

THE EFFECTS OF COMMERCIALY AVAILABLE ENERGY DRINK ON COGNITIVE PERFORMANCE

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ABSTRACT

Energy drinks are frequently purported as a non-alcoholic beverage food commodity to improve cognitive function and concentration and as such is marketed especially on vulnerable populations such as professional drivers, students, managers. We aimed to explore the acute dose-effect of commercially available multi-ingredient beverage on cognitive performance. Twenty adult university students, caffeine-deprived received two 500 ml non-alcoholic, glucose-free, multi-herbal extract drinks differing in ingredients dose: DRINK₁₀₀, threefold higher concentration dosage (DRINK₃₀₀) and ingredients-free, flavored-matched placebo (PLA) in a double-blind, three-way cross over, randomized order, separated by a 7-day wash-out period. Cognitive functions, autonomous nervous system activity, and specific mental performance were assessed. Drinks were consumed in the late evening (20 p.m.). Standardized psychomotor vigilance task (PVT) to detect reaction time, lapses and the total score and spectral analysis of heart rate variability (software-driven, standing/lying down with ~300 beats recorded in each position, relative change in total power score between consecutive measurements was used) took place immediately prior and 60, 120 and 180 min post-drink consumption (post-drink). Thirty minutes of the cognitively demanding task (continuous manual text transcription) was commenced immediately and in 90, and 150 min post-drink. Total word counts were used in assessing mental performance changes. The ecologically valid methodology was used to mimic typical students time of drink consumption.

During the 60min post-drink, the level of alertness decreased independently of the drink category, however, DRINK₃₀₀ increased correct: lapsus ratio in 120 min and this remained elevated until the end of testing. No significant effect of DRINK₁₀₀ over PLA on vigilance was present. DRINK₃₀₀ led to an increase in autonomic nervous system activity after drink administration in 60–90 minutes post-drink with a clear decline observed in PLA. This corresponds with a significant increase in the number of words transcribed in the corresponding time in DRINK₃₀₀, however, not sustained in 180 min post-drink.

We demonstrate an acute and transitional dose-effect of multi-herbal caffeine-containing non-energetic beverage on cognitive and autonomous nervous system performance. The effect appears to be evident immediately (< 30 min) post-drink. A beverage containing guarana equivalent to 120 mg of caffeine reduce cognitive performance impairment and this is sustained over ~180 min.

Keywords: caffeine; herbal extract; psychomotor vigilance task; heart rate variability

Introduction

Energy drinks are frequently purported as a non-alcoholic beverage food commodity to improve cognitive function and concentration and as such is marketed especially on vulnerable populations such as professional drivers, students, managers. Their most common active ingredient is caffeine, often in the form of Guarana extract. In addition to stimulants (caffeine), they often contain other ingredients such as Ginkgo Biloba, taurine, vitamins, and others, and these drinks are the subject of studies (McLellan & Lieberman, 2012; Mora-Rodriguez & Pallarés, 2014). The stimulating effect on the body in most energy drinks is mediated by caffeine (Giles et al., 2012). Caffeine in energy drinks leads to a demonstrable reduction of physical and mental fatigue, increased mental abilities and maintain alertness and concentration (van den Eynde, van Baelen, Portzky, & Audenaert, 2008). Similar effects affecting memory and cognitive function are also shown by Ginkgo Biloba, Panax ginseng (Ginseng) is the subject of extensive research, investigating its effect on various diseases, weakening and promoting metabolic functions via so-called apoptogenic effect. Adaptogens are compounds that increase the body's defence against exogenous stress factors (environmental factors, toxic substances) and eliminate the risk of damage caused by these factors (Winston, 2011). The effects are mainly related to the hypothalamus-pituitary-adrenal axis and this axis is part of the stress system and plays an important role in the body's response to repeated stress.

To determine cognitive performance and effects of active ingredients psychomotor vigilance task (PVT) or spectral analysis of heart rate variability (SA HRV) has been widely used for evaluating wake-promoting food-based substances (Wesensten, Belenky, Thorne, Kautz, & Balkin, 2004). It was shown that various nutritional factors (e.g. caffeine intake) (Zahn & Rapoport, 1987), health factors (e.g. presence of illness) (Kapounková et al., 2019) and/or experimental manipulations affect the sympathetic nervous system explaining high prevalence of methods used in determining sympatho-vagal disturbances (Acheson, 1993).

