PERGAMON

Behaviour Research and Therapy 37 (1999) 869–879

BEHAVIOUR RESEARCH AND THERAPY

www.elsevier.com/locate/brat

Shorter communication

Caffeine effects on mood and memory

Rachel S. Herz *

Monell Chemical Senses Center, 3500 Market St., Philadelphia, PA 19104, USA

Abstract

The purpose of the present research was to assess whether a psychoactive dose of caffeine would have differential affects on the mood dimensions of arousal versus feelings of pleasantness and whether these mood alterations would influence memory either by (1) the experience of arousal at learning and/or (2) altered and congruent mood states at learning and recall. To address these questions, the administration of 5 mg/kg caffeine or placebo at learning and retrieval sessions was manipulated and subjects' mood was evaluated by several different self-report measures. Sixteen words were incidentally studied during the learning session and memory was evaluated by the number of words correctly recalled at the retrieval session two days later. Results revealed that caffeine reliably increased arousal, but did not affect any emotion dimensions related to feelings of pleasure. Subjects who received caffeine at learning and retrieval were also in equivalent mood states at both sessions. Moreover, caffeine did not produce any effects on memory; thus, neither hypothesis concerning the influence of arousal on memory was supported. These data show that caffeine is a useful method for manipulating arousal in the laboratory without influencing feelings of pleasantness or learning and memory performance.

Keywords: Caffeine; Mood; Arousal; Memory

1. Introduction

A major theoretical position in emotion research conceptualizes mood as comprised of two orthogonal dimensions of affect: pleasure–displeasure, which is the valence of one's feelings, and arousal–sleepiness, which is the physical energy level that one feels (Russell, 1980; Tellegen, 1985; Lang, Bradley & Cuthbert, 1990). Thus, for example, the feeling of being insulted might be described as a state of moderately unpleasant feelings and moderate arousal.

* Tel.: +1-215-898-5022; fax: +1-215-898-2084; e-mail: herz@pobox.upenn.edu

0005-7967/99/$ - see front matter
PII: S0005-7967(98)00190-9

Recently, Russell, Weiss, and Mendelsohn (1989) developed a direct and simple tool for measuring affect in this way (the Mood Grid, see Fig. 1), which has been shown to be both experimentally and clinically valid and useful. This matrix view of emotion is also parsimonious in that two primary dimensions can define the spectrum of emotional behavior.

An issue of experimental and theoretical utility is whether one can separate the experience of arousal from the feeling of pleasantness in an experimental mood manipulation. That is, can one leave pleasantness stable and vary arousal level, and if so what effects on cognition might this produce? The primary aim of the present research was directed at this question.

Arousal has been shown to have positive influences on learning and memory in various situations. The general finding is that items associated with high emotional arousal at encoding show better long term retention (see Bradley, Greenwald, Petry & Lang, 1992). A demonstration that physical arousal can enhance memory was also recently reported by Nielson, Radtke, and Jensen (1996) who showed that squeezing a dynamometer (muscle tension induced arousal) during learning led to memory enhancements in a delayed recall test. However, there are also a number of studies which have failed to show laboratory induced arousal effects on memory (e.g. Herz, 1997), or which show that arousal has adverse effects on memory (see Heuer & Reisberg, 1992 for a review).

At least one reason for inconsistent laboratory results has to do with laboratory methods. The most simple issue is that in many laboratory inductions subjects must suspend disbelief and comply with the ruse that the experimenter has contrived to induce the arousal. Given that many subjects are savvy of such psychological methods it is often difficult to produce a state whereby a naturalistic level of arousal is achieved. A good solution to this problem would be to eliminate dependence on subjects' belief in the manipulations and rely on direct (e.g.

