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# Dancing hot on Ecstasy: physical activity and thermal comfort ratings are associated with the memory and other psychobiological problems reported by recreational MDMA users

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**Background** Non-drug factors such as ambient temperature can heighten the adverse effects of MDMA (3,4-methylendioxymethamphetamine) in animals. We assessed whether dancing and feeling hot on Ecstasy would be associated with more psychobiological problems in recreational users.
**Methods** In an internet study, 206 unpaid participants (modal age 16–24) reported that they had used recreational Ecstasy/MDMA. They completed a drug use questionnaire, the Prospective Memory Questionnaire (PMQ), questions about dancing and feeling hot when on Ecstasy, and psychobiological problems afterwards.
**Results** Those who danced 'all the time' when on Ecstasy, reported significantly more PMQ memory problems than the less intensive dancers. Prolonged dancing was also associated with more complaints of depression, memory problems, concentration and organizational difficulties afterwards. Feeling hot when on Ecstasy was associated with poor concentration in the comedown period, and with mood fluctuation and impulsivity off-drug. PMQ long-term problems demonstrated a significant curvilinear relationship with thermal self-ratings; more memory problems were noted by those who felt *very* hot, and by those who did *not* feel hot when on Ecstasy.
**Conclusions** Non-drug factors such as dancing and feeling hot are associated with the incidence of psychobiological problems reported by recreational Ecstasy/MDMA users. 

KEY WORDS — MDMA; Ecstasy; heat; exercise; memory; cognition

## INTRODUCTION

Ecstasy or MDMA (3,4-methylendioxymethamphetaime) is widely used as a recreational drug (Schifano, 2000; Curran *et al.*, 2004), although it is generally taken at dance clubs or raves (Parrott, 2004a,b). Tossman *et al*. (2001) noted that dance-rave music enthusiasts had 'considerably greater experience with ecstasy use than the general population of a corresponding age.' In a British survey of several thousand university students, 13% reported that they had ever used Ecstasy (Webb *et al.*, 1996), whereas in another UK survey of a thousand dancer clubbers and ravers, the equivalent usage figure was 96% (Winstock *et al.*, 2001). At a large Dutch rave, 81% reported having ever taken Ecstasy, while 64% had used it the previous night (Wijngaart *et al.*, 1999). Many others surveys have noted that Ecstasy/MDMA is generally taken at dance parties or raves, leading to it being described as a 'dance drug' (DAWN, 2000; Schifano, 2000; Riley *et al.*, 2001).

Recreational Ecstasy/MDMA users can display a range of neuropsychobiological problems when

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drug-free. These include deficits on laboratory tasks for memory, attention, and executive processing, cognitive-emotional biases, reduced appetite, poor sleep architecture, feelings of depression and anxiety, impulsivity, sexual problems, and structural changes as evidenced by neural imaging (Hegadoren *et al.*, 1998; Curran, 2000; Morgan, 2000; Schifano, 2000; Parrott, 2001, 2006; Curran *et al.*, 2004; Halpern *et al.*, 2004; Jacobsen *et al.*, 2004; McCardle *et al.*, 2004; Soar *et al.*, 2005, 2006; Reneman *et al.*, 2006; Quednow *et al.*, 2006; Reay *et al.*, 2006; Thomasius *et al.*, 2006). Yet the occurrence of these psychobiological deficits can be quite variable, leading to the question of why they are only evident in some users (Fox *et al.*, 2001; Parrott *et al.*, 2002). In a recent review, it was shown that this variance may reflect the modulating influence of various drug and non-drug factors (Parrott, 2006). Lifetime Ecstasy/MDMA usage is one important factor, with heavier drug users demonstrating more neuropsychobiological problems than novice or light users (Bolla *et al*., 1998; Semple *et al*., 1999; Topp *et al*., 1999; Parrott *et al*., 2000, 2001, 2002; Fox *et al*., 2001; Verkes *et al*., 2001; Gouzoulis-Mayfrank *et al*., 2003; see Table 3 in Morgan, 2000). Furthermore while 'pure' Ecstasy/MDMA users can display neurocognitive deficits (Halpern *et al.*, 2004; Yip and Lee, 2005), most Ecstasy users are polydrug users (Curran, 2000; Boys *et al.*, 2001; Riley *et al.*, 2001; Winstock *et al.*, 2001; Scholey *et al.*, 2004). The concomitant use of cannabis, alcohol, amphetamine, nicotine, LSD, ketamine, or other drugs, will also influence psychobiological functioning (Curran, 2000; Gouzoulis-Mayfrank *et al.*, 2000, 2003; Rodgers, 2000; Schifano, 2000; Croft *et al.*, 2001; Fox *et al.*, 2001, 2002; Parrott, 2001, 2003, 2006; Parrott *et al.*, 2001; Milani *et al.*, 2002, 2005; Ling *et al.*, 2003; Rodgers *et al.*, 2003; Heffernan *et al.*, 2005; Gouzoulis-Mayfrank and Daumann, 2006).

Non-drug factors may also contribute to the neuropsychobiological profiles of recreational users. Laboratory animal research has shown that MDMA is a serotonergic neurotoxin, but that the extent of this 5-HT distal axonal terminal loss is influenced by factors such as ambient temperature, social crowding, and dehydration (Dafters, 1995; Dafters and Lynch, 1998; Malberg and Seiden, 1998; see reviews by: Huether *et al.*, 1997; Green *et al.*, 2003). The environmental conditions at dance clubs and raves are characterized by high ambient temperatures, loud music, crowded conditions, and prolonged periods of dancing (Suy *et al.*, 1999; Parrott, 2004b). This has led to the prediction that taking MDMA in hot and crowded conditions may heighten the likelihood of subsequent psychobiological problems (Parrott, 2002, 2004b). In the absence of any systematic data on this topic, the current study was undertaken. Our aim was to investigate whether the extent of dancing while on MDMA, and feelings of being hot overheated when on MDMA, would increase the incidence of psychobiological problems reported by recreational users.

## MATERIALS AND METHODS

### *Design and general procedures*

The design and procedures were similar to our earlier Internet investigation of Ecstasy/MDMA polydrug users and non-users (Parrott *et al.*, 2002; Rodgers *et al.*, 2003; Scholey *et al.*, 2004). A www site was established where unpaid volunteers could complete a series of questions related to their use of legal and illicit recreational drugs. In this study several new sets of questions were added for those who had used Ecstasy. This report is concerned with two of these questions, those for 'dancing when on Ecstasy,' and for 'feeling hot/overheated when on Ecstasy' (see below). The findings from the other questionnaire items are presented elsewhere (Rodgers *et al.*, 2006).

