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Mood and Performance Effects of Caffeine in Relation to Acute and Chronic Caffeine Deprivation

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RICHARDSON, N. J., P. J. ROGERS, N. A. ELLIMAN AND R. J. O'DELL. *Mood and performance effects of caffeine in relation to acute and chronic caffeine deprivation.* PHARMACOL BIOCHEM BEHAV **52**(2) 313-320, 1995.—The mood and performance effects of caffeine deprivation (either 90 min, overnight, or at least 7 days) and ingestion (70 and 250 mg) were compared in young adults who were normally either moderate consumers (n = 49) or nonconsumers of caffeine (n = 18). Overnight caffeine deprivation produced dysphoric symptoms characteristic of caffeine withdrawal that were reduced, but still present, after longer-term abstinence. Acute caffeine intake affected the withdrawn consumers, nonwithdrawn consumers, and nonconsumers similarly. It increased jitteriness and decreased tiredness and headache. Furthermore, hand steadiness decreased as caffeine dose increased, whereas 70 mg, but not 250 mg, of caffeine was found to enhance performance on a simple reaction time task. These findings support the view that the negative effects experienced after overnight and longer-term caffeine deprivation play a significant role in influencing consumption of caffeine-containing drinks. Therefore, it would appear that to avoid the dysphoric symptoms resulting from both under- and overconsumption, regular caffeine consumers would have to regulate their caffeine intake fairly precisely.

Caffeine Mood Performance Caffeine withdrawal Personality

THE PSYCHOACTIVE effects of caffeine depend to a large measure on the recency and regularity of caffeine intake. Caffeine consumed by a regular consumer can result in an increase in rated alertness, energy, mood, and aid relaxation (5,38,42), whereas a nonconsumer can experience stomach upset and nervousness (10,24). Differences have also been found between low- and high-caffeine consumers (15); heavy users (five+ cups coffee/day) experienced more desirable effects after drinking coffee and more extreme dysphoric symptoms after missing a morning cup of coffee than light consumers (one to two cups/day). The most reliable psyhoactive effect of caffeine across all usage levels is that the absence of caffeine in a situation where it would normally be consumed causes withdrawal symptoms of headache, depression, anxiety, and fatigue (9,15,17,20,39,46). Association of these withdrawal symptoms with a novel flavour will produce an aversion for that novel taste (36,45), clear evidence that these symptoms are indeed dysphoric.

Previous studies have investigated the psychoactive and physiological effects of caffeine in individuals who were instructed to abstain from caffeine-containing beverages for a specific number of hours (1,4,12,26,41), days (20), or weeks (34) prior to testing. As the stimulating effects of caffeine can last up to 7 h (38) and the symptoms of caffeine withdrawal have been found to be evident at 10 days postdose (18), it is not clear whether the effects found in many studies are due to caffeine or caffeine withdrawal. The main purpose of this study was to compare the effects that either longer (up to 7 days) or shorter (90 min and overnight) time periods of caffeine abstinence have on mood and cognitive performance. The effect of caffeine in two doses on the mood and cognitive state of both regular caffeine consumers after caffeine absti-

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nence and nonconsumers was also tested. The symptomology of caffeine withdrawal and the effectiveness of caffeine in alleviating these dysphoric symptoms could be a central factor in explaining the widespread consumption of caffeinated foods and beverages worldwide (14).

Thus, previous research on the relationship between caffeine and conditioned preferences, mood, performance, and physiological parameters has often taken one of two forms: either (a) to investigate the effects of caffeine intake or (b) to investigate the effects of caffeine deprivation. As subjects in type (a) studies are usually asked to refrain from consuming caffeine prior to the experimental session, the use of a placebo condition in such studies more closely reflects the aims of type (b) studies, making many findings difficult to interpret. The aim of this paper was to combine these two approaches to give a more ecologically valid examination of the effect of caffeine consumption by testing mood and performance parameters in the context of regular caffeine consumption, short- and longer-term caffeine deprivation, and caffeine abstinence.

METHOD

Subjects

Subjects were recruited by poster advertisements in two Reading University halls of residence. The study was described as an investigation of the effect of certain ingredients of coffee, tea, and soft drinks on mood and performance. One hundred forty-three subjects who were not currently taking any medication and did not smoke before midday were recruited after they had read a description of the study and signed a consent form that had been approved by the Institute Ethics Committee. The ages of the subjects ranged from 18 to 23 years. The subjects were asked to record all beverages consumed over 5 consecutive days using daily drink intake diaries where tea (herbal, decaffeinated, and regular), coffee (instant, filter, and decaffeinated), hot chocolate, cocoa, soft drinks, fruit juice, water, milk, alcohol, and an "other" category were listed. Average daily caffeine consumption was calculated from the drink diaries using estimates (22) for coffee (filter coffee 125 mg/cup, instant coffee 70 mg/cup, and decaffeinated coffee 4.5 mg/cup), tea (60 mg/cup), cocoa/hot chocolate (5 mg/cup), and cola beverages (30 mg/can). Subjects who consumed very little or no caffeine (<15 mg/day) and those who consumed more than two to three cups of coffee or equivalent (>200 mg/day) yet less than that which has been reported in caffeinism sufferers (1000 mg/day) (16) were asked to continue in the study. The remaining subjects ($n = 71$) were thanked for their help and given a small payment.

