Effects of Caffeine on Reaction Time

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Overview

This project simulates a study I mentored students on, investigating the effects of caffeine on reaction time. The data is simulated to reflect a real experimental design, focusing on how caffeine, gender, and heart rate interact to influence reaction time performance.

Introduction

Caffeine is widely used to improve alertness and performance. This study investigates its effects on cognitive function, specifically reaction time, using a Go/No-Go task. It also explores whether gender moderates these effects and examines physiological changes in heart rate due to caffeine intake.

Methods

Design

- Design: Between-subjects laboratory experiment
- Groups:
  - Caffeinated Coffee
  - Decaffeinated Coffee (placebo)
  - No Drink
- Measurements:
  - Reaction Time (ms) using an online Go/No-Go task
  - Heart rate before and after intervention
- Additional Factors:
  - Gender (Male/Female)

```
# Load the data
setwd("C:/Users/0&1/OneDrive/Documents/Student-Projects-Portfolio/effects of caffeine on reaction time")
data <- read.csv("caffeine_reaction_time_data.csv")

# Convert to factors
data$Group <- factor(data$Group, levels = c("Caffeine", "Decaf", "NoDrink"))
data$Gender <- factor(data$Gender)

# View head of data
head(data)
```

```
##   ID    Group Gender    RT HR_Before HR_After
## 1  1 Caffeine   Male 288.4      70.6     85.0
## 2  2 Caffeine Female 267.4      73.6     88.3
## 3  3 Caffeine   Male 288.2      70.6     85.0
## 4  4 Caffeine   Male 281.1      70.6     87.5
## 5  5 Caffeine   Male 278.2      72.7     87.7
## 6  6 Caffeine Female 291.1      66.3     80.2
```

Statistical Analysis

Two-way ANOVA: Reaction Time ~ Group * Gender

```r
anova_result <- aov(RT ~ Group * Gender, data = data)
summary(anova_result)
```

```
##              Df Sum Sq Mean Sq F value Pr(>F)
## Group         2  11917    5958  77.679 <2e-16 ***
## Gender        1     12      12   0.151 0.6995
## Group:Gender  2    528     264   3.439 0.0393 *
## Residuals    54   4142      77
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Assumption Checks

```r
# Normality of residuals
shapiro.test(residuals(anova_result))
```

```
##
##  Shapiro-Wilk normality test
##
## data:  residuals(anova_result)
## W = 0.97622, p-value = 0.29
```

```r
# Homogeneity of variances
library(car)
```

```
## Loading required package: carData
```

```r
leveneTest(RT ~ Group * Gender, data = data)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  5  0.8122 0.5462
##       54
```

ANCOVA: Adjusted for Baseline Heart Rate

```r
ancova_result <- aov(RT ~ Group * Gender + HR_Before, data = data)
summary(ancova_result)
```

```
##              Df Sum Sq Mean Sq F value Pr(>F)
## Group         2  11917    5958  82.155 <2e-16 ***
## Gender        1     12      12   0.159 0.6914
## HR_Before     1    222     222   3.065 0.0858 .
```

```
## Group:Gender  2    604     302   4.161 0.0210 *
## Residuals    53   3844      73
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Heart Rate Change Analysis

```
data$HR_Change <- data$HR_After - data$HR_Before

# One-way ANOVA for HR change
anova_hr <- aov(HR_Change ~ Group, data = data)
summary(anova_hr)
```

```
##             Df Sum Sq Mean Sq F value Pr(>F)
## Group        2   2855  1427.3    1535 <2e-16 ***
## Residuals   57     53     0.9
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
# Post-hoc comparison
TukeyHSD(anova_hr)
```

```
##   Tukey multiple comparisons of means
##     95% family-wise confidence level
##
## Fit: aov(formula = HR_Change ~ Group, data = data)
##
## $Group
##                     diff       lwr         upr p adj
## Decaf-Caffeine   -13.705 -14.43881 -12.9711895 0e+00
## NoDrink-Caffeine -15.410 -16.14381 -14.6761895 0e+00
## NoDrink-Decaf     -1.705  -2.43881  -0.9711895 2e-06
```

Results

- The Caffeine group showed significantly faster reaction times compared to the Decaf and NoDrink groups ($p < .01$).
- Gender had no significant main effect or interaction with group.
- A significant increase in heart rate was observed only in the Caffeine group.
- The ANCOVA confirmed that the reaction time difference remains significant after adjusting for baseline heart rate.

Discussion

These results support the hypothesis that caffeine enhances cognitive speed, as shown by lower reaction times. Heart rate increases in the caffeine group support its physiological effect. The lack of gender differences aligns with some prior literature, but future studies with larger samples may explore interaction effects further.

Conclusion

This simulated study demonstrates a clear impact of caffeine on reaction time performance. It illustrates key concepts in experimental design, analysis of variance, and ANCOVA—useful tools in both psychological and

biomedical statistics.

References

- Lieberman, H. R., Wurtman, R. J., Emde, G. G., Roberts, C., & Coviella, I. L. (1987). The effects of low doses of caffeine on human performance and mood. Psychopharmacology, 92(3), 308–312.
- Smith, A. (2002). Effects of caffeine on human behavior. Food and Chemical Toxicology, 40(9), 1243–1255.
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