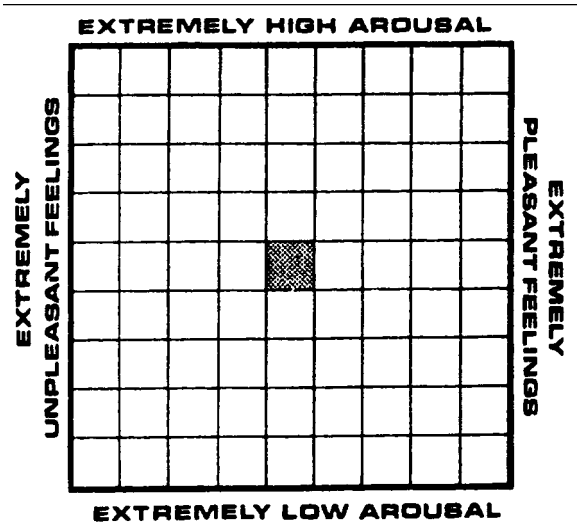

Fig. 1. The Mood Grid adapted by Eich and Metcalfe (1989) from Russell et al. (1989). Subjects place a single mark on the matrix to indicate their current mood comprised of their feelings of pleasantness (horizontal axis) and arousal (vertical axis).

pharmacological) methods to induce mood change. Thus, a secondary aim of the present study was to explore a safe, pharmacological mood manipulation that could be easily administered in the laboratory.

Of the many self-administered drugs, caffeine is the most widely consumed psychoactive substance (Gilbert, 1984). Numerous studies have shown that caffeine produces noticeable effects on mood. Variously, caffeine has been found to increase self-rated happiness, well-being, calmness and alertness (Zwyghuizen-Doorenbos, Roehrs, Lipschutz, Timms & Roth, 1990), or anger (Roache & Griffiths, 1987), anxiety and nervousness depending on the dose administered (Chait, 1992; Rush, Sullivan & Griffiths, 1995). Typically, low doses (20–200 mg) produce positive feelings (e.g. heightened energy, ability to concentrate, liking) (Lieberman, Wurtman, Emde & Coviella, 1987), while higher doses (200–800 mg) produce feelings of anxiety, nervousness and jitteriness that increase in severity with dose (Evans & Griffiths, 1991). Importantly, these behavioral and mood effects are not restricted to fatigued subjects and are observed in caffeine deprived (Griffiths & Mumford, 1995), as well as non-abstaining individuals (Warburton, 1995).

Notably, pharmacological agents that induce mood change can also have dissociative effects on memory. For example, alcohol can foster feelings of elation, relaxation and subjective 'high' (Persson, Sjoberg & Svensson, 1980). Accordingly, subjects who were exposed to a list of words while under the influence of alcohol recalled more words when later tested under a similar state of intoxication than did subjects who learned while inebriated but were tested when sober (Eich & Birnbaum, 1982). Based on findings such as these, it has been argued that drugs achieve their dissociative effects on memory by virtue of their effects on mood (Bower, 1981; Eich & Birnbaum, 1988). Mood-dependent memory is evidenced by superior recall for to-be-remembered items among subjects who are in the same moods at learning and retrieval (happy–happy, sad–sad) compared to subjects whose moods at learning and retrieval mismatch (happy–sad, sad–happy) (Bower, 1981; Eich & Metcalfe, 1989).

Following from the literature pertaining to arousal/mood and memory two hypotheses regarding caffeine's effect on cognition are possible: (1) if a specific dose of caffeine induces arousal during learning it may facilitate later memory for the learned items, independent of mood at recall and (2) if a specific dose of caffeine induces mood change it may produce dissociative effects on memory that are dependent on that mood (pharmacological state) being reinstated during recall, i.e. state-dependent memory (SDM) effects.

The purpose of the present research was to assess whether a psychoactive dose of caffeine (5 mg/kg; equivalent to 350 mg in a 70 kg person) would have differential affects on the mood dimensions of arousal and feelings of pleasantness and whether these mood alterations would influence memory either by (1) the experience of arousal at learning alone or (2) altered and congruent mood states at learning and recall. This was done by manipulating the administration of caffeine or placebo at the learning and retrieval sessions and concomitantly assessing the mood that was produced by several different self-report measures. From the outcomes of this study an assessment of the experimental utility of using caffeine to manipulate mood was sought.

