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The psychobiology of MDMA or 'ecstasy': Symposium arranged by the Psychobiology Section, at the Annual Conference of the British Psychological Society, Heriot-Watt University, Edinburgh, April 1997

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3,4-Methylenedioxymethamphetamine (MDMA) or 'ecstasy' is one of the most widely used recreational drugs today. It has been estimated that around half a million tablets of MDMA are taken each weekend in Great Britain, while it is also widely used in mainland Europe, North America and Australasia. This symposium, chaired by Keith Wesnes (Cognitive Drug Research, Reading, UK), aimed to describe its recreational use, outline its psychological and physiological effects and debate the human implications of the serotonergic neurotoxicity induced by MDMA. The speakers were selected to represent a range of different perspectives on this powerful illicit psychoactive drug.

In the first paper, Nick Saunders (London, UK) described the reasons given by recreational drug users for using MDMA. The speaker is author of two popular books on this drug (*E is for Ecstasy* and *Ecstasy and the Dance Culture*), and has personal knowledge and expertise on the recreational use of MDMA. He was therefore ideally placed to cover the drug user's perspective. The reasons usually given for taking MDMA included, for pleasure, to facilitate social interaction, to aid personal development and for spiritual enlightenment.

In the second presentation Dick Dafters (University of Glasgow, UK), summarized the animal literature on the physiological and neurotoxic effects of MDMA. He focused upon hyperthermia and the ways in which the hyperthermic response is exacerbated by high environmental temperatures or dehydration, but lessened by reductions in ambient temperature and the provision of water. The animal literature on MDMA-induced serotonergic neurotoxicity was then briefly described.

In the third presentation, Andy Parrott (University of East London, UK) summarized the effects of MDMA upon mood and cognition. Field studies with recreational drug users documented a range of positive mood effects. However negative moods occasionally develop while on-drug, and they clearly predominate afterwards during the period of acute neurochemical depletion. The effects of MDMA upon cognitive skills were then outlined. The main focus was on a recent University of East London study where significant memory decrements were found in two groups of recreational MDMA users.

In the fourth talk, Karl Jansen (Maudsley Hospital, London, UK) outlined the adverse psychiatric and medical sequelae traditionally associated with recreational MDMA use. However, it was suggested that the overall incidence of these psychiatric and medical casualties was quite small, compared with other social psychoactive drugs such as alcohol, tobacco, or amphetamine. The question was then raised of the need for firmer epidemiological evidence, to supplement the more traditional data from case studies.

This led to the final talk by Valerie Curran (University College London, UK), on future research perspectives. The difficulties inherent in illicit drug research were described, with experimental designs being very constrained. Thus placebo control, random allocation of subjects to conditions and double-blind drug administration, are generally an unattainable luxury for researchers in this field. Despite these difficulties, field research is still possible, and the findings from two studies at club raves were described. The Discussant was Mike Morgan (Substance Abuse Research Group, University of Swansea, UK), who also presented the findings from a recent study of Welsh drug users. Two groups of polydrug users were compared: those who used MDMA, and those who did not. They were matched on the use of other recreational drugs and compared with a third control group of non-drug users. A battery of neuropsychological tasks was completed, and on most tasks the three groups were similar. However, on tests of memory function and higher cognitive/executive planning, the MDMA polydrug group was significantly impaired, in comparison to *both* of the other subgroups. These findings replicated and extended the earlier cognitive data from East London, and provided confirmation that the recreational use of MDMA can have adverse cognitive consequences. One possibility is that they reflect serotonergic depletion in the hippocampus and frontal cortex. Whatever the neurochemical substrate, they certainly have worrying implications for young recreational users of MDMA.

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Appendix 1: Abstracts

Abstract 1. Recreational use of 'ecstasy': the drug user's perspective

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Although 'ecstasy' in this country is associated with young people and the rave/dance scene, it is also valued by psychotherapists, seekers of spirituality and people involved with 'personal development'.

A study of the psychological effects of 'ecstasy' was made by questioning psychiatrists while they were under the influence of the drug (Liester *et al.*, 1992). The main benefits reported were 'increased ability to interact or be open with others, decreased defensiveness and fear and decreased sense of separation or alienation from others'.

Studies of female participants in the dance scene include the papers of Henderson (1992, 1993) based on interviews with women ravers in the north of England. They revealed that a key motivation was the freedom to enjoy warmth, closeness and even physical contact with strangers of both sexes without this being a prelude to sex. This was valued as liberation from the sexual pressure experienced at alcohol-based clubs. 'The atmosphere of the rave inspires confidence and independence, for instance it is common for women to mix outside their social group of friends. This has provided a way for young women to rise above being a visual/sexual object...'