Design

Subjects who consumed a daily average of between 200–1000 mg/day caffeine were randomly allocated into one of three groups differing in the duration that they were to avoid caffeinated foods and beverages prior to every testing session (i.e., 90 min "morning," 13–15 h "overnight," and 7 days "week"). Subjects who consumed less than 15 mg of caffeine per day formed a fourth experimental group ("nonconsumers"). All the subjects attended one test session per week for 3 weeks and completed one of three conditions in each test session: 250 or 70 mg of caffeine BP (Courtin and Warner, Ltd., E. Sussex) or a cornflour placebo administered in identical opaque capsules (Size 0; Qualicaps, England) to minimise expectation effects (13). Condition order was double-blind and counterbalanced across the three test sessions. Subjects recorded daily fluid intake and mood for 5 consecutive weekdays 2 weeks prestudy and on 4 weekdays in the interval between each of the weekly test sessions.

Procedure

Subjects in the "morning" group (12 males, 7 females) were asked to abstain from consuming tea, coffee, cola, and solid or drinking chocolate for 90 min before the test session. These subjects were asked to consume a capsule containing 70 mg of caffeine 90 min before the test session to ensure that they had abstained from caffeine for exactly 90 min presession. Subjects in the "overnight" group (9 males, 8 females) were asked to not consume tea/coffee/cola/chocolate from 2000 h the evening before the test session until the session had been completed. The subjects in the "week" group (9 males, 9 females) were asked to replace their usual coffee and tea with the "formula" coffee and tea (Gold Blend Decaffeinated coffee, Nestle, UK) provided by the experimenters and to avoid chocolate (solid and drinking) and cola drinks throughout the entire study. Nonconsumers (10 males, 8 females) were asked to refrain from consuming tea, coffee, chocolate, and cola soft drinks for the entire study. All of the subjects were asked to abstain from alcohol the evening before each test session. The subjects were asked to inform the experimenters if they had taken any medication during the study. All subjects completed a practice run on the cognitive performance tasks a week before the first test session and completed the Eysenck Personality Questionnaire and Impulsivity Venturesome and Empathy Personality Inventory [EPQ, IVE (11)].

Drink diaries and mood questionnaires were completed on weekdays throughout the study; each diary listed the instructions appropriate for that day on the front cover (e.g., "Please do not drink alcohol, coffee, tea or drink/eat chocolate from 8.00 pm this evening until your session tomorrow" for the overnight group the day before their test session day). Direct monitoring of adherence to these instructions was not feasible; however, saliva samples were collected on each test day, which we implied would be used to check compliance, and interviews with the subjects and analysis of their drink diaries indicated that compliance was excellent. A 19-item mood rating scale (32) was attached to each drink diary to be completed at the end of the evening to indicate how they had felt during the day. The self-rating mood questionnaire was developed from the Profile of Mood States bipolar form (POMS-BI) (28) and the short from of the Activation-Deactivation Adjective Checklist (AD ACL) (43). It consisted of eight adjectives describing "positive" moods and eight describing "negative" moods that headed line scales anchored with the words "not at all" (i.e., 0 mm) and "extremely" (100 mm), respectively. For each of the four mood states characterised by POMS-BI two adjectives were included in the questionnaire as follows: friendly, angry (Agreeable–Hostile scale); cheerful, dejected (Elated–Depressed); confident, uncertain (Confident–Unsure); clearheaded, muddled (Clearheaded–Confused). The adjectives calm, placid, jittery, and tense described the Composed–Anxious scale (POMS-BI) (28) and the Calmness/Tension scales (AD ACL) (43), whereas the adjectives energetic, lively, drowsy, and tired described the Energy–Tiredness scales [(POMS-BI) (28) and (AD ACL) (43)]. Additional line scales were added for the assessment of headache, a recognised symptom of caffeine withdrawal (17,20,22), and hunger and thirst (35). The mood ratings were measured in millimetres from the "not at all" anchored end of the 100-mm scales. Baseline drink intake and mood were also recorded for 5 consecutive weekdays prestudy.

