Amino Acids (2001) 20: 83–89

Amino
Acids

Beneficial effects of an "energy drink" given to sleepy drivers

J. A. Horne and **L. A. Reyner**

Loughborough University Sleep Research Centre, Leicestershire, United Kingdom

Accepted February 1, 2000

Summary. 500 ml of a glucose based "energy" drink versus a control without the active ingredients (caffeine, taurine, glucuronolactone) were given double blind to 11 sleepy participants driving an interactive real-car driving simulator. Lane drifting and a secondary task (reaction time) were measured for two hours post-treatment. The energy drink significantly improved both indices, particularly for the first hour.

Keywords: Amino acids – Energy drink – Caffeine – Taurine – Sleepiness – Driving

Introduction

Our Laboratory has been investigating the effectiveness of caffeine in alleviating driver sleepiness, using feasible amounts of caffeine in the form of coffee (i.e. about two cups of coffee). Laboratory work outside the field of driving has shown that 150–200 mg caffeine significantly improves alertness in sleepy people (Lumley et al., 1987; Griffiths et al., 1990; Lorist et al., 1994; Bonnet and Arand, 1994; Muehlbach and Walsh, 1995; Åkerstedt and Ficca, 1997). We have shown that young adults sleep restricted to 5 h sleep for one night and required to drive that afternoon for two hour continuously, in a driving simulator, and under monotonous road conditions, experience significant levels of sleepiness that can be significantly reduced by this dose of caffeine given under double blind conditions (Horne and Reyner, 1996; Reyner and Horne, 1997, 2000). Significant improvements were found with the impaired driving performance, subjective sleepiness and electroencephalographic (EEG) measures of sleepiness. Caffeine at these levels has negligible adverse side effects (Arnaud, 1985; Fox, 1993).

Similar levels of caffeine (160 mg) can be obtained from two, 250 ml cans of an "energy drink" (Red Bull), which also contains glucose (11.3 g/100 ml), flavourings, vitamin B complex, glucuronolactone and the amino acid taurine (4 g/100 ml). The latter may have behaviour modulating effects (Mandel et al., 1985) in addition to those of caffeine. This pilot study assessed whether 500 ml of the energy drink also had beneficial effects in alleviating impaired driving

performance due to sleepiness.). The present study used a standard experimental protocol (Reyner and Horne, 1997, 1998) and included an additional measure of reaction time (RT) as a secondary, non-driving task. In this context RT is a poorer measure of driver sleepiness than is actual driving behaviour (lane drifting – see below), despite what is commonly thought (Horne and Reyner, 1999).

Method

Participants

Drivers most likely to have sleep related accidents are aged under 30 y (Horne and Reyner, 1995), and we targeted this group, as we have done for our previous studies (see above). Twelve graduate students (6 m, 6 f; mean age 24 y [s.e. = 2 y]) were recruited by advert and screened by interview. They were: healthy (medication-free), of normal weight range for height, experienced drivers (having driven >2 y, and for >3 h per week), good sleepers, slept regular hours, took daytime naps <once per month, moderate (2–4 cups daily) drinkers of caffeinated coffee. There is no evidence (c.f. Griffiths and Woodson, 1988; James, 1991; Batting and Welzl, 1993) that at this level of daily intake the nil caffeine treatment (Control group – see below) would have led to any caffeine withdrawal effects during the driving session. Participants had the procedures fully explained, signed consent forms, and were paid for each session. One participant was unable to complete the study, owing to a leg fracture; thus N = 11.

Design and procedure

On an initial baseline day, following a normal night's sleep, participants had a 2 h practice drive on the car simulator (see below). One week later, they underwent two experimental conditions (see below) at least a week apart, in a counterbalanced design, and with their afternoon sleepiness enhanced by sleep being restricted to 5 h (delayed bed-time) the night before. Participants slept at home, with sleep monitored by wrist-actimeters (Horne et al., 1994). For all participants, actimeters were downloaded and checked for participant compliance soon after the arrival at the Laboratory and before the drive commenced. All participants complied with their respective sleep regimens. There was nil alcohol for 36 h before each study and nil caffeinated drinks after 18:00 h the evening before.

Impaired night-time sleep leads to increased afternoon sleepiness, due to a bi-circadian rhythm of sleepiness, having its second peak in the afternoon. Sleep-related vehicle accidents show an afternoon peak (Langlois et al., 1985; Mitler et al., 1988; Åkerstedt et al., 1994; Horne and Reyner, 1995; Pack et al., 1995). Our driving task comprised an initial (pre-treatment) 30 min simulated motor-way-type, dull and tedious drive that commenced at 14:00–14:15 h. This was followed by a 30 min break (sitting at the wheel), then another 2 h post-treatment drive. Breaks comprised one of two drinks administered double blind from prepacked plain glass bottles:

1) Energy Drink – 500 ml
2) Control Drink – 500 ml of identical liquid, minus the caffeine, glucuronolactone and taurine.

