

RESEARCH REPORT

Mood and cognitive effects of \pm 3,4-methylenedioxymethamphetamine (MDMA, 'ecstasy'): week-end 'high' followed by mid-week low

H. VALERIE CURRAN & ROSS A. TRAVILL

Department of Psychology, University College London, UK

Abstract

Aims. Recreational use of \pm 3,4-methylenedioxymethamphetamine (MDMA, 'ecstasy') is widespread. The present study aimed to examine both the acute and residual effects of this drug on users' mood and cognitive function. **Design and participants.** A parallel group design was used to compare 12 participants who reported having taken MDMA with 12 participants who reported having consumed only alcohol, on the relevant night (day 1). These same participants were then re-assessed the following day (day 2) and again mid-week (day 5). **Findings.** Acute effects of MDMA broadly replicated previous findings. MDMA users rated elevated mood on day 1 but significantly low mood on day 5, at which point some participants scored within the range for clinical depression. In contrast, the alcohol group showed less pronounced changes, which followed a U-shaped curve over days with the lowest point being day 2. The MDMA group also showed significant impairments on an attentional/working memory task, compared with alcohol users. **Conclusions.** Weekend use of MDMA may lead to depressed mood mid-week. Possible mechanisms underlying the findings are discussed in terms of temporary depletion of serotonin, serotonergic neurotoxicity and psychological aspects of mood change.

Introduction

Despite legislative action and media campaigns, recreational use of (\pm) 3,4-methylenedioxymethamphetamine (MDMA, 'Ecstasy') remains widespread (Peroutka, 1987; Steele, McCann & Ricaurte, 1994). The effects of MDMA on mood and cognition have received relatively little attention from researchers. This is partly because controlled laboratory studies with humans are generally precluded for legal and ethical reasons and so studies on humans are

restricted to recreational users. Neurotoxic effects of MDMA have been demonstrated in rodents and non-human primates, but it is not clear whether similar effects occur in humans (Ricaurte *et al.*, 1992; Green, Cross & Goodwin, 1995). Use of MDMA has been associated with sleep disturbance (Allen, McCann & Ricaurte, 1993) and the literature contains a range of case reports of individuals developing psychiatric problems following MDMA use (cf. McGuire, Cope & Fahy, 1994; Steele *et al.*, 1994).

Correspondence: Dr H. Valerie Curran, Clinical Health Psychology, University College London, Gower Street, London WC1E 6BT, UK. Tel: + 44 (0) 171 380 7897; fax: + 44 (0) 171 916 1989; e-mail: v.curran@ucl.ac.uk
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Although dopamine-releasing effects of MDMA have been demonstrated (e.g. Yamamoto & Spanos, 1988), its serotonergic effects appear most prominent (Steele *et al.*, 1987; Schmidt, 1987). Deficits in serotonin in humans could be associated with both detriments in cognitive function and disturbed mood regulation (Krystal & Price, 1992; Steel *et al.*, 1994; Curran & Kopelman, 1996).

Of the studies of the effects of MDMA on mood, most have assessed only acute effects. Only one study was found which objectively assessed effects on cognitive function, and this involved chronic users of MDMA. Two studies of acute MDMA effects were conducted prior to governmental restrictions. Downing (1986) assessed effects of MDMA (average dose 2.5 mg/kg) in 21 volunteers with previous MDMA experience. Self-report measures of acute effects included euphoria, increased physical and emotional energy, heightened sensual awareness and decreased appetite. Some showed gait instability, trismus and increased deep tendon reflection. Only three had any apparent cognitive effects as indexed by problems performing mathematical calculations. Similar mood effects were reported by Greer & Talbot (1986) in a summary of 29 clinical sessions in which MDMA (initial dose range 75–150 mg followed later by a second 50–75 mg dose) was used as an adjunct to psychotherapy. There have been two retrospective studies, relying on participants' memories for prior use of MDMA. Peroutka, Newman & Harris (1988) asked students who were recreational users of MDMA to complete a questionnaire about acute and 'lingering' (>24-hour) effects of MDMA. Again, acute effects listed included a sense of closeness to others and euphoria but less than 25% of the sample rated any lingering effects of MDMA. In another retrospective study, Liester *et al.* (1992) interviewed 20 psychiatrists who had used MDMA and the most frequently noted acute effects were decreased motivation to perform mental or physical tasks, decreased appetite and trismus. Only a small minority reported any cognitive effects of the drug.

