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AP Statistics
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Statistics Experimental Study: Effect of Caffeine on Athletic Performance

Background:

Until 2004, caffeine was placed on the World Anti-Doping Agency (WADA) prohibited substance list as a performance enhancing drug. While it is no longer on the prohibited substance list, it has since been moved to the WADA monitoring program to detect athletic abuse of the substance. Known as the world's most accessible drug, caffeine is a stimulant, increasing the speed at which neuroreceptors connect the body to the brain. In simpler terms, the presence of caffeine is shown to make people faster, mentally and physically. Caffeine has been well-studied as a stimulant, so the purpose of this experiment is to test the effects of caffeine on athletic performance, both agility and endurance.

Hypotheses:

Because of the commonly accepted knowledge that caffeine enhances speed, I believe that it has both long term and short term affects on athletic ability, enhancing the users' performance, however when compared to each other, I believe there will be a closer relationship with short term.

H_o: $T_C - T_{NC} > 0$
H_a: $T_C - T_{NC} < 0$

Where T_C represents a subject's time after drinking the caffeinated beverage
Where T_{NC} represents a subject's time after drinking the de-caffeinated beverage

Conditions:

Random: Yes. I flipped a coin to determine the treatments.
Normal: No. Using 12 subjects does not satisfy that Central Limit Theorem minimum of 30.
Independent: Yes. One subject's time/treatment does no have any effect on the time/treatment of another subject. Waited a day between testing so previous tests do not affect future tests. Sample was also less than 10% of the population of Branson students.

Procedure:

Before experimentation:

1. Flip a coin to determine order in which to administer treatments to each subject (randomization)
2. Inform subjects that they will be participating in a blind experimental study, in which, they will have to consume a placebo energy drink and a caffeinated energy drink (ethical purposes)

During experimentation:

3. Have the subject drink 6 fl. oz. (measured out)
4. After consumption, wait one minute (to let the caffeine/placebo reach their system)
5. Have subject perform activity (endurance or speed and agility)
   A. Endurance: Run around the perimeter of half of the field (no cutting corners)

B. Speed and Agility: Touch each post of the soccer goal twice (four posts total), then sprint from the soccer goal to half field and back

6. Record times
7. Perform tests of significance

Data and Results:

Group A:	Day 1: LE	Day 2: SE	Day 3: LE	Day 4: SE
Subject 1	Type: 2 Time: 2:57.86	Type: 1 Time: 0:27.42	Type: 1 Time: 2:53.21	Type: 2 Time: 0:28.49
Subject 2	Type: 2 Time: 3:12.67	Type: 2 Time: 0:29.65	Type: 1 Time: 3:05.65	Type: 1 Time: 0:29.98
Subject 3	Type: 2 Time: 2:12.29	Type: 1 Time: 0:24.54	Type: 1 Time: 2:15.02	Type: 2 Time: 0:25.79
Subject 4	Type: 2 Time: 3:23.54	Type: 1 Time: 0:34.36	Type: 1 Time: 3:21.09	Type: 2 Time: 0:33.81
Subject 5	Type: 1 Time: 3:06.62	Type: 1 Time: 0:32.90	Type: 2 Time: 3:12.86	Type: 2 Time: 0:33.26
Subject 6	Type: 1 Time: 2:39.92	Type: 2 Time: 0:23.69	Type: 2 Time: 2:47.37	Type: 1 Time: 0:21.80
Group B:	**Day 1: LE**	**Day 2: SE**	**Day 3: LE**	**Day 4: SE**
Subject 7	Type: 2 Time: 2:49.97	Type: 1 Time: 0:28.12	Type: 1 Time: 2:45.08	Type: 2 Time: 0:26.89
Subject 8	Type: 1 Time: 2:44.63	Type: 2 Time: 0:29.37	Type: 2 Time: 2:48.03	Type: 1 Time: 0:30.02
Subject 9	Type: 1 Time: 2:33.76	Type: 2 Time: 0:22.86	Type: 2 Time: 2:34.78	Type: 1 Time: 0:24.10
Subject 10	Type: 1 Time: 3:11.34	Type: 2 Time: 0:29.29	Type: 2 Time: 3:16.49	Type: 1 Time: 0:28.84
Subject 11	Type: 2 Time: 2:56.42	Type: 2 Time: 0:27.93	Type: 1 Time: 2:57.85	Type: 1 Time: 0:26.29
Subject 12	Type: 2 Time: 2:54.02	Type: 1 Time: 0:29.57	Type: 1 Time: 2:49.32	Type: 2 Time: 0:30.42

Key:
LE = Long-Endurance
SE = Short-Endurance
1: Monster
2: Monster Unleaded (No Caffeine)

Endurance Treatment:

L_1 (Caffeine)	L_2 (De-Caffeinated)	L_3 (L_1 - L_2)
173.21	177.86	-4.65
185.65	192.67	-7.02
135.02	132.29	2.73
201.09	203.54	-2.45
186.62	192.86	-6.24
159.92	167.37	-7.45
165.08	169.97	-4.89
164.63	168.03	-3.40
153.76	154.78	-1.02
191.34	196.49	-5.15
177.85	176.02	1.83
169.32	174.02	-4.70

P(Caffeine < No Caffeine) in terms of time (seconds)

T-Test:
$\mu < 0$
$t = -3.851625612$
$p = .0013459671$
$\bar{x} = -3.5675$
$S_x = 3.208562762$
$n = 12$

