Sleep, Energy and Self Rated Cognition Across 7 Nights Following Recreational Ecstasy/MDMA use

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Objective: This study aimed to prospectively assess self-rated sleep length and sleep quality in recreational MDMA users (n= 18, 13 male, 5 female, 19.5 yrs) for the 7 days following ecstasy consumption, and to compare them to alcohol drinking controls (n= 18, 7 male, 11 female, 20.2yrs).
Method: Time of going to sleep, wake time, total sleep length, sleep quality, and self rated sleepiness, energy and cognition were assessed. Alcohol use each day was also reported. Ecstasy was consumed on night 1 for ecstasy users.
Results: Ecstasy users reported significantly reduced sleep time on post-ecstasy nights 2, 3, 4 and 5. They experienced significantly reduced sleep quality on nights 1, 2, 3, 4 and 5. The severest sleep length and sleep quality decrements occurred on nights 2 and 3. Self-rated cognitive measures were significantly impaired on days 3, 4, 5 and 6. By day 7 all assessment measures were similar to the control group. When controlling for alcohol use on each day the sleep length and sleep quality differences between the groups remained significant and the interactions of night or day with group remained significant.
Conclusions: Impairments in sleep, energy and self-rated cognitive measures occur for several nights and days following ecstasy use, but are not due to alcohol use across those days. **(Sleep and Hypnosis 2008;10(1):26-38)**

Key words: Ecstasy, MDMA (3, 4- Methylenedioxymethamphetamine), Sleep, Energy, Cognitive measures, Prospective

INTRODUCTION

MDMA ("Ecstasy") is an indirect 5-hydroxytrymptamine (5-HT) and dopamine agonist, which also has weaker effects on other monoamine neurotransmitter systems such as those involving noradrenaline, histamine and acetylcholine (1). The effect on serotonin has potential implications for well being, as serotonin is involved in psychobiological functions such as sleep regulation, circadian rhythms, mood, memory, sexual activity, appetite and anxiety (2). Indeed, despite the positive mood effects ecstasy users experience whilst taking the drug (3-5), users report other effects such as muscle aches, fatigue, depression, irritability, difficulty

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concentrating and headache (6-21).

Despite these serotenergic effects, there has been very limited research conducted on sleep quality and length following ecstasy use (see review, 13). Colbron et al (22) found, that MDMA 'altered the ability of the circadian clock to phase shift to photic and non-photic stimulus' in Syrian Hamsters. It has also been found that ecstasy disrupts circadian rhythms for up to 5 days in rats (23,24), but the effects on electrophysiologically assessed sleep are unclear.

Sleep disturbances, self-rated retrospectively, are a frequent problem for ecstasy users, with lethargy, insomnia, irritability and poor mood as other effects (19). Participants in the study often attributed such psychological problems to sleep disruption, but this was not further investigated. Clinical studies using humans have found reduced total sleep time, due to reduced stage 2 NREM sleep (25), but also longer sleep times, with increases in stage 3 and 4 sleep (26) and abstinent ecstasy users had less stage 2 and more stage 1 sleep than controls (27). In a recent review (28) it was concluded that alterations of sleep due to ecstasy use are suggestive of a link between 5-HT loss and sleep and circadian rhythm changes. However, another study found that an acute dose of MDMA/ecstasy did not affect self-reported sleep quality on the Groninger Sleep Scale (29).

Further indicative of damage to the serotonin system, sub acute work on ecstasy 1 – 9 days after use have been studied extensively. Self rated mood and cognitive effects throughout the week following ecstasy use were investigated (30). Ecstasy users exhibited depressive symptoms up to 4 days after consumption of the drug, including 'crying for no reason' and 'feeling low', which may indicate serotonergic sensitivity (13). Ecstasy users showed a significantly lower mood on day 5 than did alcohol users, whose mood remained fairly constant throughout the week (30). It was also found that 2 days after taking ecstasy users felt significantly 'more depressed, abnormal, unsociable, unpleasant and less good tempered than controls' (31). Furthermore, ecstasy users performed the worst on all verbal recall and visual scanning tasks. In another study aggression and depression scores were higher 4 days after use, but after 7 days the effect was no longer present (32). Elevated depression scores on the Beck Depression Inventory was found 4 days after use (33), although this finding hasn't been consistent (34). Thus it appears that there may be a dip in mood and cognitive performance post-ecstasy use between days 2 – 5. In a sleep deprivation study a single dose of MDMA in the evening decreased sleepiness scores (35) on the Stanford Sleepiness Scales (36) throughout the night compared to controls.

This raises the issue of the degree to which cognition and mood effects of ecstasy are mediated by sleep loss. In a prospective study Huxster et al (37) regular ecstasy users were tested using a nine-day mood, cognition and sleep diary. There was a significant deficit in self-rated sleep quality and cognition in the days following ecstasy use. However, when controlling for co-use of alcohol on the day after ecstasy consumption the effects of ecstasy on sleep were no longer significant. Because their participants were high alcohol consumers, this requires further investigation with a more infrequently alcohol using group.

