Use and effects of food and drinks in relation to daily rhythms of mood and cognitive performance

Effects of caffeine, lunch and alcohol on human performance, mood and cardiovascular function

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There have been many studies of the effects of caffeine (for a review, see Lieberman, 1992), lunch (for a review, see Smith & Kendrick, 1992), and alcohol (for a review, see Finnigan & Hammersley, 1992) on human performance and mood. However, these factors have usually been considered in isolation, which is not representative of what happens in real life. There have, however, been a few studies which have looked at the interactions between them. For example, Smith *et al.* (1990) examined the effects of caffeine on the post-lunch dip in sustained attention and showed that caffeine removed the post-lunch impairment. Millar *et al.* (1992) have demonstrated that consumption of lunch can reduce the negative effect of alcohol observed in some aspects of performance. In contrast to this, previous research (e.g. Oborne & Rogers, 1983) suggests that caffeine does not remove the detrimental effects of alcohol.

The main aim of the present study was to examine the separate and combined effects of caffeine, lunch and alcohol to provide further insight into their modes of action and to allow comparison of the magnitude of the effects of the different factors. Previous research has also shown that there are individual differences in the effects of caffeine, alcohol and lunch. In the case of caffeine it appears to be impulsivity which predicts the size of the effect. In contrast to this, anxious subjects tend to show a smaller post-lunch dip than non-anxious subjects. There are also individual differences in the effects of alcohol, with extravert, anxious subjects showing the greatest impairments after alcohol. These personality effects were examined in the present study but the findings are not reported here.

METHODS

Fifty-nine subjects (thirteen males and forty-six females) took part in the study. All subjects were given a practice session in the week before the experiment to familiarize them with the testing procedure. Subjects were tested before lunch at 11.30 or 12.15 hours (session 1) and these data were used as covariates to statistically adjust for individual differences in performance. Subjects were then assigned to one of the eight groups formed by combining caffeine (caffeine *v*. decaffeinated coffee), lunch (lunch *v*. no lunch) and alcohol (non-alcoholic *v*. alcoholic drink) conditions. The alcohol and caffeine manipulations were double-blind, and the alcoholic drink (or placebo) was given before the meal, whereas the coffee was consumed after the meal. The subjects returned to the laboratory for two further sessions after lunch 14.00 or 14.45 hours (session 2), 15.30 or 16.15 hours (session 3).

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Physiological measurements

Pulse and blood pressure were measured before mood rating and performance testing.

Mood ratings

Eighteen bipolar visual analogue scales (after Herbert *et al.* 1976) were used. Mood ratings were carried out before the subjects started the performance tasks.

Performance testing

Subjects carried out four tasks, the order of tasks being counterbalanced across subjects (different subjects performed the tasks in different orders).

(a) *Detection of repeated-numbers sustained-attention task.* In this task the subject was shown a sequence of three digit numbers. Successive numbers usually differed by one digit (e.g. 100 followed by 106, or 600, or 160). The numbers were presented at the rate of 100 per min. In each minute there were eight occasions when the same number was presented on successive trials. The subject had to detect these and press the keyboard as quickly as possible. The task lasted for 8 min and the number of targets correctly detected, false responses and mean response times for correct detections were recorded for each minute.

(b) *Logical reasoning task.* In this task subjects were shown a statement such as A follows B, and the letters in either the order AB or BA. The subject had to read the sentence and look at the order of the letters and decide whether the sentence was true or not. The syntactic complexity of the sentence ranged from simple active to passive negative. The speed and accuracy of responses were measured also.

(c) *Focused attention task.* A single letter (either A or B) was presented in the centre of the screen and the subject had to press the corresponding key on the keyboard. Other letters were sometimes presented to the side of the central letter to try to distract the subject. The distraction was greater if the letters at the side were different from the central letter. Sometimes the distractors were close to the target and sometimes further away. Distraction was greater when the letters were close to the target. This task made it possible to determine whether the distractibility of the subject changed, and made it possible to see whether a person's attention was focused or set to a wider visual angle.