P(Caffeine actually affects people)
1-PropZTest:
$prop > .5$
$z = 2.309401077$
$p = .0104606407$
$\hat{p} = .8333333333$
$n = 12$

Speed and Agility Treatment:

L_1 (Caffeine)	L_2 (De-Caffeinated)	L_3 (L_1 - L_2)
27.42	28.49	-1.07
29.98	29.65	0.33
24.54	25.79	-1.25
34.36	33.81	0.55
32.90	33.26	-0.36
21.80	23.69	-1.89
28.12	26.89	1.23
30.02	29.37	0.65
24.10	22.86	1.24
28.84	29.29	-0.45
26.29	27.93	-1.64
29.57	30.42	-0.85

P(Caffeine < No Caffeine) in terms of time (seconds)

T-Test:
$\mu < 0$
$t = -.9363341891$
$p = .1846014781$
$\overline{x} = -.2925$
$S_x = 1.082145386$
$n = 12$

P(Caffeine actually affects people)
1-PropZTest:
$prop > .5$
$z = .5773502691$
$p = .2818513864$
$\hat{p} = .5833333333$
$n = 12$

Results and Conclusion:

Concluding my experiment, it is interesting to note that I only received statistically significant results (at the .05 significance level) for one treatment: endurance. Based on research about the effect of caffeine, I formulated my original hypothesis on the basis that caffeine is most effective as short term energy, becoming less effective the longer it has been in your body. Because of this, I believed that my results would be more statistically significant for the speed and agility treatment rather than the endurance. However, my results showed otherwise.

For endurance, I used a T-Test for Matched Pairs to determine that the difference in times (where those who drank caffeine are faster than they were after drinking the de-caffeinated beverage) was very much significant at the .05 significance level, as my p-value result was approximately .00135. Because this is an endurance test, the times were longer than they were for the speed and agility test, having a standard deviation of approximately 3.21 (vs. approximately 1.08). This longer standard deviation could affect the data because the of the subject that did have a quicker time after drinking caffeine, their much faster times could possibly skew the data. To ensure that my data wouldn't be affect by skew, I not only relied on a T-Test of Matched Pairs to find the p-value for the mean of the times, but I also used a 1-PropZTest to test for significance of randomness in difference of times. Simply put, this would test for whether or not the caffeine *really* significant affected the sample, or whether the difference in speeds could be attributed to randomness. This test would eliminate the effects that any possible skew could have on the mean of the difference in times, and would only test the proportion of those who had faster times after drinking the caffeinated drink. The 1-PropZTest was significant at the .05 significance level, with a p-value of approximately .0105. Concluding the endurance treatment: we not only concluded that both the difference in times and the proportion of those who were faster after drinking caffeine were both statistically significant at the .05 significance level.

My results for the speed and agility treatment were not only different from my original hypothesis, but they were also different from my endurance treatment. Yet again using the T-Test for Matched Pairs and the 1-PropZTest, I found that neither my test for difference of times nor proportion of people that were faster were statistically significant at the .05 level. For the difference of times, my p-value was approximately .185 and for the proportion of the sample, my p-value was approximately .282. While the test for proportion was not as necessary in this test, due to the standard deviation being lower (about 1.08), minimizing skew. In comparison to the first test: only 7/12 people in this test improved their time after drinking caffeine, while 10/12 subjects' times improved in the test of endurance. Of those who improved, only the sample of endurance times were statistically significantly lower for those who ran after drinking caffeine.

The conclusion of this experiment helps me to determine that the consumption of caffeine has a stronger positive correlation to athletic ability for endurance activities rather than speed and agility. While we cannot prove that there is a negative correlation between the consumption of caffeine and one's short term athletic performance, we reject the premise that there is a statistically significant positive correlation between the two variables under the .05 significance level. With this said, we cannot determine that caffeine has a direct effect on athletic performance, as correlation does not imply causation, however, we can determine that there is a statistically significant positive correlation between the consumption of caffeine and one's athletic performance for endurance activities. If I were to run another test to help corroborate my findings, I would perform a test to determine whether or not there is a relationship between the amount of caffeine that is consumed and athletic performance; to determine if there is an optimum level of caffeine consumption to help enhance performance.

Sources of Error:

While my results were strongly indicative of a relationship between caffeine consumption and athletic performance in the endurance treatment and quite the opposite for the speed and agility treatment, my experiment was not perfect, as there were a couple sources of error:

1. **Human Error:** Likely the most common source of error in experiments, human error certainly had an effect on my data as my collection methods may have been slightly compromised due to imprecision in recording and timing the data. While this error would have minimal effect on my results, it is nonetheless a source of error.
2. **Inconsistencies:** There were many aspect of the experiment that I simply could not control: the weather in a given day of testing, one's difference in food consumption from day-to-day, and the subjects' motivation to run (although, I did ask that they give their best efforts). While the effects of these inconsistencies are reduced by the randomization of the treatments, performing this experiment in a completely controlled environment would provide the most precise results.
3. **"De-Caffeinated":** While I did serve two drinks that had drastically different amounts of caffeine in them, the de-caffeinated energy drink did still have caffeine, only trace amounts of it. Besides the amount of caffeine, however, the two drinks were nearly identical in taste, color, nutritional content, etc., but (of course) not identical.
4. **Lack of Diversity in Trials:** It was difficult to test the true long-term effects of caffeine on athletic ability as the longest any volunteer would be willing to run was approximately three minutes worth. It would be interesting to try this test on a population that would be willing to run longer distances (like a 5k, for example).