A High Sugar Content, Low Caffeine Drink Does Not Alleviate Sleepiness but May Worsen It

C. Anderson* and J.A. Horne

Although the ingestion of high levels of glucose might have a short acting alerting effect, there is evidence of an ensuing enhancement of sleepiness in people already sleepy. Some ‘energy drinks’ contain large quantity of sugars. We compared 250 ml of a well known ‘energy drink’ (42 g sugars, containing a low [30 mg] level of caffeine for ‘flavouring’) with a nil sugar nil caffeine, similar tasting control. These were given a week apart, in a repeated measures, double blind, balanced design, to 10 participants sleep restricted to 5 h the prior night. They had a light lunch, consumed a drink at 13:50 h, and 10 min later underwent 3x30 min consecutive periods at a reaction time (RT) task (the Psychomotor Vigilance Test), separated by 3 min breaks when self-ratings of sleepiness were made. The energy drink did not counteract sleepiness, and led to slower RTs and more lapses during the final 30 min session, around 80 min after consumption. Copyright © 2006 John Wiley & Sons, Ltd.

Introduction

Although bolus consumption of sugar, as found in many ‘soft drinks’ can improve cognitive performance for a while, Benton (2002), in his substantive review of macronutrients and mood, alluded to a delayed ‘less energetic’ reaction, about an hour later. Bolus intake of glucose will stimulate insulin output (cf. glucose tolerance tests), of course, but it is unclear whether this leads to subsequent sleepiness, as most investigations into the effects of sugars on sleepiness terminate measurement well before any putative delayed response might appear.

There are only two ‘incidental’ findings, and a single, more systematic study, which may shed light on a delayed effect of glucose in enhancing sleepiness. Landstrom et al. (2000) gave approximately 60 g glucose in 350 ml solution (vs. water), and reported an alerting effect of glucose lasting 10–15 min soon after consumption, which disappeared. However, scrutiny of the remaining hour of these data indicates a worsening of sleepiness with the glucose. The study was conducted mid-morning when there tends to be a natural, circadian rise in alertness. The second incidental finding comes from our own work (Horne and Baulk, 2004), where we reported, as an aside, following analyses of sleepiness during prolonged and monotonous driving in the early afternoon, that non-caffeinated drinks containing increasing amounts sugar, seemed to lead to greater sleepiness.

Bruck et al. (1994) studied sleepy unmedicated patients with the sleep disorder narcolepsy. A control group comprised alert, non-sleepy healthy individuals. At lunchtime, 50 g glucose versus artificial sweetener in 150 ml liquid was given double blind to both groups, with a low calorie light meal. Twenty minutes later (and apparently beyond any putative alerting effect), sleepiness was monitored for 60 min using the EEG and a vigilance task. Whereas the glucose had little effect on the alert controls, it significantly worsened sleepiness in the patients.

On the market are various low caffeine content ‘energy’ drinks containing very high sugar levels, with one prominent well known energy drink (ED) claiming to be for ‘brain and body energy’, with 100 ml containing 17 g of sugars (monosaccharides: glucose and fructose)—equivalent to about three spoonfuls of ordinary sugar (the disaccharide, sucrose). This ED contains small quantities of caffeine (12 mg per 100 ml), apparently for flavoring. For reference, 100 ml of liquid from a cup of instant coffee contains roughly about 40 mg caffeine. Glucose has a high-glycaemic index, that is, absorption from the stomach is fast, to produce a rapid increase in blood glucose, declining over an hour or more, depending on a variety of factors, especially insulin output and degree of prior fasting. Fructose has a lower glycaemic index, having to be converted in the stomach, to glucose, before absorption. This initial rise in blood glucose can produce increased alertness, as determined by EEG and subjective measurements (cf. Benton, 2002).

We were interested in utilising this specific ED, given its claims. Caffeine takes about 30 min to have an alerting effect, which can last for an hour or more, depending on the level of sleepiness, time of day etc. Of course, if sugar leads to a delayed enhancement of sleepiness, then the small amount of caffeine found in ED might partly or wholly reverse this effect of sugar.

Arguably the most sensitive psychometric test of sleepiness is the Psychomotor Vigilance Test (PVT—Dinges and Kribbs, 1991), with the key index being ‘lapses’ (i.e. delayed or missed responses to a stimulus signal, often due to ‘microsleeps’). One of the most commonly used subjective measures of sleepiness is the Karolinska Sleepiness Scale (KSS—Åkerstedt and Gillberg, 1990). We utilised both tests in a comparison of ED with a similar tasting sugar free drink, in sleepy people during prolonged testing during the afternoon ‘dip’.

Method

Participants

Ten healthy young adults (mean age: 22.4 ± 14.4 years) were: healthy (medication free), non-smokers, had a body mass
index (BMI) between 22 and 25, good sleepers (no sleeping complaints, sleeping regular hours), scored < 10 on the Epworth Sleepiness Scale (Johns, 1991), took daytime naps < 1/month, were low to moderate (0–4 cups daily) caffeine consumers, were regular but not excessive alcohol drinkers (av. 20.2 units/week [s.e. 1.5]). The procedure was fully explained to them. They signed consent forms and were paid for their services. The study was approved by our University’s Ethical Committee.

General Procedure
To ensure some afternoon sleepiness, sleep on the night prior to each experimental day was restricted to 5 h, between 02:00 and 07:00 h, and monitored by wrist-worn actimeters. For 36 h before each experimental trial, participants also completed a sleep and food diary to ensure that these factors were consistent. On trial days, participants had their usual breakfast, and refrained from eating from 09.30 h onwards. Caffeine consumption was prohibited from 22.00 h the night before the trial, and alcohol banned throughout the previous day. Participants came to the laboratory at 12.30 h, had their actimeters downloaded, and these data checked for sleep compliance. They were given a light lunch (bowl of ‘minestrone’ soup—one can). At 13:50 h drinks (see below) were administered (double blind) with PVT testing commencing at 14:00 h.