Russell Newcombe's (1994) paper identified the aim as the desire to partake in an altered state of group consciousness. This was greatly valued and not attainable without the use of drugs and dancing for long periods to music with a repetitive beat. Newcombe compares rave culture to trance dancing at tribal celebrations. 'Raving can also be viewed as a transcendental mind altering experience providing psychic relief to alienated people in a secular repressive and materialistic society. Ecstasy and other drugs are the keys that unlock the doors to these desired states of consciousness... To describe the rave as a mass illusion is not to decry its value... It is a deeply desired escape from the constraints of the self and normal behaviour, just as holidays provide an accepted form of relief... Indeed the ecstatic state achieved by ravers is arguably an expression of a primeval urge for group revelry...'

The group feelings of uplift induced by dancing on 'ecstasy' have been compared to spiritual experiences, and the rave has also been compared to a religious service in several papers including Saunders (1995). 'Last year I took a 70 year-old Zen monk to a rave party. He was curious enough to overcome his dislike of the music until his face lit up with a revelation. "This is meditation!", he shouted above the noise. Later he explained that the walking meditation he taught involved being fully aware "in the moment" without any internal dialogue separating actions from intentions, and that the same definition applied to the dancers all around him.'

These reports show examples of the use of 'ecstasy' to facilitate social intercourse, to be liberated from sexual pressure, to escape from social constraints and to fulfil spiritual needs. Why does our society impose restraints on such apparently healthy behaviour to the extent that a drug is required to overcome them?

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Abstract 2. The short- and long-term physiological effects of MDMA: animal studies of neurotoxicity

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3.4-Methylenedioxymethamphetamine (MDMA) or 'ecstasy', a ring-substituted amphetamine with psychoactive properties, is now a major drug of abuse with an estimated 500 000 young people using the drug weekly in Britain, according to a poll commissioned by the BBC in 1993. The drug is taken primarily as an adjunct to all night dances or 'raves' and has caused concern over its proven ability to cause occasional death or serious health problems in humans, and clear evidence of its long-term neurotoxicity to central serotonergic (5-HT) neurons in animals. However, the mechanisms of MDMA's toxicity is still poorly understood, as is the relationship between the acute toxic effects of the drug, such as hyperthermia and the longer-term neurotoxic effects, some of the animal research which has addressed these issues is surveyed.

Although MDMA was used quite extensively prior to the mid-1980s as a recreational drug, and even occasionally as an adjunct to psychotherapy, reports of adverse effects really only started to appear once it began to be used extensively by young people at raves or all-night dance clubs. The primary acute problem is usually attributed to the rapid body temperature elevation induced by the drug in this situation (hyperthermia) and its subsequent effects on the liver, brain and cardiovascular systems. It was the intriguing interaction between the pharmacological effect of the drug and the environmental conditions in which it was administered which prompted our research.

We have employed a remote radio-biotelemetry technique for the continuous monitoring of body temperature and activity levels in rats following administration of MDMA. The advantages of this method are that many subjects can be monitored simultaneously (up to 48 in our laboratory) and for extended periods, that drug administration can be made coincident with particular phases of the circadian rhythm of temperature and activity, and that the confounding effects of hyperthermia induced by stressful handling and rectal thermometer probing are avoided. Using this technique, the short-term consequences of MDMA administration are clear. At normal room temperatures (21–24 °C) there is a rapid (within 30 min) rise in body temperature and in activity levels following doses of 5 mg/kg or greater which last up to 6 h. Incidentally, human recreational doses of 5 or even 10 mg/kg have been reported or estimated, although 1–3 mg/kg is