2. Method

2.1. Experimental design

A 2 × 2 × 2 mixed factorial design with sex, drug dose at learning (placebo = 0, 5.00 mg/kg) × drug dose at retrieval (placebo = 0, 5.00 mg/kg) was followed. The study was conducted double-blind.

2.2. Subjects

To achieve a power of 0.70 (Stevens, 1990) with an effect size of 0.44, 12 subjects (6 males, 6 females) were randomly assigned to the four treatment conditions ($N = 48$). Power was calculated based on previously obtained effect sizes (Herz, 1997, 1998). Subjects were volunteer undergraduates from the University of Pennsylvania (mean age = 21.47, mean weight = 71.6 kg) and were paid for their participation. Initial contact with volunteers was made through an extensive telephone screening interview. Volunteers were excluded if they reported histories of psychiatric or physical disorders that might be compromised by caffeine intake. Potential subjects were also assessed for their daily caffeine consumption disguised in a series of general dietary questions. Only self-reported low-moderate daily caffeine users (50–150 mg/day) were chosen. Mean daily caffeine consumption of subjects prior to the experiment was 112.5 mg (equivalent to approximately one cup of coffee or two colas per day).

2.3. Dietary restrictions

Participants were asked to refrain from all food and beverages other than water from 20.00 the night before each of their scheduled sessions. To control for diurnal variations in arousal and variation in fast duration, all subjects were tested between 08.00 and 10.00 a.m. (Monday–Friday). At the end of each session, crackers, cookies and juice were provided and subjects were encouraged to stay with the experimenter until they felt comfortable to leave. No negative side-effects were reported by subjects in any condition.

2.4. Measures

2.4.1. Caffeine dose, preparation and administration

The caffeine dose chosen for this research (5.00 mg/kg), was selected on the basis of previous research describing dose effects on mood (Evans & Griffiths, 1991, 1992; Griffiths, 1996, personal communication). Caffeine and placebo capsules (size 0, opaque hard gelatin capsules) that looked identical were made from combinations of anhydrous caffeine (USP) and powdered lactose. When subjects first arrived for the learning session they were weighed to verify that their weight corresponded to what they had reported (±5 lb). If their weight fell outside of this range they were re-scheduled and new capsules were prepared accordingly. Regardless of the experimental condition, all subjects received two capsules at each session which they orally ingested with 100 ml of water.

2.4.2. Mood and subjective state assessments

Mood was assessed by the Profile of Mood States (POMS, McNair, Lorr & Droppleman, 1971) and the Mood Grid (Eich & Metcalfe, 1989; Russell et al., 1989). Both of these mood measures are effective at determining current affective state, as well as dose dependent mood changes induced by caffeine (Chait & Griffiths, 1983; Griffiths & Woodson, 1988; Evans & Griffiths, 1991, 1992; Russell, 1996, personal communication). The Mood Grid has also been used to demonstrate the emotional states that determine mood-dependent memory (Eich & Metcalfe, 1989; Eich, 1995). The Mood Grid is a 9×9 matrix (see Fig. 1). The horizontal axis of the matrix corresponds to varying degrees of pleasure, ranging from extremely unpleasant feelings on the far left to extremely pleasant feelings on the far right. The vertical axis ranges from extremely high arousal at the top to extremely low arousal at the bottom. Subjects were asked to rate their current mood by placing an 'X' at the appropriate location on the matrix. The Mood Grid yields two scores that range for -4 to $+4$, one for pleasantness and one for arousal. For the POMS, seven empirically derived scales were scored in the 65-item version of the test: anger/hostility, confusion/bewilderment, depression/dejection, fatigue/inertia, friendliness, tension/anxiety and vigor/activity. Subjects rated each of the 65 adjectives on a 5-point scale from 'not at all' (0) to 'extremely' (4) on the basis of how they felt at the time they filled out the form. A 16-item 'Self Report Questionnaire' (SRQ) targeting psychic and somatic symptoms related to known effects of caffeine was also employed (Rush et al., 1995). Subjects used a 4 point scale (0 = not at all, 1 = a little, 2 = moderately, 3 = very much) to rate themselves on each of the following: (1) alert, (2) well-being, (3) desire to talk to people, (4) motivation to work, (5) concentration, (6) energy/active, (7) self confidence, (8) affection for loved ones, (9) energised/active, (10) headache, (11) irritable, (12) depressed, (13) anxious/nervous, (14) upset stomach, (15) trembling/shaky/jittery and (16) heart pounding. The higher the score, the stronger the effects of caffeine.

