

RED BULL MAY NOT GIVE YOU WINGS: A COMBINATION OF CAFFEINE AND TAURINE HAS NO EFFECT ON SHORT TERM MEMORY BUT INDUCES CHANGES IN HEART RATE AND MEAN ARTERIAL BLOOD PRESSURE

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INTRODUCTION

Does Red Bull Give You Wings?

Energy drinks have recently exploded onto the mainstream US market and are popular amongst athletes, partygoers, and college students. At the top of the list is Red Bull, an energy drink that claims its active ingredients, caffeine and taurine, "give you wings," by improving performance, concentration and reaction speed, vigilance, emotional status, and stimulating metabolism (1). The Red Bull website recommends drinking Red Bull before tests, and many college students at UW-Madison and across the country drink Red Bull while studying and before exams because they believe it improves their memory and performance.

Carefully controlled studies on Red Bull's effects, particularly its influence on short-term memory, are limited. Alford *et al.* (2) found that human subjects who consumed Red Bull had improved performance on an immediate recall memory test; however, another study indicated Red Bull consumption had no effect on human verbal or spatial memory compared to placebo (3).

To our knowledge only these two studies have evaluated Red Bull's effect on memory. Neither of these studies, however, isolated Red Bull's active ingredients, caffeine and taurine. Both studies had test subjects consume a 250 ml can of the actual Red Bull energy drink, which contains a variety of other ingredients, including glucuronolactone, niacin, vitamins B6 and B12, sucrose, and glucose. A study on the combined effects of caffeine and taurine alone on short-term explicit memory is lacking.

Caffeine Effects on Memory are Unclear

Caffeine is a CNS-stimulating drug that antagonizes adenosine receptors in the brain. This antagonism has been linked to improvement in higher cognitive functions such as memory (4, 5). Caffeine also triggers the release of epinephrine, which causes some of the physiological effects associated with caffeine consumption, including increased heart rate and blood pressure (6).

A consensus on caffeine's impact on memory has not yet been reached. Studies indicate that caffeine improves reaction time, endurance, and cognitive performance in human subjects (4, 7, 8). Riedel *et al.* (5) found that caffeine improved both short and long term memory in human subjects with scopolamine-induced memory impairment. Additionally, caffeine was demonstrated to reduce the worsening of memory with time of day in older adults (9). Numerous other studies, however, have indicated that caffeine has no significant impact on memory function (10, 11, 12). A number of factors may contribute to the discrepancies between studies, including the time of day subjects were tested (9, 12), the dosage of caffeine administered (11), and the regular caffeine usage habits of test subjects (13).

Taurine Effects on Memory are Also Unclear

Taurine is a non-essential amino acid that is found in high concentrations in the brain and acts as both a neuromodulator and neurotransmitter (14, 15). It is also present in high quantities in mammalian hearts, where it has been shown to increase cardiac stroke volume (16) and may have antihypertensive activity (14).

It is believed taurine may play a role in memory function through modulation of N-methyl-D-aspartate (NMDA) receptors (17), but no studies in humans have established a concrete link between taurine and memory improvement. Studies in rodents have demonstrated that taurine improves chemically-disrupted memory function (15, 18).

Testing Procedure (see Fig. 1)

- Subjects rested for 30 minutes.
- Resting heart rate and blood pressure data were measured at 30 minutes (**TIME 1, HR1 and MABP1**).
- Subjects received treatment drugs: either caffeine/taurine or placebo.
- Subjects were allowed to quietly study for 45 minutes while the treatment took effect. During this time, they took a short practice memory test to familiarize themselves with the format of the memory assessment.
- Physiological parameters were measured again (**TIME 2, HR2 and MABP2**).
- Subjects completed the Experimental Comparative Prediction Battery, a short term explicit memory test in which subjects recall recently memorized random facts.
- Physiological parameters were measured for the last time (**TIME 3, HR3 and MABP3**).
- Subjects were free to leave. Subjects returned within a week for their second testing session and were administered the other treatment drug and completed a different version of the memory assessment.

Data Analysis

- The effect of caffeine/taurine on memory test scores was examined using the nonparametric Wilcoxon Signed Ranks test.
- The effect of caffeine/taurine on heart rate and mean arterial blood pressure data was also examined using the Wilcoxon Signed Ranks test.

OUR INVESTIGATION

While research indicates that caffeine and taurine may individually enhance memory, there are no known studies to date that have investigated their combined effects on short term memory. In light of this research void and the popularity of using Red Bull as a study aid on the UW campus, we investigated whether the caffeine and taurine present in Red Bull energy drink improve short term explicit memory.