(d) *Search task.* This was identical to the previous task except that the subject did not know in which of two possible locations the letter was going to appear. The task also made it possible to look at compatible and incompatible responses (a compatible response is where the letter is on the same side of the screen as the responding hand; an incompatible response is where the stimulus and the responding hand are on opposite sides). A detailed rationale behind the use of the focused attention and search tasks is given by Broadbent *et al.* (1989).

All the previously described tasks have been shown to be sensitive to the effects of lunch. Caffeine improves performance on sustained attention and logical reasoning tasks but there is no information on whether it affects the focused attention and search tasks. Alcohol has been shown to impair logical reasoning and vigilance, but again there is no information on what it does to performance of the two selective attention tasks.

Dose of caffeine and alcohol

In the 'no caffeine' condition subjects were given decaffeinated coffee. In the caffeine condition the subjects had 4 mg caffeine/kg body-weight added to the decaffeinated coffee. In the 'no alcohol' condition subjects were given a fruit juice with the meal. In the alcohol condition vodka was added to this (1 ml/kg).

Nature of the meal

Subjects were given the following three-course lunch (4·18 MJ (1000 kcal)): 150 ml cream of tomato soup, 60 g wholemeal bread roll; 150 g chicken breast (raw weight) casseroled with onion, tomato, mushrooms, 200 g mashed potato with 7 g polyunsaturated margarine, 75 g peas, 50 g carrots; 200 g stewed apple puree with 10 g sugar, 25 g whipping cream, whipped. Subjects in the 'no meal' condition were given a voucher for a free meal at a later date.

RESULTS

Physiological measurements

Pulse rate. The group receiving lunch showed a significant increase in pulse rate at session 2 ($P<0·001$). No significant effect of lunch was evident at session 3. A significant effect of alcohol was seen at session 2 ($P<0·005$) with the group receiving alcohol showing a significant increase in pulse rate. There was no significant difference between the alcohol and no-alcohol groups at session 3. These results are shown in Fig. 1.

Systolic blood pressure. There was no effect of lunch, alcohol or caffeine on systolic blood pressure.

Diastolic blood pressure. A significant lunch × caffeine interaction was seen at session 2 ($P<0·02$) and session 3 ($P<0·004$). All groups showed a decrease in diastolic blood pressure from the baseline value except for the no-lunch–caffeine group. Indeed, those given decaffeinated coffee showed a greater decrease than those given caffeine. An alcohol × caffeine interaction was evident by session 3 ($P<0·045$). The majority of the groups showed a decrease in diastolic blood pressure from baseline to session 3, the exception being the alcohol–caffeine group who showed an increase in diastolic blood pressure. These effects are shown in Fig. 1.

Mood

A significant main effect of lunch was evident at session 2 for two mood scales (troubled *v*. tranquil, $P<0·03$; and withdrawn *v*. sociable, $P<0·02$). The group receiving lunch felt more tranquil and sociable than those who did not receive lunch. This effect had disappeared by session 3. At session 3, a significant difference between the lunch and no-lunch groups was seen for the contented–discontented scale ($P<0·04$), with the lunch group being more contented than the no-lunch group. These effects are shown in Fig. 2.

An effect of alcohol was also evident. At session 2, the group given alcohol were more friendly ($P<0·002$), and more outward going ($P<0·02$) than the no-alcohol group. These effects were still evident at session 3 and, in addition, the alcohol group rated themselves as more sociable ($P<0·006$) than did the no-alcohol group. These effects are also shown in Fig. 2.

