Energy Drink Ingredients: Contribution of Caffeine and Taurine to Performance Outcomes

Amy Peacock[a], Frances Heritage Martin[b], and Andrea Carr[a]

[a]School of Psychology, University of Tasmania, Hobart, Tasmania, 7001, Australia

[b] School of Psychology, University of Newcastle, Ourimbah, New South Wales, 2258, Australia

Corresponding author: Amy.Peacock@utas.edu.au (Ms Amy Peacock)

School of Psychology, University of Tasmania, Private Bag 30 Hobart, Tasmania, Australia 7001; phone: +61 3 6226 7458; facsimile: +61 3 6226 2883

Abstract

While the performance-enhancing effects of energy drinks are commonly attributed to caffeine, recent research has shown greater facilitation of performance post-consumption than typically expected from caffeine content alone. Consequently, the aim of the present study was to investigate the independent and combined effect of taurine and caffeine on behavioural performance, specifically reaction time. Using a double-blind, placebo-controlled, crossover, within-subjects design, female undergraduates (N=19) completed a visual oddball task and a stimulus degradation task 45 minutes post-ingestion of capsules containing: (i) 80 mg caffeine, (ii) 1000 mg taurine, (iii) caffeine and taurine combined, and (iv) matched placebo. Participants completed each treatment condition, with sessions separated by a minimum two-day washout period. Whereas no significant treatment effects were recorded for reaction time in the visual oddball task, facilitative caffeine effects were evident in the stimulus degradation task, with significantly faster reaction time in active relative to placebo caffeine conditions. Furthermore, there was a trend towards faster mean reaction time in the caffeine condition relative to the taurine condition and combined caffeine and taurine condition. Thus, treatment effects were task-dependent, in that independent caffeine administration exerted a positive effect on performance, and co-administration with taurine tended to attenuate the facilitative effects of caffeine in the stimulus degradation task only.

Keywords: energy drink, caffeine, taurine, reaction time, performance

Energy drinks are promoted as enhancing behavioural outcomes by reversing fatigue effects and consequently increasing alertness and endurance (Heckman, Sherry, & de Mejia, 2010). Ingredients may include caffeine, taurine, glucuronolactone, sugars, and other B vitamins and herbal extracts. Despite the range of constituents, researchers generally claim caffeine as the core ingredient responsible for the stimulatory effects of energy drinks (Reissig, Strain, & Griffiths, 2009). However, recent research has suggested a synergistic interplay between energy drink constituents, with greater performance benefits conferred by the whole beverage than expected from the caffeine content alone (Marczinski, Fillmore, Bardgett, & Howard, 2011; Scholey & Kennedy, 2004). For example, Scholey and Kennedy (2004) reported that energy drink consumption improved performance on 'secondary memory' and 'attentional speed' factors relative to placebo, with no significant improvement in performance following independent caffeine ingestion. However, Scholey and Kennedy (2004) note that independent caffeine effects may have been detected with increased power, particularly in light of the small sample size used in this exploratory study (N=20).

Consequently, further systematic analysis of the independent and interactive effects of energy drink constituents is required before conclusions are drawn regarding their relative efficacy. One core energy drink ingredient which lacks such scrutiny is taurine (2-aminoethane sulfonic acid), an abundant free amino acid widely-distributed throughout the body and readily found in animal-derived dietary sources (Finnegan, 2003; Huxtable, 1992). Despite advertising claims of enhanced alertness post-energy drink consumption, and marketing of taurine as a key energy drink ingredient, there is a dearth of research regarding taurine's behavioural impact (Australia New Zealand Food