Session Procedure

The test sessions were held on weekday mornings, between 0900 and 1230, at the Institute of Food Research. The sessions lasted for approximately 90 min (see Fig. 1 for test session task schedule), with eight subjects being tested simultaneously in individual, soundproof testing booths and reading in a meeting room during the rest period.

Subjects were requested to complete the mood scales during the test session according to "how you feel at the moment." During the tapping task (Tap), subjects alternatively pressed the 1 and 2 keys of a Viglen 386 personal computer keyboard at speed until 300 taps had been made (five blocks of 60 taps, total duration approx 2 min). A simple reaction time (SRT) task involved subjects pressing the space bar at speed after an asterisk appeared on the screen (100 trials lasting approx. 6 min). The SRT and Tap tasks were programmed using the Micro Experimental Laboratory software package (Psychology Software Tools Inc., Pittsburgh, PA). Hand steadiness (Stead) was tested by the subjects inserting a stylus of 1.59 mm diameter into holes measuring 3.96, 3.18, 2.76, 2.36, and 1.98 mm in diameter (32011 Steadiness Tester, Lafayette Instrument Company, IN). The subjects were asked to hold the needle in each hole (largest to smallest) for 10 s while avoiding contact between the stylus and the side of each hole. If contact was made a buzzer sounded, and the contact duration was recorded.

Statistical Methods

Caffeine intake, scores on the personality inventories (EPQ and IVE), and baseline mood ratings (i.e., those made on 5 consecutive weekdays approximately 2 weeks prestudy) were compared across group (i.e., morning, overnight, week, or nonconsumers) by one-way analysis of variance (ANOVA). Mood ratings made on 4 weekdays between each of the three study test sessions were averaged across the first and second and then the third and fourth days to compare with baseline moods by ANOVA (day within-subjects variable, i.e., baseline and first and second or third and fourth days for 3 weeks of the study; group between-subjects variable). Mood and performance data precapsule (t −20, Fig. 1) were compared across group by one-way ANOVA. Mood ratings and performance scores completed 45 min after administration of caffeine or placebo (t 45, Fig. 1) were compared by repeated-measures ANOVA across condition (i.e., placebo, 70 mg or 250 mg of caffeine) as a within-subject measure and group as a between-subject measure. Precapsule ratings/scores (t −20, Fig. 1) were used as a covariate for this analysis.

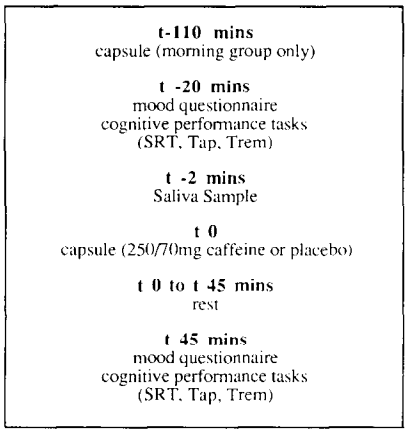

FIG. 1. Diagram of the session procedure used.

RESULTS

Of the 72 subjects who completed the baseline period, two males in the morning group and two females and a male from the overnight and 7-day groups, respectively, did not complete the experiment. Analysis of the data from the remaining 67 subjects was performed. There was no significant difference in baseline caffeine intake between the morning (255.4 ± 31 mg/day), overnight (249.2 ± 15 mg/day), and week groups (250.1 ± 20 mg/day), but there was the expected difference in baseline caffeine intake, $F(1, 63) = 132.9, p < 0.00$, between these three groups and the nonconsumers (average consumption = 2.8 ± 1 mg/day). The three groups of caffeine consumers (morning, overnight, and week) did not differ in any of the dimensions measured by the EPQ and IVE personality assessments, and the values from these groups were averaged and compared to the nonconsumers. Caffeine consumers had higher values on the addiction [consumers = 4.6 ± 1.5, nonconsumers = 3.5 ± 1.4; $F(1, 60) = 6.2, p < 0.02$], extroversion [consumers = 17.6 ± 4.0, nonconsumers = 14.8 ± 4.9; $F(1, 60) = 5.4, p < 0.05$], and impulsivity [consumers = 9.3 ± 3.9, nonconsumers = 6.2 ± 3.5; $F(1, 60) = 7.7, p < 0.01$] dimensions and lower scores on the lie factor [consumers = 5.3 ± 13.3, nonconsumers = 7.9 ± 2.9; $F(1, 60) = 7.6, p < 0.01$]. It should be noted that a positive response to questions such as "Are all your habits good and desirable ones?" and "Do you always practice what you preach?" add to the lie factor score but could equally be considered to be questions of self-discipline. The personality variables of criminality, empathy, neuroticism, psychoticism, and venturesome were not related to caffeine consumption.