Various drinks containing a combination of active naturally-based substances are marketed for a range of people. As described above, there is no doubt of a performance-enhancing potential of isolated substances. However multi-component drinks become increasingly popular, namely among students with high cognitive-performance demands (García et al., 2017; Majori et al., 2018). Therefore, we aimed to explore the effect of commercially available multi-ingredient beverage on cognitive performance in university students.

Methods

Study design

Twenty adult university students ($23 \pm 3,5$ yrs), caffeine-deprived received three drinks in a double-blind, three-way cross over, randomized order, separated by a 7-day wash-out period. Two 500 ml non-alcoholic, glucose-free, multi-herbal extract drinks differing in ingredients dose: DRINK₁₀₀ (Guarana 395mg, Ginko Biloba 45 mg, Lecithin 90 mg, Schizandra 55 mg, Ginseng 45 mg, Matcha Tea 45 mg), threefold higher concentration dosage (DRINK₃₀₀) and ingredients-free, flavored-matched placebo (PLA) were administered. The amount of administered substances was in accordance with the Czech legislation and the opinion of the European Food Safety Authority on caffeine consumption in 2015 and the drink does not pose any health risk for the consumer („Scientific Opinion on the safety of caffeine”, 2015).

The study was spread into 3 weeks with one day in every week (experimental day) a randomly assigned drink was ingested and followed by ~3 h period in which the test of cognitive functions, autonomous nervous system activity (ANS), and specific mental performance were realized. Standardized psychomotor vigilance task (PVT), spectral analysis of heart rate variability (SA HRV) and the cognitively demanding task (continuous manual text transcription (TEXT) were used to identify a post-drink effect (Figure1). participants were educated to be familiar with all the testing procedures, received complete information of the course of the experiment and were trained in manipulation with the measuring device.

As far as the drinks were consumed in the late evening (20 p.m.), the ecologically valid methodology was intentionally used to mimic typical students time of drink consumption. Each participant signed informed consent. The research was approved by the Scientific ethical board of Masaryk University.

Description of the PVT

Standard 10-min form of PVT was used to assess the level of alertness and ability to keep attention (Dinges & Powell, 1985). The participants have to react to a red-light spot that appears on a black background for 10 minutes at irregular intervals. The participants were prompted to respond by pressing the key immediately after the red dot appears. The participants responded on average to 80 stimuli. The accurate, delayed or premature reactions were examined. The correct reaction was evaluated as a sufficiently rapid response to occur within 0,5 s of the red dot appeared. A premature reaction was considered to occur before the red dot appears and the delayed reaction was considered as a lapsus, a reaction that takes place more than 0,5 s after the red dot appears and overall success defined as the score was calculated as the ratio between correct reactions and delayed reactions. The testing was carried out on desktop computers with free software described by Khitrov et al. (2014). Each participant underwent a total of 12 tests (4 within an experimental day). The principle of PVT test was blinded to the participants.

Description of the SA HRV

The heart rate variability was assessed by measuring the length of R-R intervals using the frequency-domain spectral analysis method based on Fourier transformation (Stejskal & Salinger, 1996). A mySASY software (mySASY a.s.) was used. Each participant received a chest belt to measure heart rate variability and installed a mobile application on own mobile phone for monitoring ANS via mySASY app. The measurement was audio assisted by the installed application and follows standard protocol (Stejskal & Salinger, 1996). All participants underwent ANS standardization measurements period to assess the individual level of the ANS activity, which consisted of morning and evening measurements of ANS activity during the 5 days preceding the experiment. The duration of the each ANS measurement was 15 minutes, with the first 5 minutes of the proband remaining in the lying position, the second 5 minutes of the proband remaining in the standing position, the last 5 minutes of the proband remaining in the lying position. On the experimental days, participants underwent morning standardization measurement. In the evening (at the time of the experiment), they underwent four experimental measurements (pre- and post-drink). We focused on total spectral power that reflects overall autonomic activity where the sympathetic activity is a primary contributor (Zahn & Rapoport, 1987).

