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STAT 8416: Design of Experiments

8 May 2025

Design of Experiments Final Report

Introduction

The main premise of my experiment is to test how quickly and effectively I can type, given a variety of different factors. As it is finals season, I thought it would be appropriate to determine how to maximize my efficiency when working on papers and projects. For this experiment, I decided to test this efficiency using three factors: what kind of corrective eye lens I was wearing, if I was listening to music, and if I was working in the morning or in the afternoon/evening. The motivation behind testing what corrective eye lens I was wearing stems from the fact that I have been wearing glasses and contact lenses for over a decade, and I was curious to determine if either helps me see and read better and perform tasks more efficiently. The motivation behind testing for whether I was listening to music stems from the fact that there is differing research on whether music helps a person when trying to complete a task or distracts them. This experiment aims to reach a conclusion on if and how music plays a role in effective work. And finally, I wanted to test whether I was more effective in the morning or afternoon/evening because I do not consider myself a morning person at all, so I would figure that I am more effective in the afternoon, but I want to confirm this.

Overall, the objective of my experiment is to test how fast I can type one page of text on typing.com based on the factors listed above (what type of corrective eye lens, if I am listening to music, and whether I am working in the morning or in the afternoon/evening). My initial hypothesis regarding eye lens is that contacts will have a slightly smaller time to type since the lenses are directly on my eyes, where my glasses sit a little farther from my eyes. My glasses are also ever-so-slightly big on me and will slip occasionally, so this may also delay my time to type. Regarding music, I hypothesize that listening to music will lead to a larger time to type, since I will be partially distracted by the songs and not have complete focus on what I am typing. Finally, I believe that I will type faster and have a smaller time to type in the afternoon and evening compared to in the morning. I will be more awake and have more energy in the afternoon, whereas in the morning, I will still be in a groggy state and not fully awake just yet. In addition, there is potential for interaction between eye lens and time of day. For instance, if at the end of the day my eyes are sore and tired, taking out my contacts may provide may provide a little relief and lead to clearer vision and faster typing.

Design Discussion

Before diving into the setup of the experiment, I will first define the variables of interest. Eyes will be defined as the type of eye lens worn (where "+" denotes contact lens and "-" denotes glasses). Music will be defined as whether or not I am listening to music (where "+" denotes no music and "-" denotes music). Day will be defined as whether I tested my typing in the morning or afternoon/evening (where "+" denotes afternoon/evening and "-" denotes morning). And finally, Time, the response variable, will be defined as how long it took me to type one page as defined by typing.com. The Time variable will be recorded in seconds.

This experiment has a total of 16 observations, with 2 replicates for every “Eyes”, “Music”, and “Day” combination. These observations were recorded over the course of 2 days and were completed at random using a random number generator (the numbers 1 through 8 represented each of the “Eyes”, “Music”, “Day” combination, and 9 and 0 represented to move onto the next number). To run the experiment, I sat at approximately the same distance from my computer and started typing, trying to type around the same pace throughout each run, and not speeding up or slowing down at any point. My contact lenses and glasses have the same prescription, so there was no concern that one of the lenses was providing more of an advantage to me than the other. When selecting the music for the experiments, I simply chose a randomly shuffled song from the Top Hits playlist on Spotify, which was an average volume pop song with lyrics. When running the experiment, I would always make sure I went back and correctly retyped the correct letter or character if I made a mistake. I attempted to stay consistent with all of my runs, and all but two runs had an Accuracy rating of 98% (the two others had Accuracy ratings of 97%). This way, a lot of the error in timing could be standardized and remain relatively in check. Finally, the day recordings for time were taken between 8:00 AM and 10:00 AM for the morning and between 4:00 PM and 6:00 PM for the afternoon/evening.