Chronic Effects of Caffeine Withdrawal

Baseline mood ratings across the three caffeine consumer groups were not found to be significantly different (all $p > 0.05$). Ratings of these groups were then averaged and compared to the nonconsumers for this baseline period, and no differences in moods scores could be detected (all $p > 0.05$).

Headache ratings for the week group were significantly higher (Fig. 2) whereas ratings of cheerful were lower (Fig. 2) throughout the study compared to the prestudy baseline (baseline headache ratings: morning, 17.3 ± 19.4; overnight, 21.8 ± 18.2; week, 16.1 ± 13.1; nonconsumer, 16.0 ± 14.0; and cheerful: morning, 62.9 ± 10.8; overnight, 56.3 ± 12.2; week, 54.8 ± 14.1; nonconsumer, 53.4 ± 17.0). There was a trend for subjects in the week group to become less tired as the study progressed; indeed, their tired ratings on the two days prior to the final test session were significantly lower (40.7 ± 4.9) than baseline (52.6 ± 4.5, $p < 0.05$, data not shown). Comparison of the other between-session mood ratings with baseline ratings did not reveal any significant changes from baseline (all $p > 0.05$).

Acute Effects of Caffeine Withdrawal

Mood changes. As expected, there was no significant effect of test session on precapsule mood ratings (t −20, Fig. 1, all $p > 0.05$). Precapsule mood ratings for the three test sessions were averaged to test for the effects of acute caffeine absti-

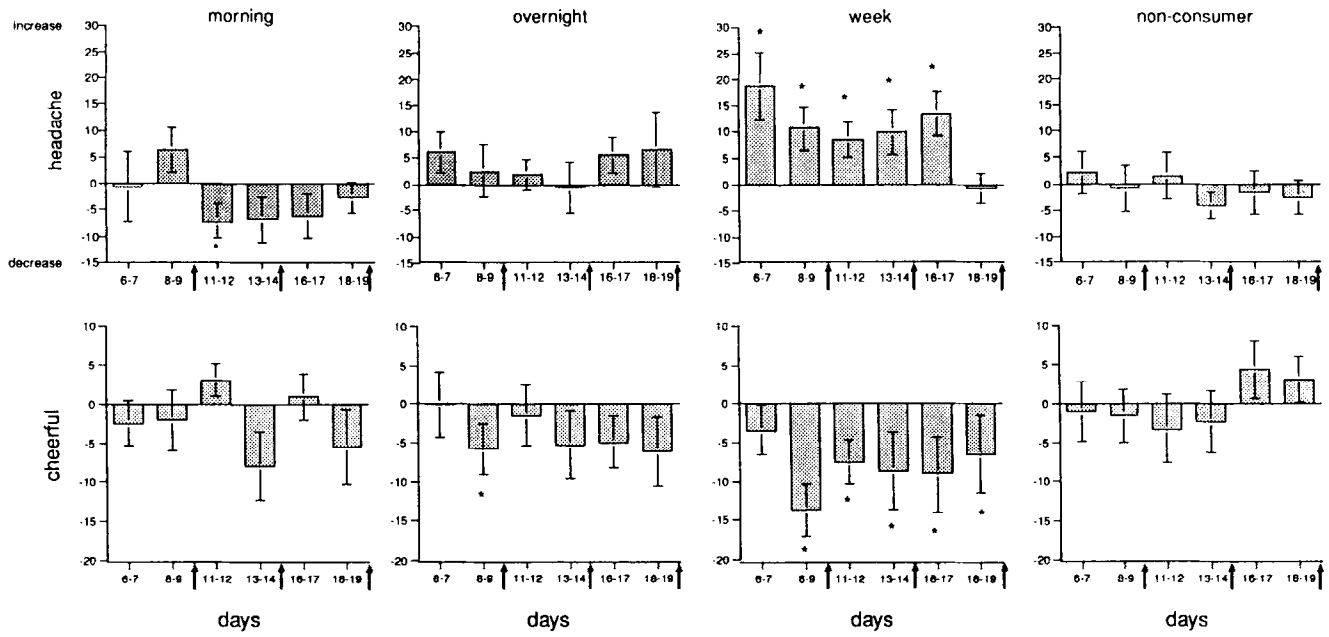

FIG. 2. Chronic effects of caffeine withdrawal on mood ratings of headache and cheerful across experimental days. Daily mood ratings relative to baseline mood ratings made over 5 days prestudy (study day − baseline). Means and SEMs are plotted. ↑ Session days. *Mood rating different from baseline ($p < 0.05$).

nence on mood. Both the overnight and the week groups had higher ratings of headache, $F(3, 63) = 2.7, p = 0.05$ (Fig. 3a) and lower ratings of clearheaded, $F(3, 61) = 2.1, p = 0.10$ (Fig. 3b), cheerful, $F(3, 61) = 2.4, p = 0.08$ (Fig. 3c), and friendly, $F(3, 61) = 4.1, p = 0.01$ (Fig. 3d), the morning of the test session. In addition, overnight abstinence from caffeine resulted in higher ratings of angry, $F(3, 61) = 2.6, p = 0.06$ (Fig. 3e), dejected, $F(3, 61) = 2.3, p = 0.08$ (Fig. 3f), tired, $F(3, 61) = 2.1, p = 0.10$ (Fig. 3g), and drowsy, $F(3, 61) = 2.7, p = 0.05$ (Fig. 3h), the following morning.