Description of the TEXT transcription

Specific mental performance task consisted of three 30min continuous manual text transcription. It commenced immediately (TEXT I) and in 60 (TEXT II), and 120 (TEXT III) min post-drink. Total word counts were used to assess mental performance changes. The printed book was selected for text rewriting. All participants were asked to start manually rewriting the given part of the text. The transcription took exactly 30 min. Time was measured with a stopwatch, started and ended with oral instruction. Three different parts of the text were selected for transcript. Individual transcribed parts (highlighted in the printed book) were then converted to the number of words using MS Word as the book was available in the *docx*. form. This procedure was used to objectively replicate real mental activity, as the number of transcribed words allows for quantification of the work done.

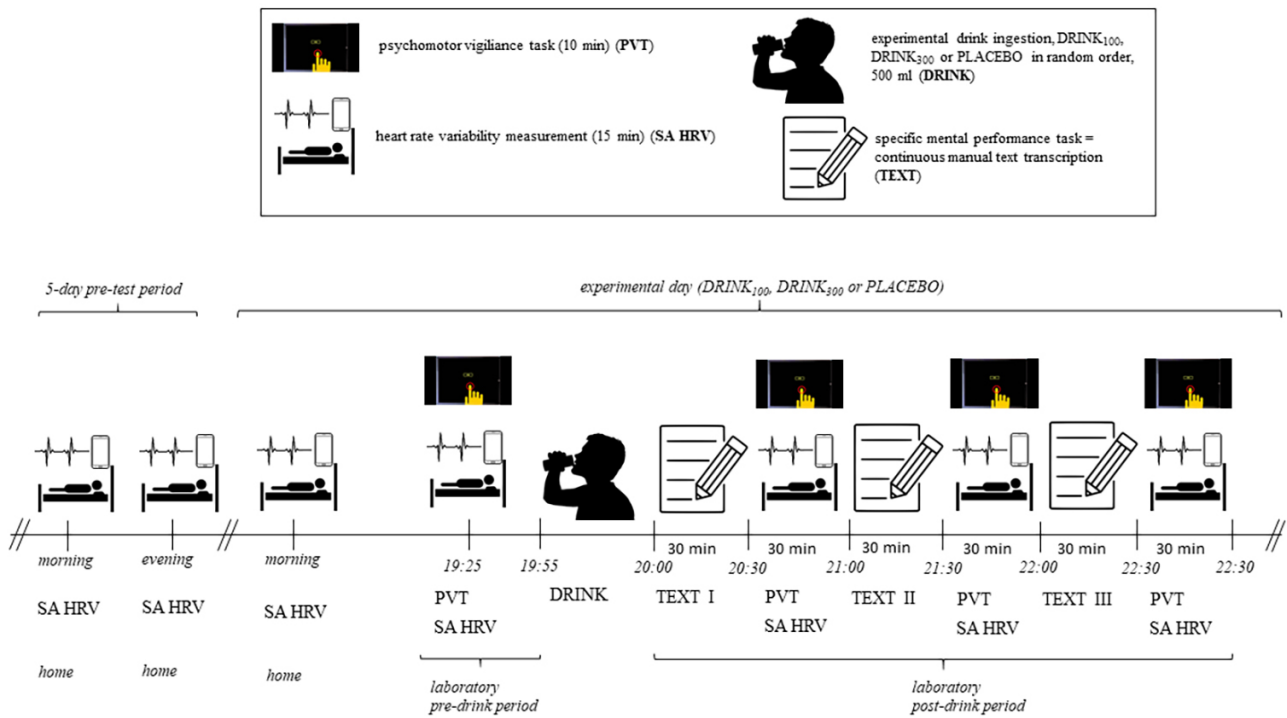


Figure 1 Illustration of the experimental design

Statistical analysis

The results of PVT are presented as a median of the “overall score” parameter (the ratio between correct reactions and delayed reactions.) in order to take into account, the high degree of inter-individual variability (mean CV in the overall score $9,75 \pm 3,9\%$). To show ANS changes, total power was used to show total spectral power that reflects the overall autonomic activity. Due to the high variability of baseline total power values in individual probands, the relative change in ANS activity was evaluated between successive measurements. The number of words transcribed was used as a marker of a specific mental performance task. Analysis of variance with repeated measurements was used to detect the time and the groups’ differences. This method tests the consistency of mean values for recurrent measurements, including the detection of statistically significant changes. Effect size is described using Cohen’s d coefficient.

