Stats 101b Final Project - Group 19

Group members: Laila Khalilieh, Danielle DeFrancisci, Shuaiheng Tao, Tishi Avvaru, Natasha Mauro

Introduction

Our experiment will explore the effects of cardiovascular exercise on memory performance within the virtual landscape of The Islands. Specifically, we are looking to compare how various durations of exercise impact memory and if memory is affected at all. Our interest in exploring this topic relates to our group members' backgrounds in physical activity and cognitive science. One of our group members heard that running could potentially lead to benefits in the phenomenon known as “runner’s high” so we chose to set up an experiment to explore this idea further.

For this specific project with The Islands, we selected two durations of jogging and one memory game to complete for our participants. We assigned the 5-minute and 30-minute jogging tasks as treatments since they were time-based activities that we could regulate better than distance-based tasks. We planned to run the memory game before and after the jogging task for each person. In addition to seeing if exercise has any impact on memory, we wanted to see if the differing durations of jogging have differing effects. To explore this we randomly assigned the two treatments to the participants and ran the analysis as will be described below. We chose a randomized complete block design in order to limit any variability among participants on different islands. We also sampled from a specific age range (30-35 years old) in order to mitigate the potential nuisance factor in our experiment. We expect that both durations of exercise could increase memory performance, but shorter exercise durations may have better improvements due to less body fatigue. Our null hypothesis is that jogging for 5 or 30 minutes does not have any impact on memory game performances. The alternative hypothesis is that different durations of jogging will impact memory game performances.

$$H_0: \tau_1 = \tau_2 = \ldots = \tau_a = 0$$
$$H_1: \tau_i \neq 0$$

First, we will be discussing the design of our experiment and our justification for choosing this design method. We then will describe how we obtained our sample from the population of The Islands and how we utilized power calculations to come to that conclusion. The next section will report on our findings in R and detail their context within our experiment. Finally, we will summarize our findings, limitations, and any potential applications to real life supported through other academic findings.

Design Of The Experiment:

For our experiment, we decided that a randomized complete block design was the best way to test our research question. We wanted our design to be a between-group study but also wanted the islanders to act as their own control. In order to do this, we forwent pairwise comparisons and just used the difference in the islander’s scores in the memory game from before and after they completed their assigned treatment. Additionally, we had some doubts in the homogeneity of the islander’s abilities. Because of this, we decided that since we wanted our conclusions to be applicable to all three islands, we would block our randomly selected islanders by the island where they were from, thus giving us a total of three blocks. By blocking the islands we are ensuring that the islands do not confound the treatment effect, 5 or

30 minutes of jogging, due to characteristics the island could have that would affect the outcome. This ultimately led us to use the randomized complete block design with our factor being the treatment levels and the blocking being set by the island of origin.

To begin our sampling process we used a random number generator in R to randomly select one city from each island. We then went to the town births registry of the randomly selected town and numbered all the names of the people in that town who have birth years corresponding to the desired age range of 30-35. Randomly, using R, we then selected 36 names from each town registry. Half of the 36 names from each island were to be randomly assigned to perform light jogging for 5 minutes and half were to be assigned to perform light jogging for 30 minutes. The limitations we faced during our random sampling were with those who did not give consent to participate in the experiment and those who were ghosts. We had to eliminate them from our list of viable persons, generate a new set of random numbers, and reselect the individuals to experiment on.

Originally, our group decided to do 36 names from each island in order to have an even split between our treatment groups. We felt that n = 36 would be sufficiently large enough given the population size of our desired age group on each island. To calculate our appropriate sample size, we used the pwr.anova.test function. We decided that we wanted the power level of our experiment to be 0.9. Once we ran our experiment, we got that the MSE was 62.08 so we added this to the effect size formula and chose our d value as 3.25 seconds as the maximum average mean distance. From this, we got an effect size of 0.41. Once we had our effect size, we ran our pwr.anova.test function since now we were only missing our n value. From this, we determined that the desired sample size would be 32 responses per island (for a total response number of 96). Since our original n was 36, this confirmed that our sample size was appropriate for the experiment and that we had an acceptable level of power in our results.

````
```{r}
library(pwr)
pwr.anova.test(k=2, f=3.25/sqrt(62.08), power = 0.9)
```
````

```
     Balanced one-way analysis of variance power calculation

              k = 2
              n = 31.86985
              f = 0.4124844
      sig.level = 0.05
          power = 0.9

NOTE: n is number in each group
```