Participants were recruited using a variety of methods. These included messages posted on ecstasy-related bulletin board, links with other online experiments, notices on web-pages, announcements at home institutions, and personal email contacts. Different web addresses were used for the various recruitment methods so that the subsamples could be compared (Rodgers *et al.*, 2006). Access was not restricted—other than by the exclusion of problematic data (see below). The majority of participants came from either Europe or the USA. Strict data screening procedures are recommended for Internet based research (Gosling *et al*., 2004), and they have been incorporated into our www designs (Rodgers *et al.*, 2003; Buchanan *et al.*, 2005; this study). Potential problems include multiple submissions by the same people, and mischievous data entry. Accordingly, responses were screened using exclusion criteria which are described elsewhere (Rodgers *et al.*, 2006). In summary, we excluded: all but the first data submission from the same Internet address (IP number); duplicate datasets caused by clicking the 'submit' button more than once; instances where the participant indicated they were under the influence of drugs or alcohol; datasets with implausible demographics (e.g., very young people claiming to have a PhD; anyone claiming to live in Antarctica);

 

also where respondents had indicated that their data should not be analyzed. Following the application of these (conservative) exclusion criteria, 417 cases remained from the initial 731 submissions. Of these, 209 indicated that they had used ecstasy on at least one occasion; the present report is based on their responses.

### *Participant characteristics*

Of the 209 participants who stated that they had taken ecstasy, 2 ticked the 'chose not to reply' box to the question on lifetime usage, so they were excluded. The question on gender was completed by 206: 124 males and 82 females. The modal age group was 16–20 years. The majority 56% reported being moderate users (10–99 lifetime occasions), 27% were novice users (1–9 occasions), while 17% were heavier users (+100 occasions). Between zero and three of the remaining cohort selected the 'choose not to reply' box to one or more of the other questions. So that while our findings mostly comprise the data from 206 users, sometimes they represent samples of 203–205.

### *Assessment measures*

The Prospective Memory Questionnaire (PMQ) comprises 52 items which cover different aspects of prospective memory – or 'remembering to remember' (Hannon *et al*., 1995). It has four subscales. Long-term episodic prospective memory is where the memory cue occurs hours or days beforehand, and the task is not regular or routine (e.g., forgetting to pick up an intended item when shopping). Short-term habitual prospective memory is when the cue to do something occurs just minutes before the task has to be carried out, and the task is more routine or everyday (e.g., forgetting to lock the front door when going out). Internally cued prospective memory is where the memory is cued internally (e.g., forgetting what to say in the middle of a sentence). Strategies for 'remembering to remember,' include activities such as making written lists, or using adhesive 'post-it' notices. Each question is followed by a 9-point Likert scale, with higher scores indicating more severe memory problems, or greater reliance upon memory strategies. The scale shows high internal validity ($r = 0.76$), and high test-retest reliability ($r = 0.88$). It has proven sensitive as a neuro-psychological test for brain damaged patients (Hannon *et al.*, 1995), and heavy alcohol drinkers (Heffernan *et al.*, 2002; Ling *et al.*, 2003). In two previous studies, scores on the long-term prospective memory subscale were significantly reduced in recreational Ecstasy/MDMA users (Heffernan *et al*., 2001; Rodgers *et al.*, 2003), so here we only analyzed the long-term prospective memory subscale.

Each participant completed the UEL Recreational Drug Use Questionnaire. This covers the self-reported lifetime usage for the main types of illicit recreational drug (amphetamine, cocaine, Ecstasy/MDMA, opiates, others), and the current/recent usage of alcohol, nicotine, and cannabis (Parrott *et al.*, 2001). For the www version of the questionnaire, each question was assessed by five response alternatives. For the lifetime drug usage questions these comprised: never, 1–9 occasions, 10–99 occasions, 100+ occasions, and prefer not to answer. Current alcohol use was assessed by five alternative responses: 0 units/week, 1–9 units/week, 10–25 units/week, +25 units/week, and prefer not to answer. Current tobacco usage was assessed with the following response choices: non-smoker, 1–4 cigs/day, 5–20 cigs/day, 15+ cigs/day, and prefer not to answer. Cannabis use was assessed by: non-user, 1–4 times/month, 5–20 times/month, 20+ times/month, and prefer not to answer. For this study, several new questions were added for the Ecstasy/MDMA users. They covered the co-usage of other drugs when on-Ecstasy, the use of certain drugs when coming down off-Ecstasy, neuroprotective strategies, and the situational factors surrounding Ecstasy usage (Rodgers *et al.*, 2006; in preparation). The current report is focused on two of these questions. First: 'While on Ecstasy did you generally experience dancing or exercise?' Second: 'While on Ecstasy did you generally experience feeling hot/overheating?' The five point response options are described in Tables 1–4.

### *Data analysis*

Drug usage and self-reported psychobiological problems were analyzed by Chi-Square. Whenever 20% of the cells had 'expected' counts of less than 5, the neighboring cells were combined and a second analysis was undertaken. The associations between drug use were calculated using Pearson correlations; given the number of correlations calculated, confidence should only be given to significance levels of $p < 0.01$ or higher. The Prospective Memory Questionnaire data were analyzed by one-way ANOVA, to assess the influence of the extent of dancing (with four levels). The Prospective Memory Questionnaire was also analyzed by one-way ANOVA, to assess the influence of the thermal comfort ratings, again at four levels. Each ANOVA was followed by a polynomial

 