Results

Vigilance decreased during the first hour after the testing began. A DRINK₃₀₀ increased alertness as depicted by the ratio between correct reactions and delayed reactions and maintained the condition until the end of the testing period (Figure 2). No significant time interaction was found in either experimental situation. However, a significant effect of DRINK₃₀₀ on the difference between the overall score over DRINK₁₀₀ was evident in 150–180 min post-drink period ($p = 0,005$). The effect of DRINK₃₀₀ is consistent as the interindividual CV in the 150–180 min post-drink was the lowest (5 %) in comparison to the DRINK₁₀₀ and PLA (14% and 11%, respectively).

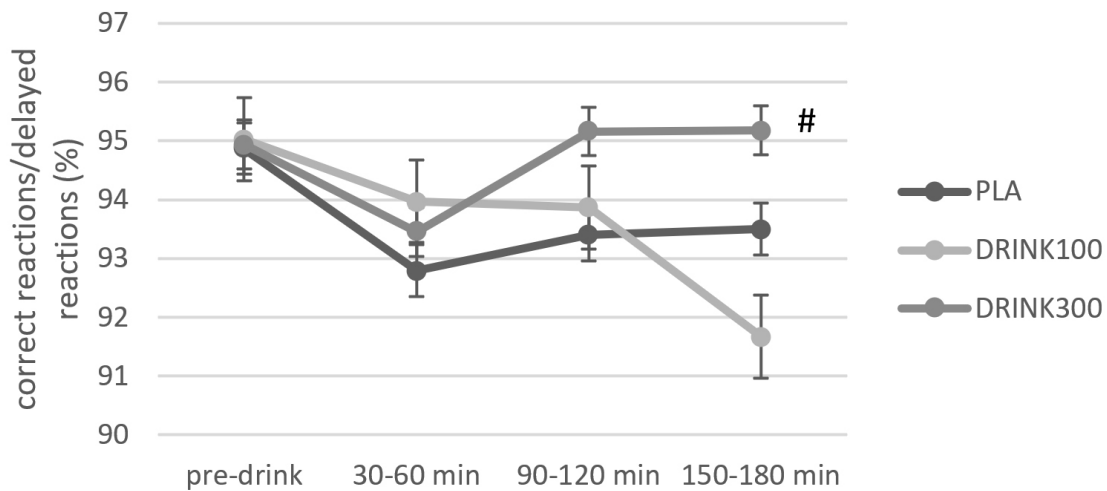


Figure 2 Overall score in PVT 30-180 min post-drink (ratio between correct reactions and delayed reactions) (%) (no significant time interaction was found; # significantly different from DRINK₁₀₀)

After 180 minutes, the number of transcribed words decreased in all experimental situations (Figure 3). The effect of drink consumption on the cognitive work done (amount of words transcribed) did not appear immediately after the drink was consumed as there was no difference between situations. Throughout the post-drink period (3 h), DRINKS_{100,300} increased the performance at 60–90 minutes after consumption, with clear but not-significant effect especially at the DRINK₃₀₀ dose over PLA and DRINK₁₀₀ ($p = 0,09$ and $0,08$, respectively). No significant time effect was found, but the trend was strong for DRINK₃₀₀ ($p = 0,05$).