2.5. Procedure

2.5.1. Learning session

The experiment was described as an investigation of natural compounds that may enhance cognitive abilities. No explicit reference to caffeine was made, however, caffeine was listed on the consent form among 10 possible compounds. To legitimize the self-report measurements that were taken, it was explained that factors such as health and mood may influence mental performance and that various assessments of such would be taken throughout the experimental sessions. Subjects were then given instructions for using the Mood Grid and the POMS and the first ratings on these measures were obtained. Next, subjects received two capsules containing either placebo or 5.00 mg/kg caffeine. To ensure that peak caffeine metabolism would coincide with the incidental word learning task, approximately 45 min elapsed before the learning phase of the experiment began (Julien, 1995). During the pre-learning period, subjects watched an emotionally neutral National Geographic nature documentary (''Jewels of the Caribbean Sea'') for 40 min. Subjects were then escorted to the testing room (the same room was used at learning and retrieval) and the Mood Grid, POMS and SRQ were administered. The incidental word learning task was then conducted (Eich & Metcalfe, 1989). Subjects received a sheet listing 16 to-be-remembered words, and for each word they were

asked to write a few sentences describing an event that has happened to them that the word reminded them of. This task has been shown to be successful at elucidating dissociative memory effects in previous studies (Eich & Metcalfe, 1989; Eich, Macauley & Ryan, 1994; Eich, 1995; Herz, 1997a,b). When subjects were finished (≈20 min later) they were engaged in some verbal and numerical distractor tasks for approximately 10 min and then the Mood Grid, POMS and SRQ were given a final time. Before departing subjects were reminded of the eating and drinking restrictions and told to return to the laboratory in 48 hr for further testing.

2.5.2. Retrieval session

Two days elapsed between the learning and retrieval session. This retention interval was chosen to be commensurate with prior research involving similar learning and recall methods (Eich & Metcalfe, 1989; Eich et al., 1994; Eich, 1995; Herz, 1997a). At the start of the retrieval session, the Mood Grid and POMS were administered. Subjects then received two capsules containing either placebo or 5.00 mg/kg caffeine. 45 min elapsed before the memory test was given, so that plasma caffeine levels would be the same as they had been during learning. During the pre-test period, subjects watched another neutral National Geographic nature documentary for 40 min (''Australia's Improbable Animals''). Subjects were then escorted to the testing room, where they filled out another set of Mood Grid, POMS and SRQ questionnaires. Upon completing the second set of mood measures, subjects were given a surprise free recall test for the words that they had been exposed to at the learning session. Subjects were told to write down as many words as they could remember in any order, within 10 min. When the memory test was over, ratings on the Mood Grid, POMS and SRQ ratings were taken for a final time. Before departing subjects were questioned regarding any insights they may have had regarding the experimental hypotheses, and their experience of the drug. Four subjects suspected that they had received caffeine during at least one session, however, no subjects knew that there memory was going to be tested. Subjects were then fully debriefed and paid.

2.6. Data analyses

To assess the effects of caffeine versus placebo on mood at the learning session, 2×2 between subjects Analyses of Variance (ANOVA's), with subject sex and compound (caffeine, placebo) as the factors were performed on the arousal and pleasantness scales of the Mood Grid, seven sub-scales of the POMS and total SRQ scores at each time these measures were administered. To assess the effects of caffeine versus placebo on mood at the retrieval session, $2 \times 2 \times 2$ mixed design ANOVA's, treating subject sex as the between subjects factor and compound at learning (caffeine, placebo), compound at retrieval (caffeine, placebo) as the within subjects factors were performed on the sub-scales of each mood measure at the times they were administered. To assess whether subjects experienced the same mood at both the learning and retrieval sessions, paired-samples *t*-tests on the each of the mood measures were conducted for the four subject groups (placebo/placebo, caffeine/placebo, placebo/caffeine, caffeine/caffeine) with session (learning, retrieval) as the factor. Only scores from assessment time 2 (45 min post ingestion) were analyzed, as this was the critical time for testing the hypothesis that mood should be the same at learning and retrieval for SDM enhancements to