Such studies are clearly limited by the lack of objective assessment of cognitive effects. In contrast, Krystal & Price (1992) assessed nine individuals who had extensive histories of MDMA use on a wide battery of neuropsychological tests. Test results revealed few clinically

significant cognitive problems. However, compared with normative data there was some indication of a mild to moderate impairment on both immediate and delayed logical memory tests from the Weschler Memory Scale. There was no indication of depressed mood (either self- or clinician-rated) in these nine people, although it should be noted that they had not taken MDMA for an average of 66 days prior to the assessment.

What is not known are the cognitive effects of MDMA following a single dose, or the possible residual effects on cognition and/or mood a few days later. Levels of 5-HT, acutely elevated by MDMA, are then depleted for an unknown period, such that mood and cognition may be affected for some days following the use of MDMA. As perhaps the majority of recreational MDMA users take the drug at the weekend, but do not take it again until the following weekend, it is important to assess the drug's effects not only acutely but also residually over subsequent days. This may be especially important for the many MDMA users who are also students (Peroutka, 1987) for whom cognitive impairment may adversely affect their learning.

The present study therefore aimed to assess both the acute and residual effects of MDMA on cognition and mood in recreational users. Given that the illicit status of the drug precludes controlled laboratory studies, the present research was a 'field' study, taking place initially in a club setting with follow-up assessments on subsequent days in each participant's home. Some control for testing was obtained in that the club provided a quiet room away from the dance area in which assessments took place. This arrangement was possible as the psychologist assessing participants had previously been employed as a part-time disc jockey at the club. Volunteers who reported use of MDMA on the Saturday night were assessed on that evening and then these same people were followed-up for repeat assessments the next day and again 4 days later. As a comparison group, we assessed people who reported use of alcohol but no illicit drugs. Ideally, the authors would have used a drug-free group as a control for repeat testing but there were no volunteers who were drug-free in the environment from which the MDMA users were recruited. Further, use of drug-free volunteers from a non-club environment would have implicated many non-specific factors in the compari-

son. The alcohol users were selected partly because cognitive effects of alcohol are well-documented (Finnigan & Hammersley, 1992). Although, some years ago, alcohol and MDMA were associated with 'club' and 'rave' settings, respectively, nowadays restriction on 'raves' has led to more overlap of drug use in club settings so that there were sufficient numbers of volunteers available who reported taking only MDMA or only alcohol.

Method

Participants

Volunteers were recruited in a club setting on successive Saturday nights over a period of 4 months. The club kindly provided a quiet room in which the study took place on day 1 (Saturday night). The study had approval from the institutional ethical committee and all participants gave written, informed consent both on the Saturday night and again the following day. Recruitment used a snowball technique (Solowij, Hall & Lee, 1992) and volunteers who reported having taken drugs other than MDMA or alcohol, or a combination of both, were not included in the study.

In all, 24 people whose ages ranged from 20 to 27 years participated in the study and they were all tested on each of the three occasions. Twelve of the sample reported that they had taken MDMA on day 1 (i.e. Saturday night); 12 reported they had taken alcohol but no other psychoactive drugs (apart from caffeine and/or nicotine) on day 1. There were eight males and four females in each group. Of the MDMA group, six subjects were students studying for a degree, six were in employment (three with GCSE and three with A-level qualifications). Of the alcohol group, seven were students studying for a degree, five were in employment (three with GCSE and two with A-level qualifications).

Procedure

Volunteers were taken individually to the quiet study room where water was available to them and they were asked to read an information sheet about the 5-day study and to discuss their participation with the experimenter. Individuals who then wished to participate were asked to give written, informed consent. They then completed the tasks (questionnaires and rating scales described below). Once the tasks were com-

pleted, arrangements were made to meet up the following day in order to conduct the day 1 testing. Participants were asked not to take any further alcohol or illicit substances between day 1 and day 2 testings. The participant was then shown back to the club.

