

# Impact of Caffeinated and Caffeine-Free Beverages on the Problem Solving Skills of A Virtual Population\*

Study for STA305 at University of Toronto Mississauga

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March 19, 2025

Caffeine is the most popular psychoactive substance in the world, particularly due to its widely known stimulating effects. As a stimulant, caffeine has mostly commonly been used to increase mental alertness, which is why the goal of our study is to determine if there is an association between caffeine use and problem solving skills. We collected data using a virtual population on The Islands. After collecting a sample of 150 virtual participants and splitting them into three age groups, a caffeinated or caffeine-free drink, with water as a control, were administered to each participant. Using a balanced Kruskal-Wallis test, we found that [summary of key findings]. [brief overview of result implications, improvements needed].

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\*Data available at <https://github.com/sheam/Beverage-Impact-on-Problem-Solving-STA305H5S2025>

# 1 Introduction

As the world’s most popular psychoactive substance, caffeine’s widely known effects have been studied extensively. Despite certain drawbacks like digestion and anxiety issues in some people, due to being a stimulant, it has most commonly been used to temporarily increase mental alertness which improves things like memory and lessens fatigue, thus providing an energy boost.

In this study, we are analyzing whether there is an association between caffeine use and problem solving skills by giving coffee, energy drinks, and caffeine-free versions of both to participants from the [The Islands](#), a virtual population developed by the University of Queensland for learning and teaching in statistics. Our sample was split into three age groups: 18-35, 36-54, and 55+. Considering the effects of caffeine, participants assigned a caffeinated drink would be expected to achieve a higher score than those that are not.

We aim to study the following research questions:

- Research Question 1 (RQ1): Does beverage type have an impact on problem solving score?
  - $H_0$ : no association between beverage type and problem solving score.
  - $H_a$ : association between beverage type and problem solving score exists.
- Research Question 2 (RQ2): Do caffeinated coffee and energy drinks have a higher impact on problem solving scores compared to their caffeine-free counterparts?
  - $H_0$ : no association between caffeinated drinks and higher score
  - $H_a$ : association between caffeinated drinks and higher score exists.

This paper consists of our methodology, analysis, results, limitations, and a conclusion for our study.

## 2 Methodology

### 2.1 Design and Setup

In February 2025, we conducted an experiment to determine if different caffeinated and caffeine-free drinks affect the problem solving skills of virtual participants on The Islands. Our experiment utilized a balanced one-way randomized complete block (RCB) design. Participants were blocked out into one of three age groups, where they were given one of five drinks (the treatment) and had their score on a 20 minute problem solving test (the response) recorded.

Each of the three age group blocks contained an equal number of participants for each treatment, per our RCB design. While we did not have any major factors that we could easily control for, to help account for nuisance factors treatments were randomly assigned among participants using an R script (See Listing ?? in Appendix).

The experiment included a total of 150 participants ( $n = 150$ ), with 50 in each of the following age blocks: 18-35, 36-54, and 55+. Each participant was given one of five 250 millilitre drinks ( $a = 5$ ): Water (Control), Energy Drink, Energy Drink Decaffeinated, Coffee, or Coffee Decaffeinated. Each treatment factor contained 30 participants ( $n_j = 30$ ), split evenly among the three age blocks thus giving a balanced design. This also provided for enough repetitions to further account for nuisance factors that might not have been dealt with through the blocking or randomization. Since each

participant was exposed to only one treatment and randomly assigned to a treatment group, this experiment utilized a between-subjects design.

## 2.2 Data Collection

Each participant was given their randomly assigned drink and then administered a 20 minute problem solving test. The test was scored from 0 to 100 and after completion, each participants score was recorded. Once all data collection was completed, it was cleaned, stripping any personally identifying information and assigning factor levels and names more easily utilizable and readable within R.

## 3 Analysis

### 3.1 Summary Statistics and Checking Assumptions

We began by gathering summary statistics of our data, presented in Table ???. The high mean and median indicate that participants generally scored well on the problem solving test. A low standard deviation indicates tight clustering around the mean and a low IQR indicates tight clustering around the median. The minimum of 67 lies well outside of  $1.5 \times \text{IQR}$ , indicating a presence of outliers on the low side, with further inspection necessary to determine the amount. The maximum of 100 along with the data being skewed to the high means that there are no outliers present on the high end.

