Effects of Energy Drink Ingestion on Alcohol Intoxication

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Background: Well-known reports suggest that the use of energy drinks might reduce the intensity of the depressant effects of alcohol. However, there is little scientific evidence to support this hypothesis.

Objective and Methods: The present study aimed at evaluating the effects of the simultaneous ingestion of an alcohol (vodka$_{37.5\%v/v}$) and an energy drink (Red Bull®—3.57 mL/kg), compared with those presented after the ingestion of an alcohol or an energy drink alone. Twenty-six young healthy volunteers were randomly assigned to 2 groups that received 0.6 or 1.0 g/kg alcohol, respectively. They all completed 3 experimental sessions in random order, 7 days apart: alcohol alone, energy drink alone, or alcohol plus energy drink. We evaluated the volunteers' breath alcohol concentration, subjective sensations of intoxication, objective effects on their motor coordination, and visual reaction time.

Results: When compared with the ingestion of alcohol alone, the ingestion of alcohol plus energy drink significantly reduced subjects' perception of headache, weakness, dry mouth, and impairment of motor coordination. However, the ingestion of the energy drink did not significantly reduce the deficits caused by alcohol on objective motor coordination and visual reaction time. The ingestion of the energy drink did not alter the breath alcohol concentration in either group.

Conclusions: Even though the subjective perceptions of some symptoms of alcohol intoxication were less intense after the combined ingestion of the alcohol plus energy drink, these effects were not detected in objective measures of motor coordination and visual reaction time, as well as on the breath alcohol concentration.

Key Words: Alcohol, Alcoholic Intoxication, Energy Drink, Caffeine, Taurine.

THE COMBINED INGESTION of alcohol and so-called "energy drinks" has recently been observed to have become rapidly popular. Users frequently report a reduction in sleepiness and an increase in the sensation of pleasure when these drinks are combined with alcoholic beverages, suggesting that they might reduce the depressant effects and/or increase the excitatory effects of alcohol. There is, however, little scientific evidence on the interaction of these substances (Ferreira et al., 2004a, 2004b).

There are reports suggesting that the ingestion of energy drinks alone improves psychomotor performance (motor reaction time, concentration, immediate memory, subjective sensation of alertness, and physical vigor), physical performance, and mood (Alford et al., 2001; Seidl et al., 2000). The main components of the marketed energy drinks are caffeine, taurine, carbohydrates, gluconolactone, inositol, niacin, pantenol, and B-complex vitamins. The effects of some of these components have been evaluated in the treatment of alcoholic intoxication, both for their influence on alcohol metabolism and for the symptoms of intoxication (Frezza et al., 1990; Souza and Masur, 1982; Wagner et al., 1976; Zimatkin et al., 1997).

Sugars such as glucose and fructose seem to have a limited effect in the antagonism of alcohol intoxication (de Souza et al., 1982; Jones, 1979; Levy et al., 1977; Zacchia et al., 1991). Even though fructose can accelerate the metabolism of alcohol, its use is limited because of the adverse effects it has, reducing its cost–benefit relationship. Vitamins were also evaluated in antagonizing alcohol intoxication (Kelly et al., 1971; Moretti et al., 1969; Muir et al., 1973). Caffeine seems to be potentially beneficial in the treatment of acute intoxication. However, although researchers have some knowledge about the interactions between caffeine and alcohol, there is no consensus on the necessary dose to reduce the intensity of the depressant effects of alcohol, as individuals present different levels of sensitivity. Liguori and Robinson (2001) observed a better psychomotor performance in individuals after the ingestion of 0.6 g/kg alcohol and 400 mg of caffeine than when alcohol alone was ingested. Nevertheless, they suggest that

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even though this dose of caffeine reduced some of the acute effects of alcohol, it did not reduce its depressant effects in a driving simulator (Liguori and Robinson, 2001). Animal studies also suggest that caffeine can increase the stimulant properties of low doses of alcohol, as well as the voluntary consumption of alcohol (Koo, 1999; Kunin et al., 2000; Kuribara et al., 1992; Waldeck, 1974).