Subsequent testing was carried out in the participant's home on day 2 (between 1200 noon and 4.00 p.m.), and on day 5 (between the approximate times of 5.30 p.m. and 8.30 p.m.). The setting was as quiet as possible, generally a room away from distractions such as TV and other people. On day 2, participants were first asked if they still wished to take part in the study and if so, to again sign an informed consent form. After testing on day 2, participants were asked to fill in a brief questionnaire detailing their age, occupation and frequency of use of a range of different drugs. Participants' retrospective reports of amount of alcohol and other drugs taken the previous night was also recorded. On day 5, the tests were run for the third time in the same order using the same instructions. Again, precautions were taken to try to keep each test the same, such as asking subjects not to drink or take illegal substances between days 2 and 5.

Assessments

Prose recall task. This task parallels the paragraph recall task from the Weschler Memory Scale used by Krystal & Price (1992). Versions used were from the Rivermead Behavioural Memory Battery (Wilson, Cockburn & Baddeley, 1985). The experimenter read a prose paragraph aloud and the participant recalled it aloud (i) immediately and (ii) after a delay filled by all other assessments (approximately 15–20 minutes later). Recall was scored in the standard way with one point being given for each of the possible 21 details recalled perfectly or a close synonym; half a point for partial recall or partial synonym. Order of the three versions used were balanced across subjects and design.

Serial sevens. This is a task tapping concentration and working memory. The participant is asked to serially subtract as many sevens from a given three-digit number as they can in 120 seconds (e.g. given 876, the correct responses would begin 869, 862, 855, 848...). The number of correct subtractions and the number of errors made in the time allotted is recorded. Three

versions were used with order balanced across subjects and design.

Beck Depression Inventory (Beck *et al.*, 1978). This standard depression inventory was given at each testing point.

Mood rating scale. This consists of 16 visual analogue scales each of 100 mm and anchored at each end with contrasting descriptors of present mood (Bond & Lader, 1974). Score on each scale is measured in mm from the left anchor to the line marked by the participant as corresponding to his/her current mood.

Bodily symptoms scale. This scale is of similar construction, consisting of 14 visual analogue scales anchored at one end by 'no physical symptom' and at the other by 'physical symptom severe'.

Results

Analysis

A repeated measures analysis of variance was carried out on all variables with group (MDMA versus alcohol) as a between-subjects factor and testing day as a within-subjects factor.

Participants' reported drug use

In terms of frequency of use of different drugs, the MDMA group reported more regular use of a range of drugs with alcohol, cannabis, MDMA and cocaine (respectively) being the most frequently used. Other drugs listed in the questionnaire included amphetamine, LSD, GHB (gamma-hydroxybutyrate), 'mushrooms' and heroin but few participants reported they had ever used these, and those that had only rarely. In the MDMA group, two people reported using

MDMA once a week, six approximately once per month and four only occasionally. In the alcohol group, three participants said they took MDMA approximately once per month, four only occasionally and five had never taken this drug.

Reports given on day 2 of drug use the previous evening confirmed that 12 participants believed they had taken MDMA but seven participants said they had also taken between 1 and 3 units (mean 1.8 units) of alcohol. For most, this alcohol use was before they arrived at the club, although for two participants it was at the club. The other 12 participants reported no illicit drug use on day 1 and between 4 and 14 units (mean 10.8 units) of alcohol on day 1. The amount of alcohol taken by 7 of the MDMA users was small compared with the 'alcohol' group, although it may have had an effect. The groups will still be referred to as 'MDMA' and 'alcohol'. Only one subject reported drinking alcohol (3 units) between days 2 and 5; none said they had taken illicit drugs.

Prose recall. There was a trend ($p < 0.06$) for the MDMA group to have lower scores on immediate recall on all three assessment days. A significant main effect of test day ($p < 0.001$) with no significant interaction between group and day reflected improved performance over days by both groups (Table 1). The pattern of results on delayed recall was broadly similar: a trend for lower scores in the MDMA group ($p < 0.06$) and a main effect of test day ($p < 0.001$). Additionally, the interaction of group with day showed a slight trend ($p = 0.092$) reflecting better performance on day 5 by the alcohol group.