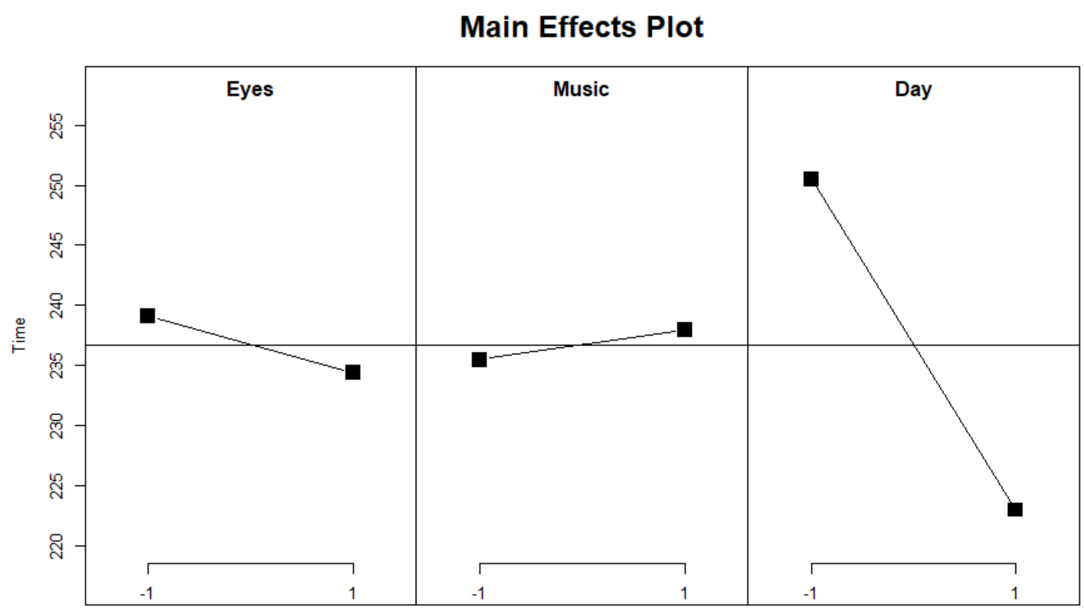
Some potential confounding variables include the amount of background noise and distractions when I was typing. I wore both of my airpods on noise-cancelling mode, both when playing music and when not playing music, in order to block out any outside noise, but this didn’t do a perfect job as some sounds still came through, particularly when no music was being played. Another potential confounding variable is that some of the pages that I typed on typing.com repeated some of the same blurbs or sections, so I was already familiar with what I had to type, potentially leading to a slightly lower total time. On a similar note, some runs may have had more difficult words to type with letters on opposite sides of the keyboard, thus increasing typing time. A third potential confounding variable could be how long I have been awake for during the morning runs. While the runs were done around the same times (between 8:00 AM and 10:00 AM), the amount of sleep I got the previous night and the time I woke up at both have an impact on how much (or little) energy I have.

One area where there could be potential error or bias in the total time to type one page is with the Eyes variable. My contacts have been bugging me lately (possibly due to allergies), so the contact lens times may be a bit inflated due to my vision being partially blurry in my left eye. However, its never bad enough where I can't see much at all, so the potential error is small.

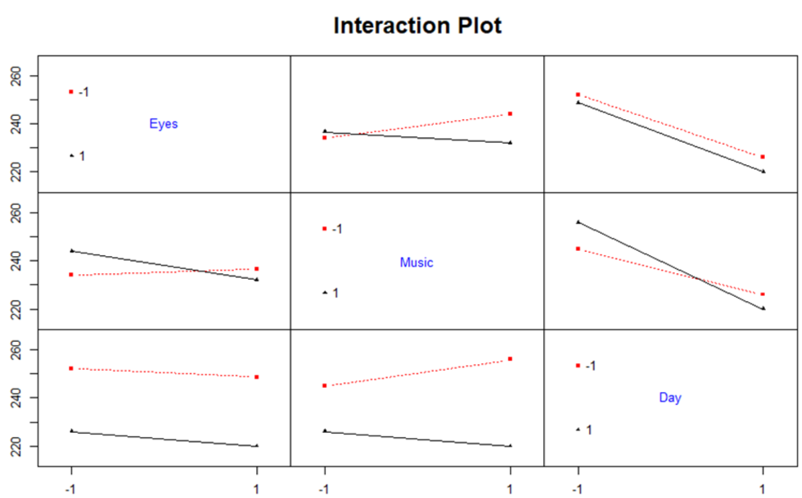
Experiment Results

Looking at Figure 1 in the Appendix, we see the raw results of the 16 runs of this experiment. Just based on initial observations and computing the averages of the two replicates in each Eye, Music, Day combination, it appears that wearing contacts, listening to no music, and assessing in the afternoon resulted in the smallest average typing time. Conversely, wearing glasses, listening to no music, and assessing in the morning resulted in the largest average typing time.