be observed. To assess the effect of caffeine and placebo ingestion at learning and retrieval on word recall, a $2 \times 2 \times 2$ between subjects ANOVA, with subject sex, compound at learning (caffeine, placebo) and compound at retrieval (caffeine, placebo) as the factors were performed on the number of words correctly remembered by each subject. For all statistical tests, effects were considered to be significant for $p < 0.05$.

3. Results

3.1. Mood effects

ANOVA revealed that a 5 mg/kg dose of caffeine reliably altered mood. Subjects who received caffeine during a session rated themselves as more *aroused* on the Mood Grid than subjects who did not. Mean caffeine = 1.42, mean placebo = −0.04, at learning, $F(1, 44) = 5.50$, $p < 0.01$; mean caffeine = 1.13, mean placebo = −0.54, at retrieval, $F(1, 40) = 12.58$, $p < 0.01$. No effects on the *pleasantness* dimension were observed. Analysis of the POMS data showed that *vigor/activity* and *fatigue/inertia* were similarly affected. Subjects who received caffeine during a session felt more vigorous and less fatigued than subjects who did not. *Vigor/activity*: mean caffeine = 13.0, mean placebo = 6.96, at learning, $F(1, 44) = 13.33$, $p < 0.01$; mean caffeine = 11.29, mean placebo = 7.54, at retrieval, $F(1, 40) = 4.87$, $p < 0.05$. None of the other POMS sub-scales were affected by treatment condition. Analysis of the SRQ scores showed that subjects rated themselves as significantly higher in caffeine-related symptoms if they had received caffeine at a session than if they had not. Mean caffeine = 19.46, mean placebo = 15.52, at learning, $F(1, 44) = 8.14$, $p < 0.01$; mean caffeine = 18.63, mean placebo = 13.79, at retrieval, $F(1, 40) = 14.93$, $p < 0.01$. No other effects or interactions with caffeine intake or subject sex were found.

To assess whether caffeine produced the same mood effects at both the learning and retrieval sessions, scores on the Mood Grid (*arousal* scale), POMS (*vigor/activity*, *fatigue/inertia*) and SRQ scales at the learning and retrieval sessions were compared using *t*-tests (see Tables 1–3).

Table 1
Mood grid *arousal* scores at learning versus retrieval (45 min post intake)

Group	Session	*N*	Mean	Standard error	*t*-statistic	Probability
0/0	learning	12	–0.17	0.46	1.29	0.22
0/0	retrieval	12	–0.75	0.46		
1/0	learning	12	1.00	0.41	**3.75**	**< 0.01**
1/0	retrieval	12	–0.33	0.48		
0/1	learning	12	0.83	0.34	**4.53**	**< 0.01**
0/1	retrieval	12	1.50	0.26		
1/1	learning	12	1.83	0.59	1.65	0.13
1/1	retrieval	12	0.75	0.55		

Group nomenclature: 0 = placebo intake; 1 = caffeine intake.

Table 2
POMS *vigor/activity* and *fatigue/inertia* scores at learning versus retrieval (45 min post intake)

Group	Session	*N*	Mean	Standard error	*t*-statistic	Probability
Vigor/activity						
0/0	learning	12	6.83	1.63	1.06	0.31
0/0	retrieval	12	5.75	1.62		
1/0	learning	12	14.75	1.56	**3.48**	**< 0.01**
1/0	retrieval	12	9.58	1.82		
0/1	learning	12	7.08	1.35	**3.37**	**< 0.01**
0/1	retrieval	12	12.67	1.95		
1/1	learning	12	14.83	1.82	**3.59**	**< 0.01**
1/1	retrieval	12	9.92	1.89		
Fatigue/inertia						
0/0	learning	12	11.17	2.17	0.09	0.93
0/0	retrieval	12	11.33	2.07		
1/0	learning	12	4.08	1.43	**3.17**	**< 0.01**
1/0	retrieval	12	7.17	2.06		
0/1	learning	12	10.00	1.92	**2.88**	**< 0.05**
0/1	retrieval	12	5.17	1.90		
1/1	learning	12	6.17	2.43	0.40	0.69
1/1	retrieval	12	7.08	1.74		