It was hypothesized that the lowered ratings of clearheaded, cheerful and friendly could be the result of the subjects experiencing a headache and that, similarly, angry, dejected, and drowsy ratings could be explained by the variance in tired ratings. Headache was found by ANCOVA to account for changes in clearheaded ratings, $F(3, 62) = 1.7, p = 0.2$, but not cheerful, $F(3, 62) = 2.5, p = 0.07$, or friendly ratings, $F(3, 62) = 4.1, p = 0.01$. Tired ratings, by ANCOVA, accounted for the differences found in angry, $F(3, 62) = 0.9, p = 0.4$, dejected, $F(3, 62) = 0.8, p = 0.5$, and drowsy ratings, $F(3, 62) = 0.6, p = 0.6$. Therefore, the primary symptoms of overnight caffeine withdrawal and withdrawal for 7 or more days can be explained by an increase in headache and decrease in cheerful and friendly moods. In addition, overnight withdrawal resulted in an increase in tiredness.

Performance. SRT and intertap interval (Tap) were recorded in milliseconds and Stead was measured as the cumulative contact time (s) across the five holes. Due to computer error there were fewer complete data sets available for analysis of the effects of caffeine withdrawal on performance. The SRT analysis was performed on 55 subjects (15, 14, 13, and 13 in the week, morning, overnight, and nonconsumers groups, respectively), Tap data were from 54 subjects (13, 14, 14, and 14) and Stead from 62 subjects (17, 16, 14, and 15). Precapsule SRT, Stead, and Tap scores ($t - 20$, Fig. 1) did not vary across test session ($p > 0.05$) and so these data were averaged for each experimental group. One-way ANOVA across the four experimental groups showed no group differences ($p > 0.10$) on performance of either the SRT, $F(3, 51) = 0.77$, Stead, $F(3, 58) = 0.88$, or Tap, $F(3, 50) = 0.70$, tasks.

Acute Effects of Caffeine Administration

Mood changes. Rated headache and tiredness were higher after the placebo capsule [headache, $F_{COND}(2, 123) = 2.69$, $p = 0.07$; tired, $F_{COND}(2, 121) = 2.68$, $p = 0.07$] (Fig. 4) whereas jittery ratings were higher after both doses of caffeine, $F_{COND}(2, 123) = 2.91, p = 0.06$ (Fig. 4), irrespective of experimental group [headache, $F_{COND \times GROUP}(6, 123) = 0.54$, $p = 0.78$; tired, $F_{COND \times GROUP}(6, 121) = 0.50$, $p = 0.78$; jittery, $F_{COND \times GROUP}(6, 123) = 1.67, p = 0.13$].

Performance changes. Hand steadiness (Fig. 5) was decreased by caffeine in a dose-related manner, $F_{COND}(2, 117) = 4.81, p = 0.01$, irrespective of the caffeine intake/withdrawal of the subjects, $F_{COND \times GROUP}(6, 117) = 1.39$. SRT (Fig. 5) was fastest after 70 mg of caffeine, $F_{COND}(2, 117) = 2.54, p = 0.08$; this difference was also found to be unrelated to the caffeine intake/withdrawal of the subjects, $F_{COND \times GROUP}(6, 117) = 0.60$. Tap performance was not found to be affected by caffeine for any of the groups [$F_{COND}(2, 101) = 1.58$; $F_{COND \times GROUP}(6, 101) = 0.12$].