Table 1. Ecstasy and other drug usage: associations with the 'extent of dancing when on Ecstasy'

| Dancing on-Ecstasy | No/occasionally | Sometimes | Frequently | All the time | Chi-Square (sig) |
|---|---|---|---|---|---|
| Participants per condition | 37 | 38 | 79 | 50 | |
| Normal Ecstasy dose/occasion | | | | | |
| 1–2 tablets ($n=150$) | 70% | 69% | 78% | 74% | |
| 3–4 tablets ($n=44$) | 27% | 20% | 19% | 24% | |
| +4 tablets ($n=8$,+) | 3% | 11% | 3% | 2% | 6.09; $p=0.41$ |
| Highest Ecstasy dosage in 1 week | | | | | |
| 1–2 tablets ($n=64$) | 32% | 34% | 31% | 28% | |
| 3–9 tablets ($n=104$) | 57% | 39% | 52% | 53% | |
| +10 tablets ($n=36$) | 11% | 27% | 17% | 19% | 4.24; $p=0.64$ |
| Ecstasy lifetime usage | | | | | |
| 1–9 times ($n=55$) | 41% | 23% | 26% | 20% | |
| 10–99 times ($n=114$) | 51% | 59% | 54% | 58% | |
| +100 times ($n=37$) | 8% | 18% | 20% | 22% | 6.63; $p=0.35$ |
| Amphetamine Lifetime usage | | | | | |
| 0 times ($n=55$) | 35% | 36% | 22% | 20% | |
| 1–9 times ($n=82$) | 35% | 36% | 36% | 52% | |
| 10–99 times ($n=45$) | 17% | 23% | 35% | 22% | |
| +100 times ($n=15$) | 13% | 5% | 7% | 6% | 12.76; $p=0.17$ |
| Amphetamine use concomitant with Ecstasy | | | | | |
| No ($n=147$) | 76% | 67% | 72% | 68% | |
| Yes ($n=57$) | 24% | 33% | 28% | 32% | 0.70; $p=0.87$ |

+Chi-Square: more than 20% of cells had an expected count of <5. The re-analysis with combined cells (3–4 tablets/occasion with +4 tablets/occasion) was also non-significant.

function analyses and paired comparison tests. The Prospective Memory Questionnaire data were then analyzed by two-way ANOVA (fixed effects model) to investigate the possible interaction between dancing and feeling hot when on MDMA. Since a $4 \times 4$ level analyses would have involved several small cells, the data were collapsed into three levels for a $3 \times 3$ analysis. This was undertaken by combining the two

Table 2. Ecstasy/MDMA and other aspects of drug usage: associations with the 'Feeling hot when on Ecstasy'

| Feeling hot/overheating when on-Ecstasy | No | Slightly | Moderately | Strongly/extremely | Chi-Square (sig) |
|---|---|---|---|---|---|
| Participants per condition | 34 | 83 | 64 | 26 | |
| Normal Ecstasy dose/occasion | | | | | |
| 1–2 tablets ($n=150$) | 77% | 75% | 70% | 77% | |
| 3–4 tablets ($n=44$) | 20% | 19% | 28% | 16% | |
| +4 tablets ($n=9$,+) | 3% | 6% | 2% | 7% | 4.76; $p=0.57$ |
| Highest Ecstasy dosage in 1 week | | | | | |
| 1–2 tablets ($n=64$) | 36% | 32% | 23% | 40% | |
| 3–9 tablets ($n=104$) | 61% | 43% | 59% | 44% | |
| +10 tablets ($n=36$) | 3% | 25% | 18% | 16% | 10.86; $p=0.09$ |
| Ecstasy lifetime usage | | | | | |
| 1–9 times ($n=55$) | 41% | 28% | 20% | 19% | |
| 10–99 times ($n=113$) | 53% | 46% | 64% | 62% | |
| +100 times ($n=39$) | 6% | 26% | 16% | 19% | **12.69; $p=0.048$** |
| Amphetamine use while on Ecstasy | | | | | |
| No ($n=148$) | 82% | 71% | 79% | 46% | |
| Yes ($n=57$) | 18% | 29% | 21% | 54% | **12.02; $p=0.007$** |
| Amphetamine use lifetime | | | | | |
| 0 times ($n=55$) | 35% | 20% | 33% | 20% | |
| 1–9 times ($n=82$) | 41% | 43% | 41% | 22% | |
| 10–99 times ($n=55$) | 20% | 28% | 19% | 50% | |
| +100 times ($n=15$) | 4% | 9% | 7% | 8% | 14.13; $p=0.118$ |

+Chi-Square: more than 20% of cells had an expected count of <5. The re-analysis with combined cells (3–4 tablets/occasion with +4 tablets/occasion) was also non-significant.

 

Table 3. Recreational Ecstasy users grouped according to the self-rated frequency of dancing when on-MDMA

| Dancing on-Ecstasy | No/occasionally | Sometimes | Frequently | All the time | Chi-Square (sig) |
|---|---|---|---|---|---|
| Participants per condition | 37 | 38 | 79 | 50 | |
| Come-down problems after Ecstasy (in the days afterwards) | | | | | |
| Post-Ecstasy depression | | | | | |
| None ($n = 64$) | 51% | 28% | 30% | 20% | |
| Mild ($n = 83$) | 38% | 36% | 47% | 37% | |
| Mod/strong/extreme (N = 57) | 11% | 36% | 23% | 43% | **17.37; $p = 0.008$** |
| Post-Ecstasy poor concentration | | | | | |
| None ($n = 47$) | 46% | 26% | 18% | 12% | |
| Mild ($n = 90$) | 35% | 41% | 54% | 37% | |
| Mod/strong/extreme ($n = 67$) | 19% | 33% | 28% | 51% | **22.97; $p = 0.001$** |
| Post-Ecstasy memory problems | | | | | |
| No problems ($n = 82$) | 51% | 41% | 43% | 26% | |
| Mild ($n = 69$) | 32% | 41% | 35% | 26% | |
| Mod/strong/extreme ($n = 53$) | 16% | 18% | 23% | 47% | **16.25; $p = 0.012$** |
| Post-Ecstasy difficulty organizing or arranging things | | | | | |
| No difficulty ($n = 81$) | 62% | 41% | 38% | 25% | |
| Mild ($n = 71$) | 32% | 38% | 34% | 35% | |
| Mod/strong/extreme ($n = 51$) | 6% | 21% | 28% | 40% | **17.87; $p = 0.007$** |
| Off-drug problems attributed to MDMA/Ecstasy use | | | | | |
| Mood fluctuation ($n = 121$) | 49% | 54% | 58% | 74% | 6.78; $p = 0.079$ |
| Depression ($n = 100$) | 38% | 46% | 45% | 66% | **8.28; $p = 0.040$** |
| Poor concentration ($n = 88$) | 32% | 46% | 37% | 58% | 7.71; $p = 0.052$ |
| Anxiety ($n = 85$) | 38% | 44% | 37% | 50% | 2.51; $p = 0.473$ |
| Poor sleep ($n = 82$) | 43% | 44% | 40% | 37% | 0.60; $p = 0.896$ |
| Memory problems ($n = 79$) | 41% | 25% | 34% | 54% | **8.33; $p = 0.040$** |
| Weight loss ($n = 72$) | 24% | 26% | 35% | 50% | **8.29; $p = 0.040$** |
| Impulsivity ($n = 53$) | 11% | 26% | 27% | 36% | 7.07; $p = 0.070$ |
| Tremors/twitches ($n = 51$) | 19% | 23% | 24% | 32% | 2.13; $p = 0.546$ |
| Sexual problems ($n = 24+$) | 5% | 20% | 10% | 10% | 4.49; $p = 0.213$ |
| Infections ($n = 20+$) | 3% | 10% | 12% | 12% | 2.65; $p = 0.448$ |

+Chi-Square: more than 20% of cells had an expected count of <5. The re-analyses with combined cells (no/occasional with sometimes dancing) were also non-significant.
Overall numbers reporting each problem ($n$), the percentages in each dancing/exercise group reporting come-down problems in the days afterwards, and off-drug problems attributed to Ecstasy usage.

smallest contingent cells; hence the 'no/occasional' and 'sometimes' dancing groups were combined, while the 'moderately' and 'strongly/extremely' feeling hot groups were also combined (see Figure 1).