The current study aims to extend previous findings on sleep quality in high alcohol users by investigating whether recreational ecstasy use results in changes to sleep length and sleep quality over a period of 7 days in low alcohol using groups. Sleep length and quality will be tracked; no single prospective study on ecstasy has utilised both of these measures. Subjects record when they use ecstasy and then complete the diary for 7 days afterwards; this follows the same model as Curran et al (30,32,33). The second aim is

to investigate to what extent MDMA affects the individuals' lethargy, energy, ease of concentration and ability to take in new information. The third aim is to control for use of alcohol, so as to investigate whether the effects of ecstasy on sleep are due to increased alcohol consumption in the days after ecstasy use. However, Huxster et al (37) only used alcohol intake one one day as the covariate, whereas the current study aims to utilize alcohol use on each of the 7 days as covariate measures for the 7-day sleep and cognition analyses. Also, whereas Huxster et al (37) recorded amount of alcohol units consumed, which was high for their participants, a dichotomous measure of alcohol use/non-use on each night is used in this study as both our groups are light alcohol drinkers with many nights of no alcohol consumption.

METHODS

Design and Treatments

A mixed within and between subjects design was employed with a group of ecstasy users and alcohol using controls who do not take any illegal recreational drugs. The day of taking ecstasy was termed day 0, which was followed by night 1. The ecstasy users did not report taking ecstasy at any other time but day 0. Control group members were matched to ecstasy group members by day of the week on which the 7 day diary started. 11% of the ecstasy group took ecstasy on a Friday, hence commencing the diary then, 11% of the control group thus commenced the diary on a Friday. 89% of the ecstasy group took ecstasy on a Saturday, and 89% of the control group thus commenced their diary on a Saturday.

Participants

36 undergraduate students were recruited from the University of Wales Swansea. They comprised 18 ecstasy users (13 male, 5 female) and 18 alcohol users (7 male, 11 female) as controls. The control group had a mean age of 20.2 years (SD= 6.23), while the ecstasy group had a mean age of 19.5 years (SD= 1.78). The mean going to sleep time for ecstasy users across the 7 days was 2:08am (SD= 0.46), the mean wake time was 10:01am (SD= 0.59). Mean going to sleep time for control subjects was 1:10am (SD= 0.32) and the mean wake time was 9:59am (0.28). Participants responded to an advert placed in the Psychology department and were offered course credits. The inclusion criterion for the ecstasy group was that they had consumed ecstasy in the last 6 months. The criterion for the control group was that they had never consumed ecstasy and do not consume illegal recreational drugs. Ecstasy users were told to report when they were planning to consume ecstasy. Lifetime ecstasy use data is not available but ecstasy group participants all confirmed that their drug of choice was ecstasy.

Assessments
Daily Questionnaire

The self rated questionnaire consisted of 16 questions which covered: bed time, waking time, quality of sleep, ease of awakening, lethargy, energy, physical sensations and sociability. Two self-rated cognitive measures were also taken: ease of taking in new information and ease of concentration. Participants were required to fill out the questionnaire after awakening each day for 7 days. Waking during the night, time of going to sleep (bed time), quality of sleep, lethargy, concentration, sociability, taking in information and energy all refer to how the participants were the previous day. Time waking, ease of waking and how participants feel physically refer to the morning they are filling the questionnaire in. All questions, apart from sleep/ wake time and whether they had

woken in the night or not, required the participant to respond on a 0-10 Visual Analogue Scale regarding how they felt the day/night before. A low score meant that sleep quality, ease of waking, physically feel, concentration, sociability, ease of taking in new information and energy were poor. A low score on lethargy meant that the participants did not feel lethargic the previous day. Sleep and wake time were recorded in hour hour minute minute (hh.mm) format, and were used to calculate total sleep time. Participants also recorded whether they had consumed alcohol or ecstasy the day before. Participants were asked, "Did you drink alcohol yesterday?" and answered "yes" or "no". Alcohol consumption was coded as 0 for no alcohol consumption and 1 for alcohol consumption. Both groups were given identical questionnaires. Waking during the night was coded as 0 for 'no' and 1 for 'yes'.

Statistical Analyses

Repeated measures analysis of variance (7 x 2 ANOVA) with group as the between subjects factor and day as the within subjects factor were performed for each questionnaire measure. An ANCOVA was then conducted for each measure with alcohol use on each day treated as a covariate. Partial eta squared analyses were conducted within the ANOVA to measure effect size according to Clark-Carter (38). A Greenhouse Geisser correction was employed if Mauchley's test for sphericity was significant. Post hoc Boneferroni tests were conducted to identify what days were significantly different from one another. Univariate tests on multivariate analysis of variance were used to calculate where the differences lay for each day. For waking during the night and alcohol use data for each day, a Mann Whitney non parametric test was conducted to compare alcohol use and waking during the night in the two groups.

RESULTS

Alcohol Consumption

Ecstasy users were significantly more likely to consume alcohol than controls on night one $z= 4.18$; $p<0.001$. However nights 2, 3, 4, 5, 6 and 7 were not significantly different between groups for alcohol consumption. The 18 ecstasy users consumed alcohol on 57% of evenings across the study, whereas on the 18 controls consumed alcohol on 44% of evenings across the study.

Sex Differences

There were significant sex differences for time of going to sleep (bed time), $F (1, 34)= 4.207$, $p<0.05$, concentration, $F (1, 34)= 5.317$, $p<0.05$ and taking in information, $F (1, 34)= 6.563$, $p<0.05$. For statistical analysis of these measures sex was included thus as a covariate, results are discussed below.

Waking During the night

Ecstasy users woke more times during the night than did controls on night 2 $z= 2.935$, $p<0.05$. There were no significant differences for nights 1, 3, 4, 5, 6 and 7 on waking during the night.