These were given at the beginning of the break; allowing adequate time for absorption of caffeine (van der Stelt and Snel, 1993). Participants consumed "energy drinks" on an infrequent basis, and as the tastes of the two experimental drinks were almost identical, participants were unable to decide which drink was which. The active ingredients of the

energy drink, such as caffeine, were not given in proportion to body weight, but as a fixed dose, as the typical driver would consume this drink by the can.

Car simulator

This comprised an immobile car with an interactive full size computer-generated bending, dull and monotonous roadway projected on to a 2.0 m × 1.5 m, screen located 2.3 m from windscreen. There were two "up" and two "down" lanes, hard shoulder and simulated auditory "rumble strips". Participants sat in the driving seat and drove at their normal cruising speed within white lane markings. Lane drifting is the usual manifestation of sleepy driving, which was automatically detected by the computer data-logger from continuously recorded steering data. A car-wheel crossing a lateral lane marking was the criterion for this detection, and identified as an "incident". An unobtrusive infrared camera filmed the driver's face, that was recorded with the roadway using a split-screen video display. The video data were further analysed by a skilled assistant "blind" to the experimental conditions, whereby all the automatically identified incidents were checked to see whether: (i) these were due to driver distraction (looking elsewhere), which were discounted, or (ii) to episodes associated with sleepiness (i.e. eye "rolling" or vacant staring ahead). Additional quality checks on these video data were undertaken "blind", by a second trained assessor. Incident data tend to have large individual differences (Reyner and Horne, 1997). These were all transformed using the square root.

Reaction time (RT)

Every 2–4 minutes (mean = 3 min) in a random manner, a computer generated audible "bleep" had to be responded to by the driver, as soon as possible, by the pushing of a steering wheel mounted button located under the preferred thumb. Response times were automatically logged.

Statistical analysis

For both incidents and RT, the pre-treatment data should be the same for both conditions. To check this statistically, the 30 min of pre-treatment data were average within groups and compared between conditions using a paired t test. If this was satisfactory, then post-treatment data were averaged in four, 30 min blocks and analysed by a two way (Conditions × Time) repeated measures ANOVA, with post hoc paired t tests when appropriate.

Results

Figure 1 shows the rate of incidents to be similar for both conditions during the pre-treatment period. Post-treatment, and under the control condition, incidents rise and then fall, whereas in comparison, for the energy drink there is a marked depression in incidents, followed by a linear rise. The ANOVA was significant for conditions ($F = 4.91$ [1,10] $p < 0.05$; Huynh-Feldt $\varepsilon = 1.0$), and there was a significant (quadratic) effect of time ($F = 5.03$ [3,30] $p < 0.006$; Huynh-Feldt $\varepsilon = 1.0$). The interaction was insignificant. Between conditions, post-hoc t tests were significant ($p < 0.05$) for the 0–30 min, 30–60 min and 60–90 periods.

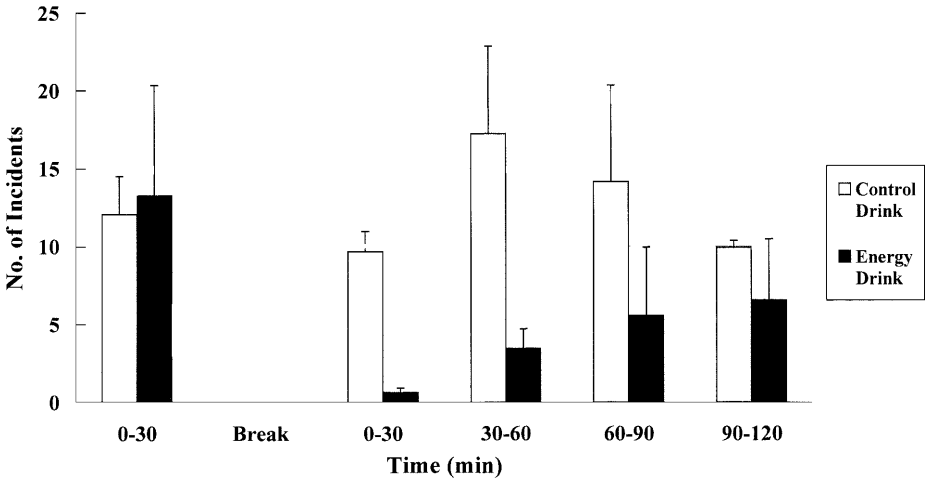

Fig. 1. Driving incidents – group mean values (with standard error bars) for consecutive 30 min periods, before and after treatment with energy or control drinks given during a 30 min break. There was an overall significant effect between conditions, with the 0–30, 30–60 and 60–90 min periods being particularly significant. There was also an overall significant (quadratic) effect of time