On completion of the study, the subjects were fully debriefed on the design and purposes of the study. They were then asked to guess the test sessions in which they were given the high (250 mg) and low (70 mg) doses of caffeine and in which they had the placebo capsule. Complete data were collected from 63 subjects. Chi-square analysis of the data revealed that subjects distinguished both the high, $\chi^2(2) =$

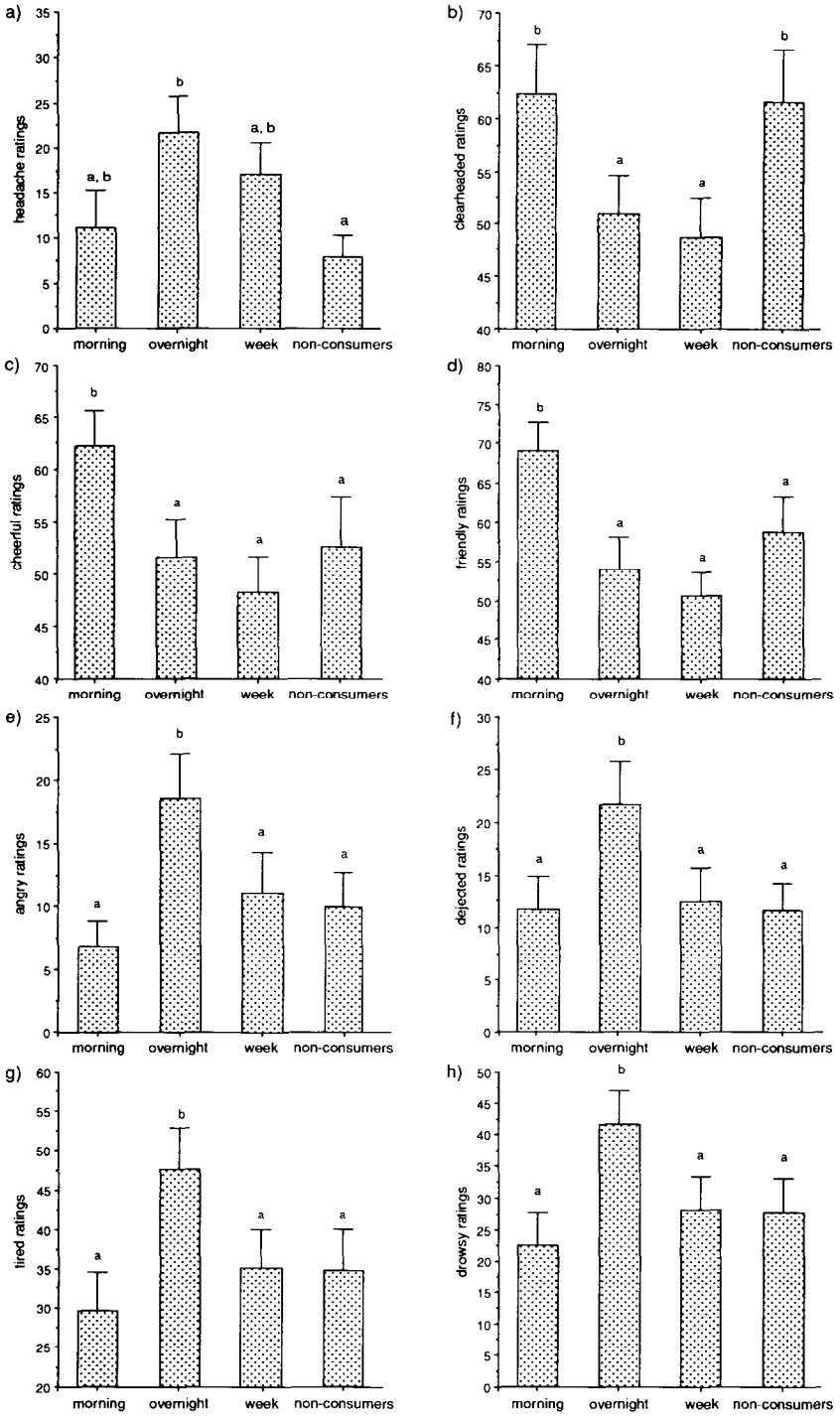

FIG. 3. Acute effects of caffeine withdrawal on mood ratings. Precapsule ratings of headache (a), clearheaded (b), cheerful (c), friendly (d), angry (e), dejected (f), tired (g), and drowsy (h) for subjects in each of the experimental groups (morning, overnight, week, and nonconsumer) are shown. Groups not sharing a letter in common are signficantly different ($p < 0.05$, least significant difference test). Means and SEMs are plotted.

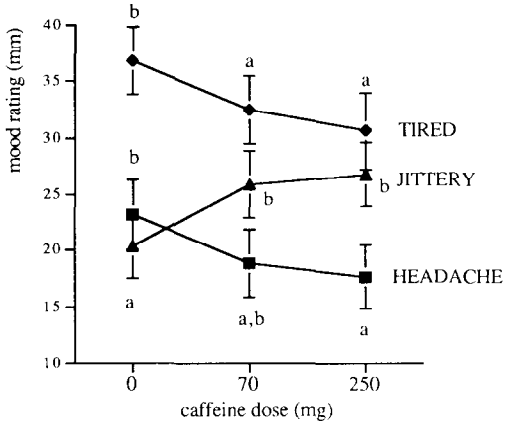

FIG. 4. Acute effects of caffeine consumption on mood ratings of tired, jittery, and headache of all subjects (n = 67). Within each mood descriptor means not sharing a letter in common are signficantly different ($p < 0.05$). Means and SEMs are plotted.