We hypothesized that consumption of caffeine and taurine in concentrations equivalent to those in one 250 ml serving of Red Bull energy drink would significantly increase performance on a short term explicit memory assessment as compared to test performance after consuming placebo. If test subjects performed better on the memory test after consuming caffeine and taurine compared to placebo, it would indicate that the combined neuromodulatory effects of these two chemicals do indeed enhance short term memory.

We tested this hypothesis by having 14 human subjects complete a memory assessment on two occasions: once after consuming caffeine and taurine pills in amounts equivalent to those found in one 250 ml Red Bull beverage, and once after consuming a placebo (sugar pills). Subject heart rate and blood pressure were also monitored throughout the trials in order to assess the cardiovascular effects of caffeine and taurine in combination.

METHODS

Subjects

- Fourteen undergraduate student volunteers (8 female and 6 male), aged 18 to 23
- No history of heart conditions
- No history of allergies to caffeine or taurine
- No consumption of caffeine or taurine 24 hours prior to testing

Subject Treatment

- Each participant received two different treatments in random order over two testing sessions:
 - o Active Treatment - 100 mg caffeine and 1000 mg taurine
 - o Placebo
- Double-blind treatment administration
- The following physiological parameters were measured:

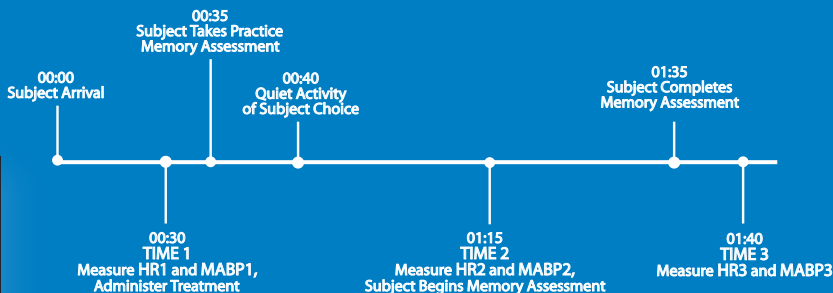


Figure 1. Timeline for subject testing session. Time 00:00 represents subjects' arrival to test room. HR1 and MABP1 represent the first time these parameters were measured 30 minutes after subject arrival, HR2 and MABP2 were measured one hour and 15 minutes after arrival, HR3 and MABP3 one hour and 40 minutes after arrival. Each session lasted one hour and 45 minutes.

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RESULTS

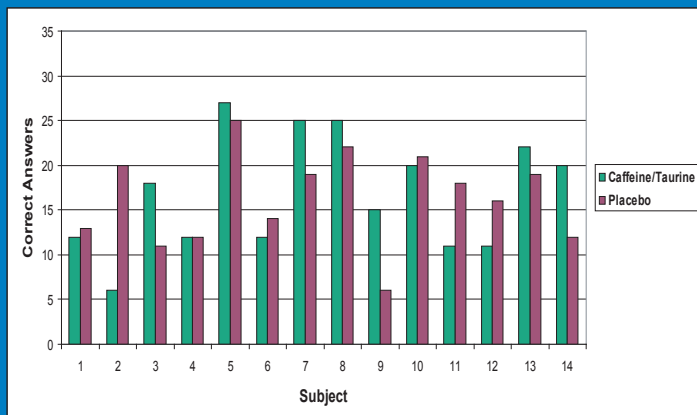


Figure 2. Each subject's raw memory assessment score (out of 35 possible) under both caffeine/taurine treatment and placebo conditions. There was no significant difference between the trial test scores ($T=36$, 2-tailed $p=0.51$).

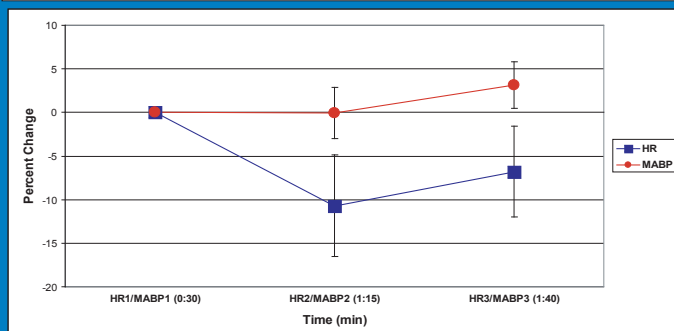


Figure 3. Average percent changes in heart rate and mean arterial blood pressure over the course of the caffeine/taurine treatment period. HR1 and MABP1 were measured when subjects ingested treatment. HR2 decreased significantly from HR1 and MABP3 increased slightly from MABP2. Error bars represent a 95% confidence interval.