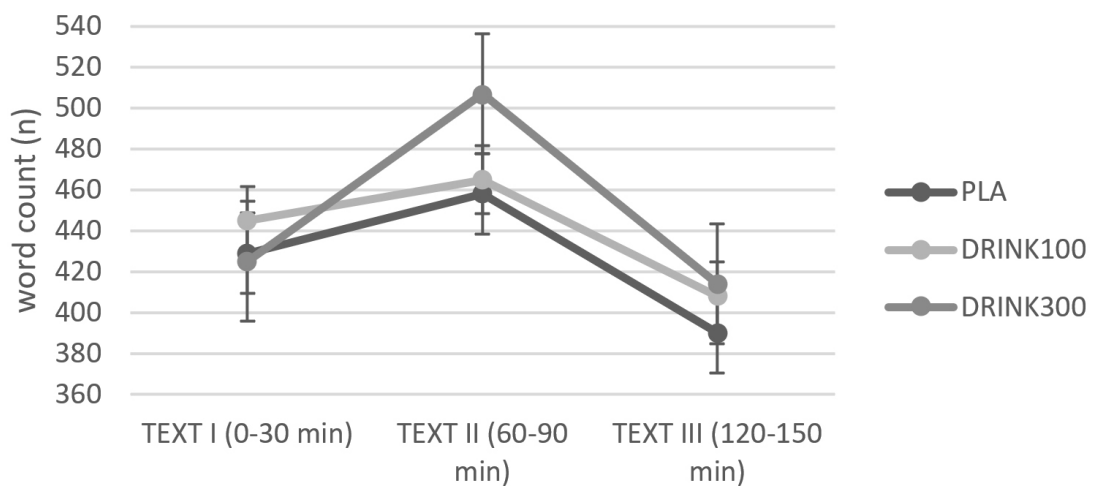


Figure 3 Total word count during the post-drink manual text transcription

Figure 4 shows the difference in spectral power at 30–180 min post-drink. The results show a trend in the influence of DRINK₁₀₀ and DRINK₃₀₀ on the overall spectral performance of participants. This is mainly due to the extreme increase in the activity of the autonomic nervous system after serving

the drink and maintaining it for about 90 minutes after use. Placebo has no significant impact. The differences are not statistically significant ($p_{\text{PLA}} = 0,92$; $p_{100} = 0,41$; $p_{300} = 0,26$). Interpretation of effect sizes (Cohen's d) can classify small effect of 100% and 300% ($d_{\text{PLA}} = 0,28$; $d_{100} = 0,35$; $d_{300} = 0,38$).

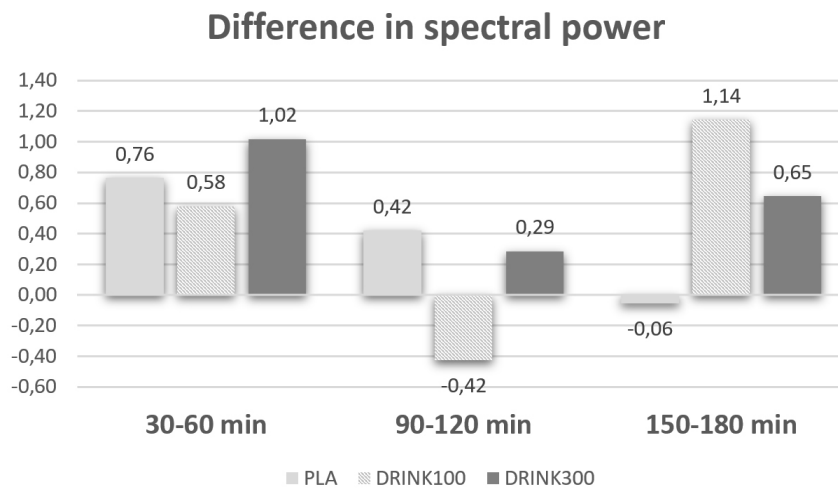


Figure 4 Differences in ANS spectral power during the post-drink period

Discussion

We aimed to assess the acute effect of commercially available non-energetic herbal blended drink on selected parameters of cognitive performance. The ecologically valid methodology with the drink administration was set at 20:00 p.m. and the post-drink period ended at midnight was intentionally used to mimic the typical time of the drink consumption by the vulnerable groups (eg. students, drivers, managers, etc.). We used standardized PVT test to detect cognitive impairments, continuous manual text transcription to measure real-work performance and ANS activity measurement. Most importantly we demonstrate an immediate dose-effect of caffeine-containing non-energetic beverage on cognitive and ANS performance.

An important aspect of caffeine-containing drink consumption is the health aspect. Mayo Clinic experts draw attention to the acute effect of such beverages on heart rate, blood pressure without changes in heart rhythm. They conclude that there is no link between long-term caffeine consumption and the risk of hypertension, and cardiovascular disease in the case of consumption of coffee and other sources of food caffeine (Higgins, Tuttle, & Higgins, 2010). Similarly, EFSA reports a safe daily dose of the caffeine of 400 mg/day and a single 200 mg dose („Scientific Opinion on the safety of caffeine”, 2015). In our research, 0, 395 and 1185 mg of guarana (equivalent to ~0, 40 and 120 mg of caffeine) were administered.

The vast majority of studies, with 50–250 mg of caffeine to be usually administered, show a positive effect on cognitive abilities. The effect always occurs after a single, acute use, with an effect lasting up to several hours, with a different time effect after administration (Heatherley, Hayward, Seers, & Rogers, 2005; van Duinen, Lorist, & Zijdwind, 2005).