probably more typical. Our research and that of others suggests that hyperthermia is not an inevitable consequence of MDMA administration. Rather it appears that the thermic consequences of the drug are strongly dependent upon such factors as the prevailing ambient temperature and the subject's level of hydration. The level of hyperthermia induced by a standard dose of MDMA is increased by a moderate rise in ambient temperature and decreased by a drop in ambient temperature. Furthermore, the rise in body temperature induced by a warm environment is augmented still further by reduced drinking during the post-drug period. The removal of the water bottles from cages for a 5-h period spanning the administration of the drug caused a profound elevation of body temperature of up to 5 °C in some rats, which could only be reversed by rapid cooling of the animals in an ice-box (Dafters, 1995). This hyperthermic response is unlikely to be due to the indirect effect of increased activity, as has sometimes been suggested, because the drug–activity profiles we obtain do not resemble the drug–hyperthermia profiles. For example, although both temperature and activity levels increase with drug dose, only the hyperthermic response is affected by the room temperature and water-availability conditions. This animal model has relevance for human drug-use problems at raves since two of the key ingredients are present, namely high ambient temperature and probably dehydration. There is also evidence for a third possible contributory factor — aggregation toxicity. This refers to the finding that the toxic effects of amphetamine, including hyperthermia, are enhanced when animals are grouped rather than housed singly, a phenomenon which is further enhanced by elevated ambient temperature. To the extent that aggregation toxicity also occurs to MDMA it could provide another contributory factor to the acute MDMA–rave toxicity effect.

The major thrust of the animal research on MDMA has been concerned with possible neurotoxic effects in the brain. Evidence has been accumulating since the early 1980s that MDMA and its demethylated metabolite, MDA, have long-term neurotoxic effects in animals. A variety of techniques including biochemical assay (high-pressure liquid chromatography), histology, radioligand binding techniques, and immunocytochemistry have revealed long-term depletions of brain levels of 5-HT (serotonin) and its uptake sites, and degenerative changes to 5-HT axons and terminals. These changes have been reported in several mammalian species including mice, rats and monkeys, and there are disturbing indications that primates may be more susceptible to the neurotoxic effects than the other species. What is still in dispute is the level of drug administration needed to produce damage, the extent of neurological recovery following cessation of drug use, and the extent to which other neurotransmitter systems of the brain are compromised. Reports of recovery are extremely varied and may reflect species differences and/or differences in sensitivity of the techniques used, however, a recent study on monkeys (Fischer *et al.*, 1995) reported that damage to nerve terminals was still apparent in some brain regions, 12 months after treatment, and that even in areas where reinnervation had apparently occurred it was highly abnormal. We have recently begun to investigate the issue of the sufficient dose for neurotoxicity and the extent to which dopamine pathways may be affected. While the great majority of studies have used high and/or repeated doses of MDMA to induce damage to 5-HT function, we have found that a single 10 mg/kg dose is sufficient to cause depletion of 5-HT and 5-HIAA levels. Our finding is supported by one other study, in which it was also noted that only a single 5 mg/kg dose of MDA was required to produce the depletion in transmitter (Colado *et al.*, 1995). Finally, in contrast to the majority of previously published studies which have not found evidence of damage to other neurotransmitter systems, we have found that a single 10 mg/kg dose caused a depletion in dopamine levels in several brain regions (Dafters *et al.*, 1997).

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Abstract 3. Emotional and cognitive effects of MDMA ('ecstasy'): the psychological perspective

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Double-blind placebo controlled investigations of MDMA are rarely feasible because of its illegal status, so most studies have monitored its effects in open trials with recreational drug users (Liester *et al.*, 1992; Solowij *et al.*, 1992); the current studies followed that procedure.

In the first study, 20 recreational drug users (nine female, 11 male; age range 18–31 years), described their past experiences with 3,4-methylenedioxymethamphetamine (MDMA) on a variety of assessment measures (Davison and Parrott, 1997). On the Profile of Mood States Questionnaire (POMS–bipolar), subjects reported feeling significantly more agreeable, elated, energetic, and mentally confused while on-drug (all $p < 0.001$). However, feelings of lethargy, moodiness, irritability, insomnia, depression and paranoia typically occurred soon afterwards, during the period of neurochemical depletion. Not all on-drug experiences were described in 'ecstatic' terms, with 25 percent of the sample having had at least one unpleasant MDMA trip. One subject now avoided all illicit drugs because of a particularly unpleasant MDMA experience. The structured interview generated a number of further findings, especially with regard to acute and chronic pharmacodynamic tolerance. For instance, most users reported the necessity for allowing a period of time between doses, in order to maintain effective drug responses. This acute tolerance may help explain the low addiction potential for MDMA.

The second study compared the mood effects of MDMA, amphetamine and lysergic acid diethylamide (LSD) in 21 polydrug users (age range: 17–34 years; 14 male, seven female). Each subject had used MDMA, amphetamine and LSD at least once. Modified POMS questionnaires were completed three times, for the recalled effects of each drug type. This allowed the mood profiles for each drug type to be directly compared (Parrott and Stuart, 1997). In energetic aspects (POMS mood factors for energy and confidence), MDMA produced scores intermediate between LSD and amphetamine. However in other aspects its mood profile was unique, with significantly higher feelings of elation, agreeableness and composure.