Sleep measures

Figures 1, 2, 3, 4, 5 and 6 show that ecstasy users had significantly later bed times, shorter sleep length and lowered sleep quality, worse ease of waking and felt poorer physically upon awakening than did controls. The ecstasy users went to sleep significantly later than controls, $F (1, 34)= 24.904$, $p<0.001$, partial eta squared= .423, there was also a significant effect of night $F (6, 204)= 3.145$, $p<0.01$, partial eta squared= .085 and a significant interaction between night and group, $F (6, 204)= 4.331$, $p<0.001$,

partial eta squared= .113. Ecstasy users went to sleep later than controls on nights 1, 3, 4 and 5 (see fig 1). There was not a significant effect of group for wake time, F (1, 34)= .010, p= NS, partial eta squared= .000. However, there was a significant effect of day, F (6, 204)= 5.811, p<0.001, partial eta squared= .146 and a significant day and group interaction, F (6, 204)= 10.679, p<0.001, partial eta squared= .239. Ecstasy users woke up significantly later than controls on days 1 and 3 (see fig 2). The ecstasy users had significantly shorter total sleep time than controls, F(1, 34)= 43.314, p<0.001, partial eta squared= .560, there was a significant effect of night, f (6, 204)= 5.155, p<0.001, partial eta squared= .132, and there was a significant interaction between night and group, F(6, 204)= 3.816, p<0.01, partial eta squared= .101. Ecstasy users had significantly less sleep than did controls on nights 2, 3, 4, 5 and 6 with the groups similar by night 7 (see fig 3). The ecstasy group had significantly worse sleep quality than did controls, F (1, 34)= 8.251, p<0.01, partial eta squared= .195, there was a significant effect of day, F (6, 204)= 2.295, p<0.05, partial eta squared= .063, and there was a significant interaction between day and group, F (6, 204)= 8.177, p<0.01, partial eta squared= .194. There were significant differences in sleep quality between the groups on nights 1, 2, 3, 4 and 5, with non significant differences on nights 6 and 7 (see fig 4).

The ecstasy group had significantly harder ease of waking than controls, F (1, 34)= 23.609, p<0.001, partial eta squared= .410, there was also an effect of day, F (6, 204)= 14.001, p<0.001, partial eta squared= .163, but no significant interaction between day and group was found. Ease of waking was significantly more difficult for ecstasy users than controls on days 1, 2, 3, 4, 5 and 7, with only day 6 showing no significant difference (see fig 5). How participants physically felt upon awakening was significantly worse for the ecstasy than for the control group, F (1, 34)= 44.199, p<0.001, partial eta squared= .565. There was also a significant effect of day, F (6, 204)= 4.169, p<0.001, partial eta squared= .109. The interaction between day and group was also significant, F (6, 204)= 5.638, p<0.001, partial eta squared= .142. Ecstasy users felt significantly physically worse than controls upon awakening on days 1, 2, 3, 4 and 5 (see fig 6).

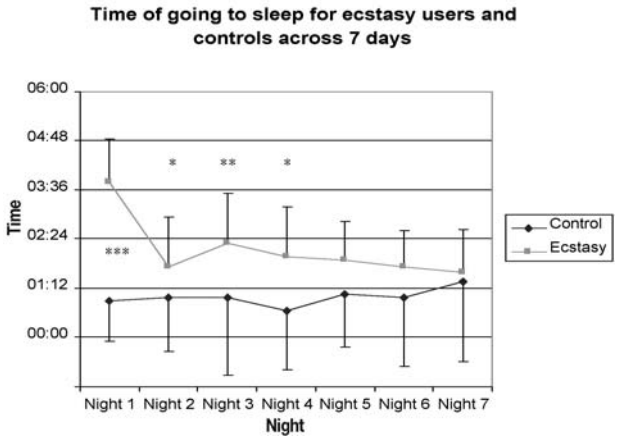

Figure 1. Time of going to sleep for 7 days. Time of going to sleep was significantly later for ecstasy users on nights 1 F(1, 34)= 73.320, p<0.001, partial eta squared= .683, 3 F(1, 34)= 6.008, p<0.05, partial eta squared= .150, 4 F(1, 34)= 8.948, p<0.01, partial eta squared= .208 and 5 F(1, 34)= 4.761, p<0.05, partial eta squared= .123.

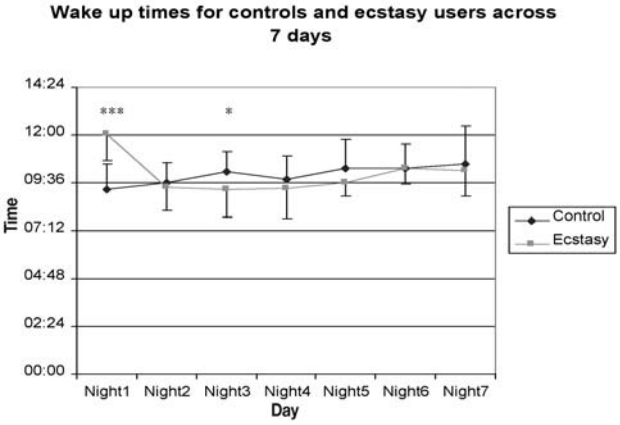

Figure 2. Wake time for 7 days. Wake time was significantly later for ecstasy users on days 1 F(1, 34)= 40.679, p<0.001, partial eta squared=.545 and 3 F(1, 34)= 4.879, p<0.05, partial eta squared=.125.