Among the other components of energy drinks, we should highlight taurine. Many studies with laboratory animals showed pharmacological interactions between alcohol and taurine on locomotor activity and dopamine release and on the deleterious effects of ethanol on liver metabolism (Aragon et al., 1992; Dahchour et al., 1996; Kerai et al., 1998). Vohra and Hui (2000) showed, in mice, that taurine can be effective in attenuating the amnesia induced by alcohol, pentobarbital, cycloheximide, and sodium nitrite without compromising the behavioral aspects. According to Olive (2002), taurine, one of the most abundant amino acids in the central nervous system, plays an important role in physiological processes such as osmoregulation, neuroprotection, and neuromodulation. Both taurine and ethanol exert positive allosteric modulatory effects on neuronal ligand-gated chloride channels (i.e., $GABA_A$ and glycine receptors) as well as inhibitory effects on other ligand-gated and voltage-gated cation channels (i.e., *N*-methyl-D-asparatate and Ca^{2+} channels). This suggests that the endogenous taurine system may be an important modulator of the effects of ethanol on the nervous system. However, there are no studies discussing the interactions of alcohol and taurine on the cognitive performance in humans. Conversely, there are some studies showing that acamprosate (calcium acetyl homotaurinate) does not alter alcohol pharmacokinetics, acute physiological, or psychomotor effects of alcohol or most of its subjective effects (Brasser et al., 2004). There is a paucity of studies on the interaction of alcohol and the remaining components of energy drinks.

To test the possible antagonism to the depressant effects of alcohol, this study aimed at investigating whether the ingestion of an energy drink alters the breath alcohol concentration, subjective perception of alcohol intoxication, or performance in tests of motor coordination and visual reaction time.

METHODS

Subjects

Twenty-six healthy male volunteers participated in the study. Their age was 23 ± 3 years, with a body mass index of 22.7 ± 1.6 kg/m^2 (weight 69 ± 8 kg and height 174 ± 8 cm) and 13 ± 1 years of formal education. All the volunteers were submitted to a standardized interview and, after being informed about the objectives and procedures of the study, signed an informed consent form. The Committee of Ethics in Research from UNIFESP approved the study (protocol 394/00). The inclusion criteria were as follows: all the individuals were submitted to a standardized clinical examination and provided blood and urine samples for laboratory tests (hematological parameters, uric acid, urea, creatinine, sodium, potassium, triglycerides, cholesterol, glucose, insulin, cortisol, T3, T4, TSH, bilirubins, lipase, alkaline phosphatase, ALT, AST, GGT; serological tests for HIV and hepatitis A, B, and C were also performed). The volunteers included in the sample presented normal laboratory and clinical exams, had no history of psychiatric disorders, and displayed a normal ergometer test with an electrocardiogram. All of them consumed alcohol moderately [defined as less than 14 standard doses of alcohol per week (1 dose = 13.6 g of ethanol), according to the Daily Drink Questionnaire (Collins et al., 1985)] and moderate users of energy drinks (fewer than 10 cans of 250 mL in the last 6 months).

Groups

The volunteers were randomly assigned to 2 groups according to the dose of alcohol ingested, group 0.6 g/kg ($n = 12$) and group 1.0 g/kg ($n = 14$). They were similar in social and demographic data and pattern of use of alcoholic beverages and energy drinks, as well as their quality of life (SF-36) (Martinez et al., 2000) and level of physical activity (Physical Activity Questionnaire) (Baecke et al., 1982).

Alcohol (Treatments)

We used the energy drink Red Bull® (made by RED BULL GmbH, Fuschl, Austria; imported by Red Bull Do Brazil Ltd. bought from retailers in Sao Paulo, Brazil) at a dose of 3.57 mL/kg (equivalent to 1 can for a 70-kg person). Alcohol (vodka, 37.5% v/v) was administered at doses of 0.6 or 1.0 g/kg. The solution administered consisted of a mixture of alcohol (0.6 or 1.0 g/kg or the same volume of water) and an energy drink (3.57 mL/kg or the same volume of water). To keep the concentration and the taste constant, we added artificial fruit juice to the mixture (Clight Diet Peach®, Kraft, Sao Paulo, Brazil; 21 g/L prepared with water) in a volume equivalent to 20% of the volume of the mixture of alcohol plus energy drink. The final volume of the mixture was 6.7 mL/kg for the group that received 0.6 g/kg alcohol and 8.3 mL/kg for the group that received 1.0 g/kg alcohol. The volunteers were allowed to spend between 10 and 20 minutes to ingest the mixture. The alcohol and energy drink doses were chosen because they are within the range of doses (around 2.5 and 4 standard alcoholic drinks and 1 can of energy drink) usually ingested on a single occasion.