Both a Main Effect Plot and an Interaction Plot are graphed next, based on a full initial model including all interaction terms. Looking at the Main Effect Plot below, we see that the Day variable has the largest change in typing time from the morning to the afternoon/evening, whereas the Music variable has the smallest change from Music to No Music. In fact, typing time actually decreases when listening to music, which goes against my initial hypothesis that listening to music would add to my total typing time. Perhaps listening to music focuses and stimulates my brain more, allowing me to work and type quicker and more efficiently.



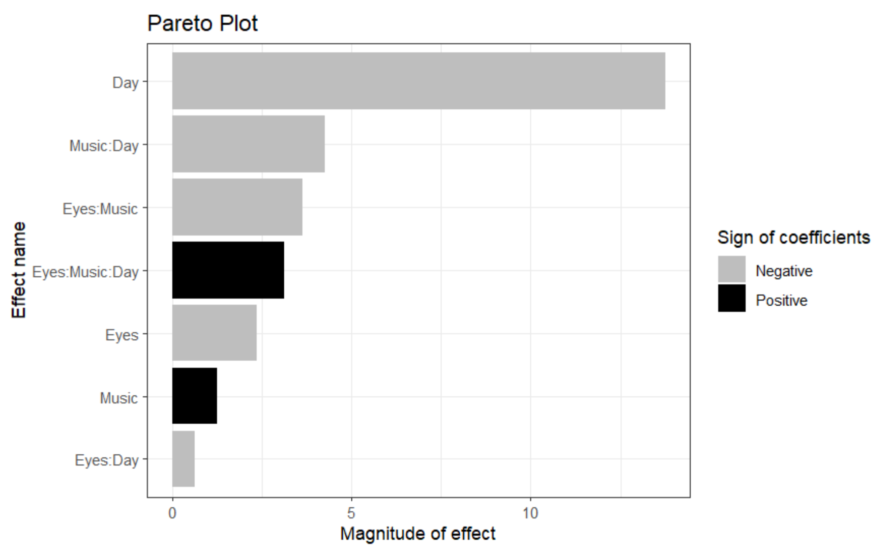
Moving on to the Interaction Plots below, it appears that there is some disorderly interaction between the Eyes and Music variables as well as the Music and Day variables. However, there doesn't really appear to be any interaction at all between Eyes and Day.



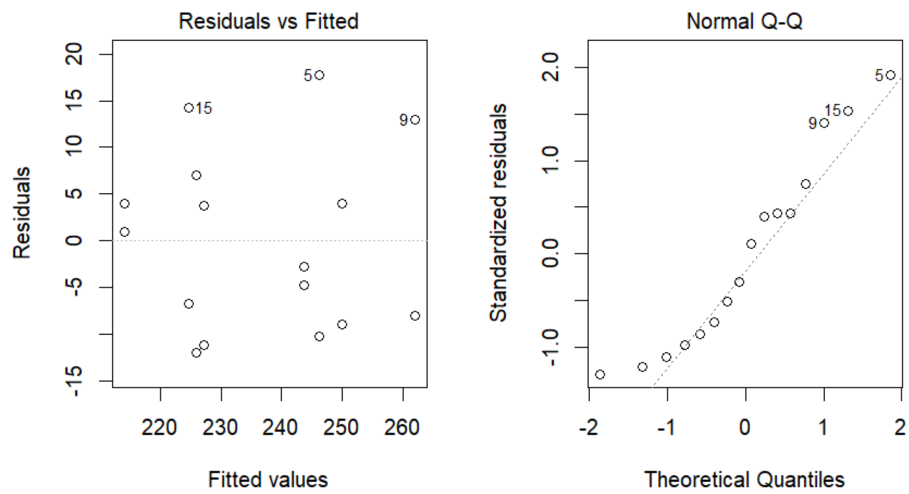
The mathematical model for our full initial model is as follows:

$$Y_{i,j,k} = \mu + \tau_i + \beta_j + \delta_k + (\tau\beta)_{ij} + (\tau\delta)_{ik} + (\beta\delta)_{jk} + (\tau\beta\delta)_{ijk} + \varepsilon_{ijk}$$

The full term descriptions can be found in Model 1 in the Appendix. To assess significance, an ANOVA analysis was run on the full model, which can be seen in Figure 2 of the Appendix. Looking at the ANOVA, we see that only the Day variable is significant at the 0.05 level, with the next most significant source, the Music and Day interaction, having an insignificant p-value of 0.20. Visualizing this information in the Pareto Plot below, we get confirmation that the Day variable is extremely significant, while the interactions between Eyes and Day, and Eyes, Music, and Day are not significant.