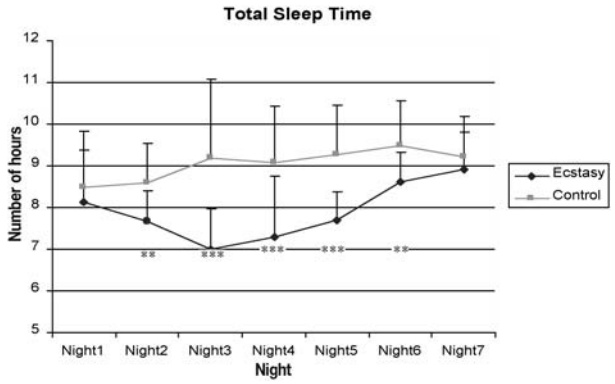

Figure 3. Total sleep time (TST) for 7 days. TST is significantly reduced on days 2 F (1, 34)= 10.702, p<0.01, partial eta squared= .239, 3 F(1, 34)= 19.274, p<0.001, partial eta squared= .362, 4 F(1, 34)= 14.572, p<0.001, partial eta squared= .300, 5 F(1,34)= 23.405, p<0.001, partial eta squared= .408 and 6 F(1, 34)= 8.187, p<0.01, partial eta squared= .194 for ecstasy users compared to non user controls
Note: Night 1 refers to the night/evening on which ecstasy was taken

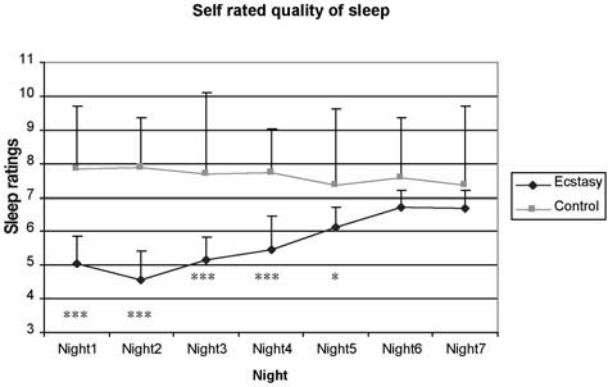

Figure 4. Self rated quality of sleep. These were significantly different on days 1F(1, 34)=34.079, p<0.001, partial eta squared= .501, 2 F(1,34)=66.886, p<0.001, partial eta squared= .663, 3 F(1, 34)= 18.339, p<0.001, partial eta squared= .350,4 F(1, 34)= 35.414, p<0.001, partial eta squared= .510 and 5 [t (19.452)= 2.346, p<0.05, partial eta squared= .139. Ecstasy users rated their quality of sleep as significantly worse for these days compared to non- user controls.
Note: Night 1 refers to the night/evening on which ecstasy was taken

Lethargy, Energy and Sociability

Figures 7, 8 and 9 show that ecstasy users were significantly more lethargic, had less energy and were less sociable than controls. No significant effect of group for lethargy was found but there was a significant effect of day, F (6, 204)= 3.845, p<0.001, partial eta

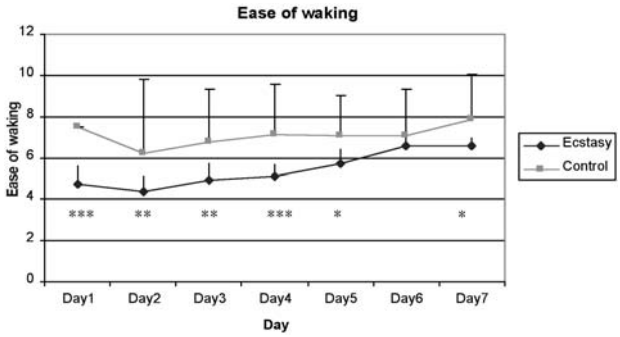

Figure 5. Self rated ease of waking. These were significantly different on days 1 F(1, 34)= 65.340, p<0.001, partial eta squared= .344, 2 F(1, 34)= 8.468, p<0.01, partial eta squared= .199, 3 F(1, 34)= 9.067, p<0.01, partial eta squared= .211, 4 F(1, 34)= 17.501, p<0.001,partial eta squared= .340, 5 F(1, 34)= 6.104, p<0.05, partial eta squared= .152 and 7 F(1, 34)= 8.462, p<0.05, partial eta squared= .199 for ecstasy users compared to controls
Note: Day 1 refers to the day after ecstasy was taken

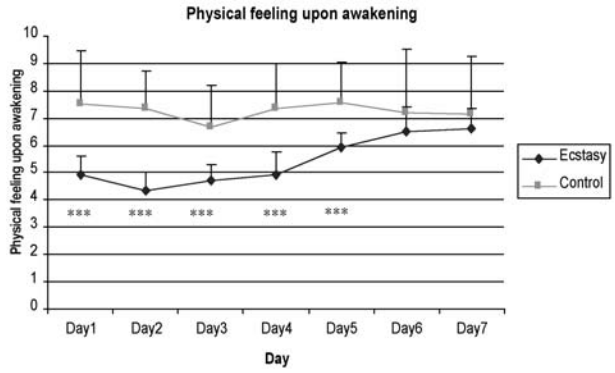

Figure 6. Self rated physical feelings upon awakening. These were significantly different on days 1 F(1, 34)= 26.948, p<0.001, partial eta squared= .441, 2 F(1, 34)= 72.917, p<0.001, partial eta squared= .682, 3 F(1, 34)=23.991, p<0.001, partial eta squared= .414, 4 F(1, 34)= 30.834, p<0.001, partial eta squared= .476 and 5 F(1, 34)= 18.826, p<0.001, partial eta squared= .356 for ecstasy users compared to controls

squared= .102 and the interaction between day and group was significant, F (6, 204)= 3.902, p<0.01, partial eta squared= .103. Ecstasy users were significantly more lethargic than controls on days 1 and 3 (see fig. 7). The ecstasy group had significantly less energy than did controls, F (1, 34)= 25.695, p<0.001, partial eta squared= .430, there was a significant effect of day, F (6, 204)= 4.476, p<0.001, partial eta squared= .116, and there was also a significant interaction between day and group, F (6,