Procedures

The volunteers were instructed to arrive at the laboratory 15 minutes before the beginning of the test treatments, which started at noon. They had a standard meal of 1,000 calories [1 Big Mac® (MacDonalds, Sao Paulo, Brazil), French fries, and a soft drink] at 12:45 PM and their basal evaluation (pretreatment) started at 13:30 PM. At the end of each session, they received a snack that consisted of fruit juice, bread, cookies, and coffee and were then taken home by taxi.

To control the learning effect and reduce the novelty effect, the volunteers were initially submitted to a control treatment (ingestion of water) in which we applied the same protocol used in the experimental treatments. Each volunteer was submitted to the 3 treatments, carried out at least 7 days apart, following a random order. This way, in the first treatment, some volunteers ingested only alcohol, some ingested the alcohol plus energy drink, and others ingested only the energy drink. We used a double-blind procedure throughout the experiment.

Evaluation of Alcohol Intoxication

Breath Alcohol Concentration. This was determined by using a breath analyzer (Alco-Sensor IV, Intoximeters Inc., St. Louis, MO)

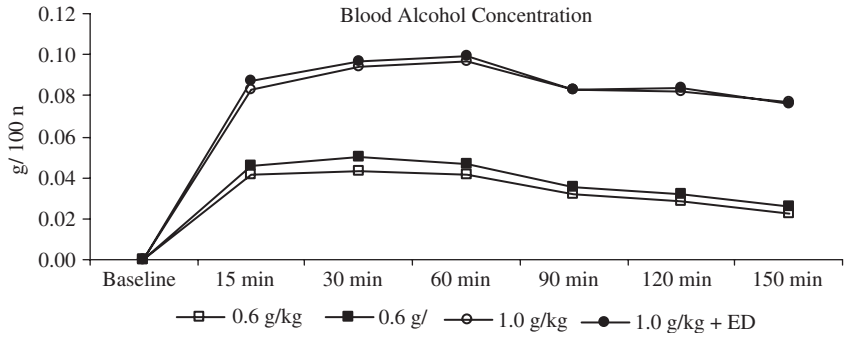

Fig. 1. Breath alcohol concentration in grams per deciliter (gm/dL), after the ingestion of 0.6 or 1.0 g/kg alcohol (vodka 37.5% v/v) plus energy drink (ED) (3.57 mL/kg) or water. (– – –) Legal limit for alcoholic intoxication according to the Brazilian Driving Code.

before and 15, 30, 60, 90, 120, and 150 minutes after the treatments (Moore and Guillen, 2004).

Subjective Effects of Intoxication. This was evaluated before and 30 and 120 minutes after the treatments through 100-mm visual-analog scales of somatic symptoms (ASSS) (Bond and Lader, 1972; Greenwood et al., 1975). Each 100-mm line represented the whole range of possible intensity of each listed symptom. The volunteers marked, with a vertical line, the location that corresponded to the intensity of their sensation at the moment of the evaluation. We added 5 items (agitation, alterations in motor coordination, hearing and speech, sensation of well-being) to the 13 items of the original version of the instrument (tiredness, headache, dizziness, tremor, weakness, muscular tension, nausea, salivation, perspiration, visual disturbances, tachycardia, difficulty in breathing or walking).

Motor Coordination. This was evaluated before the ingestion of the alcohol and 30 and 120 minutes after it, by the Grooved Pegboard test, a test of fine motor coordination consisting of a board with 25 holes where pegs are fitted. The score was the time taken to transfer all the pegs with the dominant hand (Lafayette Instrument Co., Lafayette, IN) (Dolbec et al., 2000).

Visual Reaction Time

This was evaluated by the software PSS CogReHab 95®, before the ingestion of the alcohol and 30 and 120 minutes after it. The instructions were presented on screen and reinforced by the researcher. A yellow square (30 × 30 mm) appeared in random positions on the screen and the volunteers acknowledged its appearance by pressing the mouse key. Scores were the mean time taken to press the key on 16 trials (Pompéia, 2000).