## RESULTS

The Ecstasy usage patterns are summarized in Tables 1 and 2. With respect to normal Ecstasy dose per occasion, the majority (75%) reported taking one or two tablets, 20% normally took 3–4 tablets per occasion, and 5% reported normally taking 4+ tablets/occasion (Table 1). In terms of maximum weekly Ecstasy usage, 30% reported a maximum of 1–2 tablets/week, 52% reported a maximum of 3–9 tablets/week, while 18% reported taking a maximum of 10 or more tablets/week (Table 1). With reference to lifetime Ecstasy usage, 27% reported taking it on 9 or less occasions/lifetime, 55% reported taking it on 10–99 occasions, while 18% reported having taken Ecstasy on 100 or more occasions/lifetime. Polydrug use was frequently noted, with 83% reporting alcohol use (at least weekly), 75% amphetamine use (at least once in lifetime), 67% cannabis use (monthly or more frequently), 62% cocaine use (lifetime), 61% magic mushroom use (lifetime), 52% LSD use (lifetime), 50% nicotine use (daily or more frequently), 43% benzodiazepine/barbiturate use (lifetime), 28% opiate use (lifetime), 24% solvent use (lifetime), and 2% anabolic steroid use (lifetime).

The lifetime use of Ecstasy was significantly associated with lifetime usage of amphetamine ($p < 0.001$), cocaine ($p < 0.001$), LSD ($p < 0.001$), magic mushrooms ($p < 0.001$), cannabis ($p < 0.01$), and tobacco/nicotine ($p < 0.05$). Lifetime Ecstasy usage was also positively associated with a higher

 

Table 4. Recreational Ecstasy/MDMA users grouped according to self-rated feelings of being hot/overheating while on-MDMA

| Feeling hot/overheating on-Ecstasy | No | Slightly | Moderately | Strongly/extremely | Chi-Square (sig) |
|---|---|---|---|---|---|
| Participants per condition | 34 | 83 | 64 | 26 | |
| Come-down problems after Ecstasy (in the days afterwards) | | | | | |
| Post-Ecstasy depression | | | | | |
| None ($n=64$) | 38% | 34% | 30% | 16% | |
| Mild ($n=83$) | 44% | 45% | 37% | 36% | |
| Mod/strong/extreme ($n=57$) | 18% | 21% | 33% | 48% | 10.12; $p=0.120$ |
| Post-Ecstasy poor concentration | | | | | |
| None ($n=47$) | 35% | 26% | 16% | 12% | |
| Mild ($n=90$) | 44% | 51% | 40% | 36% | |
| Mod/strong/extreme ($n=67$) | 21% | 23% | 44% | 52% | **16.32; $p=0.012$** |
| Post-Ecstasy memory problems | | | | | |
| No problems ($n=82$) | 47% | 48% | 32% | 24% | |
| Mild ($n=69$) | 32% | 32% | 35% | 36% | |
| Mod/strong/extreme ($n=53$) | 21% | 20% | 32% | 40% | 9.54; $p=0.145$ |
| Post-Ecstasy difficulty in organizing or arranging things | | | | | |
| No difficulty ($n=81$) | 41% | 49% | 35% | 24% | |
| Mild ($n=71$) | 35% | 35% | 33% | 32% | |
| Mod/strong/extreme ($n=51$) | 24% | 16% | 32% | 44% | 11.03; $p=0.087$ |
| Off-drug problems attributed to MDMA/Ecstasy use | | | | | |
| Mood fluctuation ($n=121$) | 47% | 66% | 52% | 77% | **8.17; $p=0.043$** |
| Depression ($n=100$) | 41% | 45% | 59% | 54% | 3.90; $p=0.271$ |
| Poor concentration ($n=88$) | 26% | 43% | 48% | 54% | 5.80; $p=0.122$ |
| Anxiety ($n=85$) | 32% | 43% | 44% | 46% | 1.69; $p=0.638$ |
| Poor sleep ($n=82$) | 35% | 40% | 45% | 38% | 1.00; $p=0.800$ |
| Memory problems ($n=79$) | 38% | 33% | 43% | 50% | 2.99; $p=0.392$ |
| Weight loss ($n=72$) | 32% | 29% | 40% | 50% | 4.59; $p=0.204$ |
| Impulsivity ($n=53$) | 9% | 19% | 39% | 40% | **15.09; $p=0.002$** |
| Tremors/Twitches ($n=51$) | 15% | 26% | 29% | 27% | 2.42; $p=0.489$ |
| Sexual Problems ($n=24$,+) | 6% | 10% | 13% | 23% | 4.72; $p=0.193$ |
| Infections ($n=20$,+) | 3% | 15% | 11% | 4% | 4.20; $p=0.240$ |

+Chi-Square: more than 20% of cells had an expected count of <5. The re-analyses with combined cells (moderately with strongly/extremely hot) were also non-significant.
Overall numbers reporting each problem ($n$), also the percentage in each group reporting come-down problems afterwards, and off-drug problems which they attribute to Ecstasy/MDMA use.

normal Ecstasy dose/occasion ($p<0.001$), higher maximum Ecstasy tablets/week ($p<0.001$), earlier first use ($p<0.001$), and longer time since last use ($p<0.001$). The concomitant use of other drugs *whilst on Ecstasy* was as follows: 59% nicotine, 57% cannabis, 28% amphetamine, 22% cocaine, 12% ketamine, 3% fluoxetine/Prozac (other drugs were not assessed). Psychoactive drug use *during the come-down period* was as follows: cannabis 67%, nicotine 55%, alcohol 47%, benzodiazepine/barbiturates 10%, fluoxetine/Prozac 7%, opiates 5% (other drugs were not assessed).

