

Prospective memory, everyday cognitive failure and central executive function in recreational users of Ecstasy

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Chronic use of MDMA (3,4-methylenedioxymethamphetamine), or Ecstasy, is believed to lead to impaired psychological performance, including well-documented decrements in laboratory and field tests of retrospective memory. Less is known about the impact of Ecstasy on aspects of 'everyday' memory, despite obvious concerns about such effects. The three studies reported here focused on the impact of chronic Ecstasy use on prospective memory (PM), associated central executive function and other aspects of day-to-day cognition. In study 1 46 regular Ecstasy users were compared with 46 Ecstasy-free controls using the Prospective Memory Questionnaire (PMQ). Ecstasy users reported significantly more errors in PM (remembering to do something in the future); these findings persisted after controlling for other drug use and the number of strategies used to aid memory. No difference was found between representative subgroups on the Lies Scale of the Eysenck Personality Questionnaire. In study 2 a different group of 30 regular Ecstasy users and 37 Ecstasy-free controls was assessed on the PMQ and on a central executive task comprising verbal fluency measures. The results confirmed the significant impairments in long- and short-term PM and revealed corresponding impairments in verbal fluency. In study 3 15 Ecstasy users, 15 cannabis users and 15 non-drug users were assessed using the Cognitive Failures Questionnaire, which requires participants to provide ratings of the frequency of various day-to-day cognitive slips. The results indicate that the Ecstasy users did not perceive their general cognitive performance to be worse than that of controls. Taken together, these results suggest that Ecstasy users have impaired PM that cannot be explained by an increased propensity to exaggerate cognitive failures. These may be attributable, in part, to central executive deficits that are due to frontal lobe damage associated with Ecstasy use. Copyright © 2001 John Wiley & Sons, Ltd.

KEY WORDS—Ecstasy; MDMA; cannabis; prospective memory; central executive; cognitive failures

INTRODUCTION

Regular use of MDMA (3,4-methylenedioxymethamphetamine), or Ecstasy, has a deleterious effect on human memory, particular upon the recall of previously presented verbal material (Rodgers, 2000; Parrott, 2000; Morgan, 1999). Recent work has demonstrated that Ecstasy users also exhibit impairments of working memory, including central executive processes (Wareing *et al.*, 2000). Although important, such studies tell us little about cognitive

functioning in Ecstasy users within an everyday context.

Prospective memory (PM) is an important aspect of 'day-to-day' functioning that may rely on central executive resources. Heffernan *et al.* (2001) examined PM functioning in heavy Ecstasy users using the Prospective Memory Questionnaire (PMQ), a self-report measure that requires the participant to recount errors for short- and long-term PM, internally cued PM, as well as the number of strategies used to aid memory (Hannon *et al.*, 1995). After statistically controlling for other drug use and strategy use, Heffernan *et al.* (2001) revealed that Ecstasy users reported significant global impairments in PM skills compared with non-users. On the other hand, Rodgers (2000) found no significant differences between Ecstasy users and drug-free and cannabis-only control participants, in

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terms of their self-perceived everyday cognitive performance, as measured by the Cognitive Failures Questionnaire (Broadbent *et al.*, 1982). The extent to which self-reported deficits in cognitive function are specific to PM was the focus of one of the studies reported here.

Ecstasy may, in part, exert its effects by causing a depletion of forebrain serotonin, including within the frontal cortices (Ricaurte *et al.*, 1992). One aspect of cognition that is thought to be mediated by the frontal lobes is the central executive component of working memory. Central executive processes are involved in planning and executing behaviour, which would include those involved in formulating and remembering future activities. There is evidence that central executive functioning is impaired in regular users of Ecstasy. For example, Wareing *et al.* (2000) demonstrated that Ecstasy was linked to working memory decrements, particularly when the central executive becomes heavily involved. Central executive functions are thought to play a critical role in PM (Kopp and Thone, 2000). If this were the case, one would expect comparable deficits in both prospective remembering and central executive resources within the same cohort of Ecstasy users. The second in the present series of studies explored this possibility.

In order to overcome the many problems associated with retesting participants across a number of studies, each study reported here used a separate group of Ecstasy users. The first study examined the impact on PM functioning in Ecstasy users by presenting an extended data base from the study by Heffernan *et al.* (2001) and also attempted to determine the extent to which participants may be lying during data collection. The second study assessed a separate group to that in study 1 in order to assess the reproducibility of the findings from study 1, and additionally explored central executive functions in Ecstasy users. The third study focused on general cognitive failures in a new group of Ecstasy users and compared these with a group of cannabis users and a matched control group.