204)= 10.956, p<0.001, partial eta squared= .244. Ecstasy users had significantly less energy than controls on days 3, 4, 5 and 6 (see fig. 8). The ecstasy group were significantly less sociable than controls, F (1, 34)= 57.348, p<0.001, partial eta squared= .628. There was a significant effect of day, F (6, 204)= 5.341, p<0.001, partial eta squared= .136, and the day by group interaction was also significant, F (6, 204)= 14.616, p<0.001, partial eta squared= .301. Ecstasy users were significantly less sociable than controls on days 3, 4, 5, 6 and 7 (see fig.9).

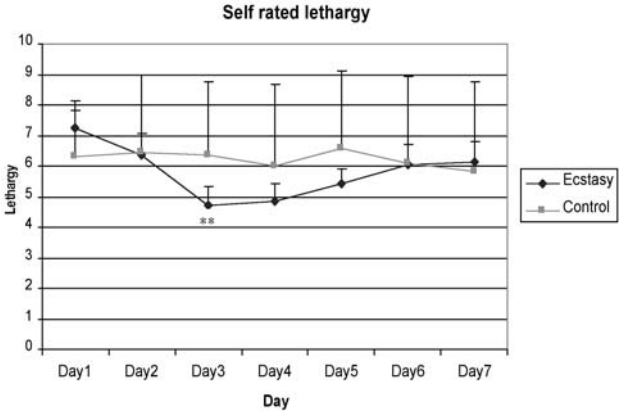

Figure 7. Self rated lethargy. This was significantly different on days 1 F(1, 34)= 4.213, p<0.05, partial eta squared= .110 and 3 F(1, 34)= 8.076, p<0.01, partial eta squared= .192 for ecstasy users compared to controls.

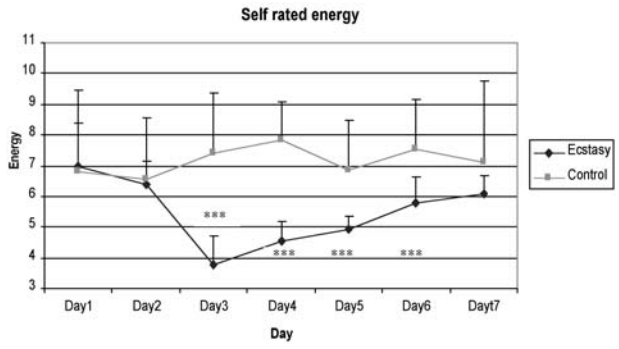

Figure 8. Self rated energy. This was significantly different on days 3 F(1,34)= 47.851, p<0.001, partial eta squared= .585, 4 F(1, 34)= 101.777, p<0.001, partial eta squared= .750, 5 F(1, 34)= 23.163, p<0.001, partial eta squared= .405 and 6 F(1, 34)= 15.224, p<0.001, partial eta squared= .309 for ecstasy users compared to controls Ecstasy users rated their energy as significantly lower for these days compared to non user controls

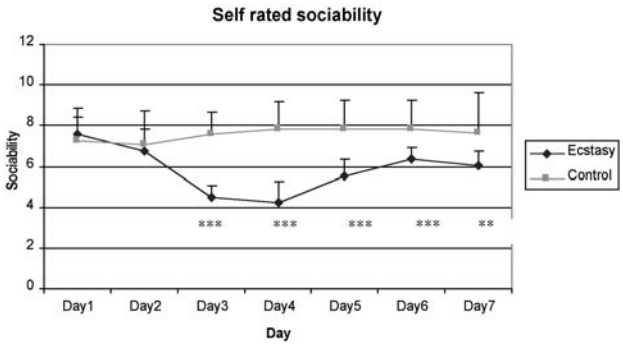

Figure 9. Self rated sociability. This was significantly different on days 3 F(1, 34)= 112.046, p<0.001, partial eta squared= .767, 4 F(1, 34)= 85.351, p<0.001, partial eta squared= .715, 5 F(1, 34)= 28.169, p<0.001, partial eta squared= .453, 6 F (1, 34)= 18.969, p<0.001, partial eta squared= .358 and 7 F(1, 34)= 10.370, p<0.01, partial eta squared= .234 for ecstasy users compared to controls

Self rated ease of taking in new information and concentration

Figures 10 and 11 show that the ecstasy group had significantly poorer concentration and ease of taking in new information than did controls. The ecstasy group had significantly poorer concentration than controls, F (1, 34)= 34.634, p<0.001, partial eta squared= .505. There was a significant effect of day, F (6, 204)= 6.388, p<0.001, partial eta squared= .158, and the interaction between day and group was significant F (6, 204)= 12.323, p<0.001, partial eta squared= .266. Concentration was significantly impaired for the ecstasy group on days 3, 4, 5, 6 and 7, there were no differences between the groups on days 1 and 2 (see fig 10). The ecstasy group rated themselves as significantly worse at taking in new information than controls, F (1, 34)= 34.069, p<0.001, partial eta squared= .501. There was a significant effect of day, F (6, 204)= 6.642, p<0.001, partial eta squared= .163. The interaction between day and group was significant, F (6, 204)= 15.158, p<0.001. Ease of taking in information was impaired for the ecstasy group on days 3, 4, 5 and 6 with non-significant results on day 1, 2 and 7 (see fig 11).