The distribution of responses to the question: 'While on Ecstasy did you generally experience dancing or exercise?' was as follows: none, $n=12$, occasionally, $n=25$; sometimes, $n=38$; frequently, $n=79$; all the time, $n=50$. Since the data were being analyzed using Pearson Chi-Square (SPSS for Windows), given the low numbers in the first group, it was combined with the second to form an overall 'no or occasional dancing' group of $n=37$ (Tables 1 and 3). The distribution of responses to the question: 'While on Ecstasy did you generally experience feeling hot/overheating?' was as follows: no, $n=34$; slightly, $n=83$; moderately, $n=64$; strongly, $n=21$; extremely, $n=5$. Because of the low numbers in the final category, it was combined with the previous category to form a single 'feeling strongly or extremely hot' group of $n=26$ (Table 4).

The associations between the extent of 'dancing when on ecstasy' and the various Ecstasy usage parameters are shown in Table 1. They demonstrate that the extent of 'dancing on Ecstasy' was not associated with normal Ecstasy dose/occasion, nor with maximum Ecstasy tablets/week, nor with lifetime Ecstasy usage. The associations with other drug

 

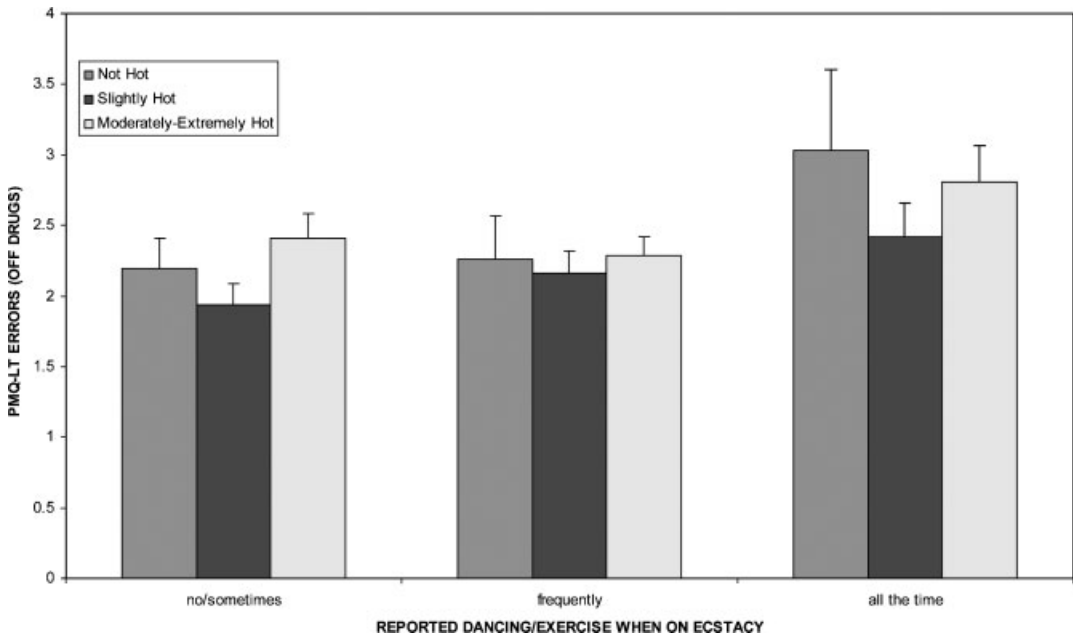


Figure 1. Prospective Memory Questionnaire long-term errors in nine subgroups of recreational Ecstasy /MDMA users: stratified according to the self-reported extent of dancing when on Ecstasy (none, to all-the-time), and subjective feelings of being hot when on Ecstasy (not feeling hot, to feeling extremely hot)

parameters were also assessed using Chi-Square, and again none was significant (Table 1). The associations between 'feeling hot when on ecstasy' and the various Ecstasy parameters are shown in Table 2. One of the Chi-Square associations was significant, for lifetime Ecstasy/MDMA usage ($p = 0.048$), although it did not fit a cumulative dosage pattern. Table 2 reveals that those who reported not-feeling-hot tended to come from the novice user group, those who felt slightly-hot came more from the heaviest users, while those who reported feeling most-hot came predominantly from the moderate Ecstasy user group. The associations with other drug parameters were also assessed, and one was significant, for amphetamine use when on Ecstasy (Table 2). Here the underlying pattern was clearer, with a larger percentage of amphetamine co-users in the highest temperature group: 18% (not feeling hot), 29% (feeling slightly hot), 21% (feeling moderately hot), and 54% (feeling strongly/extremely hot).

The Prospective Memory Questionnaire long-term problem scores for the four dancing/exercise subgroups were as follows (mean and standard error): no/occasional dancing, $2.13 \pm 0.14$; sometimes dancing, $2.21 \pm 0.15$; frequent dancing, $2.21 \pm 0.10$; dancing all-the-time, $2.74 \pm 0.19$. The one-way ANOVA across the four dancing/exercise subgroups was significant ($F = 3.68$, df $= 3.202$; $p = 0.013$), as was the first order or linear polynomial function ($p = 0.010$). The quadratic and cubic terms were not significant ($p = 0.124$, $p = 0.341$, respectively). Tukey B tests revealed that the group who reported dancing 'all the time' while on Ecstasy was significantly different from each of the other three groups (each paired comparison $p < 0.05$). The Prospective Memory Questionnaire long-term problem scores for the four 'feeling hot' subgroups were as follows (mean and standard error): not feeling hot/overheated, $2.42 \pm 0.20$; feeling slightly hot/overheated, $2.14 \pm 0.10$; moderately hot/overheated, $2.41 \pm 0.13$; strongly or extremely hot/overheated, $2.66 \pm 0.21$. The one-way ANOVA across subgroups was non-significant ($F = 2.05$, df $= 3.203$; $p = 0.108$).