It was consistently found that subjects who received a different compound at learning and retrieval were in different moods. However, subjects who received the same compound at learning and retrieval did not differ in mood state, except that subjects who received caffeine at both sessions were higher in *vigor/activity* at the learning session than at the retrieval session. Thus, 5 mg/kg caffeine had a direct and reliable effect on affect that was restricted to the mood dimension of arousal.

Table 3
SRQ scores at learning versus retrieval (45 min post intake)

Group	Session	*N*	Mean	Standard error	*t*-statistic	Probability
0/0	learning	12	14.25	1.42	2.08	0.06
0/0	retrieval	12	12.21	1.68		
1/0	learning	12	17.83	1.30	**2.68**	**< 0.05**
1/0	retrieval	12	15.00	1.10		
0/1	learning	12	16.67	1.18	**2.34**	**< 0.05**
0/1	retrieval	12	18.83	1.26		
1/1	learning	12	20.83	1.21	1.75	0.11
1/1	retrieval	12	18.42	1.25		

Table 4
Effect on word recall as a function of treatment group

Group	*N*	Mean	Standard error
0/0	12	6.17	0.77
1/0	12	7.17	0.90
0/1	12	5.42	0.56
1/1	12	5.92	0.96

3.2. Memory effects

ANOVA on the number of words correctly recalled showed no effects or interactions due to any variable. That is, subjects correctly recalled the same number of words (overall mean = 6.2) regardless of whether they had received caffeine at one session, both sessions or neither sessions, $F(1, 40) = 0.10$ (see Table 4). Thus, a 5 mg/kg dose of caffeine neither produced any facilitation (or harm) to learning or memory, nor did it induce dissociative (SDM) effects.

4. Discussion

The primary aim of this study was to determine whether it was possible to dissociate the mood effects of arousal from pleasantness with a 5 mg/kg dose of caffeine and to assess what effects on cognition (memory) this might have. Two hypotheses were considered: (1) arousal experienced during learning would facilitate later recall, independent of mood at recall and/or (2) congruent arousal experienced at learning and memory would produce state-dependent facilitation of recall.

Results showed that 5 mg/kg caffeine induced reliable and reproducible changes in mood which were restricted to the arousal dimension of affect. The Mood Grid *arousal* scale and the POMS *vigor/activity* and *fatigue/inertia* scales were significantly altered by the dose of caffeine given. Thus caffeine can be used as a simple, reliable and safe laboratory method for manipulating the arousal aspect of mood. However, neither prediction regarding arousal effects on memory was supported. Irrespective of whether subjects received caffeine at both sessions, only one session, or not at all, the same number of words was accurately recalled. Thus, an arousing dose of caffeine did not impact on memory performance in any way. Mean word recall across groups was comparable to the number of words recalled in analogous paradigms (Eich et al., 1994; Herz, 1997a,b).

Despite the fact that various studies have shown that caffeine can influence cognitive performance, such as decrease reaction time (Kerr, Sherwood & Hindmarch, 1991), improve vigilance (Koelega, 1993) and intensify stimulus encoding (Lorist, Snel & Kok, 1994), the direct effects of caffeine in this type of cognitive paradigm have not been previously tested. The present results showed that a psychoactive dose of caffeine does not impair or enhance memory, even though it produced a significant mood elevation in arousal.

Several possible explanations for the present findings are offered. With regard to the arousal at encoding hypothesis, it may be that caffeine did not affect memory because it did not have the 'right' impact on mood during learning. It has been proposed that arousal elevation sufficient to alter memory encoding must impact on β-adrenergic systems (Nielson et al., 1996; Cahill & McGaugh, 1998) and 5 mg/kg caffeine may not have produced this effect.