Authority, 2001; Finnegan, 2003). Caffeinated taurine drink consumption has generally resulted in significantly shorter mean reaction times on attention tasks relative to placebo and control beverages (Reyner & Horne, 2002; Seidl, Peyrl, Nicham, & Hauser, 2000; Warburton, Bersellini, & Sweeney, 2001). However, the presence of other psychoactive ingredients (e.g., glucose) in the beverage has confounded inferences regarding taurine's independent and interactive effects on behavioural performance. For example, Childs and de Wit (2008) reported significantly faster simple and choice reaction time following ingestion of a caffeine-containing supplement (200 mg) relative to placebo. While the authors attributed these outcomes to the caffeine content, they noted that capsules contained taurine (10 mg) in addition to other active ingredients (50 mg white willow bark and 30 mg magnesium oxide). Similarly, Seidl et al. (2000) reported enhanced performance on a auditory oddball task following caffeine and taurine consumption. While placebo administration resulted in significantly longer reaction time relative to baseline, there was no significant difference in reaction time after co-administration of taurine (1000 mg) and caffeine (80 mg) relative to baseline. However, the capsules contained glucuronolactone (600 mg), another primary energy drink ingredient. The absence of comparative independent administration conditions in these studies have precluded any inferences regarding: (i) the independent effects of these substances, and (ii) whether outcomes are driven by one substance or the combination of substances.

To our current knowledge, there has only been one study specifically assessing the independent and combined effects of caffeine and taurine on behavioural performance. Giles et al. (2012) reported significantly faster simple and choice reaction time

following active (200 mg) relative to placebo caffeine consumption, with no independent effect of taurine (2000 mg) or interactive effect of taurine and caffeine evident for reaction time. However, the quantity of caffeine and taurine in a standard energy drink is typically less than the administered doses, with approximately 80 mg caffeine and 1000 mg taurine per 250 mL serving.

Consequently, the aim of the present study was to determine the independent and combined effects of two primary energy drink ingredients, caffeine and taurine, on behavioural performance, specifically reaction time. Based on previous research assessing the effects of caffeine and energy drinks on attention (e.g., Lorist et al., 1994; Seidl et al., 2000), an oddball task and a stimulus degradation task were selected to assess behavioural performance. Caffeine (80 mg) and taurine (1000 mg) doses were matched to the typical content of a standard 250 mL energy drink serving to increase the generalisability of results.

Method

Participants

The sample comprised 19 healthy non-smoking right-handed female undergraduates (19-22 years old, *M*=20.8, *SD*=0.9); the sample size was based on power analysis conducted in G*Power 2 (Erdfelder, Faul, & Buchner, 1996) yielding a moderate effect size (Cohen's *f*=.3). Inclusion criteria specified that participants had a minimum intake of 50 mg caffeine daily and 1000 mg taurine monthly; participants' self-reported average daily caffeine intake (*M*=228 mg, range 50 mg to 405 mg) and average monthly taurine intake (*M*=2579 mg, range 1000 mg to 8000 mg) indicated regular use of the two substances. Recruitment occurred via self-selection, with advertisements displayed

at the University of Tasmania, Australia. Informed consent was provided prior to participation; volunteers were advised that the aim of the study was to assess the performance effects of two energy drink ingredients, caffeine and taurine. Project approval was granted by the Human Research Ethics Committee (Tasmania) Network, Australia and the research was conducted in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

Procedure

This was a single-site, double-blind, placebo-controlled, crossover study with four 90 minute experimental sessions, each separated by a minimum of two and maximum of seven days to ensure washout. Participants abstained from food for four hours, caffeine and energy drinks for eight hours, alcohol for 24 hours, and psychoactive substances for 48 hours prior to experimental sessions; compliance was verbally ascertained prior to treatment administration. Experimental sessions were conducted between 0845 and 1400 hours. Following ingestion of the two-capsule treatment, participants were fitted with a 32 channel Aegis Array electrode cap; electroencephalographic data were collected during the tasks as part of an alternate study. Participants commenced the counterbalanced tasks 45 minutes post treatment administration, with a three minute rest between tasks. At the session's cessation, participants answered two forced-choice questions assessing: (i) perceived treatment administration and (ii) treatment effects.

Treatment Administration

During each session, participants received a two-capsule combination administered in counterbalanced order: placebo/placebo (*placebo*), taurine/placebo (*taurine*), caffeine/placebo (*caffeine*), and caffeine/taurine (*combined*). Treatment doses corresponded to the content of a standard 250 mL Red Bull® energy drink (80 mg

caffeine and 1000 mg taurine). Treatments were administered in identical opaque capsules of matched weight (achieved via use of cornflour) and ingested with 100 mL water. Participants, data collectors, and data analysts were blind to treatment administration order; participants were informed they could receive active and/or placebo caffeine and taurine doses, with maximum active doses equivalent to those contained in a standard 250 mL energy drink.