The Prospective Memory Questionnaire group means from the two-way ANOVA are shown in Figure 1. The ANOVA effect for dancing/exercise was significant ($F = 4.50$, df $= 2.196$; $p = 0.012$), temperature was non-significant ($F = 2.26$, df $= 2.196$; $p = 0.107$), and the dancing $\times$ temperature interaction was non-significant ($F = 0.45$, df $= 4.196$; $p = 0.766$). The polynomial functions for dancing/exercise revealed a significant linear function ($p = 0.005$),

 

while the quadratic term was non-significant ($p = 0.194$). Paired comparisons (LSD or least significant difference test) showed that those who danced 'all the time' on Ecstasy, reported significantly more memory problems than the other two subgroups ($p = 0.003$ and $p = 0.005$). The polynomial analysis for feelings of being hot/overheating on Ecstasy/MDMA, revealed a non-significant linear effect ($p = 0.979$), but a significant quadratic term ($p = 0.047$). Paired comparisons (LSD test) showed that the group who felt moderately/strongly/extremely hot or overheated when on Ecstasy, reported significantly more memory problems than those who only felt slightly hot while on Ecstasy ($p = 0.021$). The other paired comparisons were both non-significant. Figure 1 illustrates the combined influence of dancing/exercise and subjective feelings of being hot when on Ecstasy. The lowest PMQ scores were reported by those who danced intermittently and reported feeling moderately hot; whereas the worst memory scores were reported by those who danced all the time but did not feel hot.

Table 3 shows the percentages in each of the four dancing/exercise subgroups, who reported post-Ecstasy/MDMA come-down problems, and off-drug problems which they attributed to Ecstasy/MDMA use. Chi-Square analyses revealed significant relationships between the extent of dancing/exercise while on Ecstasy, with post-E depression ($p = 0.008$), post-E poor concentration ($p = 0.001$), post-E memory problems ($p = 0.012$), and post-E difficulty organizing/arranging things ($p = 0.007$). In each instance, relatively few of those who reported no or occasional dancing on Ecstasy reported psychobiological come-down problems. Whereas a higher proportion of those who danced all the time while on drug, reported post-Ecstasy problems in the days afterwards. Table 3 also presents the data for the off-drug problems attributed to Ecstasy/MDMA use. In overall terms (i.e., irrespective of dancing subgroup), mood fluctuation attributed to Ecstasy was reported by 59%, depression by 49%, poor concentration by 43%, poor sleep by 40%, memory problems by 39%, weight loss by 35%, tremors/twitches by 25%, sexual problems by 12%, and infections (all attributed to Ecstasy) by 10% of the overall sample. Chi-Square comparisons across the dancing/exercise subgroups were significant for three of these variables (depression, memory, weight loss), and were borderline for three of the others (poor concentration, impulsivity, mood fluctuation). In general, problems were reported more frequently by those who had danced the most when on the drug (Table 3). The post-Ecstasy come-down problems, and the off-drug problems attributed to Ecstasy, for the four subgroups who reported different feelings of being hot/overheated while on Ecstasy, are shown in Table 4. Chi-Square analyses revealed a significant relationship between feeling hot while on Ecstasy, and poor concentration in the post-E come-down period ($p = 0.012$), with those who felt most hot reporting the most problems afterwards (Table 4). Finally, off-drug mood fluctuation and impulsivity attributed to Ecstasy/MDMA, were also significantly associated with feeling hot when on drug (Table 4).

## DISCUSSION

This is the first empirical demonstration that non-drug factors are associated with the incidence of neuropsychobiological problems reported by recreational Ecstasy/MDMA users. The extent of dancing when on Ecstasy/MDMA had a significant influence on several aspects of well-being. Prospective Memory Questionnaire long-term problem scores were significantly higher in those who stated that they danced 'all the time' when on Ecstasy/MDMA, in comparison with the other subgroups of more intermittent dancers (Figure 1). The adverse effects of prolonged dancing/exercise were also evident in the higher ratings for memory problem in the days after taking Ecstasy, and in the higher rates of off-drug memory problems attributed to Ecstasy usage (Table 3). In broader terms, prolonged dancing on Ecstasy was also related to more reports of depression, poor concentration, and organizational difficulties, in the come-down period, and to more reports of depression and weight loss (attributed to Ecstasy/MDMA) when off-drug. The variance in empirical findings on recreational Ecstasy was noted earlier (Fox *et al.*, 2001, 2002; Halpern *et al.*, 2004; Jacobsen *et al.*, 2004; McCardle *et al.*, 2004; Soar *et al.*, 2005, 2006; Quednow *et al.*, 2006; Reay *et al.*, 2006). So that while there is clear evidence for neuropsychobiological problems (reviews: Morgan, 2000; Schifano, 2000; Parrott, 2001, 2006), the rationale for the variation in findings also needs to be investigated (Parrott, 2006). The present study may help to explain some of this variance (Tables 3 and 4). It should however also be noted that several of the psychobiological variables were *not* associated with on-drug dancing. For instance, 'poor sleep' ratings were similar across subgroups (Table 3), with even a slight trend for better sleep in those who had danced the most (possibly because physical tiredness facilitated sleep).

The Prospective Memory Questionnaire long-term problems were related to the thermal self-ratings in a

 

curvilinear fashion (Figure 1). Those who felt slightly hot when on Ecstasy reported the least memory problems. Whereas feelings of not being hot, or of being moderately strongly extremely hot when on Ecstasy, were each associated with more PMQ long-term memory problems. This pattern was evident at each level of dancing/exercise, and the additive nature of these two factors was confirmed by the absence of an ANOVA interaction (Figure 1). It should be noted that this pattern emerged from a true factorial design with nine separate subgroups, and was therefore not an artifact of a mixed or split-plot design. The poor PMQ memory scores of those who felt very hot when on Ecstasy were in line with our predictions (see below). The memory problems reported by those who did not feel hot when on Ecstasy, were not predicted, although in retrospect they may not be too difficult to explain. They may reflect poor temperature awareness, which might be because of an uncoupling of basic hypothalamic temperature regulation mechanisms from conscious awareness. This would allow subjective thermal aspects to become functionally dissociated from actual body temperature levels. Or they might reflect general cognitive confusion, in the same way that some clubbers/ravers experience difficulties in monitoring their own fluid intake, so increasing the likelihood of hyponatraemia (Hegadoren *et al.*, 1998; Parrott, 2002). Whatever the underlying psychophysiological rationale, one practical consequence is that *not* feeling hot, may have allowed those individuals to continue dancing for longer. This may help to explain why the highest PMQ scores were found in those who did not feel hot, but also danced all the time (Figure 1). Turning to the other psychobiological variables, three of them were positively associated with the subjective thermal ratings. Those who felt most hot when on Ecstasy, reported significantly more concentration difficulties in the come-down period, also more impulsivity and mood fluctuation (attributed to Ecstasy) when off-drug (Table 4).