With regard to the mood-congruent hypothesis, the present results did not support the prediction that drug-induced SDM effects are predicated upon the experience of altered and congruent mood states at learning and retrieval (Bower, 1981; Eich & Birnbaum, 1988). However, the caffeine dose used only affected arousal without influencing feelings of pleasure. This suggests that arousal alone may not be sufficient to mediate SDM and rather that more complex emotionality may be required. In a similar vein, the issue of whether emotional arousal or physical arousal was manipulated by 5 mg/kg caffeine should be discussed. Physical arousal is what one feels as a result of physical activity independent of emotional state and emotional arousal is what one feels dependent on emotional state. For example, after running on a treadmill one might feel moderately pleasant and highly aroused. Using the same descriptors, one might report the feeling produced by unexpectedly running into a friend you had lost contact. However, these two experiences may have quite different effects on encoding and memory. Perhaps 5 mg/kg caffeine induced physical arousal and not emotional arousal, and even though physical arousal can have positive effects on memory under certain conditions (Nielson et al., 1996), it may not be able to induce SDM effects. Further work investigating the singular and interactive effects of arousal and pleasure in assessments of physical versus emotional arousal mediating SDM are required.

In sum, the present results showed that a 5 mg/kg dose of caffeine reliably alters the arousal aspect of mood without affecting feelings of pleasantness. The arousal changes induced by caffeine were also the same at two different times of exposure and this dose of caffeine did not alter learning-memory performance. These findings are valuable for researchers who wish to induce arousal in the laboratory and who do not want the mood manipulation to confound cognitive effects.

Acknowledgements

This research was supported by a grant from the National Institute on Drug Abuse (RO3 DA10953-01). Thanks to Roland Griffiths for training and expert advice on all aspects of the caffeine methodology and to Alice Laneader for experimental assistance. R.S.H. is a Morley R. Kare Fellow.

References

Bower, G. H. (1981). Mood and memory. *American Psychologist, 36,* 129–148.

Bradley, M. M., Greenwald, M. K., Petry, M. C., & Lang, P. J. (1992). Remembering pictures: pleasure and arousal in memory. *Journal of Experimental Psychology: Learning, Memory and Cognition, 18,* 379–390.

Cahill, L., & McGaugh, J. L. (1998). Mechanisms of emotional arousal and lasting declarative memory. *Trends in Neuroscience, 21,* 294–299.