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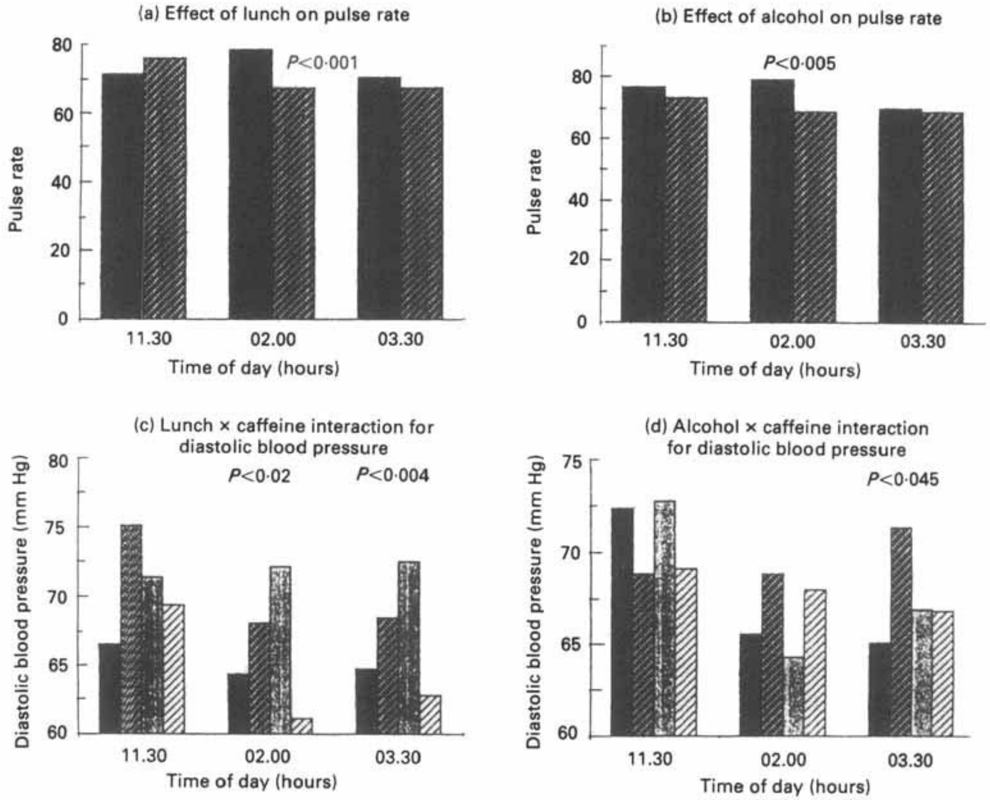

Fig. 1. Effects of alcohol, lunch and caffeine on cardiovascular function of male and female subjects. (a) (■), Lunch; (▨), no lunch; (b) (■), alcohol; (▨), no alcohol; (c) (■, lunch–caffeine; (▨), lunch–no caffeine; (▨), no lunch–caffeine; (▨), no lunch–no caffeine; (d) (■), no alcohol–no caffeine; (▨), alcohol–caffeine; (▨), alcohol–no caffeine; (▨), no alcohol–caffeine. For details of subjects and procedures, see pp. 325–326.

Several effects of caffeine on mood were evident. The caffeine group rated themselves as more happy ($P<0{\cdot}03$), more friendly ($P<0{\cdot}002$), more sociable ($P<0{\cdot}007$), less depressed ($P<0{\cdot}03$) and more outward going ($P<0{\cdot}02$) at session 2 than did the no-caffeine group. The majority of these effects were still apparent at session 3, an exception being the self-centred–outward-going scale which by session 3 showed no effect of caffeine. In addition, the caffeine group rated themselves as more attentive ($P<0{\cdot}04$) than the no-caffeine group at session 3. These effects are shown in Fig. 3.

Performance testing

(a) *Detection of repeated-numbers sustained-attention task.* (1) Reaction times were not affected by lunch, alcohol or caffeine.

(2) False alarms: a significant effect of alcohol was seen at session 2 ($P<0{\cdot}006$) with the group receiving alcohol having a significantly increased false alarm rate. This is shown in Fig. 4. No significant findings were seen at session 3.

(3) Hits: No significant effects of lunch, alcohol or caffeine were obtained.