There is an extensive animal literature on the contributory roles of non-drug factors, especially temperature. MDMA is a powerful CNS stimulant, being an indirect agonist on serotonergic, dopaminergic, and other neurochemical systems (Hegadoren *et al.*, 1998; Green *et al.*, 2003). In laboratory rats, this acute stimulation can be heightened by administering MDMA under hyperthermic conditions, such as under high ambient temperatures or in thermally restricted environments (Gordon *et al.*, 1991; Gordon and Fogelson, 1994; Dafters, 1995; Green *et al.*, 2003). Brown and Kiyakin (2004) measured the brain and body musculature temperature of male rats. Under quiet rest at 23°C MDMA induced a moderate but prolonged hyperthermia, with temperatures in the nucleus accumbens and hippocampus increasing more than in muscle. Social interaction with a female under this level of ambient temperature markedly potentiated the hyperthermic response. At 29°C MDMA pushed brain temperatures to biological limits, resulting in many fatalities. Pre-dosing with MDMA can also impair the ability of rats to cope with subsequent doses in the heat. Green *et al*. (2004) found that the contribution of high ambient temperature to the acute MDMA response was even greater in rats which had been given a prior neurotoxic regimen of MDMA (see below). Cornish *et al*. (2003) noted that MDMA self-administration in rats was significantly enhanced under an ambient temperature of 30°C compared with 21°C. In a parallel fashion, social interaction in pairs of rat was also significantly enhanced under the higher temperature condition (Cornish *et al.*, 2003). This may reflect a form of aggregate toxicity, when the stimulatory effects of amphetamines are enhanced in socially grouped animals (Gunn and Gurd, 1940; Green *et al.*, 2003; Brown and Kiyakin, 2004).

This acute enhancement by environmental stimulation in MDMA-treated laboratory animals has led to the hypothesis that human recreational users may be boosting the acute effects of Ecstasy/MDMA by taking it in hot and crowded conditions (Parrott, 2002, 2004b, 2006); although it should be noted that this prediction was not being assessed in the current study. However the effects of MDMA on body temperature in humans have been empirically assessed. Vollenweider *et al*. (1998) undertook a placebo controlled study in a quiet laboratory, and found that MDMA produced 'a discrete increase of body temperature of about 0.2 to 0.5°C, which however did not reach statistical significance.' Tancer *et al.* (2003) found that acute MDMA produced a significant increase in body temperature and metabolic rate, again in the laboratory. Freedman *et al.* (2005) noted a significant increase in core body temperature, under both cool and hot ambient temperature conditions. In another placebo-controlled human study, De la Torre *et al.* (2005) noted a slight temperature increase in 'good' MDMA metabolizers, but a far stronger temperature rise in the single 'poor' MDMA metabolizer; it was hypothesized that this might reflect their higher level of plasma MDMA. In a field study, Parrott and Young (2005) found that dance clubbers on Ecstasy had significantly higher thermal self-ratings, and significantly higher body temperatures, than non-users at the

 

same dance club venues. In contrast, Cole *et al*. (2005) reported that Ecstasy users did not differ in body temperature from non-users out clubbing. They also found that the ambient temperature at the club was not particularly hot, and questioned whether dance clubs should be conceptualized as hot thermal environments. Questionnaire surveys have however shown that feeling hot, sweaty, and dehydrated, are typical experiences for many Ecstasy/MDMA users (Davison and Parrott, 1997; Topp *et al.*, 1999), although the current findings indicate considerable individual variation in these changes (Tables 2 and 4).

In terms of an explanatory model, Huether *et al*. (1997) suggested that the extent of long-term neuronal damage caused by MDMA in animals was a direct reflection of acute cellular distress. By enhancing the effects of acute MDMA, environmental stimulation can further boost neurotransmitter release, and so additionally stress the process of cellular recovery and repair within the distal axon terminal. Hence the combination of drug and non-drug stimulatory factors will generate even more neuronal (axon terminal) damage in the longer term. The underlying mechanisms for this cellular damage may be free radical production, and hence greater oxidative stress, or greater production of neurotoxic metabolites, or alternative mechanisms (Green *et al.*, 2003). The human implications of this animal model have been debated elsewhere (Parrott, 2001, 2002, 2004b, 2006). It is hypothesized that when humans take MDMA in stimulatory conditions, it may lead to a stronger acute drug response, with more severe recovery problems immediately afterwards, and more neuropsychobiological problems in the longer term: 'If this also occurs in humans, then the stimulatory environments of clubs and raves may heighten the likelihood of adverse neuropsychological sequelae in recreational Ecstasy users' (Parrott, 2004b). Many of the current findings (Tables 3 and 4; Figure 1), are therefore predicted by this 'energetic stress' model (Parrott, 2006).

One unexpected finding was that the extents of dancing and thermal self-ratings were largely independent of Ecstasy/MDMA usage (Tables 1 and 2). There are several possible reasons for the paucity of dosage effects. First, many regular Ecstasy users develop chronic tolerance to MDMA (Parrott, 2005). Hence an increase in self-dosing will often represent an attempt to *maintain* a given level of efficacy, rather than a desire to achieve a stronger effect. Second, the extent of dancing would be influenced by non-drug factors such as body type physical fitness, personality, and a number of psychosocial influences. This would help to explain why the dancing subgroups were largely independent of drug status. The crucial point is that the dancing and thermal influences described here (Figure 1, Tables 3 and 4) cannot be explained as an artifact of differences in drug usage. However the majority of Ecstasy/MDMA users were polydrug users (Tables 1 and 2). This pattern of extensive polydrug use is typical for many recreational Ecstasy users (Topp *et al.*, 1999; Morgan, 2000; Parrott *et al.*, 2000, 2001; Schifano, 2000; Fox *et al.*, 2001, 2002; Heffernan *et al.*, 2001; Riley *et al.*, 2001; Tossman *et al.*, 2001; Verkes *et al.*, 2001; Bellis *et al.*, 2002; Milani *et al.*, 2002, 2005; Curran *et al.*, 2004; Scholey *et al.*, 2004; Sumnall *et al.*, 2004; Fisk *et al.*, 2005). Relatively pure MDMA users display significant neurocognitive deficits (Halpern *et al*., 2004; Yip and Lee, 2005), but these additional substances will influence the psychobiological profiles of Ecstasy polydrug users (Schifano, 2000; Parrott, 2001; Parrott, 2003; Rodgers *et al.*, 2003; Parrott *et al.*, 2004). The thermal comfort self-ratings were mostly independent of drug status, although the concomitant use of amphetamine was significantly associated with more reports of feeling hot (Table 2). This agrees with Kiyatkin (2004), who found that the temperature increase in MDMA treated rats was potentiated by methamphetamine. In future studies it would be interesting to compare MDMA and amphetamine, both alone and in combination, for their effects on body temperature and psychobiological functioning. Finally, although this report is not concerned with the overall Ecstasy/polydrug findings, it should be noted that lifetime Ecstasy/MDMA use was associated with a higher incidence of Ecstasy-attributed problems (i.e., irrespective of the dancing and thermal influences described here). Self-rated memory problems, mood fluctuation, poor concentration, depression, impulsivity, and weight loss (attributed to Ecstasy), were each significantly more prevalent amongst the heavier Ecstasy users (Rodgers *et al.*, in preparation). These lifetime dosage findings were broadly similar to those in our earlier Ecstasy study (see Table 1 in Parrott *et al.*, 2002).