Serial sevens. The number of correct subtractions on this task revealed a significant group by days interaction ($p < 0.05$) as well as a main

Table 1. Group means (standard deviations) over days for serial sevens and prose recall tasks

	MDMA			Alcohol		
	Day 1	Day 2	Day 5	Day 1	Day 2	Day 5
Serial sevens: <i>n</i>	2.7 (1.9)	14.2 (6.7)	25.1 (7.1)	6.3 (3.4)	26.6 (10.7)	31.1 (11.1)
Serial sevens: error	2.3 (2.8)	2.6 (2.9)	2.3 (1.9)	2.8 (1.5)	2.1 (2.4)	1.1 (1.4)
Recall: immediate	1.2 (1.5)	5.9 (2.8)	8.5 (3.1)	3.5 (2.8)	9.0 (4.4)	10.2 (4.6)
Recall: delayed	1.1 (1.0)	4.0 (1.8)	6.4 (3.7)	2.0 (2.0)	7.5 (3.9)	6.9 (3.3)

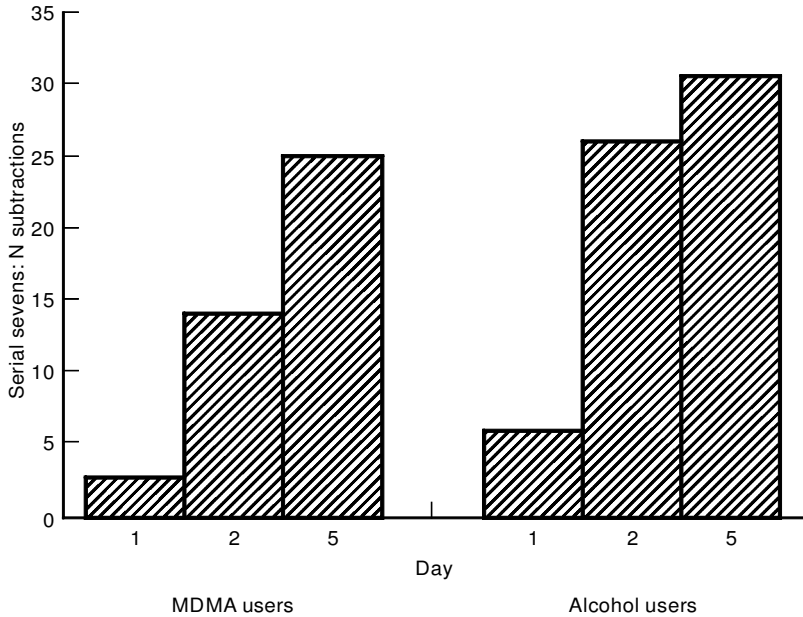


Figure 1. Mean number correct on the serial sevens task for the MDMA and alcohol groups on days 1, 2 and 5.

effect of both group ($p < 0.01$) and days ($p < 0.001$) (Fig. 1). The MDMA group made fewer subtractions than the alcohol group at all assessment points, but these group differences were more marked on day 2 than days 1 and 5. There were no significant group differences in number of errors made.

Beck Depression Inventory. Scores on this inventory showed a very significant interaction between group and day of testing ($p < 0.001$). As seen in Fig. 2, the two groups of participants had very similar scores on day 2. On day 1, MDMA users scored lower than alcohol users. On day 5, this pattern was reversed such that the MDMA users scored a mean of 11.75, whereas alcohol users' scores were similar to their initial ratings on day 1. Scores of less than 9 on the BDI are considered within the normal range (Elkin, 1994) and those above 16 as indicative of clinical depression (Shapiro *et al.*, 1994). On day 5, the variance in BDI scores of the MDMA group was higher than on the previous 2 test days, such that some individuals in this group were scoring within the normal range whereas others were scoring within the mild to moderate clinical depression range.

Mood rating scale. Visual analogue ratings showed marked group differences over the 3 test days, with 11 of the 16 scales showing significant group \times test-day interactions (Table 2). The most significant group \times day interactions ($p < 0.001$) were contented-discontented; happy-sad and interested-bored. Thus, as seen in Table 2, the MDMA group on day 1 were more contented, happy and interested than alcohol users. MDMA users became progressively more discontented, sad and bored over the subsequent test days whereas alcohol users showed a slight 'U-shape' curve over the 3 days, rating slightly lower mood on day 2 compared with either day 1 or 5.