The third study was undertaken to assess whether the recreational use of MDMA affects cognitive functioning (Parrott *et al.*, unpublished). Three subject groups were compared: 10 regular MDMA users who had taken MDMA on more than 10 occasions; 10 novice users who had taken it less than 10 times; and 10 control subjects who had never taken MDMA. All subjects were in the age range 18–30 years. They were tested on a standardized battery of cognitive tests (Cognitive Drug Research battery), in an individual test cubicle, on a day when they were drug-free. On most cognitive tasks (e.g. simple reaction time, choice reaction time, number vigilance), performance levels were similar across groups. However, on two memory tasks (immediate and delayed word recall), both MDMA subgroups were significantly impaired in contrast to the controls. This finding agrees with Krystal *et al.* (1992) in America, where nine regular MDMA users were assessed on a standardized battery of cognitive tasks. Performance on most tasks were similar to age-matched norms, whereas memory task performance was lower than expected.

The general methodology of these studies was far from ideal, with no control over the drugs taken, expectancy, and other confounding factors. Placebo-controlled studies are therefore urgently needed. However, the current findings raise concerns for recreational users of MDMA. Plans are therefore underway for further studies with improved levels of experimental control.

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Abstract 3. 'Ecstasy' (MDMA): adverse psychological effects and their management

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3,4-Methylenedioxymethamphetamine (MDMA) was initially presented as a drug with therapeutic promise and few adverse effects, as amphetamine had been until the late 1960s. As with amphetamine, however, widespread recreational use has resulted in reports of confusion, anxiety, panic attacks, depression, sleep disturbance, Pandora's box syndrome, depersonalization/derealization, hallucinations, flashbacks, psychosis and possible cognitive changes. Pandora's box syndrome ('busy head syndrome') is a term coined to describe a high level of internal imagery, possibly arising from perforations in defences separating conscious from unconscious material. However, many of these reports are based on single case studies and short, uncontrolled series. There is often no evidence that the drug taken was MDMA, that other drug use (particularly cannabis and amphetamine) was not a significant contributor to the symptoms, and that urine samples were free of other drugs and their metabolites. It is rarely clear that the condition would not have occurred by chance and that the person was not predisposed to the condition.

Animal studies have shown that large quantities of MDMA can result in persistently low serotonin levels. Attempts to relate these chemical changes to adverse effects usually ignore the role of psychological changes due to the emotional and insight-oriented effects of MDMA, which can release potentially disturbing material from the unconscious. While this effect has been used as an aid to psychotherapy, the same release may result in symptoms such as anxiety, depression and sleep disturbance, for example, particularly when it occurs in a setting where there is no opportunity to contain or work through the released material.

Psychological explanations for adverse effects should be considered in addition to neurochemical factors, particularly as some of the adverse effects are reported after just a few doses rather than chronic dosing. Expectations are important. Although serious physical effects are relatively rare, a perception by users that they are experiencing such effects has increased due to media-generated concern, leading to more persons presenting with false beliefs that they are in physical extremis. Heavy weekend users tend to have midweek problems such as low mood/irritability and may develop a cyclical pattern of use. Management may include assessment, urinalysis to confirm the nature of drugs taken, counselling, psychotherapy and cognitive-behavioural therapy (Jansen, 1997). The denial defence may be more effectively overcome using facts from the person's own life rather than discussing nerve terminal changes. Other techniques include relapse prevention, motivational interviewing, meditation, relaxation, physical exercise and sports, and medication including the serotonin reuptake inhibitors such as fluoxetine ('Prozac'), antioxidants such as vitamins E and C, tyrosine and tryptophan (serotonin precursors) and a short course of benzodiazepines. Neuroleptics should be avoided. Acupuncture may also be useful. In view of the animal neurotoxicity data, further research in this area is urgently required.

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Abstract 4. Future perspectives for psychological research on MDMA ('ecstasy')

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The controlled methods used in research with prescribed psychotropics and licit recreational drugs like alcohol are often precluded in research with human participants on class A drugs like 3,4-methylenedioxymethamphetamine (MDMA) or 'ecstasy'. Legal and ethical considerations in research with MDMA are summarized and their implications are drawn out for the methodologies that studies can and cannot employ. Recent studies of psychological effects of MDMA are used to illustrate the various stumbling blocks researchers need to negotiate. For example, in field 'experiments', what biological markers can we realistically use to determine which drugs were actually taken? Or again, without clear baseline measures, placebo controls and double-blind conditions, how can we fully detail the psychological effects of taking MDMA? How reliable are self-report data about centrally-acting drugs which may affect memory and cognition?