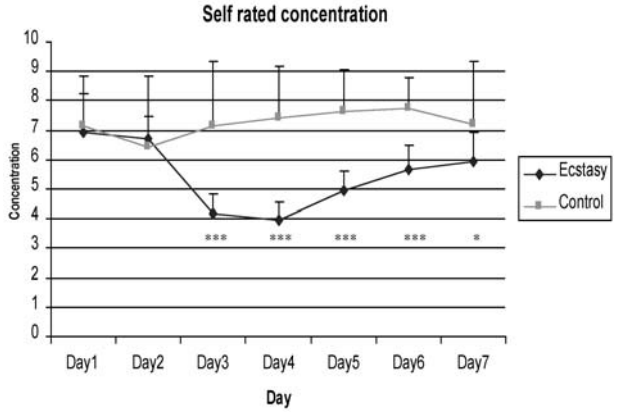

Figure 10. Self rated concentration. This was significantly different on days 3 F (1, 34)= 31.271, p<0.001, partial eta squared= .479, 4 F(1, 34)= 64.386, p<0.001, partial eta squared= .654, 5 F(1, 34)= 51.594, p<0.001, partial eta squared= .603, 6 F(1, 34)= 42.962, p<0.001, partial eta squared= .558 and 7 F(1, 34)= 5.097, p<0.05, partial eta squared= .130

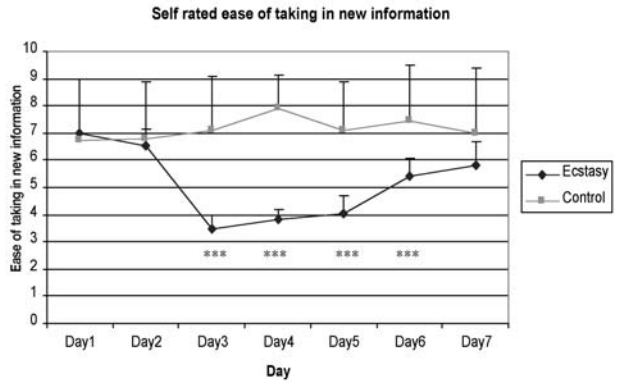

Figure 11. Self rated ease of taking in new information. This was significantly different on days 3 F(1, 34)= 55.216, p<0.001, partial eta squared= .619, 4 F(1, 34)= 185.734, p<0.001, partial eta squared= .845, 5 F(1, 34)= 21.720, p<0.001, partial eta squared= .390 and 6 F(1, 34)= 16.720, p<0.001, partial eta squared= .330 for ecstasy users compared to controls

Daily Alcohol Consumption as a Covariate

Consumption of alcohol on each of the 7 days was then used as a covariate. Table 1 shows the results of repeated measures ANOVAs using this covariate, compared to the ANOVA results without the covariate. There was still a significant effect of ecstasy use on time of going to sleep (bed time), F (1, 33)= 19.638, p<0.001, partial eta squared= .373 but night was no longer significant, F (6, 198)= 1.521, p= NS, partial eta squared= .044. However, the night and group interaction was still significant F (6, 198)= 3.753, p<0.001, partial eta squared= .102. There was no effect of ecstasy use on wake time, F (1, 33)= 0.965, p= NS, partial eta squared= .000, or day F (6, 198)= 1.381, p= NS, partial eta squared= .040. However, the day and group interaction was still significant, F (6, 198)= 8.628, p<0.001, partial eta squared= .207. There was still a significant effect of ecstasy use on total sleep time, F (1, 27)= 11.871, p<0.01, partial eta squared= .305, the effect of day remained significant, F (6, 162)= 3.680, p<0.01, partial eta squared= .120 as did the day by group interaction, F(6, 162)= 3.786, p<0.001, partial eta squared= .123. The effect of ecstasy use on sleep quality remained significant, F (1, 27)= 14.321, p<0.001, partial eta squared= .347, but the effect of day was no longer significant, F (6, 162)= 1.967, NS, partial eta squared= .068.The day by group interaction remained significant, F (6, 162)= 3.116, p<0.05, partial eta squared= .103. There was also still a significant effect of ecstasy use on ease of waking, F (1, 27)= 5.138, p<0.05, partial eta squared= .160, the effect of day was significant, F(6, 162)= 2.770, p<0.05, partial eta squared=.093, but there was no longer a significant day by group interaction, F(6, 162)= 1.944, NS, partial eta squared= .067. The effect of ecstasy use was still significant for physical feelings upon awakening, F (1, 27)= 16.671, p<0.001, partial eta squared= .382 as was the significant effect of day, F (6, 162)= 2.152, p<0.05, partial eta squared= .074 and the day by group interaction, F (6, 162)= 3.229, p<0.01, partial eta squared= .107

The effect of ecstasy use was no longer significant for lethargy, F (1, 27)= 0.557, NS, partial eta squared= .020, but there was still a significant effect of day, F(6, 162)= 2.261, p<0.05, partial eta squared= .077 and day by group interaction, F(6, 162)= 5.076, p<0.001, partial eta squared= .158. The significant effect of ecstasy use on energy remained, F (1,

Table 1. Means and Standard Deviations for all questionnaire measures for Ecstasy users and controls