Five scales showed group \times day interactions at $p < 0.01$. Drowsiness (alert-drowsy) ratings were high for both groups on day 2 with the main group difference stemming from high alertness ratings by MDMA users on day 1. Ratings of strong-feeble showed MDMA users rating themselves very strong on day 1, and then more feeble than alcohol users on day 2. 'Muzzy clear-headed' ratings also showed MDMA users as more clear headed on day 1 but rather more muzzy on day 2 than alcohol users. This pattern of group differences over days was also seen on

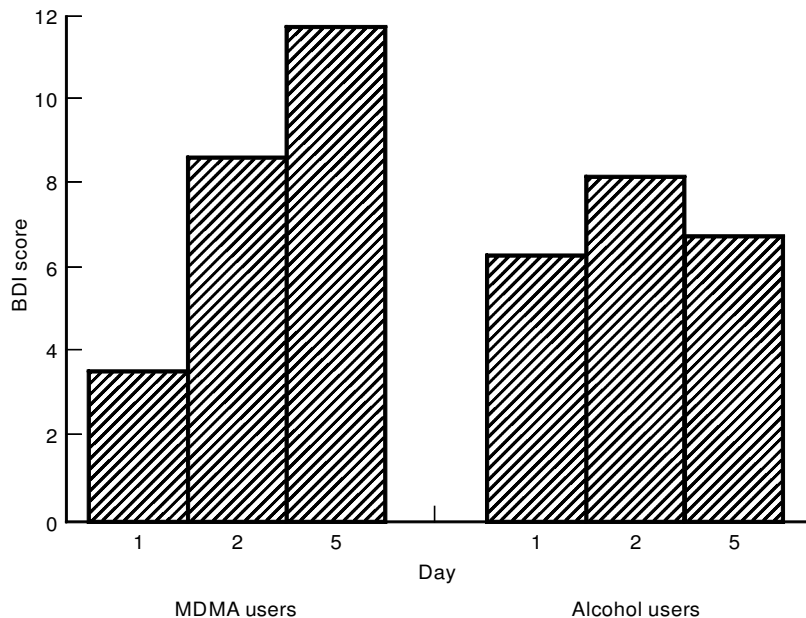


Figure 2. Mean scores on the Beck Depression Inventory for the MDMA and alcohol groups on days 1, 2 and 5.

ratings of 'lethargic-energetic' and 'troubled-tranquil' with MDMA users rating very high on energy and tranquillity on day 1, but lower than alcohol users on day 2. A similar pattern was obtained for scales showing a group \times day interaction which reached significance at 0.05: MDMA users rated themselves as more amicable, more proficient and less clumsy than alcohol users on day 1.

Bodily Symptoms Scale. Three scales showed group \times day interactions at the 0.001 level. Predictably, MDMA users had very high 'sweating' scores only on day 1. They also veered from relatively high energy and lack of tiredness on day 1 to marked lack of energy and tiredness on day 2 which persisted somewhat to day 5 (compared with alcohol users). Ratings of anxiety, depression and agitation (all yielding group \times day interactions significant at the $p < 0.01$ level) each showed a progressive increase over days for the MDMA group, while the alcohol group showed less extreme changes over days which again followed a 'U-shaped' curve. Two scales revealed group \times day interactions at the 0.05 level, although they should be interpreted with caution given that the analysis of 34 variables in this study would produce 1.7

significant results at 0.05 by chance. Irritability ratings ($p < 0.05$) revealed the same pattern of effects over days; dry mouth ($p < 0.05$) had high ratings by MDMA users on day 1. Ratings of impaired concentration were highest for alcohol users on day 1, and highest for MDMA users on day 2.

Discussion

The main result of this study indicates that use of MDMA at the weekend is associated with a lowering of mood mid-week. Scores on the Beck Depression Inventory (BDI), on several mood rating scales (happy-sad; contented-discontented; interested-bored) and bodily symptoms scales (depressed, anxious, agitated) all showed very significant group differences over the 5 days. On all these, MDMA users rated elevated mood on day 1 which progressively lowered over subsequent testing days. In contrast, the alcohol group showed a 'U-shaped' curve, with the lowest point being day 2, presumably a hang-over effect from day 1's consumption. On day 2, both groups were broadly similar in ratings on these variables, implying that the 'day after' effects of MDMA (including lack of sleep) are not dissimilar in some respects to an alcohol hang-over.