STUDY 1: MATERIALS AND METHODS

This study examined the impact on PM functioning in Ecstasy users, based on an extended database from the study by Heffernan *et al.* (2001), and attempted to determine the extent to which participants may be lying during data collection.

Participants

Forty-six regular Ecstasy users (28 males; mean age 24.6 years, range 18–43 years), taking the drug 6–30

times per month (average of 10 times per month), with an average of one tablet per session, and 46 non-user controls (17 males; mean age 26.1 years, range 18–40 years) were recruited using the 'snowball' technique (Davison and Parrott, 1997). Participants reported that they had been 'drug-free' for at least 24 h prior to testing.

Drug use characteristics

Other drug use was assessed by a questionnaire gauging the number of times alcohol (in units), cannabis and cocaine were consumed per week or month. The Ecstasy group had smoked cannabis ($n=35$) on average once a week over an 8 year period (with an average of 2 joints per session), and some of the participants had reported using cocaine ($n=14$) on 4–8 occasions, and 42 had consumed an average of 20 units of alcohol per week over an 8–10 year period. None had taken LSD. The Ecstasy-free control group had smoked cannabis ($n=15$) on average 1.5 times per week over a 6 year period (with an average of 1–2 joints per session), and some of the participants had reported using cocaine ($n=6$) on 1–4 occasions, and 34 had consumed an average of 19 units of alcohol per week over a 9–10 year period. None had taken LSD. The two groups had not smoked cannabis for at least 3 days, had not used cocaine for at least 1 week, and had not consumed alcohol or Ecstasy for at least 24 h. Apart from the drug use questionnaire no other drug screening was used.

Other measures

PM was assessed using the PMQ, a valid and reliable self-report measure (Hannon *et al.*, 1995). The PMQ provides measures of three aspects of PM on a series of 9 point scales. Fourteen questions measure short-term habitual PM, e.g. 'I forgot to turn my alarm clock off when I got up this morning'. Fourteen items measure long-term episodic PM, e.g. 'I forgot to pass on a message to someone'. Ten questions measure internally cued PM, e.g. 'I forgot what I wanted to say in the middle of a sentence'. The PMQ provides a measure of self-reported errors in the previous week, month or year. The scale ranges from 1 (where least forgetting is evident) to 9 (where there is a great deal of forgetting). Additionally, 14 questions make up the 'techniques to remember' scale, providing a measure of the number of strategies used to aid remembering. The techniques to remember scale ranges from 1 (few strategies used) to 9 (a high number of strategies used). On this latter scale the greater the score, the

Table 1. Summary (means and SDs) of comparison of Ecstasy users with controls on measures from study 1. *F* and *p* values are derived from the analyses of variance of the age, lies and strategy data, and the analyses of covariance of the data from the subscales of the Prospective Memory Questionnaire (PMQ). EPQ lies: lie scale of the Eysenck Personality Questionnaire; PMQ strategies: score on strategy use of the PMQ; Long-term PM, short-term PM and internally cued PM refer to scores from three subscales of the PMQ

	Controls (n = 46)	Ecstasy users (n = 46)	<i>F</i>	<i>p</i>
Age	26.1 ± 6.53	24.6 ± 5.89	1.14	0.23
EPQ lies*	2.42 ± 1.69	3.25 ± 2.59	0.71	0.40
PMQ strategies	3.75 ± 2.15	3.79 ± 1.64	0.01	0.91
Long-term PM	2.72 ± 1.25	4.17 ± 1.62	23.6	< 0.001
Short-term PM	1.47 ± 0.59	2.37 ± 1.03	23.4	< 0.001
Internally cued PM	3.09 ± 1.18	4.35 ± 1.84	21.6	< 0.001

*This measure was applied to a representative subgroup from each group.

more memory aids used. Completion of the PMQ preceded the drug-use questionnaire. Twenty-one participants from the control group and 24 from the Ecstasy group were tested on the Lies Scale of the Eysenck Personality Questionnaire (Eysenck and Eysenck, 1991) in an attempt to test for lying during data collection.