Behavioural Tasks

Two tasks were administered via Neuroscan Stim² (Compumedics Neuroscan, 2003) software on a PC: a visual oddball task and a stimulus degradation task. In the visual oddball task, participants discriminated between safe traffic condition images (e.g., an open highway), and imminent accident images (e.g., a child standing within the driving path), responding to imminent accident images using a standard response pad (see Martin & Siddle, 2003; Martin, Siddle, Gourley, Taylor, & Dick, 1992). Stimulus presentation time was 250ms (maximum response window 1000 ms, ISI 1100 ms); with an 8:2 ratio of safe to imminent accident trials (total trials N=200).

The stimulus degradation task, adapted from Lorist, Snel, and Kok (1994), comprised three digits (2, 4 and 5) individually presented in digital form at three levels of degradation (intact, low, and high) to increase stimulus complexity (Figure 1). Low and high degradation trials were achieved by altering 150 and 250 randomly selected black border dots to filler grey respectively, with the corresponding amount of filler grey dots altered to black; the digit itself remained intact. Each digit was presented for 400 ms (maximum response window 1400 ms; ISI 1750 ms to 2200 ms), with 28 trials

randomly presented for each digit at each level of degradation (total trial *N*=336). Each digit was assigned an independent response button on a standard keyboard number pad.

Insert Figure 1 approximately here

Data Analysis

The primary dependent measure for the visual oddball task was the mean reaction time (ms) to correctly identified imminent accident scenes; the primary dependent measure for the stimulus degradation task was the mean reaction time (ms) to correctly identified intact, low, and high degraded stimuli. Data were analysed in SPSS Statistics Version 19 (IBM, Somers, NY) using 2 (Caffeine: 80mg, Placebo) × 2 (Taurine: 1000mg, Placebo) repeated measures ANOVAs, with Degradation (Intact, Low, High) as an additional factor for the stimulus degradation task. Significance levels were maintained at $p<.050$, with significant interactions followed up by Bonferroni-corrected paired-samples *t*-tests. Hedges' *g* was calculated as a measure of effect size. Accuracy was not analysed for the visual oddball task, as correct detection rates exceeded 99% for all participants across the four treatment conditions

Results

Descriptive data for the visual oddball and stimulus degradation task are displayed in Table 1. Analyses revealed no significant main effect of Taurine ($p=.253$) or Caffeine ($p=.126$), or significant Taurine x Caffeine interaction ($p=.454$) for mean reaction time in the visual oddball task.

Insert Table 1 approximately here

For the stimulus degradation task, a significant main effect of Degradation, $F(1.75, 31.56)=68.526$, $p<.001$, showed that mean reaction time was significantly faster for intact (M=625, SD=65) compared to low (M=637, SD=64) and high (M=667, SD=62) degraded stimuli, and for low compared to high degraded stimuli (ps<.001, gs=0.20-0.66). While the main effect of Taurine was not significant (p=.821), there was a significant main effect of Caffeine, $F(1, 18)=4.939$, p=.039, g=0.30, whereby a moderate magnitude decrease in mean reaction time was evident in active (M=633, SD=71) compared to placebo (M=653, SD=60) caffeine conditions.

The main effect of Caffeine was modified by a significant Taurine × Caffeine interaction, $F(1, 18)=11.182$, p=.004. Follow up-tests revealed a significant and strong magnitude decrease in mean reaction time in the caffeine condition (M=622, SD=64) relative to the placebo (M=662, SD=55) (p<.001, g=0.67) condition. While the comparisons trended towards significance, there was a moderate magnitude decrease in mean reaction time in the caffeine condition relative to the combined condition (M=644, SD=83) (p=.033, g=0.30) and the taurine condition (M=644, SD=73) (p=.061, g=0.32); no other follow-up paired comparisons were significant. There were no further significant interactions for reaction time. Analysis of the proportion of correct detections revealed no significant main effects of, or interactions between, Caffeine, Taurine, and Degradation.