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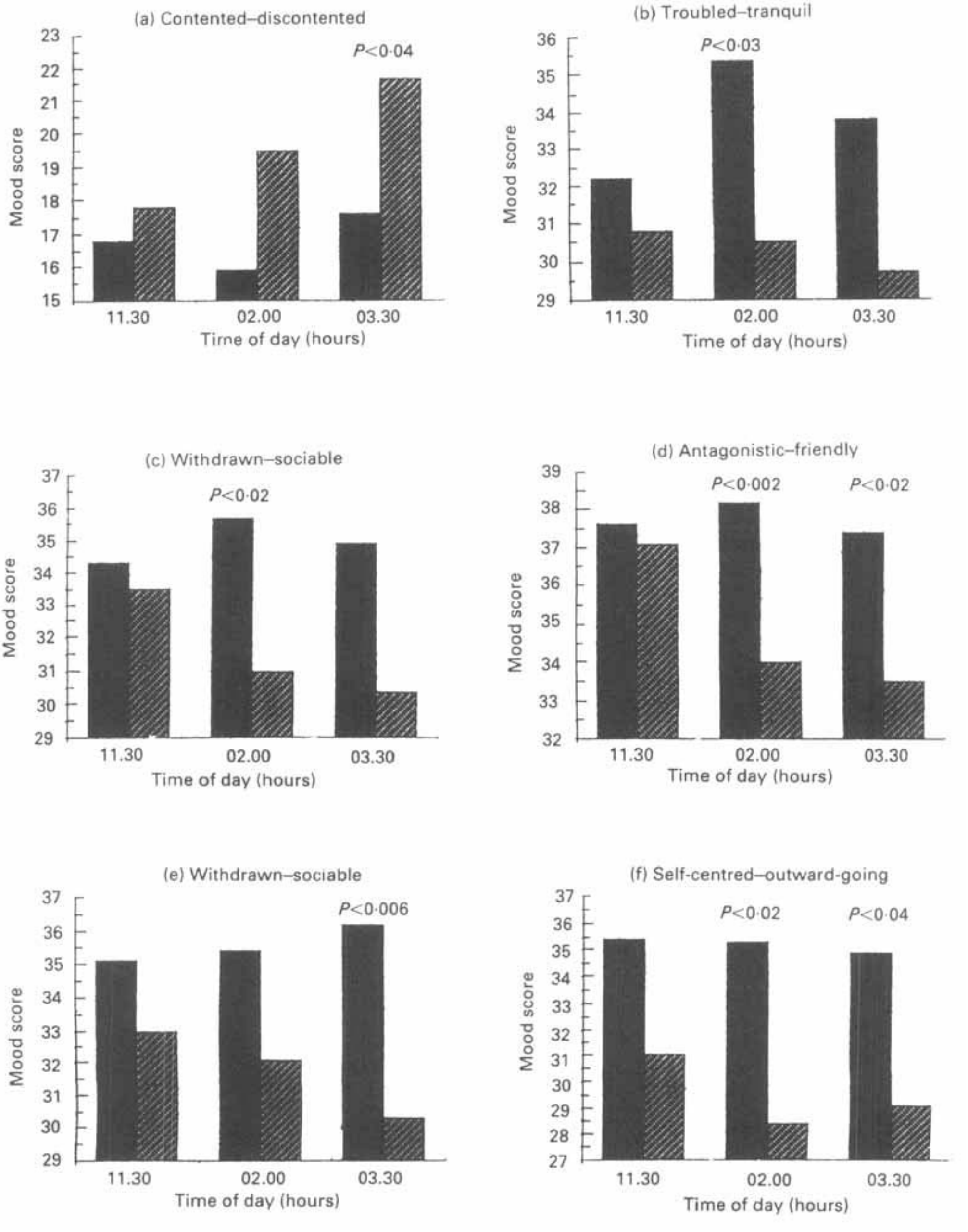

Fig. 2. Effects of alcohol and lunch on mood of male and female subjects. (Mood scores are distances, in arbitrary units from 0 to 50, from the left-hand end of a bipolar scale, for example in the case of antagonistic–friendly a high score indicates the person feels friendly, a low score indicates the person feels antagonistic.) (a–c), Effects of lunch on mood; (d–f) effect of alcohol on mood. (■), Lunch or alcohol; (▨), no lunch or no alcohol. For details of subjects and procedures, see pp. 325–326.