		Night1	Night2	Night3	Night4	Night5	Night6	Night7
Bed time (hh.mm)	Ecstasy	3:48 (1:03)	1:43 (1:13)	2:18 (1:13)	1:59 (1:12)	1:53 (0:56)	1:43 (0:53)	1:35 (1:03)
	Control	0:53 (0:58)	0:58 (1:18)	0:59 (1:54)	0:39 (1:26)	1:04 (1:18)	0:58 (1:40)	1:22 (1:58)
Wake time (hh.mm)	Ecstasy	12:03 (1:19)	9.24 (1:12)	9:15 (1:22)	9:18 (1:29)	9:36 (0:39)	10:20 (0:48)	10:13 (1:17)
	Control	9:16 (1:16)	9:35 (1:00)	10:09 (1:02)	9:45 (1:12)	10:20 (1:28)	10:20 (1:12)	10:34 (1:54)
Total Sleep Time (TST)	Ecstasy	8.14 (1.25)	7.68 (0.73)	7.01 (0.95)	7.3 (1.46)	7.71 (0.66)	8.61 (0.72)	8.92 (0.88)
	Control	8.50 (1.33)	8.60 (0.95)	9.18 (1.89)	9.09 (1.34)	9.27 (1.19)	9.49 (1.09)	9.21 (0.97)
Sleep quality	Ecstasy	5.03 (0.85)	4.58 (0.82)	5.15 (0.95)	5.44 (1.01)	6.12 (0.61)	6.73 (0.49)	6.69 (0.52)
	Control	7.85 (1.86)	7.86 (1.49)	7.69 (2.43)	7.74 (1.28)	7.34 (2.28)	7.59 (1.76)	7.35 (2.35)
Waking	Ecstasy	4.78 (0.85)	4.4 (0.73)	4.91 (0.83)	5.12 (0.52)	5.71 (0.69)	6.58 (0.71)	6.58 (0.37)
	Control	7.47 (3.57)	6.24 (2.57)	6.75 (2.43)	7.12 (1.96)	7.08 (2.26)	7.04 (2.22)	7.84 (1.80)
Physical	Ecstasy	4.94 (0.67)	4.36 (0.68)	4.72 (0.55)	4.93 (0.85)	5.94 (0.51)	6.5 (0.93)	6.6 (0.78)
	Ecstasy	7.49 (1.97)	7.35 (1.38)	6.68 (1.54)	7.36 (1.65)	7.57 (1.50)	7.19 (2.32)	7.12 (2.15)
Lethargy	Ecstasy	6.93 (1.31)	6.36 (0.69)	4.69 (0.63)	4.86 (0.56)	5.43 (0.47)	6.05 (0.65)	6.14 (0.65)
	Control	6.32 (1.81)	6.44 (2.55)	6.35 (2.55)	6.01 (2.42)	6.59 (2.54)	6.11 (2.82)	5.82 (2.95)
Energy	Ecstasy	6.98 (1.41)	6.37 (0.78)	3.78 (0.94)	4.52 (0.66)	4.92 (0.42)	5.78 (0.86)	6.08 (0.60)
	Control	6.82 (2.63)	6.54 (2.01)	7.39 (2.0)	7.85 (1.22)	6.83 (1.63)	7.55 (1.61)	7.12 (2.66)
Sociability	Ecstasy	7.58 (0.83)	6.73 (1.09)	4.47 (0.59)	4.26 (1.01)	5.54 (0.81)	6.33 (0.63)	6.01 (0.70)
	Control	7.22 (1.63)	7.08 (1.66)	7.57 (1.10)	7.85 (1.30)	7.85 (1.41)	7.86 (1.35)	7.63 (2.00)
Concentration	Ecstasy	6.93 (1.31)	6.69 (0.80)	4.15 (0.71)	3.96 (0.59)	4.93 (0.66)	5.65 (0.81)	5.96 (0.97)
	Control	7.13 (1.70)	6.43 (2.44)	7.17 (2.19)	7.42 (1.73)	7.64 (1.45)	7.72 (1.06)	7.21 (2.14)
New info	Ecstasy	6.97 (1.04)	6.54 (0.58)	3.49 (0.50)	3.81 (0.38)	4.93 (0.66)	5.40 (0.69)	5.83 (0.83)
	Control	6.76 (2.23)	6.78 (2.09)	7.11 (1.99)	7.91 (1.22)	7.07 (1.83)	7.47 (2.03)	7.01 (2.39)

27)= 8.702, p<0.01, partial eta squared= .244, as did the day by group interaction F(6, 162)= 5.934, p<0.001, partial eta squared= .180, but the effect of day was no longer significant F(6, 162)= 1.580, NS, partial eta squared= .055. The significant effect of ecstasy use on sociability remained F(1, 27)= 11.591, p<0.01, partial eta squared= .300, as did the day by group interaction F(6, 162)= 7.316, p<0.001, partial eta squared= .213. The effect of day was no longer significant F(6, 162)= 1.311, NS, partial eta squared= .046. The effect of ecstasy use was no longer significant for concentration F (6, 162)= 1.467, NS, partial eta squared=. 052. The effect of day was no longer significant F (6, 162)= 1.467, NS, partial eta squared= .052. However, the day by group interaction remained significant F (6, 162)= 7.316, p<0.001, partial eta squared= .213. There was still a significant effect of ecstasy use on taking in new information F(1, 27)= 11.616, p<0.01, partial eta squared= .301. The effect of day was no longer significant F (6, 162)= 0.968, NS, partial eta squared=.035. However, the day by group interaction remained significant F (6, 162)= 5.740, p<0.001, partial eta squared= .175.

