STA305 Project Report

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Description

Over the summer, I have been taking several courses from the university. However, I had a sense of inconsistency about my productivity when dealing with coursework, and I felt left behind in comparison with my cohorts. For example, it took me three or four hours to finish an assignment, whereas I could a spend a whole day on another one that is similar and I was very upset about that. Therefore, I started to think about what might affect my productivity. Based on my experience, I generally feel distracted by people surrounding me, not drinking coffee and spending too much time on my phone. In order to find out how to better manage study in general, I planned out a 2^3 factorial design to investigate the effects of multi-person environment, drinking coffee, phone usage on productivity.

For experiment, I decided to examine 3 factors at two levels each, and the response variable productivity was measured using a score out of 10, where a bigger number denotes more self-satisfaction from an observation. A table of how the components are categorized is listed:

	Multi-person environment	Drinking coffee	Phone usage
−	studying alone	no	cell phone turned off
+	another person present in the room	yes	cell phone is on

Note that the other person (mostly their parents) mentioned under the first factor simply proceeded normal activities of daily living (ADLs), which may include but not limited to sleeping, eating, reading etc. The person stayed quiet as much as possible over the period.

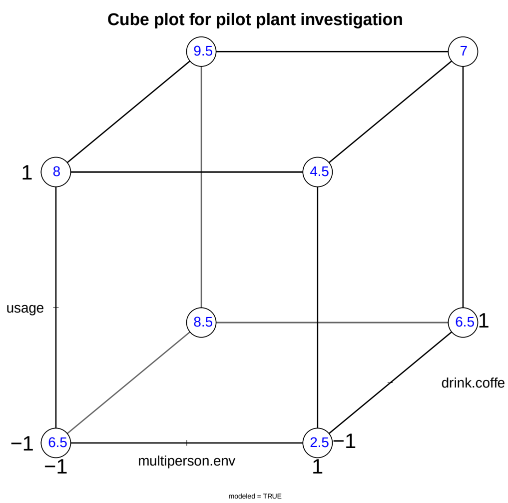
There would be 2^3=8 experimental conditions to test in total. Considering potential variance at each measurement, I replicated them for one more set of experiments. In particular, I invited 4 friends of mine who had similar grades in school to participate. The 4 participants were randomly assigned to 2 conditions, under which they were asked to study for 3 hours for each. After that, they gave a productivity score. As people's work may differ by content and difficulty, the productivity score was given on a scale of how much time the participant focus on doing their work, rather than the amount of work completed. Furthermore, it is believed that the productivity score is given individually, and that does not vary with others. To better facilitate the participants' need, the 2 conditions were tested over two separate days. I started another random assignment and repeated the above procedure on another two days. Eventually, I finished up the experiment with 16 measurements.

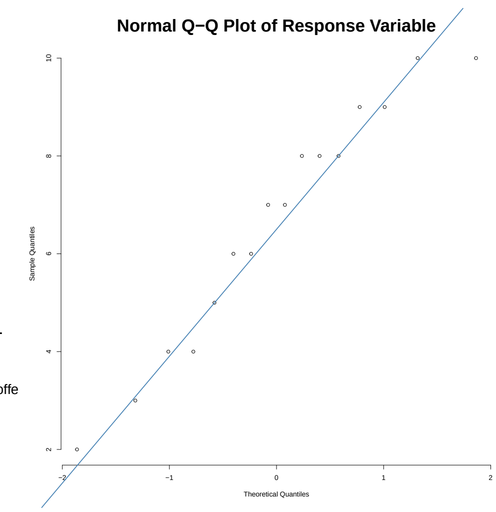
To reduce bias from having one person to test the same conditions repeatedly, I randomized the participants to ensure the reliability of further casual inference, so they had the chance to be assigned to any condition. In details, I used a deck of 8 cards from Ace to 8, shuffled and assigned my friends to the corresponding conditions with the cards they got. I also assumed subjects' productivity was identically independent. Given the fact that their grades were similar, each participant was assumed to have similar productivity and similar working habits except for the control, and their inherent attributes did not impact the outcome significantly. Such differences were simply negligible here. To better ensure the same productivity assumption, I also confirmed they had similar typing and writing speed per hour prior to experiments.