Of particular concern are the BDI scores of

Table 2. Group means (standard deviations) over days for scores on the Beck Depression Inventory and individual mood ratings; ANOVA results for each rating

	MDMA					Alcohol					ANOVA			
	Day 1	Day 2	Day 5	Day 1	Day 2	Day 1	Day 2	Day 5	Day 1	Day 2	Day 5	Group	Day	Group × day
BDI	3.5 (3.5)	8.7 (3.8)	11.8 (7.2)	6.4 (5.3)	8.3 (5.2)	6.9 (4.1)						NS	***	***
Mood ratings (mm)														
Drowsy	19.6 (27.1)	77.9 (14.5)	42.9 (23.8)	45.7 (27.0)	66.0 (14.1)	36.8 (19.1)						NS	***	**
Excited	63.3 (37.6)	14.9 (9.4)	38.9 (14.8)	56.8 (26.3)	30.4 (15.1)	36.6 (14.9)						NS	***	NS
Feeble	17.9 (16.4)	74.5 (15.0)	35.7 (16.6)	37.2 (17.7)	58.0 (9.7)	38.8 (18.2)						NS	***	**
Clear-headed	65.1 (33.2)	24.1 (16.1)	58.1 (26.5)	34.2 (13.3)	37.3 (11.1)	63.0 (16.2)						NS	***	**
Clumsy	41.4 (26.4)	67.6 (20.1)	35.6 (23.6)	62.8 (12.6)	51.7 (15.2)	40.0 (17.0)						NS	**	*
Energetic	88.3 (11.8)	17.8 (11.7)	46.8 (24.7)	61.0 (24.7)	31.8 (19.8)	49.2 (14.8)						NS	***	**
Discontented	9.4 (9.1)	38.3 (24.0)	59.4 (23.3)	35.4 (18.5)	44.4 (19.5)	42.5 (18.5)						NS	***	***
Tranquil	75.8 (15.7)	65.9 (24.5)	38.8 (19.1)	52.4 (12.6)	45.1 (17.9)	48.2 (11.4)						***	**	**
Quick-witted	51.9 (31.6)	24.4 (16.6)	54.1 (21.9)	46.4 (22.8)	40.5 (19.7)	61.3 (19.8)						NS	***	NS
Relaxed	71.6 (15.2)	65.3 (24.6)	43.8 (30.3)	58.8 (22.6)	44.7 (20.9)	49.4 (20.0)						NS	*	NS
Dreamy	44.5 (37.3)	82.8 (13.1)	42.6 (25.0)	49.6 (22.3)	58.2 (15.2)	38.4 (17.5)						NS	***	NS
Proficient	60.8 (28.3)	35.8 (16.5)	65.6 (20.8)	48.8 (19.9)	49.8 (13.5)	64.7 (20.3)						NS	***	*
Sad	7.0 (9.9)	33.5 (20.7)	54.6 (27.7)	26.9 (21.8)	41.6 (18.5)	35.1 (16.9)						NS	***	***
Amicable	82.8 (14.5)	67.4 (18.7)	50.5 (28.7)	60.8 (25.1)	58.2 (22.2)	60.0 (14.6)						NS	*	*
Bored	14.4 (14.9)	49.6 (19.5)	62.8 (25.1)	41.9 (28.7)	55.9 (21.6)	39.4 (10.7)						NS	***	***
Gregarious	68.1 (19.3)	37.2 (18.4)	47.4 (22.8)	66.7 (18.8)	46.4 (18.3)	55.5 (11.6)						NS	***	NS

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; NS not significant.