Statistical Analysis

To compare the groups (0.6 and 1.0 g/kg alcohol) for interval variables, we used Student's t test. The comparison of groups taking into account the amount of alcohol administered (treatments) and the time was made by the 3-way ($2 \times 3 \times 6$) analysis of variance (ANOVA) for repeated measures [3 factors: group (2 doses of alcohol), treatment (alcohol × alcohol plus energy drink × energy drink), and time (15, 30, 60, 90, 120, 150)]. To compare each group in the different times, we used the 1-way ANOVA for repeated measures, followed by Tukey's honestly significant difference test, if necessary. The level of significance was set at 5%. To compare the performance (number of errors) on the visual reaction time task, we used the nonparametric ANOVA of Kruskal–Wallis. The results are presented as mean ± standard deviation. The software STATISTICA (StatSoft Inc.) was used to perform the analysis.

RESULTS

Breath Alcohol Concentration

The breath alcohol concentration of the group that received 1.0 g/kg was significantly higher than that of the group that received 0.6 g/kg, on both occasions, i.e., when they received alcohol alone (factor group $F_{1,24} = 206{,}6$, $p < 0.001$; factor time $F_{5,120} = 30{,}1$, $p < 0.001$; interaction $F_{5,120} = 3{,}32$ $p < 0.01$) and when they received the alcohol plus energy drink (factor group $F_{1,24} = 195{,}2$, $p < 0.001$; factor time $F_{5,120} = 38{,}9$, $p < 0.001$; interaction $F_{5,120} = 1{,}97$ $p = 0.09$, NS). Both groups had started off with a basal level equal to zero (Fig. 1).

In the 0.6 g/kg group the peak of breath alcohol concentration was observed 30 minutes after the volunteers finished drinking the mixture, reaching 0.044 ± 0.011 g/dL in the alcohol treatment and 0.050 ± 0.007 g/dL in the alcohol plus energy drink treatment. No differences were observed between the 2 treatments. In the 1.0 g/kg group, the peak of breath alcohol concentration was observed 60 minutes after the volunteers finished drinking the mixture, reaching similar levels in the alcohol treatment (0.097 ± 0.010 g/dL) and in the alcohol plus energy drink treatment (0.099 ± 0.012 g/dL). In both treatments, the breath alcohol concentration 30 and 60 minutes after the ingestion of the mixture was higher than after 15, 90, 120, and 150 minutes. No differences were observed between the 2 treatments.

Subjective Feelings of Alcoholic Intoxication

The subjective feelings evaluated by the ASSS under the 3 treatments are presented in Table 1. Even though the groups (0.6 and 1.0 g/kg) presented different breath alcohol concentrations, only small differences were observed in their perception of intoxication symptoms. Under the effect of alcohol alone, the 1.0 g/kg group presented higher levels of weakness [at 30 ($t = -2.13$, $p < 0.05$) and 120 minutes ($t = -2.08$, $p < 0.05$)], difficulty in walking (at 30 minutes, $t = -2.20$, $p < 0.05$), and an increase in muscular tension (at 120 minutes, $t = -2.46$, $p < 0.05$). At no other moment under the effect of alcohol, as well as under

Table 1. Subjective Effects of Intoxication Evaluated by the Analogical Scale of Subjective Symptoms (ASSS) after the Ingestion of Energy Drink, Alcohol, and Alcohol + Energy Drink