STUDY 1: RESULTS

The results of the study are summarised in Table 1. Three one-way ANOVAS revealed no significant differences between the groups in terms of age, the number of strategies used or (between representative subgroups) on the Lies Scale of the Eysenck Personality Questionnaire.

Amounts of alcohol, cannabis and cocaine used were incorporated into the analyses of covariance (ANCOVA) applied to the data from each subscale. These revealed a significant difference between the Ecstasy and control groups in the reported error rate in short-term habitual PM, long-term episodic PM and internally cued PM.

These results suggest that all aspects of PM are impaired in Ecstasy users. The findings require replication in order to assess their reliability. How PM is linked to more established memory mechanisms, such as central executive processes in working memory, also requires further clarification. These issues formed the basis for the second study.

STUDY 2: MATERIALS AND METHODS

Participants

Thirty Ecstasy users (17 males; mean age 23.9 years, range 19–40 years), taking the drug 2–20 times per month (average of 5.6 tablets per month), and 37

non-Ecstasy controls (10 males; mean age 25.5 years, range 19–50 years) were recruited using the 'snowball' technique. No participant had taken part in study 1.

Drug use characteristics

Drug use was assessed as in study 1. The Ecstasy group had smoked cannabis (n = 27) on average 3.5 times per week over an average of 4–5 years (with an average of 2 joints per session), some of the participants had reported using cocaine (n = 12) on an average of 6 occasions, and all 30 had consumed an average of 18 units of alcohol per week over a 3–23 year period. None reported having used LSD. Of the Ecstasy-free control group, four had smoked cannabis on average 0.21 times per week over a 5 year period (with an average of 1–2 joints per session), none of the participants had reported using cocaine, and 36 had consumed an average of 10 units of alcohol per week over a 3–30 year period. None had used LSD. The two groups had not smoked cannabis for at least 3 days and had not consumed alcohol or Ecstasy for at least 24 h prior to taking part in the study. No other drug screening was used.

Other measures

PM and other drug use was assessed using the same questionnaires as in study 1. In addition, central executive (CE) functioning was measured using three tasks: a verbal fluency task (recalling as many words beginning with the letter 'C'), a semantic fluency task (recalling as many items from the category 'animals') and a combined verbal/semantic fluency task (recalling as many household items beginning with the letter 'T'), within a 1 min period set for each task. Responses were written. The more items recalled

Table 2. Summary (means and SDs) of comparison of Ecstasy users with controls on prospective memory (PM) and central executive measures used in the study. *F* and *p* values are derived from the analyses of variance of the age and strategy data, and the analyses of covariance of the data from the subscales of the Prospective Memory Questionnaire (PMQ) and the three fluency measures. PMQ strategies: score on strategy use scale of the PMQ; long-term PM, short-term PM and internally cued PM refer to scores from three subscales of the PMQ; verbal fluency, semantic fluency and combined fluency refer to scores from three measures of central executive function

	Controls (n = 37)	Ecstasy users (n = 30)	<i>F</i>	<i>p</i>
Age	25.5 ± 8.76	23.9 ± 4.47	0.72	0.39
PMQ strategies	3.33 ± 1.61	2.91 ± 1.17	1.44	0.23
Long-term PM	2.25 ± 0.82	3.45 ± 0.91	6.50	< 0.05
Short-term PM	1.34 ± 0.47	2.39 ± 1.12	15.5	< 0.001
Internally cued PM	2.85 ± 1.30	3.35 ± 1.15	0.02	0.89
Verbal fluency	14.2 ± 4.06	10.3 ± 2.68	15.6	< 0.001
Semantic fluency	14.5 ± 3.40	10.9 ± 3.51	6.62	< 0.05
Combined fluency	6.57 ± 1.82	5.57 ± 2.36	7.36	< 0.01

within 1 min, the greater the CE ability. Fluency tasks of this nature are seen as good measures of CE functioning (e.g. Rabbitt, 1997). Each participant completed the CE tasks first, followed by the PMQ and then the drug use questionnaire.

STUDY 2: RESULTS

The results of the study are summarised in Table 2. Two one-way ANOVAS revealed no significant differences between the groups in terms of age or the number of strategies used.

Amounts of alcohol, marijuana and cocaine used were incorporated into the analyses of covariance (ANCOVA) applied to the data from each PM subscale and for the CE measures. These revealed a significant difference between the Ecstasy and control groups in terms of their short-term habitual PM and their long-term episodic PM, but not in their internally cued PM. In addition, the Ecstasy users performed significantly worse on the verbal fluency, semantic fluency and combined fluency tasks.