The effect of guarana is not only explained by caffeine, but a possible synergistic action with other ingredients such as ginseng is questioned. Kennedy, Haskell, Wesnes, & Scholey (2004) administered 75 mg guarana and/or 200 mg ginseng and observed the acute effect of the administered active ingredients 1-6h after administration on various computer-controlled cognitive abilities (similar to PVT). The positive effects of an acute dose of ginseng on cognitive abilities and mood 1–6h after administration was first presented by Kennedy, Scholey, & Wesnes (2001). The authors administered higher doses and observed a beneficial effect already at doses of 200 mg in attention and response rate indicators

and the effect persisted for up to 6 hours. In the research, 0 and lower doses of 45 mg or 135 mg were administered. The acute effect of schizandra on attention (standardized d2 attention test) at 100mg, ie the amount corresponding to the dose administered by us (55 or 165 mg) was observed 2 hours after administration of the combined plant extract (Aslanyan et al., 2010). A synergistic effect of caffeine on cognitive abilities has also been observed with L-theanine, the active ingredient with similar effects to caffeine, present in green tea such as Matcha tea, at a dose of 50 mg caffeine and 100 mg L-theanine (Owen, Parnell, De Bruin, & Rycroft, 2008). L-theanine interferes with the production of dopamine and serotonin, known as fatigue inducers.

A high rate of delayed or premature reactions in PVT as the testing period progressed indicates lower alertness, intense concentration, fatigue and possible sleep deficit (Table 1). The *time × lapsus* effect was positively correlated ($r = 0,85$). Caffeine was shown to improve concentration and motor coordination. The desired effects persist for about three to four hours (Nehlig, 2010) which was confirmed by the effects of DRINK₃₀₀ in a reduction of cognitive performance impairment seen as the post-drink time progressed. The average number of lapses in PVT within 3h post-DRINK₃₀₀ discontinue to increase in contrast to the DRINK₁₀₀ and PLA and was significantly lower (10,1 vs. 14,2 and 13,4, respectively) ($p < 0,01$).

Table 1 Correct and delayed responses in PVT (average)

PLA		Correct (n)			Lapsus (n)		
		DRINK ₁₀₀	DRINK ₃₀₀	PLA	DRINK ₁₀₀	DRINK ₃₀₀	
Pre-drink		74,2	71,7	74,7	8,2	9,7	8,2
Post drink	30–60 min	70,3	72,2	70,6	10,3	9,8	8,6
	90–120 min	70,6	70,0	70,4	11,3	10,8	10,3
	150–180 min	69,0	67,1	72,5	13,4	14,2	10,1

Our results correspond with findings by Giles et al. (2012). The vigilance and the reaction ability test outcomes significantly improved 30 and 60 minutes after administration of 200 mg caffeine. Interestingly, there was no superior effect when glucose (50 g) was administered. The immediate effect of beverages, even without energy, was therefore predominantly mediated by effective stimulants (caffeine). This conclusion supports the positive properties of the glucose-free beverage.

Despite the fact that the number of words transcribed period decreased significantly towards the end of the post-drink period (180 min) from ~433 to ~404 words ($p = 0,003$), the DRINK₃₀₀ even improved the word-count and therefore specific mental performance by 19% in the 60–90 min post-drink (~507 words). This was strongly correlated with an overall score in PVT ($r = 0,69$) supporting the fact that a number of words method was sensitive enough in the determination of real cognitive performance. The effect of DRINK₃₀₀ on ANS does not correspond with the cognitive task. The DRINK₁₀₀ effect on total spectral power (expressed as the difference in two consecutive time-point measurements, eg. 30–60 min vs. 90–120 min) revealed the most prolonged stimulation of ANS as the spectral power increased.

The above discussion objectively justifies the inclusion of a combination of active substances and given dosages in the researched beverage as psychoactive effects of tested substances were widely confirmed. Besides, we may speculate to what extent the blended substances can interact and strengthen the effect as this remained to be established.

Conclusions

We demonstrate an acute, transitional dose-effect of multi-herbal caffeine-containing non-energetic beverage on cognitive and autonomous nervous system performance. The effect appears to be evident immediately (< 30 min) post-drink. A beverage containing guarana equivalent to 120 mg of caffeine reduce cognitive performance impairment and this is sustained over ~180 min.

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