We then remove those two interactions and refit the model with an ANOVA test, yielding the results seen in Figure 3 of the Appendix. All of the variables left in the model get more significant, but the Day variable still remains the only predictor significant at the 0.05 level. Nevertheless, assumption checks are run on this model by plotting both a Residuals vs Fitted Plot and a Normal Q-Q Plot, as seen below:



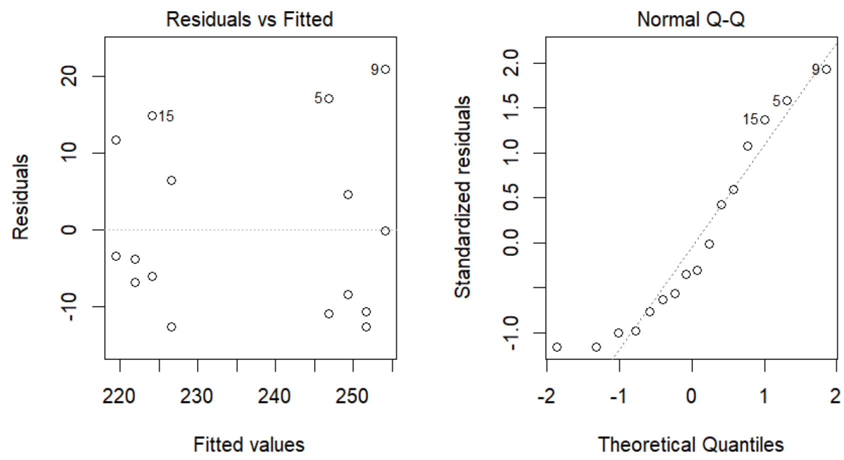
The Residuals vs Fitted Plot seems to have an even spread about zero with no real trend or shape, so the constant variance assumption seems reasonable. The Normal Q-Q Plot also looks pretty normal too. The tails aren't super concerning, thus the normality of error assumption also seems reasonable.

To ensure that the variables we removed for the reduced model weren't significant, we ran a Partial F-Test:

$$F = \frac{(1691.2 - 1132.5 \big/ (11-8)}{141.6} = 1.315 < F_{3,11,.05} = 3.60$$

Since F < 3.60, we fail to reject the null hypothesis that the terms are not significant, thus the terms can be removed from the model.

Finally, we remove all of the interactions and run a Main Effects Model, as seen in Figure 4 of the Appendix. Yet again, the only result we get is that the Day variable is significant at the 0.05 level, and in fact, the Eyes and Music variables increase in their p-values. Looking at the Residuals vs Fitted Plot and Normal Q-Q Plot, we check the assumptions again:



The Residuals vs Fitted Plot still has a relatively even spread about zero with no shapes or trends, so the constant variance assumption seems reasonable. The Normal Q-Q Plot also remains normal-looking, although the left tail strays a little more from the line compared to the reduced model above. Nevertheless, the normality of errors assumption seems reasonable.

Conclusions

In conclusion, the optimal solution to minimize the time to type one page as defined by typing.com is to wear my contacts, listen to music, and run the test in the afternoon/evening. However, the only variable that was significant in any of the models was the Day variable, indicating that I type faster and work more efficiently in the afternoon and evening than in the morning when I am more tired. There was no real difference in typing time between wearing my glasses and my contacts, although contacts had a slightly lower mean typing time. This makes sense though because I have the same prescription for both, so I should be able to see the same out of both. As mentioned earlier, there was no significant difference in typing time between listening to music and not listening to music, although the mean typing time has smaller when listening to music than when listening to no music. And finally, there was no significant interaction between eye lens and time of day; in fact, it had the least significance of any variable in the full model.