Analysis of Data

In this section, I will present a comprehensive statistical analysis in the following aspects:
1) Data visualization
2) Estimation of factorial effects and their interpretation
3) Estimate the error variance of each measurement and the effect estimates
4) Inference by confidence intervals on true values

I created a cube plot illustrating the relationship between the factors and outcome. From edge to edge, it represents the change of levels in one factor while holding others constant. Meanwhile, I made a normal QQ plot for the response, even though it does not indicate a perfect normal distribution.





By using the data collected, I fitted a linear model which be expressed as,

$$\hat{y_i} = 6.625 - 1.50X_{i,1} + 1.25X_{i,2} + 0.625X_{i,3} + 0.375X_{i,1}X_{i,2} - 0.25X_{i,2}X_{i,3} - 0.125X_{i,1}X_{i,2}X_{i,3}$$

where $X_{i,1}, X_{i,2}, X_{i,3}$ denote the factors of multi-person environment, drinking coffee and phone usage from i-th run, respectively. $\hat{y_i}$ is the corresponding productivity score in that session. In addition, it is noticeable that the interaction variable $X_{i,1}X_{i,3}$ between multi-person environment and phone usage has an coefficient estimate of 0, which is excluded in the expression. The fitted model report a residual standard error of 1.62 on 8 degrees of freedom.

To calculate the main and interaction effect estimates, I multiplied the least squares coefficients by 2, and the results are listed in Table 2. Assuming independence between measurements, I can estimate the error variance of individual measurement by $s^2 = \sum_{i=1}^{8} {s_i}^2/8 = \frac{21}{8} = 2.625$, where s_i is the variance term at single experimental condition, and there are eight of them. Thus, I used this value to estimate the variance of factorial effects, which is $(\frac{1}{8} + \frac{1}{8})s^2 = 0.65625$. This result is consistent with another approach to compute Var(Effect) = $(2 * SE(Estimate))^2$, in which it is worth noting SE(Estimate) is the same across the variables.

Based on their associated p-values, I performed hypothesis tests to evaluate whether a factorial effect exists. Testing $H_0 : \beta_i = 0$ vs $H_1 : \beta_i \neq 0$ from i = 0 to 7, I found that only the coefficients of variables multiperson.env, drink.coffee and the intercept term are statistically significant from zero. Their p-values are smaller than the 5% significance level, so the null hypothesis is rejected. Furthermore, when holding others constant, they could be interpreted as follows:
$\hat{\beta}_0$: the sample mean of productivity is 6.625
$\hat{\beta}_1$: studying when surrounded by others decreases productivity by 1.5, while self-studying increases by 1.5
$\hat{\beta}_2$: drinking coffee increases productivity by 1.25, while not drinking decreases by 1.25

Namely, the main effect of multi-person environment on productivity is -3, and that of drinking coffee is 2.5 on productivity. For other variables defined in the linear fit, the data collected does not provide evidence on significant effects on productivity, as their p-values are greater than the 5% significance level and fail to reject their H_0. In other words, it could be also understood that the effects of studying in a multi-person environment and drinking coffee are rather independent, and no effect of cell phone usage on productivity is found, not even mention the interaction effects. The conclusion can be confirmed by the figure below, in which no curves intersect in the interaction plots as observed.

To make further inference, I obtained the 95% confidence intervals for the factorial effects in Table 3. Take variable multiperson.env as an example, if I repeat this factorial experiment over and over, then about 95% of the times its CI will capture the true main effect of studying in a multi-person environment. Such an interpretation also works for other parameters. The significance of variables is assessed here once again; all significant variables or their factorial effects do not include zero in their CIs.