Factor	Session	Basal	30 minutes	120 minutes
Tiredness 1	Energy drink	5 ± 8	2 ± 4	18 ± 19
	Alcohol	4 ± 7	11 ± 14[a]	18 ± 19
	Alcohol–energy drink	6 ± 13	9 ± 20[a]	17 ± 20
Headache 2	Energy drink	1 ± 2	1 ± 2	2 ± 4
	Alcohol	2 ± 9	7 ± 13[a]	9 ± 19
	Alcohol–energy drink	1 ± 3	5 ± 11	7 ± 14
Dizziness 3	Energy drink	1 ± 3	1 ± 2	2 ± 4
	Alcohol	4 ± 13	14 ± 14[a]	14 ± 22[a]
	Alcohol–energy drink	1 ± 3	13 ± 18[a]	10 ± 16[a]
Tremor 4	Energy drink	2 ± 3	3 ± 6	3 ± 6
	Alcohol	3 ± 6	5 ± 12	7 ± 15
	Alcohol–energy drink	1 ± 2	3 ± 9	5 ± 13
Weakness 5	Energy drink	2 ± 4	1 ± 4	7 ± 11
	Alcohol	3 ± 5	10 ± 17[a]	14 ± 18[a]
	Alcohol–energy drink	2 ± 6	9 ± 18[a]	10 ± 15
Tension 6	Energy drink	5 ± 12	3 ± 7	10 ± 17
	Alcohol	6 ± 16	3 ± 7	12 ± 19
	Alcohol–energy drink	5 ± 14	5 ± 10	9 ± 18
Nausea 7	Energy drink	1 ± 3	1 ± 2	1 ± 4
	Alcohol	1 ± 1	2 ± 3	6 ± 13
	Alcohol–energy drink	1 ± 3	2 ± 5	5 ± 12
Salivation 8	Energy drink	0 ± 7	0 ± 11	–3 ± 14
	Alcohol	–1 ± 8	–2 ± 12	–15 ± 16[b]
	Alcohol–energy drink	0 ± 8	–1 ± 8	–7 ± 13
Perspiration 9	Energy drink	6 ± 14	5 ± 11	9 ± 13
	Alcohol	6 ± 15	12 ± 21	9 ± 16
	Alcohol–energy drink	4 ± 7	7 ± 14	10 ± 17
Alterations in sight 10	Energy drink	1 ± 3	1 ± 3	4 ± 12
	Alcohol	2 ± 4	12 ± 17[a]	6 ± 12
	Alcohol–energy drink	2 ± 5	8 ± 14[ac]	6 ± 13
Tachycardia 11	Energy drink	2 ± 4	2 ± 5	2 ± 6
	Alcohol	1 ± 3	5 ± 14	4 ± 10
	Alcohol–energy drink	1 ± 4	4 ± 12	5 ± 11
Breathing difficulty 12	Energy drink	2 ± 4	1 ± 5	2 ± 6
	Alcohol	5 ± 18	4 ± 11	3 ± 10
	Alcohol–energy drink	2 ± 5	4 ± 9	3 ± 7
Alterations in walking 13	Energy drink	1 ± 3	1 ± 3	3 ± 10
	Alcohol	2 ± 8	9 ± 15[a]	8 ± 15[a]
	Alcohol–energy drink	3 ± 10	12 ± 21[a]	8 ± 15[a]
Agitation 14	Energy drink	10 ± 19	13 ± 23	10 ± 19
	Alcohol	11 ± 25	10 ± 16	10 ± 20
	Alcohol–energy drink	4 ± 7	17 ± 25	11 ± 18
Alterations in motor coordination 15	Energy drink	5 ± 12	6 ± 12	6 ± 12
	Alcohol	8 ± 16	20 ± 18[a]	15 ± 15[b]
	Alcohol–energy drink	3 ± 7	16 ± 18[a]	11 ± 12
Alterations in hearing 16	Energy drink	1 ± 3	1 ± 4	1 ± 4
	Alcohol	2 ± 5	1 ± 3	4 ± 11
	Alcohol–energy drink	1 ± 4	1 ± 4	2 ± 4
Alterations in speech 17	Energy drink	1 ± 3	1 ± 3	2 ± 5
	Alcohol	1 ± 3	4 ± 8[a]	3 ± 7
	Alcohol–energy drink	1 ± 4	4 ± 7[a]	3 ± 7
Well-being 18	Energy drink	3 ± 7	2 ± 6	3 ± 5
	Alcohol	3 ± 7	7 ± 12	7 ± 9[a]
	Alcohol–energy drink	2 ± 5	9 ± 16[a]	6 ± 9[a]

Values 0 and 100 represent, respectively, the absence and the highest sensation of disorders in the factor, except in the item Salivation (0, normal; positive values, excess; negative values, dry mouth).
[a]Higher than in the energy drink session.
[b]Higher than in the other sessions.
[c]Lower than in the alcohol session ($p<0.05$).

the alcohol plus energy drink or energy drink alone, were differences detected between the doses of 0.6 and 1.0 g/kg (Student's t test, $p>0.05$). Therefore, the analyses that follow were carried out regardless of the group divisions on the dose of alcohol.

