB	28.125	8.81%
AC	84.500	26.46%
AD	2.000	0.63%
Total	319.375	

It is evident that some treatment combinations are negligible. The treatment combinations associated with A, C, AB, and AC account for 98.87% of the effects.

Reduced Model

We can use the treatment combinations associated with B, D, and AD as error to obtain the following results:

Recall the factors:

Factor	Description
Y	Test score out of 50 points
A	Average minutes sleep per night
B	Average minutes on social media per day
C	Average commute time in minutes
D	Average minutes studying

With the interaction of AB considered, the design can be projected into a full 2^3 factorial with factors A, B, and C. The results are obtained as follows:

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	316.2500000	63.2500000	40.48	0.0243
Error	2	3.1250000	1.5625000		
Corrected Total	7	319.3750000			

R-Square	Coeff Var	Root MSE	y Mean
0.990215	3.300330	1.250000	37.87500

Source	DF	Type I SS	Mean Square	F Value	Pr > F
A	1	32.0000000	32.0000000	20.48	0.0455
B	1	0.5000000	0.5000000	0.32	0.6286
C	1	171.1250000	171.1250000	109.52	0.0090
AB	1	28.1250000	28.1250000	18.00	0.0513
AC	1	84.5000000	84.5000000	54.08	0.0180

Parameter	Estimate	Standard Error	t Value	Pr > |t|
A	4.00000000	0.88388348	4.53	0.0455
B	-0.50000000	0.88388348	-0.57	0.6286
C	-9.25000000	0.88388348	-10.47	0.0090
AB	3.75000000	0.88388348	4.24	0.0513
AC	6.50000000	0.88388348	7.35	0.0180

From the ANOVA, the main effects of A and C both have statistically significant effects on the average exam scores. Furthermore, the interaction effects of AC have a statistically significant effect on average exam scores. The interaction of A and B have a p-value of 0.0513, which is not significant at the 5% significance level, but it is significant at the 10% significance level.

Based on the analysis, the model obtained that can be used to predict exam scores is as follows:

$$\hat{y} = 37.875 + 4x_1 - 0.5x_2 - 9.25x_3 + 3.75x_1x_2 + 6.5x_1x_3$$

Tukey's Multiple Comparison Procedures

Following the ANOVA, multiple comparison procedures were carried out to see the effects when the factors are set at their high and low levels.

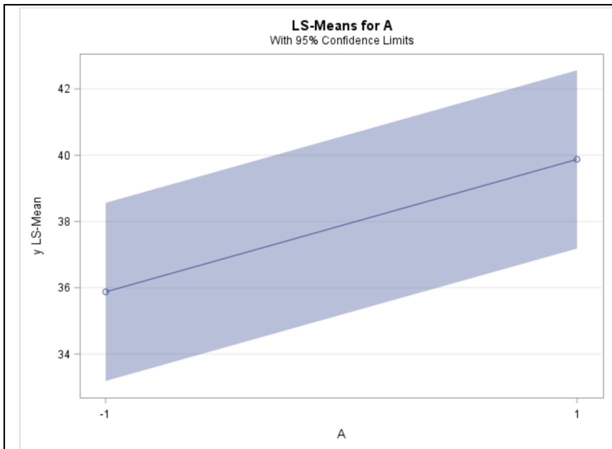
Main Effects:

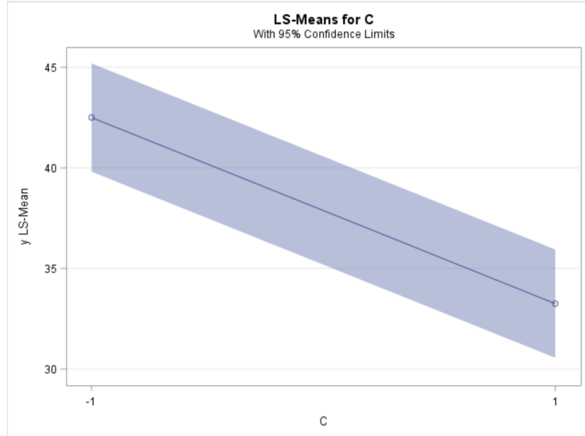
Factor A

Tukey Comparison Lines for Least Squares Means of A			
LS-means with the same letter are not significantly different.			
	y LSMEAN	A	LSMEAN Number
A	39.875	1	2
B	35.875	-1	1

Factor C

Tukey Comparison Lines for Least Squares Means of C			
LS-means with the same letter are not significantly different.			
	y LSMEAN	C	LSMEAN Number
A	42.50	-1	1
B	33.25	1	2





From Tukey's multiple comparisons, it is evident that average exam scores were higher when A is set at a high level. Also, the average exam scores were higher for C when it was set at a low level. The effects of B were not considered because it was not considered by itself.