If I were to run this experiment again, I would first want to try different volumes and genres of music, because focusing with classical music versus heavy metal is very different. Similarly, I would like to try listening to loud music and compare that to being in a dead-silent room in order to have a starker contrast in music and potentially pick up more separation in typing times. If I were to repeat this experiment, I would also try testing for longer-distance reading since I am nearsighted and can see a computer screen well either way. This way, there’s a better chance to pick up more of a separation in typing times with respect to what type of corrective lens I am using.

Appendix

Model 1:

$Y_{i,j,k} = \mu + \tau_i + \beta_j + \delta_k + (\tau\beta)_{ij} + (\tau\delta)_{ik} + (\beta\delta)_{jk} + (\tau\beta\delta)_{ijk} + \varepsilon_{ijk}$, where $\varepsilon_{ijk} \sim$ iid N(0,σ^2)

where τ_i is the effect of the i^{th} level of Eyes, i = Contacts, Glasses

where β_j is the effect of the j^{th} level of Music, j = Music, No Music

where δ_k is the effect of the k^{th} level of Day, k = Morning, Afternoon/Evening

where $(\tau\beta)_{ij}$ is the interaction effect of the i^{th} level of Eyes and j^{th} level of Music

where $(\tau\delta)_{ik}$ is the interaction effect of the i^{th} level of Eyes and k^{th} level of Day

where $(\beta\delta)_{jk}$ is the interaction effect of the j^{th} level of Music and k^{th} level of Day

where $(\tau\beta\delta)_{ijk}$ is the interaction effect of the i^{th} level of Eyes, the j^{th} level of Music, and

the k^{th} level of Day

Figure 1:

Contacts, No Music, Morning	Contacts, No Music, Afternoon	Contacts, Music, Morning	Contacts, Music, Afternoon	Glasses, No Music, Morning	Glasses, No Music, Afternoon	Glasses, Music, Morning	Glasses, Music, Afternoon
Run 1:	Run 1:	Run 1:	Run 1:	Run 1:	Run 1:	Run 1:	Run 1:
(8:30 AM)	(4:15 PM)	(8:45 AM)	(5:00 PM)	(9:15 AM)	(5:30 PM)	(8:15 AM)	(4:20 PM)
254 sec	**218 sec**	**264 sec**	**275 sec**	**275 sec**	**214 sec**	**241 sec**	**239 sec**
Run 2:	Run 2:	Run 2:	Run 2:	Run 2:	Run 2:	Run 2:	Run 2:
(8:45 AM)	(4:35 PM)	(9:00 AM)	(5:15 PM)	(9:30 AM)	(5:45 PM)	(8:30 AM)	(4:40 PM)
241 sec	**215 sec**	**236 sec**	**216 sec**	**254 sec**	**233 sec**	**239 sec**	**218 sec**
Avg: **247.5 sec**	Avg: **216.5 sec**	Avg: **250 sec**	Avg: **223.5 sec**	Avg: **264.5 sec**	Avg: **223.5 sec**	Avg: **240 sec**	Avg: **228.5 sec**

Figure 2 (Full Model ANOVA):

Source	df	Sum of Squares	Mean Square	F Value	P-value
Eyes	1	90.3	90.3	0.593	0.46330
Music	1	25.0	25.0	0.164	0.69582
Day	1	3025.0	3025.0	19.885	0.00211 **
Eyes:Music	1	210.3	210.3	1.382	0.27354
Eyes:Day	1	6.2	6.2	0.041	0.84443
Music:Day	1	289.0	289.0	1.900	0.20542
Eyes:Music:Day	1	156.3	156.3	1.027	0.34050
Residuals	8	1217.0	152.1		

Figure 3 (Reduced Model):

Source	df	Sum of Squares	Mean Square	F Value	P-value
Eyes	1	90.3	333.1	2.166	0.16909
Music	1	25.0	25.0	0.181	0.679339
Day	1	3025.0	3025.0	21.928	0.000864 **
Eyes:Music	1	210.3	210.3	1.524	0.245223
Music:Day	1	289.0	289.0	2.095	0.178398
Residuals	10	1379.5	137.9		

Figure 4 (Main Effects Model ANOVA):

Source	df	Sum of Squares	Mean Square	F Value	P-value
Eyes	1	90.3	90.3	0.576	0.462363
Music	1	25.0	25.0	0.160	0.696472
Day	1	3025.0	3025.0	19.321	0.000872 ***
Residuals	12	1878.8	156.6		