Table 1: Summary of Problem Solving Test Scores

	Min	Max	Mean	Median	SD	IQR
Value	67	100	93.4867	96	6.9618	6.75

More preliminary information is obtained plotting the treatments in relation to scores in Figure ??.

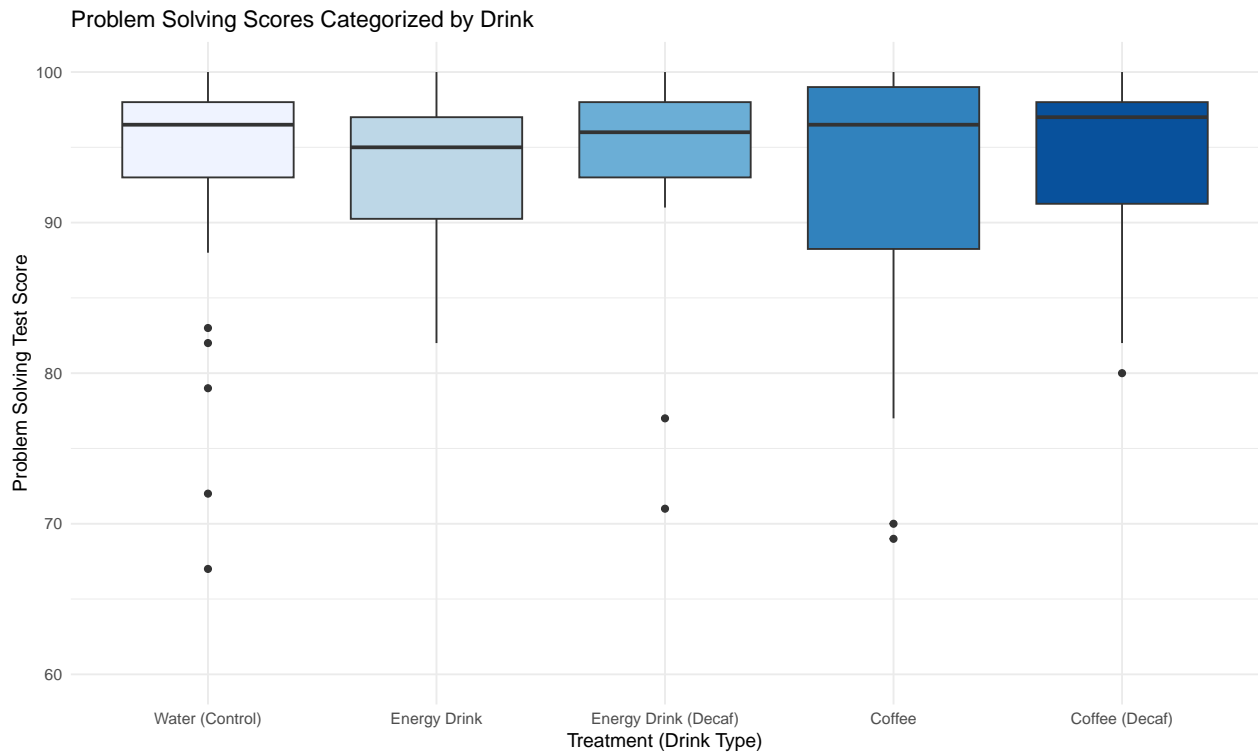


Figure 1: Boxplot of Scores by Treatment

From the boxplot, we can make an initial inference that the means are likely similar among groups, however the variances are different. To confirm this, further analysis will be utilized, but prior to that we must check assumptions to determine if a one-way ANOVA can be utilized, or if we must proceed with a Kruskal-Wallis non-parametric test. The three assumptions that must be checked are independence, normally distributed, and homogeneous variance.

1. Independence: This assumption is satisfied by design. All data points are collected from unique individuals whose results do not depend on the others.
2. Normality: Violated, as seen in Figure ??
3. Homogeneity of Variance: Violated, as seen in Figure ??