When compared with the ingestion of energy drink alone, alcohol caused significantly higher sensations of tiredness ($F_{2,50}=4.1$, $p<0.02$), headache ($F_{2,50}=3.6$, $p<0.03$), dizziness ($F_{2,50}=12.6$, $p<0.01$), and weakness ($F_{2,50}=5.9$, $p<0.01$), as well as alterations in sight

($F_{2,50} = 10.4$, $p < 0.01$), walking ($F_{2,50} = 6.8$, $p < 0.01$), hearing ($F_{2,50} = 8.9$, $p < 0.01$), and speech ($F_{2,50} = 5.3$, $p < 0.02$) in the evaluation carried out 30 minutes after its ingestion. In the evaluation carried out 120 minutes after alcohol ingestion, the volunteers reported higher sensations of dizziness ($F_{2,50} = 6.7$, $p < 0.01$) and dry mouth ($F_{2,50} = 6.3$, $p < 0.01$), as well as alterations in walking ($F_{2,50} = 3.9$, $p < 0.03$), motor coordination ($F_{2,50} = 8.3$, $p < 0.01$), and in general well-being ($F_{2,50} = 3.0$, $p < 0.05$).

The ingestion of alcohol plus energy drink prevented the sensation of headache at 30 minutes induced by alcohol (Tukey's $p < 0.05$), but similar to alcohol, it also caused sensations of tiredness, dizziness, and weakness, as well as altered sight, walking, hearing, and speech when compared with the ingestion of the energy drink alone.

The sensation of "general well-being" was less after the ingestion of the alcohol plus energy drink than after the ingestion of the energy drink alone, in the evaluation carried out 30 minutes after its ingestion ($F_{2,50} = 4.0$, $p < 0.02$). In the evaluation performed 120 minutes after the ingestion, 2 sensations caused by the ingestion of alcohol were significantly reduced by the combined ingestion of energy drink, dry mouth ($F_{2,50} = 6.3$, $p < 0.01$; Tukey's $p < 0.05$) and alterations in the motor coordination ($F_{2,50} = 8.3$, $p < 0.01$; Tukey's $p < 0.05$). Conversely, the ingestion of this mixture also increased sensations of dizziness and alterations in walking and well-being, similar to those observed after alcohol ingestion.

Motor Coordination

Figure 2 shows the performance of the volunteers in the motor coordination test under the 3 treatments The 3-way ANOVA (group × treatment × time) detected significant

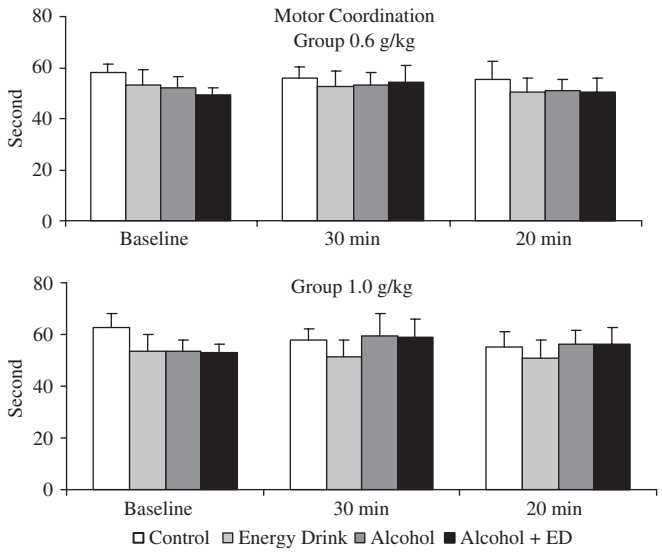

Fig. 2. Motor coordination evaluated by the Grooved Pegboard test, after the ingestion of water (control), energy drink (ED) (3.57 mL/kg), alcohol (0.6 or 1.0 g/kg vodka 37.5% v/v) plus energy drink (3.57 mL/kg), or water.