These results suggest that short-term habitual and long-term episodic aspects of PM are impaired in Ecstasy users, which is broadly consistent with the findings from study 1. However, study 2 failed to find any difference between Ecstasy users and controls on the internally cued PM (see Discussion). The fact that Ecstasy users show corresponding impairments in verbal fluency measures of central executive function support the notion that PM and CE are linked. The findings also raise the questions of whether Ecstasy users have an increased perception of general cognitive failure and to what extent any such impairment may be drug-specific. These issues formed the focus of the third study.

STUDY 3: MATERIALS AND METHODS

Participants

This study used separate groups of participants from those used in studies 1 and 2.

Fifteen Ecstasy users (seven men; mean age 31.4 years, range 23–44 years) who reported taking the drug on average 20 times over a 5 year period, with an average of one tablet per session, 15 regular cannabis users (seven men; mean age 30.3 years, range 21–43 years) who reported taking the drug on average 4 times per week over a period of 11 years, with an average of 3 joints per session, and 15 drug-free controls (six men; mean age 32.1 years, range 26–39 years) were recruited using the 'snowball' technique.

Drug use characteristics

Results from a drug use questionnaire confirmed that the Ecstasy group reported being cannabis-free for 1 month and had not taken Ecstasy for at least 2 months prior to testing. The Ecstasy group had smoked cannabis on average 4 times per week over a 10 year period (with an average of 2 joints per session), and some of the participants had used LSD on a couple of occasions (*n* = 2), cocaine (*n* = 3) on four, five and one occasion respectively, all at least 3 years prior to testing. The cannabis group reported never having taken any other psychoactive drug and had not taken cannabis for at least 1 month prior to testing. The control group reported never having taken any illegal substance. All three groups described themselves as 'social drinkers' and used 2–3 units of alcohol per week. Apart from the drug use questionnaire no other drug screening was used.

Other measures

Participants completed Broadbent *et al.*s (1982) Cognitive Failures Questionnaire (CFQ), a self-rating scale of the perception of frequency of a variety of cognitive slips over the past 4 weeks. Participants rate their performance using a 5 point scale from 'never' (assigned a score of 0) to 'very often' (assigned a score of 4) on 25 statements relating to everyday cognitive performance' e.g. 'Do you find you forget whether you've turned off a light or a fire or locked a door?' The scale provides a score between 0 and 100.

STUDY 3: RESULTS

There were no significant differences in CFQ scores between the Ecstasy, cannabis and alcohol groups [$F_{(2,42)} = 1.42, p = 0.09$]. The mean scores for the three groups were 45.20 (SD 8.11), 40.80 (SD 8.23) and 45.13 (SD 8.23), respectively.

DISCUSSION

The results of study 1 demonstrate that, compared with non-users, Ecstasy users report global impairments in their prospective memory functioning, an effect that appears to be unrelated to any differences in the use of other drugs or to the number strategies used to aid remembering, or to an increased propensity to lie. The results of study 2 confirmed self-reported impairments in short- and long-term PM and further revealed corresponding impairments in CE processes. The findings from study 3 suggest that these PM and CE impairments cannot be attributed to a general increase in reported cognitive failures, since no significant differences were found between Ecstasy users, cannabis users and drug-free controls as measured using the CFQ.

If one were to consider the results of study 3 in isolation, it could be suggested that there is a meta-cognitive deficit amongst drug users, which would render them unable to monitor and judge their own cognitive state accurately. This seems to be an unlikely explanation, however, when one takes into consideration the results of study 1 and study 2, which clearly suggest that Ecstasy users perceive their PM to be impaired, compared with controls. There are two obvious explanations for this discrepancy. Firstly, it could be that results from study 3 reflect the relative insensitivity of the CFQ, an issue that could be partially addressed by using a variety of self-report measures. Secondly, one needs to consider the differences between the two measures used. The CFQ largely focuses on cognitive slips that are retrospective in

nature, whereas by definition the PMQ assesses prospective memory (with the caveat that completing the questionnaire relies on retrospective memory). It could therefore be suggested that the use of Ecstasy differentially impairs PM functioning. It should be noted that study 3 had fewer participants in each group and that the amount of Ecstasy use was lower than in studies 1 and 2. It is possible that these factors contributed to the negative results in the groups from study 3. Clearly, laboratory tests comparing retrospective and prospective memory functioning are necessary before firm conclusions can be drawn.