Perceived Administration and Treatment Effects

Participants correctly identified their administered treatment condition in less than one-quarter of sessions (22%); 47% correctly identified the placebo condition, 21% correctly identified the taurine condition, 11% correctly identified the caffeine condition, and

11% correctly identified the combined condition. Consequently, it can be presumed that the treatment manipulation was successful as the accuracy rate overall fell below chance (25%).

Between one-third and half of the sample reported treatment administration effects in the taurine (32%), caffeine (53%), and combined (37%) conditions, with the majority reporting increased alertness (83%, 90%, and 57% respectively). However, it should be noted that less than one-third of those reporting treatment effects correctly identified the administered treatment (taurine condition: 17%, caffeine condition: 20%, combined condition: 29%), with 42% of participants reporting treatment effects in the placebo condition.

Discussion

The aim of the present study was to determine the independent and combined effect of two primary energy drink ingredients, caffeine and taurine, on behavioural performance. Caffeine's independent impact of performance was task-dependent. While caffeine did not impact performance on the visual oddball-task, significant facilitative effects of caffeine were evident for the stimulus degradation task. Independent ingestion of taurine exerted no effect on reaction time for either task. However, there was evidence that taurine may attenuate caffeine's effects dependent on the behavioural task, with a trend towards significantly slower mean reaction time following co-ingestion of caffeine and taurine or independent ingestion of taurine relative to independent caffeine consumption. This interactive effect was evident only in the stimulus degradation task, with no significant interactive treatment effect observed during the visual oddball task.

The task-dependent effects of independent caffeine consumption align with previous research utilising similar task paradigms. Previous research has revealed no significant effect of a moderate (5 mg/kg; approximately 350 mg caffeine per 70 kg person; Pan, Takeshita, & Morimoto, 2000) or high caffeine dose (400 mg to 500 mg; Kawamura, Maeda, Nakamura, Morita, & Nakazawa, 1996) on reaction time using an auditory oddball task. Although F. H. Martin and Garfield (2006) reported significantly faster reaction times following ingestion of 200 mg caffeine in a choice reaction time task, but not in a simple reaction time task. Lorist et al. (1994) reported faster mean reaction time on a stimulus degradation task in active caffeine conditions relative to placebo. While the present study showed a consistent effect of caffeine across each level of degradation, Lorist et al. (1994) reported that the effect of caffeine was greater with reduced stimulus quality. This disparity could be attributed to the different dose administered (80 mg versus 250 mg respectively), whereby the lower caffeine dose of the present study may have exerted a generalised positive effect on performance, regardless of stimulus quality.

There was no evidence of independent taurine effects on behavioural performance in the present study. These findings support those of Giles et al. (2012), who reported no significant independent effect of taurine (2000 mg) on simple and choice reaction time relative to placebo. These results are not surprising, in that reviews of energy drink safety indicate that taurine primary role is to synthesise bile salts, generally offering physiological therapeutic benefits (Australia New Zealand Food Authority, 2001; European Food Safety Authority, 2009; Food Safety Promotion Board). However, as noted by Giles et al. (2012), taurine peak plasma concentrations are typically not

achieved until 60 minutes post-ingestion (Ghandforoush-Sattari, Mashayekhi, Krishna, & Routledge, 2010). As task administration commenced 45 minutes after capsule administration, any inferences regarding the independent effect of taurine based on the present results remain tentative.

