The Impact of Nicotine Consumption on Cognitive Memory Performance

Final Project Group 21
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I. Introduction

Nicotine, a potent chemical found in tobacco products, has been the subject of several research studies and scientific experiments in recent years due to its widespread use and potential health implications. While nicotine is known for its addictive properties, numerous studies have explored the effects of nicotine on various physiological and cognitive functions, often highlighting its detrimental impact on cognitive memory performance. One study, published by the *American Journal of Public Health*, focused on smoking and cognitive decline among middle-aged men and women, and it claimed that "compared with [non] smokers, smokers performed worse at baseline on speed of cognitive processes, cognitive flexibility, and global cognition." Research has shown that nicotine can negatively affect cognitive processes, including memory recall and information processing speed. This cognitive decline associated with nicotine consumption is particularly concerning given its prevalence among smokers worldwide.

Understanding the implications of nicotine on cognitive function is critical for public health, as well as for initiatives that are aimed at reducing public smoking rates and preventing its harmful effects. By raising awareness about the cognitive risks associated with nicotine consumption, more and more people will begin to realize the importance of stopping harmful smoking habits. This report aims to explore these themes in more detail, presenting data from our experiment where we assessed the cognitive memory performance of participants before and after consuming nicotine. Because several studies have indicated that individuals who smoke nicotine cigarettes tend to experience slower memory recall, we decided to focus on memory performance as a measurable variable in our experiment. In order to guide our study, we formulated the following research question: *What is the effect of nicotine consumption through cigarettes on cognitive memory performance?* By addressing this question, our research seeks to provide a clearer understanding of how nicotine impacts cognitive performance, thereby contributing to the broader discourse on smoking and public health.

II. Design of the Experiment

For this experiment, we had a total of 60 participants, 10 random participants from each village on the island of Ironbard. To test whether or not nicotine has any effect on cognitive memory, we had each participant first take a memory test then timed how long they took to complete the test. The test consisted of pairing 30 cards as quickly as they could. Then, following the memory test, we had participants smoke one nicotine cigarette. After waiting five minutes for the effect of the cigarette to fully take effect, we had the participant take the memory test again. According to Keck Medicine of USC[1], nicotine has an effect on your body from when you first inhale it up until eight hours later. It fully goes into effect 20 minutes after your first intake, which is why we had participants wait five minutes after they had finished their cigarette to retake the memory test.

For our experimental design, we first decided to use a Randomized Complete Block Design (RCBD). The effect model for RCBD is:

$$y_{ij} = \mu + \tau_i + \beta_j + \varepsilon_{ij}$$

[1] Keck Medicine of USC. (n.d.). What happens to your body when you take a puff of a cigarette? Keck Medicine of USC. Retrieved June 9, 2024, from https://www.keckmedicine.org/blog/what-happens-to-your-body-when-you-take-a-puff-of-a-cigarette/

where y_{ij} is the *ijt*h observation, μ is an overall mean, τ_i is the effect of the *it*h treatment, β_j is the effect of *jt*h block, and ε_{ij} is a random error component that assumed to follow $N(0, \sigma^2)$.

Many factors could affect the outcome of our experiment, from age to the patient's smoking history. However, we only wanted to measure the correlation between nicotine and one's memory, therefore making all other factors, such as age, gender, hometown, and smoking history, to be nuisance factors. An RCBD covered all of those bases as it allowed us to analyze the correlation between nicotine and memory while accounting for the nuisance factors by blocking. Initially, we thought there would be a high amount of variability between patients who had no smoking history versus patients who had a light to moderate smoking history. So, we had planned to block the different levels of smokers. However, when we recorded each participant's smoking history within the last year, we discovered that the majority of the adults on the island of Ironbard had no smoking history at all. This caused little to no blocking for levels of smoking history, forcing us to consider other factors to block. After further research, we decided to block using age. According to studies, memory decline begins to become evident in one's 50s or 60s[2], so noticeably, Block 1 was defined as patients who were under the age of 50, and Block 2 was defined as patients who were of the age 50 or older.