Chait, L. D. (1992). Factors influencing the subjective response to caffeine. *Behavioral Pharmacology, 3,* 219–228.
Chait, L. D., & Griffiths, R. R. (1983). Effects of caffeine on cigarette smoking and subjective response. *Clinical Pharmacology and Therapeutics, 34,* 612–622.
Eich, E. (1995). Mood as a mediator of place dependent memory. *Journal of Experimental Psychology: General, 124,* 293–308.
Eich, E., & Birnbaum, I. M. (1982). Repetition, cuing and state-dependent memory. *Memory and Cognition, 10,* 103–114.
Eich, E., & Birnbaum, I. M. (1988). On the relationship between the dissociative and affective properties of drugs. In G. M. Davies & D. M. Thomson (Eds.), *Memory in context: context in memory* (pp. 81–93). New York: John Wiley & Sons.
Eich, E., Macauley, D., & Ryan, L. (1994). Mood dependent memory for events of the personal past. *Journal of Experimental Psychology: General, 123,* 201–215.
Eich, E., & Metcalfe, J. (1989). Mood dependent memory for internal versus external events. *Journal of Experimental Psychology: Learning, Memory and Cognition, 15,* 443–455.
Evans, S. M., & Griffiths, R. R. (1992). Caffeine tolerance and choice in humans. *Psychopharmacology, 108,* 51–59.
Evans, S. M., & Griffiths, R. R. (1991). Dose related caffeine discrimination in normal volunteers: individual differences in subjective effects and self-reported cues. *Behavioral Pharmacology, 2,* 345–356.
Gilbert, R. M. (1984). Caffeine consumption. In G. A. Spiller (Ed.), *The methylxanthine beverages and foods: chemistry, consumption and health effects*. New York: Alan R. Liss.
Griffiths, R. R., & Mumford, G. K. (1995). Caffeine-a drug of abuse? In F. E. Bloom & D. J. Kupfer (Eds.), *Psychopharmacology: the fourth generation of progress* (pp. 1699–1713). New York: Raven Press.
Griffiths, R. R., & Woodson, P. P. (1988). Reinforcing effects of caffeine in humans. *Journal of Pharmacology and Experimental Therapeutics, 246,* 21–29.
Heuer, F., & Reisberg, D. (1992). Emotion, arousal and memory for detail. In S.-A. Christianson (Ed.), *Handbook of emotion and memory* (pp. 151–180). Hillsdale, NJ: Erlbaum.
Herz, R. S. (1997a). The effects of cue distinctiveness on odor-based context dependent memory. *Memory and Cognition, 25,* 375–380.
Herz, R. S. (1997b). Emotion experienced during encoding enhances odor retrieval cue effectiveness. *American Journal of Psychology, 110,* 489–505.
Julien, R. M. (1995). *A primer of drug action* (7th ed.). New York: W.H. Freeman and Co.
Kerr, J. S., Sherwood, N., & Hindmarch, I. (1991). Separate and combined effects of the social drugs on psychomotor performance. *Psychopharmacology, 104,* 113–119.
Koelega, H. (1993). Stimulant drugs and vigilance performance: a review. *Psychopharmacology, 111,* 1–16.
Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1990). Emotion, attention and the startle reflex. *Psychological Review, 97,* 377–398.
Lieberman, H. R., Wurtman, R. J., Emde, G. G., & Coviella, I. L. G. (1987). The effects of caffeine and aspirin on mood and performance. *Journal of Clinical Pharmacology, 7,* 315–320.
Lorist, M. M., Snel, J., & Kok, A. (1994). Influence of caffeine on information processing stages in well rested and fatigued subjects. *Psychopharmacology, 113,* 411–421.
McNair, D.M., Lorr, M., & Droppleman, L.F. (1971). *EITS manual for the profile of mood states*. San Diego, CA: Educational and Industrial Testing Service.
Nielson, K. A., Radtke, R. C., & Jensen, R. A. (1996). Arousal-induced modulation of memory storage processes in humans. *Neurobiology of Learning and Memory, 66,* 133–142.
Persson, L. O., Sjoberg, L., & Svensson, E. (1980). Mood effects of alcohol. *Psychopharmacology, 68,* 295–299.
Roache, J. D., & Griffiths, R. R. (1987). Interactions of diazepam and caffeine: behavioral and subjective dose effects in humans. *Pharmacology, Biochemistry and Behavior, 26,* 801–812.
Rush, C. R., Sullivan, J. T., & Griffiths, R. R. (1995). Intravenous caffeine in stimulant drug abusers: subjective reports and physiological effects. *The Journal of Pharmacology and Experimental Therapeutics, 273,* 351–358.
Russell, J. A. (1980). A circumplex model of affect. *Journal of Personality and Social Psychology, 39,* 1161–1178.
Russell, J. A., Weiss, A., & Mendelsohn, G. A. (1989). Affect grid: a single-item scale of pleasure and arousal. *Journal of Personality and Social Psychology, 57,* 493–502.
Stevens, J. P. (1990). *Intermediate statistics: a modern approach*. Hillsdale, NJ: Erlbaum.
Tellegen, A. (1985). Structures of mood and personality and their relevance to assessing anxiety, with an emphasis on self-report. In A. H. Tuma & J. D. Maser (Eds.), *Anxiety and the anxiety disorders* (pp. 681–706). Hillsday, NJ: Erlbaum.
Warburton, D. M. (1995). Effects of caffeine on cognition and mood without caffeine abstinence. *Psychopharmacology, 119,* 66–70.
Zwyghuizen-Doorenbos, A., Roehrs, T. A., Lipschutz, L., Timms, V., & Roth, T. (1990). The effects of caffeine on alertness. *Psychopharmacology, 100,* 36–39.