4.56, $p < 0.1$, and low, $\chi^2(2) = 4.65$, $p < 0.1$, doses of caffeine somewhat above chance, but not the placebo capsule, $\chi^2(2) = 2.67$, p = NS, which was confused with the low dose of caffeine by almost a third of the subjects (see Table 1 for frequencies). When trying to decide, the subjects often stated that they thought a headache was a symptom associated with the high dose of caffeine.

DISCUSSION

This study provided a unique comparison of the mood and performance effects of caffeine deprivation (either 90 min, overnight, or at least 7 days) and ingestion (70 and 250 mg) in young adults who were either moderate caffeine consumers or nonconsumers. Overnight caffeine deprivation had the most profound effect on mood, producing dysphoric symptoms characteristic of caffeine withdrawal that were reduced but still present after longer-term abstinence. Regular consumers who had caffeine in the morning of the test session reported none of the symptoms of caffeine withdrawal and their rated moods were not, on the whole, different from those of nonconsumers of caffeine. The tiredness experienced after overnight caffeine deprivation was increasingly less evident after 7 or more days. This is consistent with previous findings and indicates that tiredness and lethargy are transient symptoms of caffeine withdrawal (6). Although withdrawal headaches have been reported by high-caffeine consumers (average of 12 cups of coffee per day) up to 17 days after the cessation of caffeine intake (18), the higher headache ratings found here were amongst moderate caffeine consumers (three to four cups per day) and lasted for up to 21 days. Caffeine withdrawal headaches can be debilitating (9), and it has been suggested that caffeine withdrawal (but not caffeine abuse) should be added to the DSM and ICD psychiatric disorder classification systems (21).

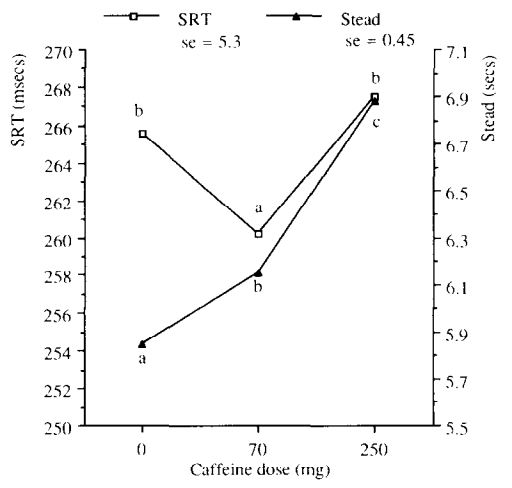

FIG. 5. Acute effects of caffeine consumption on performance of all subjects (SRT n = 55, Stead n = 62). SRT is measured in milliseconds, where a larger value indicates a longer reaction time, and Stead is measured in seconds, where a larger value indicates increased contact time. Within each performance measure means not sharing a letter in common are signficantly different ($p < 0.05$). Means and averaged SEMs are shown.

TABLE 1

POSTSTUDY SUBJECT ESTIMATES OF CAPSULE RECEIVED AND THE ACTUAL CAPSULE RECEIVED ON EACH OF THREE SESSIONS WHERE CAPSULE ORDER WAS COUNTERBALANCED AND CAPSULE ADMINISTRATION WAS DOUBLE-BLIND (n = 63)

	Guessed Capsule		
Actual Capsule	Placebo	Caffeine (70 mg)	Caffeine (250 mg)
Placebo	27	19	17
Caffeine (70 mg)	16	29	18
Caffeine (250 mg)	17	17	29

Performances on the tapping, simple reaction time, and hand steadiness tasks were not found to be affected by length of caffeine deprivation (6). Caffeine did not affect the tapping performance of either the consumers or nonconsumers after the low (70 mg) or high (250) doses. A study of individuals with a wide range of caffeine intakes found that high consumers over the age of 35 did show enhanced performance (23), suggesting the absence of an effect on tapping found here could have been due to the ages of the subjects who took part in this study (18–23 years). Further research is needed to investigate if older people are more susceptible to the performance-improving effects of caffeine and whether this is a function of the number of years that these subjects have consumed caffeinated drinks (presumably more in older subjects), or if old age itself lowers performance on these tasks, which is then enhanced by caffeine. It may be that a longer, more tedious task battery than that used in the present study would be more sensitive to caffeine deprivation in young adult consumers.