Results And Interpretation:

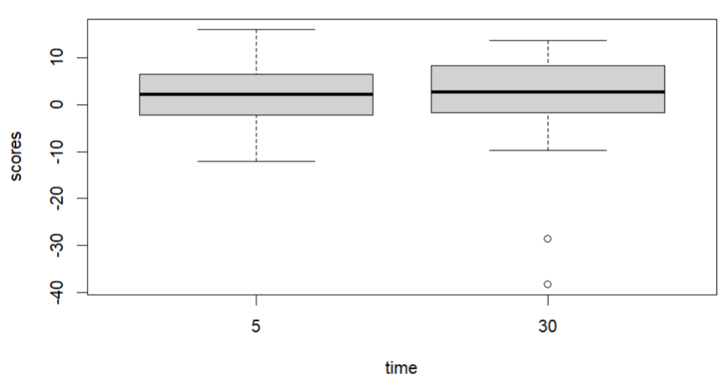
```r
# Data and ANOVA
```{r}
block <- c(rep("nidomo", 36), rep("hayarano", 36), rep("blonduos", 36))
time <- rep(c(rep(5, 18), rep(30, 18)), 3)
scores <- c(2.3, 3.1, -6.8, 7.3, -3.8, -2.7, 0.4, -2.4, -1, -12.1, 5.9, 12.5,
            -2.1, 2.2, 6.7, 3.2, 10.1, 7.8, 4.6, 0.5, 1.8, -2.5, 0.1, 13.7,
            -38.3, 9.6, -2.9, -0.1, 10.9, 10.6, 4.3, -28.6, 2.1, 10.4, 9.5,
            -4, 12.5, 13.7, 8.1, 10.3, 16.1, 0.2, -5.6, 6.5, 2.9, 3.9, 6.2,
            -8, 2.2, -1.1, 3.6, 11, -5.3, -10.9, -5.2, 0.1, 4.3, -2.6, 1.1,
            -4.4, -1.3, -9.7, 9.4, 12.4, 0, 7.2, 8.7, -1.7, -0.4, -2.4, 4.1,
            1.2, 1.2, 0.9, -0.9, 1.9, 1.9, 2.6, 3.9, -7.6, 0.9, -7, -2, -5.3,
            9.8, 7.7, -5.9, 2.9, 4, 0.3, 2.4, -9.7, 12.5, 8.6, 9.9, -3, 7,
            -2.4, 8.3, 7.6, 0.6, 8.1, 8.1, 9.5, 6.5, 8, 2.9, 3.5)

model <- aov(scores ~ factor(time) + factor(block))
summary(model)
```
```

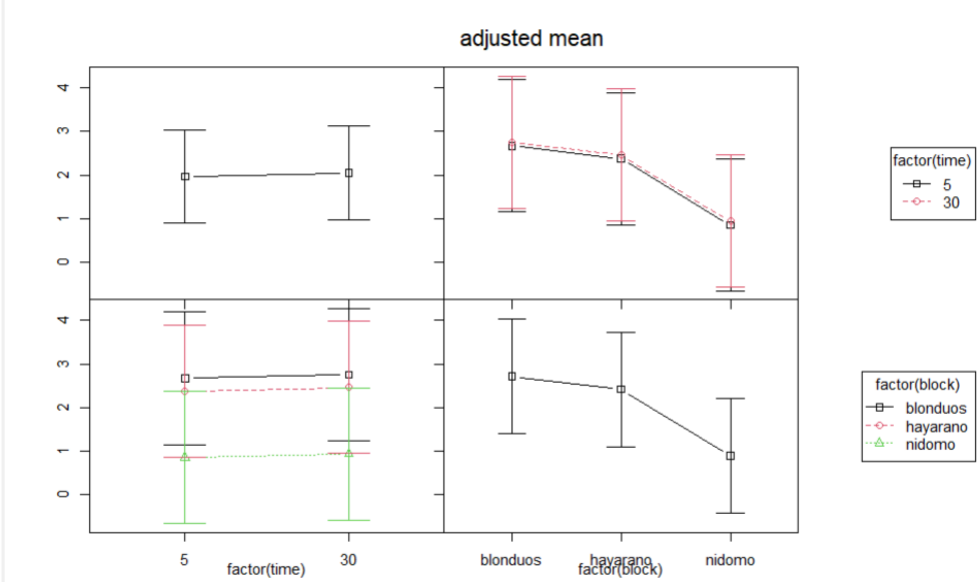
```
               Df Sum Sq Mean Sq F value Pr(>F)
factor(time)    1      0    0.20   0.003  0.954
factor(block)   2     68   34.22   0.551  0.578
Residuals     104   6456   62.08
```