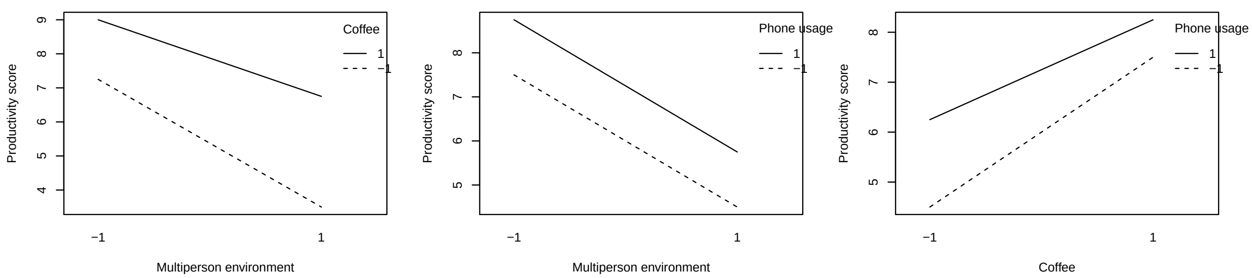


Table 2: Summary table from the multiple linear regression

	Estimate	Std. Error	t value	Pr(>|t|)	Effect
(Intercept)	6.625	0.405	16.3562	0.0000	13.25
multiperson.env	-1.500	0.405	-3.7033	0.0060	-3.00
drink.coffee	1.250	0.405	3.0861	0.0150	2.50
phone.usage	0.625	0.405	1.5430	0.1614	1.25
multiperson.env:drink.coffee	0.375	0.405	0.9258	0.3816	0.75
multiperson.env:phone.usage	0.000	0.405	0.0000	1.0000	0.00
drink.coffee:phone.usage	-0.250	0.405	-0.6172	0.5543	-0.50
multiperson.env:drink.coffee:phone.usage	-0.125	0.405	-0.3086	0.7655	-0.25

Table 3: The lower and upper limits of 95% confidence intervals for the factorial effects

	2.5 %	97.5 %
(Intercept)	11.3819231	15.118077
multiperson.env	-4.8680769	-1.131923
drink.coffee	0.6319231	4.368077
phone.usage	-0.6180769	3.118077
multiperson.env:drink.coffee	-1.1180769	2.618077
multiperson.env:phone.usage	-1.8680769	1.868077
drink.coffee:phone.usage	-2.3680769	1.368077
multiperson.env:drink.coffee:phone.usage	-2.1180769	1.618077

Conclusions

Under a 2^3 factor design, I invited 4 subjects to participate in replicated experiment conditions totaling 16 observations to investigate how multi-person environment, drinking coffee, phone usage affect productivity when studying. In my research, there is evidence supporting that multi-person environment and drinking coffee exert a significant effect on productivity. Specifically, when studying alone productivity appears to increase by 1.5, but decrease by 1.5 when someone else present on site. Drinking coffee also helps with productivity score by 1.25, but it declines by 1.25 if one does not drink coffee. The two variables report p-values of 0.006 and 0.015 respectively. It is safe to conclude that multi-person environment poses a negative main effect of 3 on productivity, whereas drinking coffee has a positive main effect of 2.5 on productivity. Surprisingly, I found phone usage does not significantly influence productivity, and there does not exist any of two-way or three way interaction effects among the variables. Therefore, I would recommend people study alone and drink coffee to better focus on their study.

For discussion, I would like to address potential limitations in the experiment. Although I randomized the order of the participants beforehand, it is still possible that they gave the final productivity score with bias. Productivity was very challenging to be quantified, even after I encouraged the subjects to rate their productivity as much objective as they can. There might exist confounding variables such as hunger and due dates of work. These might be the factors which I did not take account sufficiently. Additionally, phone usage is found insignificant to affect productivity, which seems not intuitive in real life. Perhaps due to selection bias, some subjects would enjoy a break using cell phones between hours, and that might be even beneficial to productivity. Alternatively, people who had a unproductive day could spend lots of time on their laptops instead of cell phones, or there are other unobserved factors as portrayed. Thus, it is recommended that further research undertakes a more rigorous scheme of controlling variables and sample selection, and increase the sample size for power of the test if possible.