Most pertinent to energy drink consumers is the potential antagonistic relationship between caffeine and taurine evident in the stimulus degradation task, suggesting that taurine may attenuate some facilitative effects of caffeine. This outcome contrasts with previous research by Giles et al. (2012), who reported no significant interactive effect of caffeine and taurine on simple and choice reaction time. However, caution should be employed when using the present results to inform beverage choice for peak performance, not only because the paired comparison trended towards significance. Energy drinks commonly contain other ingredients (e.g., glucose) which may exert independent and interactive effects on performance (Scholey & Kennedy, 2004). Furthermore, energy drinks' effects on performance may not be purely pharmacologically-dependent. Previous research has shown that inducing positive or negative caffeine expectancies can result in enhanced or impaired performance post-consumption (Fillmore, Mulvihill, & Vogel-Sprott, 1994; Fillmore & Vogel-Sprott, 1992). In contrast to the marketing of other caffeinated beverages (e.g., soft drinks) which focus on pleasurable taste and refreshment, energy drink marketing emphasises the stimulant and psychoactive beverage properties (Reissig et al., 2009). Thus, the performance-enhancing effects of energy drinks in real-life may also be attributed to consumer expectancies. While the present results suggest that expectancy may alter perceived caffeine and taurine treatment effects, the validity of this conclusion remains

to be established due to a dearth of literature regarding energy drink expectancies and their impact on performance outcomes.

The generalisability of the present results are constrained by the sample characteristics (i.e., young adult female undergraduate students), with higher prevalence of energy drink use reported amongst those who are younger and male (Wells et al., 2012). As such, future research should explore potential sex differences in performance outcomes post-energy drink consumption, particularly as sex differences have been commonly overlooked in previous research due to small sample size (e.g., Alford, Cox, & Wescott, 2001; Seidl et al., 2000). Furthermore, the treatment administration method reduced the ecological validity of the study, with energy drinks typically ingested as a ready-to-drink beverage rather than the capsule format adopted in the present study (Reissig et al., 2009). However, the present findings of a potential antagonistic relationship between taurine and caffeine may encourage further research into the interactive effects of the ingredients and the performance-benefits conferred by energy drink relative to alternative caffeinated beverages, allowing for a more informed consumer choice.

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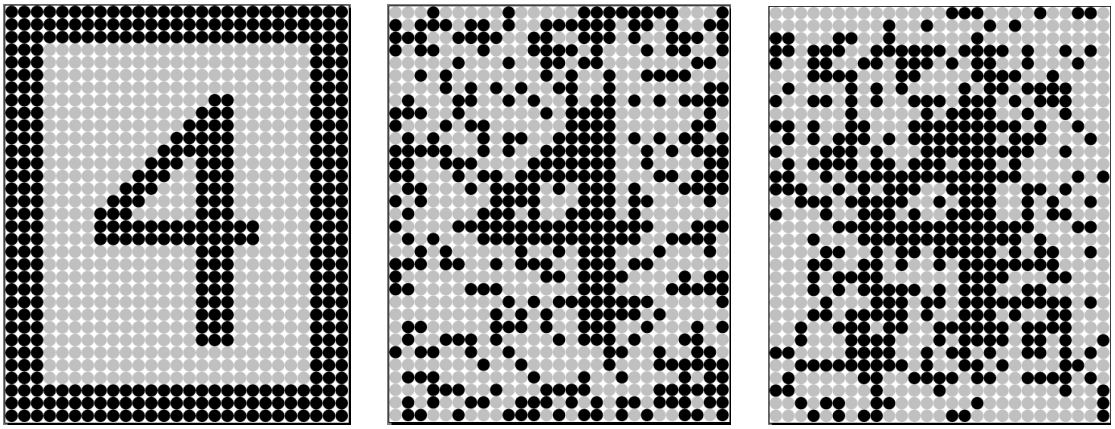
Table 1

Mean RT (ms) to Imminent Accident Images (Visual Oddball Task) and Intact, Low, and High Degraded Stimuli (Stimulus Degradation Task) According to Treatment Condition (N=19)

	Placebo		Caffeine		Taurine		Combined	
	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*
Visual Oddball Task								
Imminent Accident Images	406	40	399	44	403	44	389	33
Stimulus Degradation Task								
Intact Degradation	642	12	604	15	625	17	623	22
Low Degradation	655	14	617	15	637	16	641	20
High Degradation	688	14	646	15	670	18	663	18



(A) (B) (C)

Figure 1. Example of the stimulus degradation task stimuli (A: intact, B: low degradation, C: high degradation).