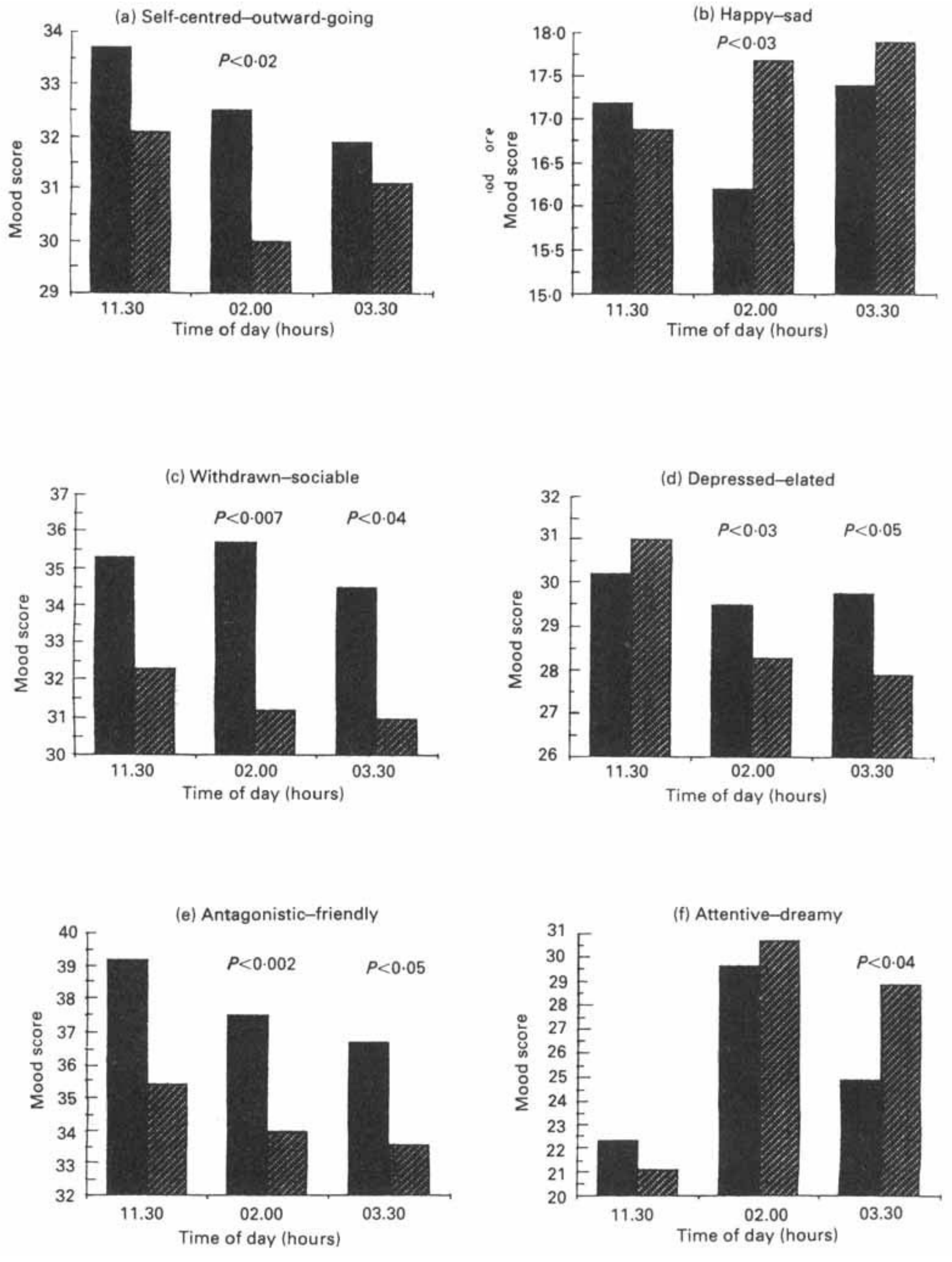

Fig. 3. Effects of caffeine on mood of male and female subjects. (Mood scores are distances, in arbitrary units from 0 to 50, from the left-hand end of a bipolar scale, for example in the case antagonistic–friendly a high score indicates the person feels friendly, a low score indicates the person feels antagonistic.) (■), Caffeine; (▨), no caffeine. For details of subjects and procedures, see pp. 325–326.