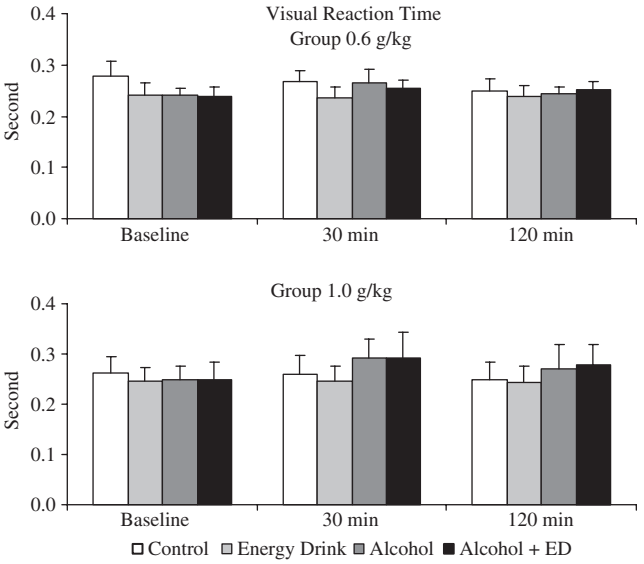

Fig. 3. Visual reaction time (Software PSS CogRehab 95), after the ingestion of water (control), energy drink (ED) (3.57 mL/kg), alcohol (0.6 or 1.0 g/kg vodka 37.5% v/v) plus energy drink (3.57 mL/kg), or water.

effects of the factors treatment ($F_{2,48} = 4.99$, $p < 0.01$) and time ($F_{2,48} = 7.93$, $p < 0.01$), but not of the factor group (alcohol dose, 0.6 or 1.0 g/kg—$F_{1,24} = 2.8$, $p = 0.11$). The volunteers presented their worst performance (longer time to carry out the task) after the ingestion of alcohol or the alcohol plus energy drink than after the ingestion of the energy drink alone. Their performance was significantly worse after 30 minutes than in the basal tests and after 120 minutes, which presented no differences among themselves. There were significant interactions between the factors group and treatment ($F_{2,48} = 6.30$, $p < 0.01$) and between the factors perspiration, treatment, and time ($F_{2,48} = 6.24$, $p < 0.01$).

Visual Reaction Time

Figure 3 shows the performance of the volunteers in the visual reaction time test under the 3 treatments. The 3-way ANOVA (group × treatment × test) detected significant effects of the factors treatment ($F_{2,48} = 19.0$, $p < 0.01$) and time ($F_{2,48} = 18.2$, $p < 0.01$), but not of the factor group (alcohol dose, 0.6 or 1.0 g/kg) ($F_{1,24} = 2.7$, $p = 0.12$). The volunteers presented a better performance (shorter time to carry out the task) after the ingestion of the energy drink than after the ingestion of alcohol or the alcohol plus energy drink. Their performance 30 minutes after the ingestion of the alcohol was significantly worse than after 120 minutes ($p < 0.01$), and both were worse than in the basal tests. We observed significant interactions between the factors group and treatment ($F_{2,48} = 4.1$, $p < 0.02$), group and time ($F_{2,48} = 3.3$, $p < 0.05$), and treatment and time ($F_{2,96} = 12.2$, $p < 0.01$). For the total number of errors on the task, the groups that received 0.6 or 1.0 g/kg

alcohol did not present any differences among each other nor among the 3 experimental sessions (Kruskal–Wallis ANOVA $H_{(1,\ n=26)} = 2.79$, $p = 0.10$).

DISCUSSION

In this study, we showed that the ingestion of one dose of an energy drink reduced the intensity of some subjective symptoms of alcoholic intoxication, as reported by the users of these drinks (Ferreira et al., 2004a), but did not significantly reduce the deficits because of alcohol ingestion, evaluated by objective tests. In the doses utilized (0.6 and 1.0 g/kg), alcohol induced evident damage to the motor coordination and the visual reaction time of healthy volunteers. After the combined ingestion of an alcohol and energy drink, volunteers reported fewer sensations of intoxication in symptoms such as headache, weakness, dry mouth, and motor coordination than when they ingested the alcoholic beverage without the energy drink. This might be due to a possible reduction in the depressant effects of alcohol, as well as due to an increase in the duration/intensity of its excitatory effects (Ferreira et al., 2004c). We cannot discard the possibility that at higher doses energy drinks could counteract other effects of alcohol intoxication, as in experiments with mice, carried out in our laboratory, we showed that only higher doses of energy drinks (equivalent to 3 times the dose administered to the volunteers) significantly reduced the depressant effect of ethanol on the locomotor's activity, increasing its stimulant effect (Ferreira et al., 2004c).

As reported previously, volunteers who received 1.0 g/kg plus energy drink showed no improvement in performance in a physical effort test, nor changes in the effects of alcohol on heart rate at the ventilatory threshold, energy expenditure, respiratory exchange rate, blood lactate, or noradrenaline levels (Ferreira et al., 2004b).