In addition to confirming self-rated PM impairments, the findings from study 2 also revealed corresponding central executive impairments: the Ecstasy group scored significantly lower on verbal fluency semantic fluency and combined verbal/semantic fluency tasks. Taking these results at face value, one might conclude that PM and CE share similar resources and may be sub-served by prefrontal and frontal lobe function—an explanation which is consistent with current thinking (Kopp and Thone, 2000).

However, there is a need for caution in interpreting the results from the CE measures used here. Although research has identified CE impairments in Ecstasy users (Wareing *et al.*, 2000), there are also reports of selectively unimpaired fluency performance in Ecstasy users (Klugman *et al.*, 1999; Croft *et al.*, 2001). Nevertheless there are important methodological differences between these studies. The Croft *et al.* study had relatively small sample sizes for the MDMA/cannabis and cannabis-only sub-samples. Additionally Croft *et al.* report that participants generated means of 44–49 words per min in a spoken/verbal fluency measure, a figure which is roughly three times the number generated by the participants during the written version in study 2 here. The performance of all groups in Croft *et al.*'s study is at the higher end of the distribution of established norms (Tombaugh *et al.*, 1999), which may indicate ceiling effects in their sample. Additionally, it may be that written fluency tasks are more sensitive to the effects of Ecstasy use than the oral versions utilised by Croft *et al.* and Klugman *et al.* (whose study had similar sample sizes to the present study 2). It is also possible that psychomotor impairment may contribute to this effect, although previous studies have not found enduring psychomotor deficits in Ecstasy users (Parrott and Lasky, 1998). There were similar scores for the semantic and verbal fluency tasks in study 2—a similarity not observed in oral fluency task norms (Tombaugh *et al.*, 1999), which may reflect similar difficulties in the written versions of the tasks. On

the other hand the Ecstasy group's relatively poorer performance was maintained during the combined fluency task, despite relatively lower scores in both groups, presumably due to a higher cognitive load involved in performing this task.

Comparing the results of study 1 and study 2, it is interesting that the latter found no impairment of self-reported internally cued PM, whereas the former found highly significant deficits. It may be relevant that the level of Ecstasy use in the drug group in study 1 was roughly double that in study 2. Therefore the differences may reflect the use of different resources by internally cued PM to those underpinning short- and long-term PM. This raises the intriguing possibility that internally cued PM is relatively preserved until a threshold of Ecstasy use has been reached. On the other hand a large Internet-based study by our group found internally cued PM to be differentially susceptible to cannabis but not Ecstasy (Rodgers *et al.*, this issue). It may be relevant that the pattern of cannabis use was different amongst the Ecstasy users in studies 1 and 2, with the former group displaying more intense use but over a shorter duration. Additionally it is probably worth noting that, apart from the short-term PM scale, error scores on all subscales of the PMQ were substantially higher in the Ecstasy group in study 1 than in study 2 (compare Tables 1 and 2).

Another issue that needs to be considered here is the duration of abstinence from using Ecstasy (and indeed other drugs) prior to the study. In studies 1 and 2 the Ecstasy users reported having been 'drug-free' for at least 24 h, whereas in study 3 the participants reported being 'drug-free' for at least 1 month. Since no biological drug screen analyses were used in any of the studies it is possible that (particularly in studies 1 and 2) there were some sub-acute drug effects persisting into the day of testing. Future research should attempt to replicate the findings presented here using groups of participants who have been shown to be 'drug-free' using objective measures, including physiological drug-screening techniques, and who have been abstinent for a number of days, weeks or months.

Like many studies into illegal substances that rely upon self-report measures, the present study has accompanying methodological problems (see Heffernan *et al.*, 2001 for a consideration of these). Nevertheless these findings add weight to growing evidence that regular Ecstasy use impairs memory function (Morgan, 1999; Parrott, 1998, 2000; Gouzoulis-Mayfrank *et al.*, 2000; Wareing *et al.*, 2000) and confirm that PM impairments should be

added to the growing list of neuropsychological sequelae associated with a history of Ecstasy use. However, before drawing any firm conclusions, further studies are needed that use sample sizes large enough to allow more rigorous statistical analysis of the contribution of drug use to aspects of day-to-day cognitive function.

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