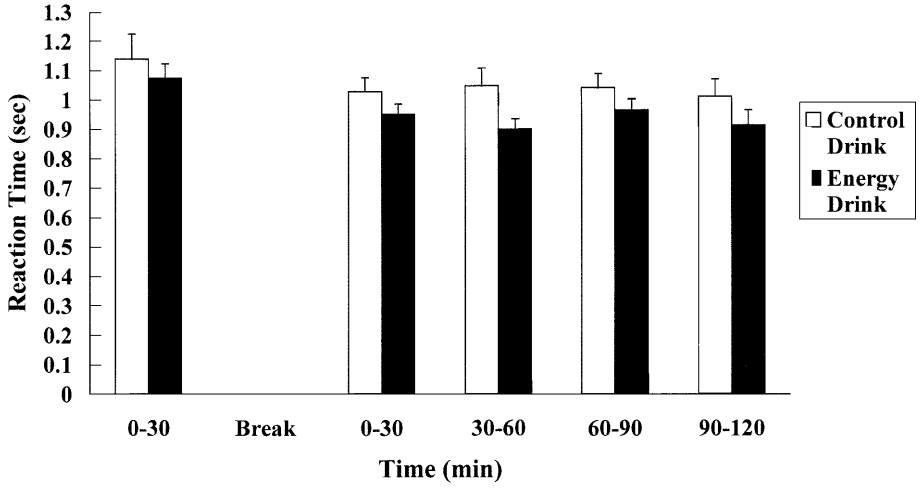

Fig. 2. Reaction Time (seconds) – group mean values (with standard error) bars for consecutive 30 min periods, before and after treatment with energy or control drinks given during a 30 min break. There was an overall significant effect between conditions, with the 30–60 min period being particularly significant

Figure 2 shows similar RTs for both conditions in the pre-treatment period. There is a small quadratic trend in the control condition following treatment. With the energy drink RT appears generally faster throughout the two-hour period. The ANOVA is significant for condition ($F = 4.97$ [1,10] $p < 0.05$; Huynh-Feldt $\varepsilon = 1.0$), but not for time or for the interaction. Post-

hoc t-tests show significant ($p < 0.05$) between condition effects for the 30–60 min period only.

Discussion

Our participants were sleep restricted on the nights prior to the afternoon driving. Under control conditions this sleepiness was particularly evident mid-afternoon, around 30–60 min into the drive. Half an hour following ingestion of 500 ml of the energy drink both driving incidents and RT showed a significant improvement in the adverse effects of sleepiness, that lasted for about 60 minutes. This beneficial effect was particularly evident in the second half hour (30–60 min) period, coinciding with the bi-circadian surge in sleepiness. It should be noted that p values for ANOVAs are given as two-tail, although for the effects of the energy drink, one tail significance levels could have been used.

RT was a "secondary task" as drivers have to give priority to their driving, and it appears that as the effects of the energy drink wear off after about an hour, drivers pay more attention to the driving, probably to minimise incidents at the expense of any sustained improvements to RT.

Glucose can have an alerting effect on the CNS, and although this can be rapid following ingestion, the effect is usually of short duration (about 10 min). Both drinks contained equal amounts of glucose, and as the post-treatment driving did not commence until about 30 min after ingestion, it is unlikely that this dose of glucose had any pervading effect.

From the viewpoint of sleepiness, and in comparison with our other studies using 150–200 mg caffeine (Reyner and Horne, 1997, 2000), the main action of the energy drink must presumably be through its caffeine and perhaps taurine content. Caffeine blocks adenosine receptors, and as adenosine is thought to be a potent sleep promoter (Radulovacki, 1995; Porkka-Heiskanen et al., 1997), then caffeine may well have a direct inhibitory effect on the sleep system. There are other routes by which caffeine can act on alertness, for example, through its effects on the synthesis and turnover of catecholamines (Battig and Welzl, 1993). Caffeine also increases the free amino acid pool in the cerebral cortex, especially taurine (Portoles et al., 1985). This amino acid has a variety of other effects on the CNS (Mandel et al., 1985), largely of an inhibitory nature (Lapin et al., 1982; Lidsky et al., 1995; Birdsall, 1998). For example, taurine modulates mood (e.g. Mandel et al., 1985; Lidsky et al., 1995). Compared with our studies using caffeine only, and under an identical experimental protocol, the present findings indicate that the energy drink may be somewhat more effective in alleviating sleepiness. Whether this is a real effect, and if so whether this might be associated with the other constituents of the energy drink, such as taurine, are matters that have yet to be resolved.

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Authors' address: Dr. J. A. Horne, Sleep Research Centre, Human Sciences Department, Loughborough University, Leicestershire LE11 3TU, U.K.,
E-mail: j.a.horne@lboro.ac.uk

Received January 2, 2000