Sex differences

After performing ANCOVAs on time slept, concentration and taking in information with sex controlled for it was found that the effect of group and day x group was still significant for time slept, F (1, 33)= 34.912, p<0.001,

Table 2. Repeated measures ANOVA results for day, group and day x group interaction effects before and after controlling for alcohol use.

	Group	Day/night	Group x day	Group (A)	Day (A)	Day x group (A)
Bed time	***	**	***	***	NS	***
Wake time	NS	***	***	NS	NS	***
Total sleep time	***	***	**	**	**	***
Quality of sleep	**	*	**	***	NS	*
Easy or difficult to get up?	***	***	NS	*	*	NS
Physically feel	***	***	***	***	*	**
Lethargic	NS	***	**	NS	*	***
Energy	***	***	***	**	NS	***
Sociability	***	***	***	**	NS	***
Take in information	***	***	***	**	NS	***
Concentration	***	***	***	NS	NS	***

*** p<0.001; ** p<0.01; * p<0.05; NS= not significant; (A)= alcohol as a covariate

partial eta squared= .514, and F (6, 198)= 3.139, p<0.01, partial eta squared= .087 respectively. For concentration, group was still significant, F (1, 33)= 26.898, p<0.001, partial eta squared= .449 as was day x group, F (6, 198)= 13.273, p<0.001, partial eta squared= .287. Finally, for taking in information, group remained significant, F (1, 33)= 25.999, p<0.001, partial eta squared= .441 as did day x group, F (6, 198)= 14.474, p<0.001, partial eta squared= .305.

DISCUSSION

Recreational ecstasy use was associated with a 'dip' in psychobiological functioning on days 2 and 3 after ecstasy use, with significantly reduced total amount of sleep, sleep quality, ease of waking, energy and increased lethargy. The dip lasted until day 6 for most measures; these measures began to resemble those of the control group only by day 7. These results are in accordance with previous findings that subacute effects of ecstasy are present for a number of days after consumption (30,32,34,37). These findings also agree with Parrott et al (39) who surveyed 282 recreational Ecstasy/MDMA users, and found that 40% of users reported 'poor sleep' which they attributed to Ecstasy/MDMA usage.

Controlling for alcohol use each day did not eliminate these effects of ecstasy, with the exception of difficulty getting up and lethargy. Alcohol use thus does not account for the significant differences in sleep between ecstasy users and controls. Further, it does not account for differences on other variables, such as concentration, energy and taking in new information. It may be that the difference in our results from those of Huxster et al (37) is because the ecstasy users in Huxster et al's (37) study were heavy alcohol users who consumed alcohol almost every day.

Previous studies have found effects of ecstasy on fatigue, irritability, anxiety and depressed mood 5 - 7 days after a single dose of MDMA (5,40). Although acute MDMA induces feelings of warmth and empathy for a few hours (41), this is followed by feelings of irritability, depression and aggressiveness for several days afterwards (31,32,42). Other rebound/recovery problems include lethargy, unsociability, and reduced appetite, and there is an extensive list of longer-term problems, including memory deficits, cognitive processing disorders, and impaired social intelligence (43,13,14,44,45,46,12,47). Curran and Travill (30) found that ecstasy users had a mid week low after use at the weekend. The current findings support this previous work on cognitive deficits. This study also supports the findings of Allen et al (25) that ecstasy use results in shorter sleep.

However, whether that disturbed sleep is playing a casual role in the cognitive and mood problems of ecstasy users, as suggested by Colbron and Biello (22), is yet to be determined. Recreational MDMA also adversely affects neuroendocrine functioning. The energetic stress hormone cortisol is increased by 150% in acute dose laboratory studies (48,49), but by around 800% in MDMA using dance clubbers (50). These acute and sub-acute neurohormonal changes may relate to the sleep effects being reported here (Figures 1- 4 and Table 1).

A wider implication for these findings on residual effects days after usage of Ecstasy/MDMA is concentration and cognitive performance in real world situations comma for example, previous studies have found that car driving is adversely affected by the drug. Logan and Couper (51) reviewed the literature on the effects of recreational Ecstasy/MDMA on car driving and related psychomotor skills. They described eighteen case studies of car drivers on Ecstasy, including six where the blood samples were positive for MDMA alone. They noted elevated pulse, increased blood pressure, lack of balance and coordination, and poor performance on standard field sobriety tests, concluding that 'MDMA use is not consistent with safe driving, and impairments of various types may persist for a considerable time after last use'. Brookhuis et al (52) investigated MDMA users and MDMA-polydrug users on a driving simulator, and came to very similar conclusions about its damaging effects.

One limitation of the current design was the absence of a pre-drug baseline for the sleep and cognitive measures. This limitation is present in many of the earlier prospective studies [e.g., 30,32,33,34], but future studies should involve pre-drug baseline measures being collected. In the current study day 7 in effect served as a baseline in that ecstasy had not been taken for 7 days. Another limitation in the present study is the possible co-use of cannabis in the ecstasy group, for which we do not have data, and which would have neuropsychobiological effects and interactions (53,14).

In conclusion, it appears that sub acute effects of ecstasy on sleep, energy and cognition are present for up to 6 days after use. These effects are not due to a confound of alcohol use. Ecstasy users' self rated sleep, cognition, energy and sociability does not recover until day 7, when measures begin to resemble these for the control group. This adds to the mounting body of evidence that ecstasy use impairs individuals for many days after the drug is consumed, and has important implications for the young ecstasy using population, including increased risk of road accidents on the days after a Friday or Saturday night.

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