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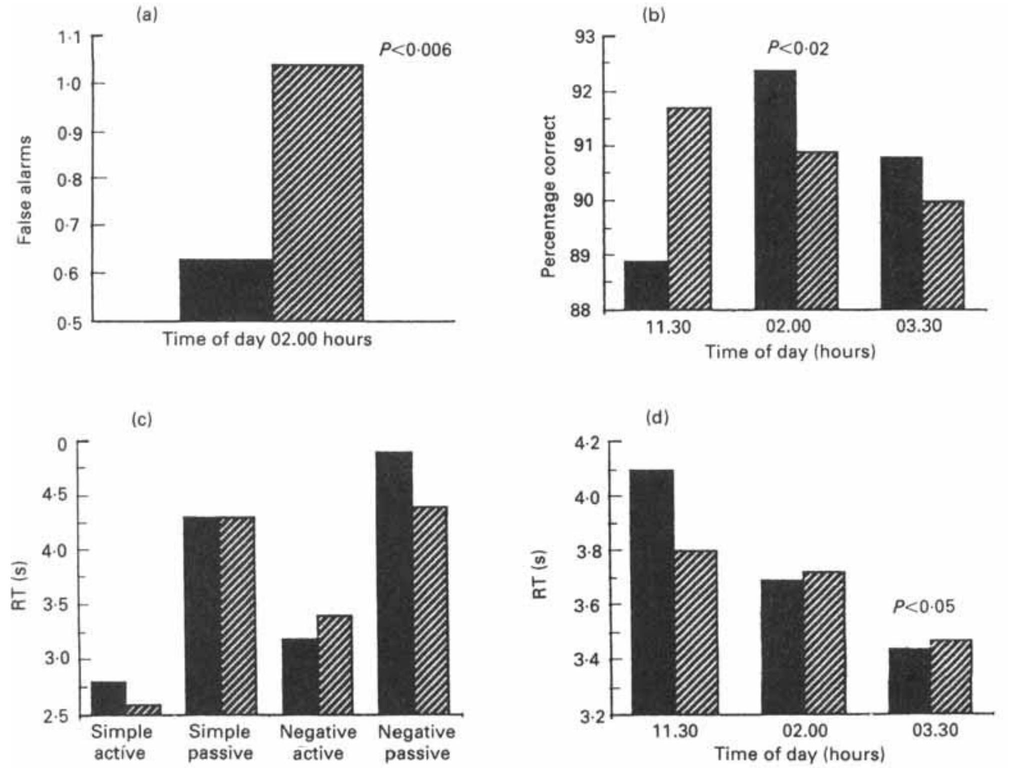

Fig. 4. Effects of alcohol and caffeine on sustained attention and logical reasoning of male and female subjects. (a) Effect of alcohol on false alarm rate for sustained-attention task, (b) effect of caffeine on logical reasoning task (% of sentences correct), (c) alcohol × sentence-type interaction ($P<0{\cdot}003$) on logical reasoning task at session 2, (d) effect of caffeine on logical reasoning task (reaction times (RT)). (a), (■), No alcohol; (▨), alcohol; (b, d), (■), caffeine; (▨), no caffeine; (c), (■), alcohol; (▨), no alcohol. For details of subjects and procedures, see pp. 325–326.

(b) *Logical reasoning task.* (1) Percentage correct: a significant effect of caffeine was seen at session 2 ($P<0{\cdot}02$), with the caffeine group having a significantly higher percentage of correct responses. These effects are shown in Fig. 4.