This study was conducted via the Internet, which provides an efficient means for obtaining large and demographically diverse samples. Gosling *et al*. (2003) investigated the similarities and differences between Internet studies and the more traditional (questionnaire based) approached. They noted that the demographic characteristics of Internet participants were often more diverse, even though neither approach produced samples which were truly representative of the general population. The motivation

 

levels and psychosocial profiles of participants were generally similar. One concern with the Internet was the possibility of multiple submissions from the same individual. Gosling *et al*. (2003) urged internet researchers to take steps to eliminate this problem, and their recommendations have been followed here. Repeated submissions from the same machine were therefore excluded, while other quality assurance procedures developed for Internet research (Buchanan and Smith, 1999), have also been implemented (Rodgers *et al.*, 2003; Buchanan *et al.*, 2005). Another key topic is construct validity – whether Internet studies generate similar types of finding to more traditional methods. Krantz and Dalal (2000) reviewed a number of studies and concluded that there was a high level of construct concordance between the findings from online and laboratory investigations. Gosling *et al*. (2003) also noted that 'evidence so far suggests that Internet based findings are consistent with findings based on traditional methods . . . but more data are needed.' Construct validity was evident in the current findings. The more intensive polydrug usage by the heavier Ecstasy/MDMA users was similar to those found in previous Internet (Scholey *et al.*, 2004) and questionnaire studies (Parrott *et al.*, 2001; Fox *et al.*, 2002). The incidence of Ecstasy-attributed psychobiological problems was also similar to those found in our earlier www study (Parrott *et al.*, 2002). Further studies are however needed to directly assess the degree of concordance between Internet and pencil-and-paper findings. They would illuminate the question of which approach is best for sensitive topics like illicit drug use; by guaranteeing anonymity, the Internet may even have some advantages over more traditional methods (Rodgers *et al.*, 2003; Gosling *et al.*, 2004; Buchanan *et al.*, 2005).

There were several methodological limitations to the current study. The main problem was the absence of a control group. In future studies we plan to assess dancing and thermal comfort ratings independently of drug status (instead of the current questions which only covered dancing and thermal self-ratings *when on-Ecstasy*). This would address the question of whether the current associations between physical exercise, heat and psychobiological functioning (Tables 3 and 4) are specific to Ecstasy users, or reflect a more general pattern of psychobiological inter-relationships. High levels of ambient temperature and physical exhaustion can adversely affect psychophysiological and psychobiological functioning (Lieberman *et al.*, 2005; review by Hancock and Vasmatzidis, 2003). Furthermore these adverse factors can be exacerbated by psychoactive drugs (Parrott and Pindar, 1985), although the level of environmental stress which causes psychobiological problems tends be extreme. We are not aware of empirical studies into the psychobiological correlates of social dancing, nor of the ambient temperature conditions found at dance clubs, which may not be particularly hot (Note: Cole *et al.*, 2005, reported a maximum ambient temperature of 26°C). Nevertheless prolonged dancing in hot and crowded conditions may still have adverse psychobiological consequences, irrespective of concomitant drug use.

Another methodological issue is that dancing and thermal aspects were assessed via self-report, and future studies should also incorporate more objective measures. Physical activity could be directly assessed by using actigraphs. Indeed in a recent study which employed them, Lock *et al*. (2006) found that Ecstasy users demonstrated higher levels of physical activity on self-administered MDMA than when at the same Saturday night dance club venue but when off-drug. In another field study, body temperature was significantly higher amongst Ecstasy users compared to non-users (Parrott and Young, 2005). Subjective feelings of being hot were also assessed and they were also significantly higher. Furthermore the objective and subjective temperature measures correlated positively ($p < 0.001$; Parrott and Young, 2005), providing empirical support for the validity of our thermal self-ratings (Tables 2, 4). However the primary focus for concern should be brain temperature rather than body temperature, yet that is far more difficult to measure. In a review of the animal and human literature on brain hyperthermia, Kiyatkin (2004) noted that only indirect indices of brain temperature could generally be employed with humans (e.g., thermistor probes in the venous blood supply exiting the brain). Furthermore, body and brain display different ways of heating and cooling so that core body temperature measurements (e.g., from the tympanic membrane) may often diverge from the brain temperature indices.

Another complicating issue is that 'dancing on ecstasy' represents an amalgam of closely related factors. Prolonged periods of physical exertion will be associated with minimal rest, longer periods of exposure to loud noise/music and greater dehydration (Dafters, 1995; Suy *et al.*, 1999; Parrott, 2002). These factors may contribute to a general heightening of arousal, or more specifically to a stronger acute serotonin syndrome response (Morton *et al.*, 2001; Parrott, 2002). Our prediction is that all these factors will have contributory roles, since any non-drug factor which contributes to psychophysical arousal and

 

neurochemical overstimulation might contribute to acute cellular distress, and hence more neurotoxic damage in the longer term (Huether *et al.*, 1997: Parrott, 2001, 2004b, 2006; see earlier). These ideas could be investigated using laboratory animals. Individual factors such as noise, temperature, crowding, hydration, and MDMA dosage could be systematically manipulated and their interactions directly studied (Gordon *et al.*, 1991; Dafters, 1995; Malberg and Seiden, 1998). One of the factors identified here as potentially important, namely physical activity (Table 3), does not seem to have been empirically studied in laboratory animals as an *independent* variable. However it could be investigated through 'yoked' behavioral activity paradigms; the prediction being that prolonged periods of imposed physical activity when on MDMA would lead to greater acute neuronal metabolic activity – and hence greater chronic neurotoxicity. Any adverse effects of exercise would also be expected to be greater under high ambient temperature, dehydration, loud noise, and/or social crowding. Under these conditions of high environmental stimulation, even quite low doses of MDMA might lead to neuropsychobiological distress.

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