Based on the ANOVA table, both the time of jogging and block (island) seem to be statistically insignificant under alpha = 0.05. This means performing light jogging for 30 minutes or 5 minutes before taking a memory test will not have any effect on the scores of the memory game. In addition, since the block's SSR is very low compared to the SSR of residuals, the block is not necessary, meaning the birthplace of the participants will not affect the performance of the memory games.

The box plot suggests that the difference in means of memory game scores from the 5-minute treatment and the 30-minute treatment is statistically insignificant.

```r
# Box plot
```{r}
boxplot(scores ~ time)
```
```



```
# Fitted Equation
```{r}
lm(scores ~ factor(time))
```
```

```
Call:
lm(formula = scores ~ factor(time))

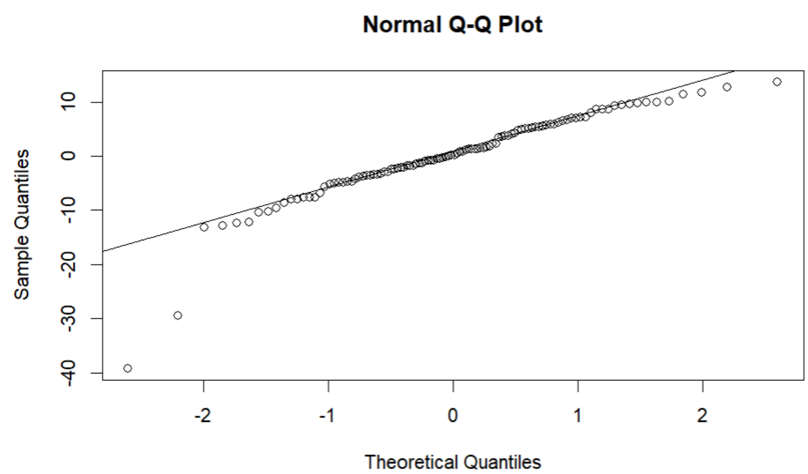
Coefficients:
    (Intercept)  factor(time)30
        1.96667          0.08704
```

The fitted equation would be

$$y = 1.96667 + 0.08704x$$

Based on the low coefficient of x, the time factor does not statistically significantly affect participants' performances in the memory game.

```
# Interaction Plots
```{r}
library(phia)
mip1 <- interactionMeans(model)
plot(mip1)
```
```



The interaction plot shows that every line is parallel to each other, meaning that there is no significant interaction between the factors. When looking at the factors, we can observe that Nidomo has the lowest score differences compared to Blonduos who has the highest score differences although these differences clearly are not significant based on the ANOVA table.

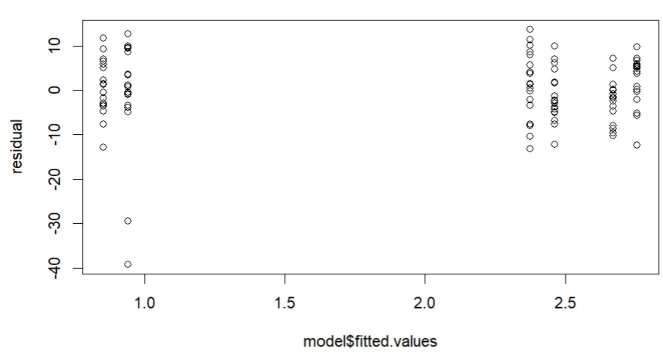
Model Assumptions

```{r}
residual <- model$residuals
qqnorm(residual)
qqline(residual)
```



Based on the Normal Q-Q plot, the residuals from ANOVA follow a normal distribution.

```{r}
plot(model$fitted.values, residual)
```



Since the data is evenly distributed with respect to x=0, the equal-variance assumption is also satisfied.