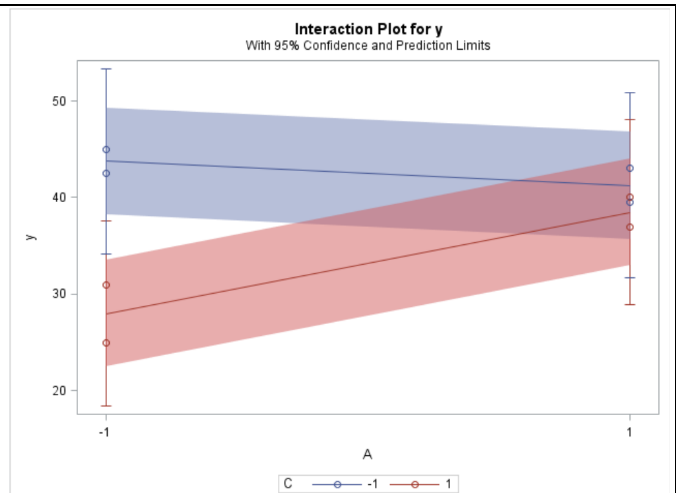
Interaction Effects

The interaction plot and the values for the interaction AC are shown below:

Tukey Comparison Lines for Least Squares Means of A*C

LS-means with the same letter are not significantly different.

		y LSMEAN	A	C	LSMEAN Number
	A	43.75	-1	-1	1
	A				
	A	41.25	1	-1	3
	A				
B	A	38.50	1	1	4
B					
B		28.00	-1	1	2



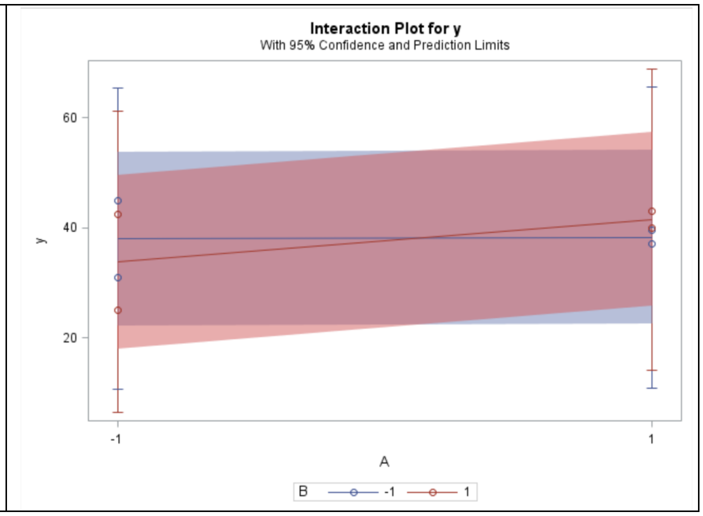
For the interaction AC, the averages are consistent when A is set at the high level, but there is a drastic difference for the levels of C when A is set at a low level. The difference when A is set at high is only 2.75 but when A is set at low the difference in means is 15.75.

The interaction plot and the values for the interaction AB are shown below:

Tukey Comparison Lines for Least Squares Means of A*B

LS-means with the same letter are not significantly different.

	y LSMEAN	A	B	LSMEAN Number
A	41.50	1	1	4
A				
A	38.25	1	-1	3
A				
A	38.00	-1	-1	1
A				
A	33.75	-1	1	2



Observing the interaction AB, there is not much difference. The main difference is when A is set at the low level, the difference in means is 4.25 for the different levels of B.

CONCLUSION

From conducting the experiment, it was of note to learn that average minutes of sleep and commute time were significant factors in influencing these students' exam performances. These two factors being significant were of little surprise since rigorous study in research has confirmed that sleep is an important component of health. Many of the students polled in this study say that on average for the sleep, they slept around 5-6 hours per day when in fact, the Mayo Clinic recommends that people aged 18 and up should sleep 7-9 hours per day on average. The fact that these students are sleeping less than they should is not a cause of concern for their studies, but for their health as well, as they prepare for more rigorous coursework in the coming semesters.

The majority of students in the study stated that their average commute time was between 20-30 minutes so it was of surprise to learn that commute time was a significant factor in exam performance. If commute times were in fact around 45-60 minutes, this would have been understandable, but upon delving deeper, the students' math class begins at 7:30 am. As such, taking up to 25 minutes to arrive at school means that these students are waking up much earlier to compensate for getting to class on time.

Furthermore, because these students are having to get up earlier, based on the influence of factor A, since these students only receive between 5-6 hours of sleep a night, it is within the realm of possibility that these students are going to bed much later than they should be. As a result, their bodies are having to overcompensate and their exam performances are paying the price for this. This is supported by the notion that AC (interaction term of average sleep and commute time) is significant.

In order to help remedy this situation, the advisor for these students can host a time management workshop to help students learn how to manage their time. Furthermore, the advisor can also help go over important health factors related to sleep in order to galvanize these students to get the proper amount of sleep they need. By helping them get the proper amount of sleep needed and by continuing to support these students of interest in the review sessions, there is a possibility that these students will be able to improve their exam performances and consequently their grades in the class.

While the results of this experiment were reasonable, it is also important to consider that these students may have invented some numbers that were considered reasonable in order to fulfill the obligation of participating in the study. As a result, when analyzing the data, it is possible for this data set to be noisy and to expect error. Even though, this can be minimized by a hypothesis test (ANOVA) to a level of significance, it is still possible that there are other potential factors that could be affecting students' exam scores.

In addition, since only eight students were used in this experiment, it is likely that other students who are struggling could have been potential subjects of interest in the study. Having only eight students to study and attempting to generalize the results obtained over a class of forty can be a misleading way to better aid the class through its difficulties. If possible, more students could have been studied and more factors that were not considered in this study could have been used.

While these possibilities are of concern to the professor and the advisor, there is a clear understanding that a beginning must be made somewhere. As such for these struggling students, they need to be informed on how their lack of sleep is affecting their exam scores. By making this start and by encouraging students to commit to improving their sleep patterns will other factors be considered and improvements to be made.