The final variables of our design were:

- Response Variable - *Memory*
- Treatment Factor - *Cigarette*
- Nuisance Factor/Block - *Age*

so therefore,

$$y_{ij} = Memory\ (measured\ in\ seconds)$$
$$\tau_i = cigarette\ (-1 = Not\ Smoked;\ 1 = Smoked)$$
$$\beta_j = age\ (-1 = Block\ 1;\ 1 = Block\ 2)$$
$$j = 1, 2$$

and our hypothesis is:

$$H_0\colon \tau_1 = \tau_2 = \ldots = \tau_a = 0$$
$$H_a\colon \tau_i \neq 0\ (for\ at\ least\ one\ i)$$

During the analysis of the data from our experiment, we also decided to use a Randomized Block Design (RBD) to further test and affirm our conclusions. After our initial design, we discovered that it appeared that the blocks did not have significant variability between them, so we decided to use the RBD to directly test whether or not there was a correlation between cigarettes and memory. Our new statistical model would be:

$$y_{ij} = \mu + \beta_j + \varepsilon_{ij}$$

where y_{ij} is the *ijt*h observation, μ is an overall mean, and β_j is the effect on memory due to the of *jt*h specimen. Our hypothesis then became:

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[2] Queensland Brain Institute. (n.d.). Memory and age. The University of Queensland. Retrieved June 9, 2024, from https://qbi.uq.edu.au/brain-basics/memory/memory-and-age#:~:text=Our%20ability%20to%20remember%20new,role%20in%20memory%20and%20learning.

$$H_0\colon \mu_d = 0$$
$$H_a\colon \mu_d \neq 0$$

where μ_d is the average difference between each pair.

For our sample population, we selected 10 random houses from each village on the island, Ironbard. From each house, we selected one participant to be in our study. How the houses were selected were by a random number generator created in R Studio for complete randomization. We then tested whether or not our sample size was correct using power calculations.

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

              k = 2
              n = 60
              f = 0.2601097
      sig.level = 0.05
          power = 0.8067921

NOTE: n is number in each group
```

The power calculations were used using these parameters: $k = 2$ (number of groups, cigarette and no cigarette), $n = 60$ (sample size per group), $f = 0.2601097$ (effect size calculated using $f = d/\sqrt{MSE}$, where d is the difference in mean between No Cigarette and Cigarette memory test results), and $sig.level = 0.05$ (significance level of the test). These calculations helped determine the level of power, or the likelihood of correctly rejecting the null hypothesis given that the alternative hypothesis is true. The results showed **power = 0.8067921**. This indicated that there was about a 80% chance in correctly detecting a difference between the No Cigarette vs. Cigarette group. We can therefore conclude that our sample population for our experiment is a sufficient size.

III. Results and Interpretation

To determine if our treatment (cigarettes) or block (age) had any significant effect on memory, we used two ANOVA tables: one using the RCBD design with cigarettes as the treatment and age as the block, and another without using the age block.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
cigarette	1	73	73.48	0.419	0.519
Over50	1	8	8.03	0.046	0.831
Residuals	117	20529	175.47		

From the first ANOVA table, the age block and cigarette treatment were not statistically significant at the 5% level as the p-value for both these factors was above 0.05 (0.519 for cigarettes and 0.831 for age). These results indicated that neither smoking a cigarette nor the age of a participant had a significant effect on the memory test results. Given that the RCBD showed the treatment and block to be insignificant, the blocking factor was removed and tested again with just the cigarette treatment.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
cigarette	1	73	73.48	0.422	0.517
Residuals	118	20538	174.05		

This ANOVA table also showed that the cigarette treatment was not statistically significant at the 5% level as the p-value was 0.517. Furthermore, the low F-values in both models further imply that the age block had minimal effect on the memory test results. Overall, neither smoking nor the participant's age had any significant effect on the memory test results.

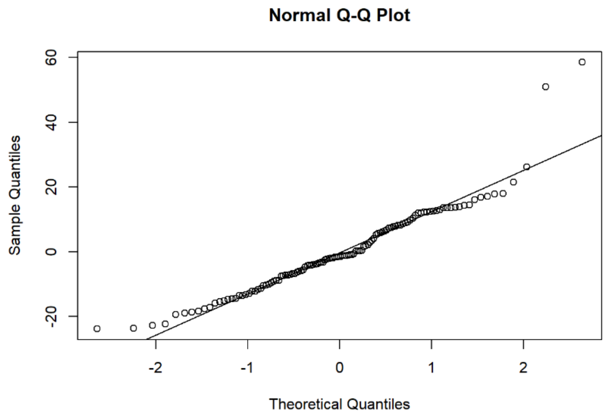
Knowing the block was ineffective, we decided to pivot and conduct a paired t-test to see if the difference in treatments (No Cigarettes vs Cigarettes) was significantly different from 0 or not. First, we had to determine whether the variances between the No Cigarettes and Cigarettes values were equal for the t-test. To do this, an F-test is done to compare the two variances.

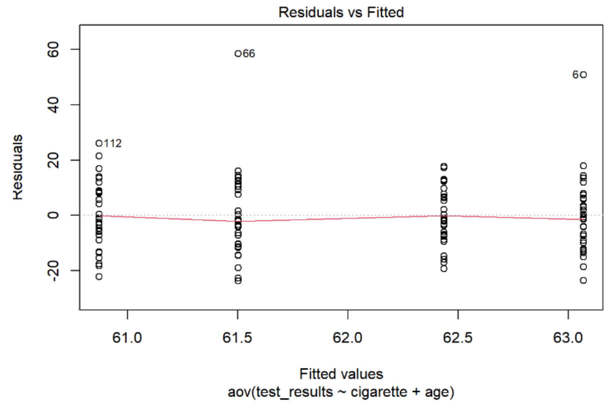
```
        F test to compare two variances