Discussion:

This experiment ultimately investigates the impacts of cardiovascular exercise in two intervals (jogging for five minutes and thirty minutes) on the scores of a memory test. The data collection was done using participants from three randomly selected cities, with one city from each island. Within this, the pool of residents was again chosen by random selection, as were the assigned jogging times for participants. Following this, we ran the appropriate ANOVA model. Using the results of the ANOVA alongside the Q-Q plot and residuals vs. fitted plot, we concluded that the model is valid, and neither the island a participant was born on, nor the amount of time they spent jogging had a significant impact on their scores in the memory game. As a result, we failed to reject the null hypothesis and concluded that jogging for 5 or 30 minutes does not have any impact on memory game performances.

In regards to any real-world implications of this study, there have been many explorations into the association or effect between cardiovascular exercise and memory. However, these studies tend to conclude that, while continued or chronic exercise has a significant effect on the improvement of memory. However, these studies tend to complicate this issue into something much more complex than explored in this experiment. A plethora of studies also reported that the type of exercise has an impact on which specific form of memory is affected. For example, a study regarding data from fitness trackers[1] revealed that cardiovascular exercise improves recall on naturalistic memory tasks (recall from a video), whereas a different study regarding acute and chronic cardiovascular exercise[2] shows a significant impact by both acute (or a short duration) and chronic (a long duration) exercise on episodic memory, the ability to recall personal experiences from the past. Furthermore, a study specifically regarding the impacts of acute cardiovascular exercise on matching tasks and short-term memory games[3] (which were seemingly similar to the memory game used in our experiment) showed that several weeks or months of exercise proved a significant increase in performance, while also presenting no beneficial effect of a single cardiovascular exercise on memory consolidation. Another similar study showed no association between physical activity and memory strategy use[4].

Overall, this experiment addresses only a small complexity of this overarching topic, and our results prove to be consistent with studies which isolate the impacts of acute cardiovascular exercise on memory consolidation.

Our key limitation was the randomization in the sampling process. In order to remain consistent with the n given to us through the pwr.anova.test function, we were forced to replace any dead or nonconsenting participants by conducting another random number generation until we found an individual who was alive and consenting to participate. As such, our overall randomization was most likely harmed. Furthermore, we were unable to control for nuisance factors which may have been impacting memory (e.g. lifestyle habits, genetic components)

For improvements to our experimental design, we would suggest a revised method of random sampling, in which a total complication of alive residents is compiled and used to then randomly select participants. Furthermore, we would suggest sampling a number greater than the n given in the pwr.anova.test function, in order to maintain a level of randomization while accounting for any nonconsenting individuals. In future experiments, we would consider an increase in duration, possibly increasing the length of this experiment to study the effect of chronic cardiovascular exercise on memory game scores in a more evenly dispersed sample population.

---

[1] Manning, J.R., Notaro, G.M., Chen, E. et al. Fitness tracking reveals task-specific associations between memory, mental health, and physical activity. Sci Rep 12, 13822 (2022). https://doi.org/10.1038/s41598-022-17781-0

[2] Loprinzi PD, Roig M, Etnier JL, Tomporowski PD, Voss M. Acute and Chronic Exercise Effects on Human Memory: What We Know and Where to Go from Here. J Clin Med. 2021 Oct 20;10(21):4812. doi: 10.3390/jcm10214812. PMID: 34768329; PMCID: PMC8584999.

[3] Kuhne LA, Ksiezarczyk AM, Braumann KM, Reer R, Jacobs T, Röder B, Hötting K. The Effects of Acute Cardiovascular Exercise on Memory and Its Associations With Exercise-Induced Increases in Neurotrophic Factors. Front Aging Neurosci. 2021 Nov 8;13:750401. doi: 10.3389/fnagi.2021.750401. PMID: 34858160; PMCID: PMC8630591.

[4] Loprinzi PD. Association between habitual physical activity on episodic memory strategy use and memory controllability. Health Promot Perspect. 2019 Jan 23;9(1):65-70. doi: 10.15171/hpp.2019.08. PMID: 30788269; PMCID: PMC6377694.