The two drinks, given a week apart in a counter-balanced double blind design, comprised:

- Energy Drink (ED)—high sugar-250 ml ED (42 g sugars + 30 mg caffeine—lightly carbonated).
- Control-nil sugar-250 ml sugar-free orange flavoured drink, with nil caffeine, and having a similar taste to ED—lightly carbonated.

PVT
Prior to the main study participants underwent a practice session on the PVT. The test was always conducted in a sound dampened cubicle with participants seated at a computer screen with their preferred index finger or thumb of the dominant hand resting on a response button, with which they responded immediately to a digital millisecond clock appearing on the screen. This stopped the clock, which remained visible for 2s (giving the participant ‘knowledge of results’); then the screen went blank. Inter-stimulus intervals averaged 7s, within a random range between 2 and 12s. Testing began with a 5 min ‘warm up’, followed by 90 min of PVT, including two, 3 min breaks (with participants remaining seated) after 30 and 60 min. Typically, the PVT is only administered for single 10 min periods (Dinges and Kribbs, 1991) and we gave the test for a particularly extensive duration; hence the need for short breaks. We were particularly interested in assessing the characteristics of sleepiness about an hour after consumption of the drinks. ‘Lapses’ are defined (Dinges and Kribbs, 1991) as responses in excess of 500 ms. Reaction times (RTs) are based on all data below this threshold.

KSS
This 9 point scale (Akerstedt and Gillberg, 1990) requires the participant to respond with a number: 1 = extremely alert, 2 = very alert, 3 = alert, 4 = rather alert, 5 = neither alert nor sleepy, 6 = some signs of sleepiness, 7 = sleepy, no effort to stay awake, 8 = sleepy, some effort to stay awake, 9 = very sleepy, great effort to keep awake, fighting sleep. The KSS was given at the end of each 30 min period.

Analysis
PVT data (RTs and lapses) were analysed in 10 min epochs, which were then treated as three 30 min blocks (separated by the breaks). Because of our differential interest in these blocks, they were assessed separately, each by two way (epoch × condition) repeated measures ANOVAs, with the Huynh-feldt [e] adjustment. Post-hoc testing was by t-tests, where appropriate. The KSS was assessed by a single (block × condition) repeated measures ANOVA.
Results

PVT

Figures 1 and 2 show mean and standard errors for RTs and lapses per 10 min epochs.

RT. As expected, there was a significant effect of time for the first \( F = 17.4, \text{df} 2, 18, p < 0.001 \) and second blocks \( F = 11.2, \text{df} 2, 18, p < 0.002 \), whereas there was no significant condition effect for these two blocks, nor any interaction. However, the third 30 min block shows increased RTs following ED, with a significant condition effect \( F = 6.4, \text{df} 1, 9, p < 0.03 \) effect, as well as significance for time \( F = 5.6, \text{df} 2, 18, p < 0.01 \), but no interaction. Although there was a trend for the greatest ED effect, here, to be at 70 min (Figure 1), it was not significant \( p = 0.180 \).

Lapses. With respect to the first two blocks, the outcomes were similar to those for RTs, with significant time effects (respectively: \( F = 6.5, \text{df} 2, 18, p < 0.02 \); and \( F = 6.4, \text{df} 2, 18, p < 0.02 \)), but no condition effect. Again, the third block was significant for condition \( F = 6.4, \text{df}, 1, 9, p < 0.03 \) and time \( F = 5.4, \text{df} 2, 18, p < 0.01 \), but with no interaction. Similarly, the worsening with ED appears to peak at 70–80 min, which was significant \( t = 2.4, \text{df} 9, p < 0.03 \), but post hoc tests were not significant for the other two epochs in this block.

KSS

Subjective sleepiness at the end of each 30 min period is shown in Figure 3. Although there was a trend for greater overall sleepiness with ED, this was not significant, and neither was time.
Discussion
It is clear that under these conditions, 250 ml ED given with a light lunch does not alleviate a moderate level of afternoon sleepiness. In contrast, and after about an hour, sleepiness determined by the PVT was significantly worse, although, this was reflected in only a trend in increasing subjective sleepiness. It is unlikely that this fall in performance in these healthy individuals could be due to any major alterations in blood glucose levels (e.g. a ‘hypoglycaemic rebound’). The caffeine contained in the ED was low, and we can only speculate whether it was effective, and whether it may have counteracted any greater sleepiness apparently caused by the sugar.

Whilst there is good evidence that a bolus sugar intake can boost ‘physical energy’ (cf. Benton, 2002) one must be circumspect that, without prior signs of hypoglycaemia, there is little support for it having any benefits for a sleepy brain. People wishing to alleviate sleepiness through the use of high sugar content soft drinks, erroneously believing what is commonly assumed to be a ‘sugar rush’ to be effective in this respect, should be selective and avoid those drinks containing little or no caffeine. It is caffeine which is particularly effective, here (Reyner and Horne, 2000, 2002), especially when combined with a short nap, taken in the approximately 20 min period between consumption of the caffeine and the nap (Reyner and Horne, 1997).

Our testing ended after 90 min and, given the findings, it is possible that had we gone on for longer, then the results would have been more interesting. As the PVT is very tedious, and as we wanted to track changes from soon after consumption of the drink, participants would not have wanted to go on for much longer. Clearly, a future study could delay the onset of such measurements.

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References