Curran and Travill (1997) set up a mini laboratory in a large night club. They recruited a group of MDMA users and, as a control, alcohol users (drug-free controls were not available in the club). This was after ethical approval had been obtained which, among other things, involved considering whether people high on MDMA or alcohol were able to give informed consent. Participants were tested individually over a period of 5 days at these separate testing times (Day 1 in the nightclub, Days 2 and 5 in the participant's own home) in order to assess any differences between groups over days in mood, memory and concentration. There were marked group differences over days in mood, in particular, Group 1 (MDMA) showed an increase in score on the Beck Depression Inventory (BDI) over days ($p<0.001$) and when compared to group 2 (Alcohol) there was a significant interaction between groups and days ($p<0.001$). These effects remained when scores were re-analysed omitting all somatic items from the BDI. This provides some evidence for the midweek depression syndrome anecdotally reported by recreational MDMA which may reflect a temporary depletion in serotonin a few days after MDMA is taken (cf. Smith *et al.*, 1997). MDMA users also showed impairment on an attentional/working memory task compared with alcohol users.

A subsequent study was designed to assess whether low mood lifts over time when MDMA is not taken again for 2 weeks. Twenty MDMA users were recruited into a partial cross-over study whereby they were assessed on the night of MDMA use (Day 1), Days 5 and 8. A 'washout' week ensued, with alcohol only being allowed the following Saturday night (Day 15) and testing again on Days 19 and 22. MDMA users showed higher scores on the BDI on Day 15, when they were allowed only alcohol. The residual effects of MDMA were more pronounced than those of alcohol on memory and concentration. These findings imply that weekend use of MDMA can be associated with low mood and cognitive impairment several days later which could adversely affect young people's educational/work performance and psychological well-being. The need is emphasized for further, more controlled research on the acute, chronic and residual effects of MDMA on mood and cognition.

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Abstract 5. Lasting psychological sequelae of recreational use of MDMA ('ecstasy'): controlled studies in humans

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Preclinical evidence suggests that repeated administration of 3-, 4-methylenedioxymethamphetamine (MDMA) 'ecstasy' produces long-lasting changes in serotonin (5-HT) systems (decreased brain 5-HT and 5-HIAA concentrations and suspected 5-HT axon terminal degeneration) in rodents and primates. In humans, serotonin is believed to play a modulatory role in a variety of psychological processes, including learning and memory, but the lasting psychological sequelae of chronic MDMA exposure have rarely been investigated.

There is a preliminary report, however, that, although otherwise unimpaired, heavy users of 'ecstasy' exhibited mild-to-moderate deficits in the initial and delayed paragraph test of the Wechsler Memory Scale (Krystal *et al.*, 1992). The latter finding has been supported by a recent report of significant decrements in working memory in 'ecstasy' users compared with alcohol users, and a trend in the same direction for prose recall (Curran and Travill, 1997), and a report that both novice and more experienced recreational 'ecstasy' users were impaired on tests of immediate and delayed recall compared to non-users, but were not impaired on other neuropsychological tests (Parrott, 1997).

There were a number of methodological problems with the Krystal *et al.* (1992) study, however, several of the participants had psychiatric histories, all had been administered tryptophan prior to testing, and there was no control group of non-users. The performance of the recreational 'ecstasy' users was simply compared with age-matched norms. There is a related methodological problem, that is common to all previous investigations of memory performance in 'ecstasy' users. The possible long-term influence of other illicit and legal drugs on behaviour was not adequately controlled for in any of these studies.

One strategy that can be adopted to identify the psychological sequelae associated with 'ecstasy' use specifically, as distinct from those associated with the use of illicit drugs generally, is to compare the performance of 'ecstasy' users not only with that of polydrug users who have used similar

amounts of other illicit drugs, but have never never taken 'ecstasy', but also with a third group of participants who have never taken any illicit drugs. This is the approach adopted in all of the author's studies since 1992. A highly-controlled design in which three groups of participants were recruited: (1) MDMA group, polydrug users who have used 'ecstasy' more than 20 times; (2) polydrug group: polydrug users who have never taken 'ecstasy', but whose use of other illicit drugs was similar to that of the MDMA group; and (3) control group: participants who have never used illicit drugs were used. Participants in all three groups were selected so that the following were not significantly different: age, gender ratio, height, weight, education level achieved and estimated premorbid IQ (NART). Participants in the two groups that used illicit drugs (MDMA and polydrug) were further selected such that histories of use of alcohol, cigarettes, cannabis, amphetamine and lysergic acid diethylamide were not significantly different. Measures included total consumption over various periods and duration of use.