Table 3. Group means (standard deviations) over days for bodily symptoms ratings; ANOVA results for each rating

	MDMA					Alcohol					ANOVA			
	Day 1		Day 2		Day 5	Day 1		Day 2		Day 5	Group	Day	Group	× day
Restlessness	44.4 (32.1)	52.9 (28.4)	58.7 (17.9)	37.8 (24.7)	58.8 (14.7)	38.8 (16.8)	NS	NS	NS	NS	NS	NS	NS	NS
Irritability	17.6 (14.1)	56.0 (21.1)	63.6 (17.6)	33.7 (25.7)	55.7 (20.0)	44.1 (18.3)	NS	NS	NS	NS	NS	NS	NS	*
Physical tiredness	15.1 (18.7)	78.9 (11.7)	60.0 (21.3)	41.9 (23.1)	64.5 (5.9)	46.1 (23.1)	NS	NS	NS	NS	NS	NS	NS	***
Lack of energy	10.6 (9.7)	82.2 (11.4)	68.6 (15.1)	38.8 (22.5)	65.8 (8.5)	48.7 (23.8)	NS	NS	NS	NS	NS	NS	NS	***
Impaired concentration	47.3 (29.9)	74.2 (9.3)	62.1 (24.0)	67.3 (9.5)	60.3 (16.2)	50.3 (25.5)	NS	NS	NS	NS	NS	NS	NS	*
Headache	18.3 (18.5)	58.3 (24.3)	37.6 (36.0)	21.8 (17.1)	50.2 (31.7)	25.8 (22.4)	NS	NS	NS	NS	NS	NS	NS	NS
Difficulty breathing	33.7 (23.2)	29.7 (25.0)	19.8 (25.2)	16.3 (17.3)	24.0 (26.4)	16.3 (15.6)	NS	NS	NS	NS	NS	NS	NS	NS
Dry mouth	73.2 (27.3)	50.1 (26.0)	23.8 (31.0)	34.8 (21.9)	43.8 (28.6)	18.7 (22.5)	*	*	*	*	*	*	*	*
Nausea	31.1 (20.5)	30.3 (26.1)	9.3 (9.2)	16.0 (14.0)	30.7 (29.1)	13.5 (15.2)	NS	NS	NS	NS	NS	NS	NS	NS
Anxiety	20.8 (15.6)	34.7 (23.5)	52.2 (21.2)	18.7 (16.0)	40.9 (21.4)	26.9 (18.7)	NS	NS	NS	NS	NS	NS	NS	**
Sweating	73.6 (30.7)	18.6 (15.2)	8.6 (12.0)	21.8 (21.3)	33.9 (22.3)	14.8 (18.5)	*	*	*	*	*	*	*	***
Blurred vision	55.8 (28.2)	21.3 (21.2)	12.4 (20.5)	29.1 (23.9)	18.5 (18.0)	8.8 (13.4)	*	*	*	*	*	*	*	NS
Depression	13.3 (11.0)	45.2 (23.1)	56.3 (24.4)	17.4 (16.5)	34.7 (25.5)	20.7 (13.6)	*	*	*	*	*	*	*	**
Agitation	20.7 (20.7)	49.1 (15.6)	60.8 (21.1)	30.5 (27.1)	44.5 (18.4)	24.5 (15.4)	*	*	*	*	*	*	*	**

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; NS not significant.

MDMA users which indicate that some participants are within the mild to moderate clinical range for depression. The BDI includes several somatic items referring to changes in sleeping/eating patterns. MDMA is known to affect sleep (Allen *et al.*, 1993) and subjective reports of decreased appetite are common (Solowij *et al.*, 1992; Liester *et al.*, 1992). To explore whether high scores on these somatic items might have contributed to group differences in depression, BDI scores with these items omitted were re-analysed. However, the pattern of scores over days and the significance of the group \times days interaction ($p < 0.001$) remained. (Group means for days 1, 2 and 5, respectively, were: MDMA 2.25; 6.91; 9.92; ALCOHOL 5.08; 6.83; 5.49). Thus somatic effects of MDMA were not main contributory factors to group differences in depression scores. This also accords with the results on visual analogue scales. Our results are consistent with anecdotal reports that MDMA can lead to depression during the week after it is taken (Barnes, 1988; Saunders, 1995).