(2) Reaction times:correct responses: at session 3 a significant effect of caffeine was seen ($P<0{\cdot}048$) with the caffeine group having significantly faster reaction times compared with the no-caffeine group. In addition, a significant interaction between alcohol and sentence difficulty was obtained (session 2, $P<0{\cdot}003$). It was found that alcohol only impaired performance on the most complex sentences, with the reaction time for the negative passive sentence type being significantly longer in the alcohol group as compared with the no-alcohol group. These effects are shown in Fig. 4.

(c) *Focused attention and categoric search tasks.* Only the overall effects on these tasks rather than interactions with task variables are presented here.

If one considers the search task the following effects emerge. (1) Reaction times: Subjects in the alcohol, no-lunch, no-caffeine condition showed the greatest impairment on session 2. Both caffeine and lunch reduced this effect of alcohol. In the analysis of the

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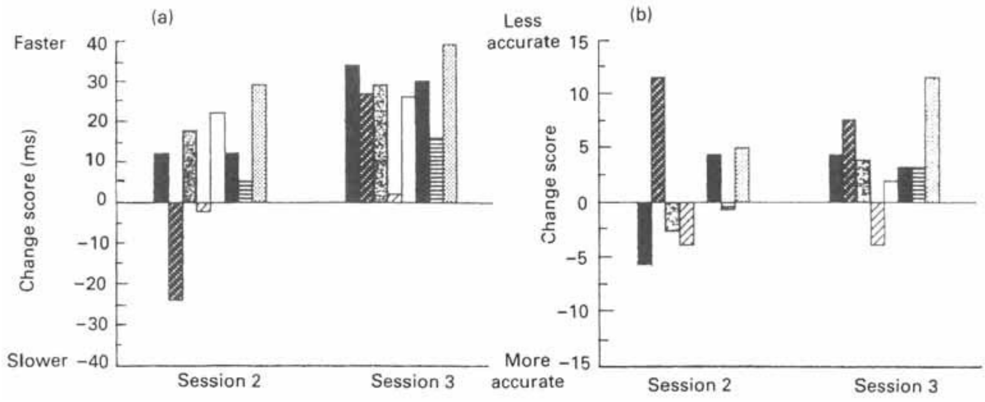

Fig 5. Effects of alcohol, lunch and caffeine on performance of the categoric search task in male and female subjects. (a) Reaction times (difference from baseline; calculated as baseline score minus session score), (b) number correct (difference from baseline). (■), No lunch (NL)–no caffeine (NC)–no alcohol (NA); (▨), NL–NC–alcohol (A); (▩), NL–caffeine (C)–NA; (▧), NL–C–A; (□), lunch (L)–NC–NA; (▦), L–NC–A; (▤), L–C–NA; (▥), L–C–A. For details of subjects and procedures, see pp. 325–326.

session 3 data there was a significant lunch × alcohol interaction with the no-lunch–alcohol group being slower than the no-lunch–no-alcohol groups and the reverse applying for those given lunch. These effects are shown in Fig. 5.

(2) Accuracy: The session 2 data confirm that the alcohol–no-lunch–no-caffeine group showed the worst performance. In the third session performance was generally worse than baseline except for the no-lunch–caffeine–alcohol condition. However, the accuracy effects were small compared with the speed effects. These effects are shown in Fig. 5.

In contrast to the previously mentioned effects, there were no effects of caffeine, alcohol or food in the analysis of overall mean scores from the focused attention task.

DISCUSSION

The results reported here show two different patterns of effects of alcohol, lunch and caffeine. The subjective mood data show effects of all three factors but these appear to be largely independent. In contrast to this, the physiological data and performance data show some independent effects but also instances where the factors interact. This demonstrates that any conclusions about the effects of lunch, alcohol and caffeine on performance will depend on the nature of the activity being carried out. Also, their effects on physiological function will vary depending on the variable measured. When one considers a range of mental functions one finds that some show no effect of any of the factors, others show independent effects, and interactions are observed in some.