Short Term Memory

- Caffeine/taurine did not significantly change performance on the memory assessment as compared to placebo ($T=36$, 2-tailed $p=0.506$; see Fig. 2).
- Subject test scores did not improve with experience (no significant differences in test scores between days one and two of testing, $T=33.5$, $p=0.401$).

Heart Rate

- Significantly decreased by ~ 8 beats/min in the 45 minutes after caffeine and taurine were ingested (comparison of HR1 vs. HR2: $T=6$, 2-tailed $p=0.006$; see Fig. 3).
- Heart rate remained lowered for the remainder of the testing period (comparison of HR2 vs. HR3: $T=28.5$, 2-tailed $p=0.233$).
- These changes were not observed during placebo trials.

Mean Arterial Blood Pressure

- Did not significantly change in the 45 minutes following caffeine/taurine administration (comparison of MABP1 vs. MABP2: $T=51$, 2-tailed $p=0.925$).
- A slight increase of ~ 3 mm Hg was observed after completion of the memory assessment. Nonparametric tests indicated that this was a statistically significant increase (comparison of MABP2 vs. MABP3: $T=9$, 2-tailed $p=0.032$; see Fig. 3).
- These changes were not observed during placebo trials.

DISCUSSION

Combination of Caffeine and Taurine Does Not Improve Short Term Memory

Our results indicate that a combination of caffeine and taurine in amounts similar to those in one 250 ml serving of Red Bull energy drink have no effect on short term memory in young college students. Our study represents the only research to date on the combined effects of caffeine and taurine on human memory. This is relevant to the student body at UW-Madison, many of whom drink Red Bull to perform better on exams. It should be noted, however, that there are multiple forms of memory besides short term recall. Simple short term recall may not be representative of the type of memory students utilize when studying for or taking exams. It is possible that a combination of caffeine and taurine can improve other types of memory function.

Caffeine and Taurine Induced Unexpected Changes in Cardiovascular Physiology

While the main goal of our study was to test how a combination of caffeine and taurine impacted short term memory, we noted the drugs had unexpected effects on heart rate and mean arterial blood pressure. We found that the combination of caffeine and taurine significantly decreased heart rate but increased mean arterial blood pressure.

Taurine May Override Effects of Caffeine on Heart Rate

Subject heart rates decreased by ~8 beats per minute within 45 minutes of consuming caffeine and taurine. Ingestion of caffeine, however, is expected to increase heart rate by triggering the release of epinephrine (19). The decrease in heart rate might therefore be attributed to the effects of taurine. Baum and Weis (16) found that taurine in combination with caffeine significantly increased cardiac stroke volume in young endurance athletes after exercise. The relationship between stroke volume and heart rate can be defined as:

$$\text{Heart Rate} \times \text{Stroke Volume} = \text{Cardiac Output} \quad (19)$$

If stroke volume increases, cardiac output will increase, causing mean arterial blood pressure to elevate ($\text{Cardiac Output} \times \text{Total Peripheral Resistance} = \text{MABP}$). Arterial baroreceptors detect increases in blood pressure and immediately compensate by triggering a decrease in heart rate to reduce cardiac output and return blood pressure to normal levels. While we cannot be certain that taurine triggered this sequence of events, the fact that heart rate did not increase as expected with caffeine consumption suggests that taurine was doing something to alter cardiovascular physiology.

Stress May Impact Mean Arterial Blood Pressure

Mean arterial blood pressure had not increased 45 minutes after consumption of caffeine and taurine (immediately prior to taking the memory assessment), but was slightly yet significantly elevated at the end of the testing session by ~ 3 mm Hg, after subjects had completed the memory test. It may be that:

- caffeine and taurine in combination with a release of epinephrine due to a stressful event (such as taking a test) may elevate blood pressure. Stressful situations trigger epinephrine release from the adrenal glands, which stimulates vasoconstriction, thereby increasing blood pressure (20). As mentioned above, however, epinephrine should also induce an increase in heart rate, which we did not observe in our trials.
- caffeine and taurine in combination elevate blood pressure, but the effect occurs more slowly than the drugs' actions on heart rate (i.e., HR decreased 45 minutes after treatment was ingested while MABP changes were not observed until after 70 minutes had passed).

Recommendations for Future Studies

- Have subjects refrain from caffeine and taurine consumption for longer than 24 hours prior to testing to better ensure that subjects were free of residual caffeine and taurine.
- Compare how caffeine and taurine affect habitual caffeine consumers and non-users.
- Test if the other ingredients present in Red Bull energy drink (glucuronolactone and other sugars) act in conjunction with caffeine and taurine (2).
- Test the effects of caffeine and taurine individually as well as in combination.

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