Previous studies have demonstrated pharmacological interactions between alcohol and some of the main components of energy drinks (taurine and caffeine). According to Olive (2002), taurine can alter the locomotor stimulatory, sedating, and motivational effects of ethanol in a strongly dose-dependent manner. Microdialysis studies have revealed that ethanol elevates extracellular levels of taurine in numerous brain regions and can reduce ethanol self-administration and relapse to drinking in both animals and humans. Many studies suggest that the endogenous taurine system may be an important modulator of effects of ethanol on the nervous system (Olive, 2002).

Caffeine has been used in the treatment of moderate intoxication by depressors of the nervous system (DeLucia and Oliveira-Filho, 2004). Its stimulant actions could account for its partial antagonism to the depressant effects of alcohol (Liguori and Robinson, 2001). However, researchers did not reach a consensus on to the dose necessary for a significant effect in the reduction in depression caused by the ingestion of alcohol to be observed. Most studies on the effects of caffeine on the impairment caused by the ingestion of alcohol used tests of locomotor performance. In general, the reduction in the impairment caused by alcohol was only observed after the administration of high doses of caffeine, which would contraindicate its use (Fudin and Nicastro, 1988; Jain et al., 1999).

Studies on the interaction of the other components of energy drinks with alcohol are rare. Other substances present in energy drinks, namely carbohydrates and B-complex vitamins, when administered together, could promote the stimulation of the energy metabolism (McArdle et al., 1996), thus contributing to reduced depressant effects of alcohol. Consequently, we should not discard a possible contribution of other components of energy drinks in decreasing the intensity of alcoholic intoxication. Although the influence of carbohydrates should not be disregarded, the data on its influence on alcohol intoxication are controversial. Masur et al. (1983) reported no significant effects of glucose administration in reducing the subjective effects (self-evaluated) of alcohol intoxication or in promoting a significant reduction in blood alcohol levels, in patients who attended an emergency room (Masur et al., 1983). However, Zacchia et al. (1991) reported that sucrose administration attenuated some subjective effects of alcohol intoxication without influencing breath alcohol concentration. Besides, the "placebo effect" could not be ignored (Zacchia et al., 1991). As no differences in blood alcohol levels were found between the session in which only alcohol was administered and the session where the alcohol plus energy drink was administered, energy drinks (at least in the dose tested) probably did not affect the alcohol and/or aldehyde dehydrogenase systems.

There are few studies in the literature on the effects of energy drinks. Horne and Reyner (2001) observed that the ingestion of energy drinks increased reaction time in a driving simulator when compared with the ingestion of a carbohydrate mixture. According to the authors, the improvement is most evident within the first hour of the test (Horne and Reyner, 2001). Warburton et al. (2001) showed that the administration of energy drinks to volunteers enhanced their concentration and verbal performance when compared with the administration of drinks containing carbohydrates alone.

Even though different studies have demonstrated that some components of energy drinks might present properties that antagonize some of the effects of alcohol, in this study we observed that the ingestion of one dose of an energy drink (3.57 mL/kg: 1.14 mg/kg caffeine, 14.3 mg/kg taurine, and 0.4 mg/kg sugar) was not enough to antagonize most of the objectively measured effects of alcohol (0.6 and 1.0 g/kg) in tests of motor coordination and reaction time, nor to reduce the breath alcohol concentration. Nevertheless, we observed a reduction in the subjective sensation of intoxication. These data are in agreement with the only case report we found in the

literature on the interaction of alcohol and energy drinks, in which Riesselmann et al. (1996) suggested that users of alcohol plus energy drinks might have their judgment affected by the reduced subjective sensation of intoxication, thus increasing the probability of their becoming involved in accidents after the combined ingestion of these drinks. Besides, the increase in the alcohol palatability reported by many users of energy drinks could lead youth toward a higher consumption of alcoholic beverages. For these reasons, knowledge about the effects of the interaction between alcoholic beverages and energy drinks may be relevant to preventive programs, such as that proposed by Holder et al. (2000), who reported that a coordinated, comprehensive, community-based intervention can reduce high-risk alcohol consumption and alcohol-related injuries resulting from motor vehicle crashes and assaults.

According to our previous data from studies performed with animals, the interaction of alcohol and energy drinks seems to depend on the dose and individual sensitivity (Ferreira et al., 2004c; Trindade et al., 2004). Further studies are under way in our laboratory, aiming at a better understanding of the effects and mechanisms of the interaction between alcohol and energy drinks, as well as with their main components.

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