data:  df$NoCig and df$Cig
F = 0.78012, num df = 59, denom df = 59, p-value =
0.3429
alternative hypothesis: true ratio of variances is not equal to
1
95 percent confidence interval:
 0.4659871 1.3060303
sample estimates:
ratio of variances
         0.7801239
```

From the F-test, we failed to reject the null hypothesis as the p-value was 0.3429, which is greater than our significance level (0.05). There was insufficient evidence to prove that the variances were significantly different from each other. Using this information, a paired t-test is conducted using the var.equal = TRUE argument. The paired t-test again shows that, since p-value > 0.05 (0.05053).

```
        Paired t-test

data:  df$NoCig and df$Cig
t = 1.9963, df = 59, p-value = 0.05053
alternative hypothesis: true difference in means is not equal
to 0
95 percent confidence interval:
 -0.003698997  3.133698997
sample estimates:
mean of the differences
                  1.565
```

We failed to reject the null hypothesis again concluding that the values in No Cigarettes vs Cigarettes groups were not significantly different. In general, this means that whether a participant smokes a cigarette or not, there seems to be no significant difference in the memory test results.





To check for model adequacy, two plots were formed: the normal probability plot (QQ plot) and the residuals vs. fitted plot. Looking at the QQ plot, most of the points seem to fall on the line only with the exception of a couple outliers, indicating the passing of the normality assumption. Furthermore, the residuals vs. fitted plot shows similar results. Other than two potential outliers, the variance of residuals seems to be constant over different treatments, indicating roughly equal variance. As both of these plots show that our model meets the necessary assumptions, it is safe to assume that the results we reach through our model can be considered accurate and reliable.

IV. Discussion

Through a randomized complete block design, we analyzed whether nicotine through cigarettes has a significant effect on memory test results. We also performed a paired t-test, which compared the speed of the memory game before and after smoking nicotine. Based on the results, the consumption of nicotine through cigarettes doesn't appear to have a significant effect on memory test results, and the age block we used did not appear to have a significant effect either. These results indicated that neither smoking a cigarette nor the participant's age had a significant effect on the memory test results. The results may be different in a real-world situation as studies have found that memory is affected by smoking and age. In a real-world situation however, there would likely be many more factors that would need to be considered.

With that, there are also several limitations to our study. For instance, the memory test measured the speed of completing the memory game rather than precision. As such, to better understand the relationship between nicotine and memory, more factors of memory should be measured. Furthermore, we tested participants on short-term memory performance. Research has shown that cognitive decline is often made worse by the cumulative effects of long-term smoking, therefore studying long-term effects may provide more conclusive evidence, though this would be more difficult to study in our context. Additionally, since the effect of nicotine takes time to kick in in the real world, we waited five minutes after the participants smoked to make them perform a second memory test. On the virtual island that we used to conduct the study, the effect of the cigarette may have already gone away.

Nonetheless, our study represents a small-scale examination into the short-term effects of nicotine on cognitive memory performance. While our findings can contribute to the broader understanding of nicotine's impact on cognitive health, they also do highlight the need for more extensive research to better understand the relationship between nicotine and cognitive performance. Future research studies could explore various aspects of memory, including long-term effects, to provide a more conclusive understanding of nicotine's cognitive risks.