Caffeine (250 and 70 mg) consumed during the test session prevented/alleviated headaches in both regular consumers and nonconsumers. These doses, therefore, protected against the occurrence of headache that both caffeine consumers and nonconsumers can develop during an intensive testing session. When subjects were asked to guess the sessions on which they they had been given each of the three capsules they often associated the experience of a headache with the high-caffeine

condition, even though both caffeine doses were actually found to be effective in lowering headache ratings. In a questionnaire study of coffee and tea drinkers, only 10% of coffee drinkers and 6% of tea drinkers attributed a headache to missing their morning tea or coffee drink (37). In experimental investigations of caffeine withdrawal, an increase in rated headache is one of the most reliable findings (20,30), this withdrawal symptom being alleviated by the drug itself (17). It is intriguing that the subjects in this study made the opposite association, that is, headache was thought to be a symptom of caffeine ingestion. It could be that both relatively low and high levels of blood caffeine will result in regular consumers experiencing a headache, and that the subjects in this study considered that the high dose (250 mg) would produce a headache whereas the caffeine content of their normal caffeinated drink would not. This would suggest that caffeine consumers would have to regulate their blood caffeine levels, through caffeine intake, with some care to avoid such dysphoric states.

Caffeine increased jitteriness and decreased tiredness across all subject groups. These effects were, therefore, not dependent on regular caffeine intake or recent caffeine withdrawal. The alerting effects of caffeine have been widely reported amongst consumers after varying lengths of deprivation (7,38,40) and also amongst nonconsumers (33). The alerting effects of caffeine were evident 2.5 h after ingestion of a 70-mg dose (the approximate amount in a cup of instant coffee). When caffeine was not consumed during the session then both caffeine consumers and nonconsumers experienced lower lively and higher tiredness ratings.

Clear personality differences were found between caffeine consumers and nonconsumers along the dimensions of extroversion and impulsivity, replicating previous findings (29). Yet no differences were found between these groups in the effect of caffeine on rated mood. One possible explanation is that the mood measures were not sensitive to the differences between these self-selected groups. Mood scales measure mood state relative to what that individual considers to be "extreme," so actual mood states experienced by two individuals could be very different yet scored identically. Direct comparisons between these self-selected populations should, therefore, be made with caution (23).

Acute caffeine intake affected the performance of the withdrawn consumers, nonwithdrawn consumers, and nonconsumers similarly; hand steadiness decreased as caffeine dose increased and a possible optimum dose of 70 mg of caffeine (equivalent to a cup of instant coffee) was found to enhance performance on the simple reaction time task. The decrease in hand steadiness found with increasing doses of caffeine paralleled the increase in rated jitteriness. Jittery ratings here could have described an increase in muscle tremors rather than an increase in anxiety (8,27), as the subject's attention was drawn to their "shakiness" by the audio feedback during the hand steadiness task.

The finding that the caffeine doses used affected the performance and mood of consumers (both deprived and nondeprived) and nonconsumers similarly was surprising. This was especially puzzling as there were clear differences in the mood states prior to capsule ingestion. There are two possible explanations for this. The nonconsumers who took part in this study could have been exconsumers who, although clearly not suffering from the chronic effects of caffeine withdrawal, might still have been sensitive to the effects of caffeine. Howver, as the average age of the subjects was low (<24 years) it would be unlikely that they had been regular caffeine consumers for very many years prior to abstaining. A second explanation is based on the reported stimulant effect of caffeine when performance and/or mood has been lowered by other factors such as boredom (25,31,44), age (42), the post-lunch dip (41), or menstruation (2). Caffeine is known to stimulate many parts of the central nervous system, which makes it unlikely that a single arousal mechanism is affected by caffeine. Although the symptoms of caffeine withdrawal are well defined and known to be alleviated by caffeine, caffeine ingestion may increase arousal if lowered by other factors. Factors that could have initially reduced arousal during this study were the length and monotony of the testing session (1.5 h duration, most tests repeated twice). Caffeine in this instance could have increased the arousal of all subjects during the session, irrespective of prior caffeine consumption or caffeine deprivation.

The findings of this study support the view that the negative effects experienced after overnight and longer-term caffeine deprivation play a significant role in influencing consumption of caffeine-containing drinks (32,36). The moderate dose of caffeine (70 mg $\approx$ a cup of instant coffee) was found to reduce tiredness and improve performance, whereas the higher dose (250 mg) reduced hand steadiness and increased reported jitteriness in addition to a therapeutic effect on reported headache. Further investigation is needed to identify why this therapeutic property of caffeine, which is used by producers of headache remedies, was not widely recognised by the regular caffeine consumers who took part in this study. Therefore, it would appear that to avoid the dysphoric symptoms resulting from both under- and overconsumption, regular caffeine consumers would have to regulate their caffeine intake fairly precisely.

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