In the first pilot study in which this design was used (Z. Barnard, unpublished data) we compared measures of cognitive performance between three groups of nine participants. We found that although the three groups were not significantly different with respect to their performance in two subtests of the Wechsler Adult Intelligence scale, both drug groups tended to perform worse in the Stroop test, and the MDMA group tended to exhibit a specific deficit (failure to maintain set) in the Wisconsin Card Sort.

In another pilot study (C. Rose, unpublished data) we found that there were no significant differences between the three groups [control ($n=20$), polydrug ($n=14$), MDMA ($n=17$)], in terms of mood state (Profile of Mood States—POMS), or anxiety (State/Trait Anxiety Inventory), but we did find a significant negative correlation within participants in the MDMA group, between duration of use of 'ecstasy' and mean scores for the 'clear-headedness' factor of the POMS. More recently, we conducted two further studies of the lasting emotional sequelae of recreational 'ecstasy' use. One compared 12 participants per group in the laboratory (Davies, 1996), the other used a 'snowball' technique to distribute questionnaires and test participants outside the laboratory, [control ($n=30$), poly drug ($n=27$), MDMA ($n=29$)] (Calow, 1996). No group differences were observed in either study, for mood (General Health Questionnaire—GHQ, Beck Depression Inventory), or state/trait anger (State Trait Anger Expression Inventory), but in the latter study, both drug-using groups scored higher than controls on trait impulsiveness from the Impulsiveness, Venturesomeness, and Empathy questionnaire (IVE). We also conducted another study of the lasting neuropsychological sequelae of recreational 'ecstasy' use [control ($n=16$), polydrug, ($n=12$), MDMA ($n=16$)], (Morgan *et al.*, 1997). Again we found no significant group differences in state/trait anxiety, or state/trait anger, and no significant differences in performance of two tests from the CANTAB Working Memory and Planning Battery—the Spatial Span test and the 'Tower of London' test (TOL). However, we did find that the MDMA group committed significantly more errors, than the other two groups, in a version of the Matching Familiar Figures test (MFF20), which has been previously used as a behavioural measure of impulsivity.

Finally, we replicated and extended the previous study in our most recent investigation (Morgan, 1997), in which we tested a larger number of participants [control ($n=19$), polydrug ($n=20$), MDMA ($n=26$)]. Participants were administered the GHQ and IVE, and presented with a passage of prose from the Rivermead Behavioural Memory test and asked to write down as much of the passage as possible, verbatim, immediately after audio presentation. They were then administered a TOL test, followed by the MFF20, and a second TOL test, before their delayed recall was assessed. Once more we found no significant group differences in the performance of the two TOL tests. However, we did find that MDMA participants were more psychologically disturbed (GHQ) than non-drug controls, and we partially replicated the earlier MFF20 finding—the MDMA group committed significantly more errors on the MFF20 than participants in the polydrug use group. Furthermore, when data from the present study were combined with those from the previous study, MDMA participants were found to score significantly higher, than participants in the other two groups, on trait impulsiveness (IVE), and the MDMA users who had taken the most 'ecstasy' scored significantly higher on impulsiveness than those who had only taken the entry level amount (20 tablets). Perhaps the most important finding of the most recent study, however, was that both the immediate and delayed recall performance of the MDMA users were markedly impaired, compared to participants in the other two groups.

In conclusion, the evidence suggests that there are, indeed, lasting psychological problems that are specifically associated with recreational consumption of 'ecstasy', but that these psychological sequelae are highly selective. The principal lasting psychological sequelae appear to fall into two categories: (1) elevated impulsivity and (2) impaired memory. The latter finding is congruent with the observations of Krystal *et al.* (1992), Curran and Travill (1997) and Parrott (1997), but is the first direct evidence of an association between lasting memory deficits and the recreational use of 'ecstasy' specifically, rather than with the use of illicit drugs generally. Clearly, these findings raise concerns about the neuropsychological status of hundreds of thousands of young people who have taken 'ecstasy' on a regular basis.

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