Low mood days after MDMA is taken may reflect serotonergic depletion which might be temporary following acute elevation of serotonin induced by MDMA. If this is the case, one would expect mood to lift over a longer time course. If MDMA is serotonergically neurotoxic, complete recovery of mood may not occur. It could also be argued that the link between depression and MDMA may not be a direct consequence of neurochemical changes. The apparent 'low' experienced in the days after MDMA use could be a psychological consequence of the acute 'high' following MDMA. As one MDMA user put it:

By dancing all night on E, a feeling of total bliss and utter fulfilment is achieved, and of course the downside to this is that nothing else beats that feeling, thus reality can seem boring (quoted in Saunders, 1995).

The present 'field' study has clear limitations compared with a double-blind, controlled laboratory study. Neither experimenter nor participants had objective confirmation of what drugs or dosages were actually taken by the MDMA group. Tablets sold as MDMA can contain MDA (3,4 methylenedioxy-amphetamine), MDEA ('Eve'-3,4 methylenedioxyethylamphetamine), or various mixtures of a range of

compounds (e.g. amphetamine, ketamine, LSD, caffeine, ephedrine). It was beyond the scope of the present study to attempt biochemical assays: requests to take blood or other bodily fluids may have mitigated against people volunteering for the study as well as presenting health/safety problems for the investigator in a club setting. It could be argued that a further limitation of the present study was the conjoint use of alcohol reported by some of the MDMA users on day 1. However, this was at low doses, with the MDMA group consuming less than 17% of the average dose reported by the alcohol group.

Although we cannot be sure that the tablets taken by the MDMA group contained pure MDMA, the profile of mood effects reported on the night accords with previous findings from studies of acute effects of known doses of pure MDMA carried out before governmental restrictions (Downing, 1986; Greer & Talbot, 1986). This provides some evidence that the participants in the present study had taken MDMA. Further, our findings also accord with more recent retrospective studies which could not confirm that MDMA was actually taken (Peroutka *et al.*, 1988; Solowij *et al.*, 1992; Leister *et al.*, 1992). The profile of physical side-effects obtained in this study, including high levels of energy, severe dry mouth and sweating, also accords with reports in those studies.

Cognitive effects were sampled by relatively few tests, and future studies may explore a more comprehensive range of cognitive function. The prose recall task (immediate and delayed) was chosen on the basis of findings by Krystal & Price (1992) implying that performance on both immediate and delayed aspects of this task showed some disruption in chronic MDMA users. The present study found that MDMA users generally performed poorer than alcohol users on this task, and both groups improved over the 3 test days. A non-significant ($p < 0.10$) tendency emerged on delayed recall reflecting marginally worse performance by MDMA users on day 2. Had the sample size been larger, this difference might have reached significance.

The serial sevens task was selected partly to provide an index of attention/working memory and partly following Downing *et al.* (1986) who reported a small number of MDMA users having problems carrying out mathematical calculations. MDMA users were impaired on this task (compared with alcohol users) on all 3 testing

days although impairments were most pronounced on day 2. It is not clear whether this is a direct drug effect or whether lack of sleep, reported by most MDMA users on day 2, also contributed to impairment. Impaired attentional function could in turn affect performance on a range of tasks, including comprehension and encoding in the prose recall task. Indeed, it is possible that apparent memory problems linked to MDMA could be explained by the contribution of concentration and linked encoding deficits.

As far as we are aware, the present study is the first to investigate the mood and cognitive effects of weekend MDMA use in terms of both acute and residual effects over subsequent days. We are currently assessing MDMA users over a longer time period. If the mid-week low mood is due to a temporary depletion in 5-HT, as opposed to 5-HT neurotoxicity, there would be a time course over which mood would lift.

In terms of the debate about the use of MDMA as an adjunct to psychotherapy, the results of the present study would caution against the use of a drug which in some people might compound problems by inducing a lowering of mood some days after a therapy session. The present findings also add to the list of adverse consequences of MDMA use, in that the 'high' at the weekend may lead to a 'low' mid-week and to attentional problems. This may be of particular concern to those whose studies or job performance may suffer from impaired attentional function.

In summary, the results of this study imply that MDMA use at the weekend is associated with subsequent low mood mid-week and with impaired attentional function. It is not clear to what extent this may reflect a temporary serotonergic depletion, a more serious serotonergic neurotoxicity or a psychological consequence of the acute 'high' mood induced by weekend MDMA use.

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