Such results presumably reflect the fact that alcohol, caffeine and lunch have many possible modes of action. For example, it has been suggested that lunch produces its behavioural effects by increasing blood glucose, which in turn leads to a hypoglycaemic state and a reduction in arousal (Karlan & Cohn, 1946). Others (e.g. Woods & Porte, 1974) have proposed that the increased blood glucose leads to a parasympathetic initiation of an insulin surge, which is responsible for the behavioural effects. Other researchers suggest that changes in serotonin (Spring *et al.* 1983) or cortisol (Follenius *et al.* 1982) are responsible for these effects. Caffeine is a stimulant of both the central nervous system (CNS) and the autonomic nervous system (Boulenger & Unde, 1982; Zahn & Rapaport, 1987) and it is known to (a) increase central and peripheral catecholamines, (b) inhibit phosphodiesterase (*EC* 3.1.15.1), the enzyme that promotes degradation of cyclic adenosine monophosphate, and (c) block many of the peripheral effects of adenosine. Alcohol is a general CNS depressant and as the dose increases so the more primitive of the brain functions are depressed (Tiplady, 1991). The precise effects observed will, therefore, depend on the factors which influence blood alcohol level and also on changes that produce direct effects on different CNS functions. Further studies are now required to determine what underlies the independent and interactive effects of lunch, caffeine and alcohol that have been demonstrated in the present study.

REFERENCES

Boulenger, J.-P. & Unde, T. W. (1982). Caffeine consumption and anxiety: preliminary results of a survey comparing patients with anxiety disorders and normal controls. *Psychopharmacology Bulletin* **18,** 53–57.

Broadbent, D. E., Broadbent, M. H. P. & Jones, J. L. (1989). Time of day as an instrument for the analysis of attention. *European Journal of Cognitive Psychology* **1,** 69–94.

Finnigan, F. & Hammersley, R. (1992). The effects of alcohol on performance. In *Handbook of Human Performance*, pp. 73–126 [A. P. Smith and D. M. Jones, editors]. London: Academic Press.

Follenius, M., Brandenberger, G. & Hietter, B. (1982). Diurnal cortisol peaks and their relationship to meals. *Journal of Clinical Endocrinology* **55,** 757–761.

Herbert, M., Johns, M. W. & Dore, C. (1976). Factor analysis of analogue scales measuring subjective feelings before and after sleep. *British Journal of Medical Psychology* **49,** 373–379.

Karlan, S. C. & Cohn, C. (1946). Hypoglycaemic fatigue. *Journal of the American Medical Association* **130,** 553–555.

Lieberman, H. R. (1992). Caffeine. In *Handbook of Human Performance*, pp. 48–72 [A. P. Smith and D. M. Jones, editors]. London: Academic Press.

Millar, K., Hammersley, R. H. & Finnigan, F. (1992). Reduction of alcohol-induced impairment by prior ingestion of food. *British Journal of Psychology* **83,** 261–278.

Oborne, D. J. & Rogers. Y. (1983). Interactions of alcohol and caffeine on human reaction time. *Aviation and Space Medicine* **54,** 528–534.

Smith, A. P. & Kendrick, A. (1992). Meals and performance. In *Handbook of Human Performance*, pp. 1–23 [A. P. Smith and D. M. Jones, editors]. London: Academic Press.

Smith, A. P., Rusted, J. M., Eaton-Williams, P., Savory, M. & Leathwood, P. (1990). Effects of caffeine given before and after lunch on sustained attention. *Neuropsychobiology* **23,** 160–163.

Spring, B., Maller, O., Wurtman, J., Digman, L. & Gozolino, L. (1983). Effects of protein and carbohydrate meals on mood and performance: interactions with sex and age. *Journal of Psychiatric Research* **17,** 155–167.

Tiplady, B. (1991). Alcohol as a comparator. In *Ambulatory Anaesthesia and Sedation: Impairment and Recovery*, pp. 26–37 [I. D. Keppler, L. D. Sanders and M. Rosen, editors]. Oxford: Blackwell.

Woods, S. C. & Porte, D. (1974). Neural control of the endocrine process. *Physiological Review* **54,** 596–619.

Zahn, T. P. & Rapaport, J. L. (1987). Acute autonomic nervous system effects of caffeine on prepubertal boys. *Psychopharmacology* **91,** 40–44.

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