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# 3,4-Methylenedioxymethamphetamine (MDMA, Ecstasy) and Driving Impairment

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**ABSTRACT:** 3,4-Methylenedioxymethamphetamine, or MDMA, is increasing in popularity in the United States as a drug of abuse. It has stimulant and empathogenic mood altering properties with the potential to affect psychomotor skills and impact driving. This report reviews the literature relating to the relevant psychomotor effects of the drug, the relationship between dose and blood concentrations, and studies and case reports on specific effects of the drug on driving. The latter reports include both laboratory driving simulator studies and anecdotal reports, and case series. We also report details of eighteen cases of apparent MDMA impaired driving, including six drivers whose blood tested positive for MDMA alone. Most subjects displayed muscle twitching and body tremors, dilated pupils, slow pupillary reaction to light, elevated pulse and blood pressure, lack of balance and coordination, and most were perspiring profusely. Five of the six subjects were given field sobriety tests (one leg stand, walk and turn test), and all five performed poorly. There was no clear correlation between the blood concentration of MDMA and the specific demeanor of the subject. These findings are consistent with other reports, and lead to the conclusion that MDMA use is not consistent with safe driving, and that impairment of various types may persist for a considerable time after last use.

**KEYWORDS:** forensic science, MDMA, ecstasy, driving impairment

This review of the literature with a short series of cases is prompted by the increasing incidence with which MDMA has been implicated in driving under the influence cases, including traffic fatalities in which the driver tested positive for the drug. While methamphetamine is a potent CNS stimulant, its methylenedioxy derivative, 3,4-methylenedioxymethamphetamine (MDMA, ADAM, ecstasy, E, X, XTC, M&M, euphoria, rave, hug drug, disco biscuits, white doves, love drug, rolls, and essence), has significantly less CNS stimulant properties than the parent, but can be categorized as a stimulant as a result of its sympathomimetic effects. It also has other properties detailed below that have made it extremely popular as a recreational, party, rave, or dance drug. Users report as positive effects, changes in feelings and emotions, enhanced communication, empathy or understanding, changes in cognitive or mental associations, euphoria or ecstasy, and changes in perception, including hallucinations (1). Other reported effects include a great sense of pleasure, dissociation, sexual stimulation, relaxation, increased responsiveness to intimate touch, increased self-esteem, and high energy (2,3). These effects have led to the drug being classed as an empathogen or entactogen (4).

A range of negative effects invariably accompanies the perceived positive effects. These include muscle tension or jaw clenching leading to muscle pain, increased sweating, blurred vision, ataxia, nausea, and anxiety (1), pupillary dilation, nystagmus, a nervous desire to be in motion, panic attacks, urinary urgency, diplopia, and insomnia (5), hyperthermia, hyponatrenia, convulsions, catatonic stupor, vomiting, and motor tics (6,7). There is also evidence for prolonged cognitive deficits in regular users for at least several weeks after use has stopped (8,9).

Given these properties, it is reasonable to expect that at some point following the consumption of MDMA, a user would suffer effects that would impact their ability to safely operate a motor vehicle.

We review the growing body of literature that suggests an established link between recreational use of MDMA and impairment in skills critical for safe driving. Most of these reports fail to measure blood drug concentrations, which may have allowed the assessment of whether impairment resulted from normal recreational use, or was associated with overdosage. We describe behavioral and quantitative blood toxicology data in a series of cases of alleged driving under the influence of MDMA.

## Methods

Cases submitted to the Washington State Toxicology Laboratory for drug screening in suspected driving under the influence of alcohol or drugs cases, were tested for alcohol, and screened for drugs by immunoassay and gas chromatography/mass spectrometry (GCMS) techniques. For alcohol analysis, blood specimens (0.2 mL) were mixed with internal standard (2 mL of 0.15 mL *n*-propanol/1L deionized water/10 g sodium chloride solution), and injected on a headspace GC with flame ionization detection (GC-FID). Blood specimens (1 mL) also underwent protein precipitation with methanol (1 mL) and acetonitrile (5 mL) while vortex mixing. The sample was centrifuged, and the supernatant evaporated to 100 μL, then reconstituted to 300 μL with methanol/EMIT buffer (1:1). The resulting extract was then assayed by Enzyme Multiplied Immunoassay Technique (EMIT), (SYVA) using an Olympus AU400 autoanalyzer. The EMIT procedure screened for cocaine metabolites (cutoff limit 100 ng/mL), opiates (20 ng/mL), amphetamines (200 ng/mL), carboxy tetrahydrocannabinols (10 ng/mL), methadone (100 ng/mL), phencyclidine (10 ng/mL), propoxyphene (100 ng/mL), barbiturates (100 ng/mL), benzodiazepines (100 ng/mL), and tricyclic antidepressants (100 ng/mL).

Blood specimens were also extracted prior to analysis by gas chromatography with nitrogen/phosphorus detection (GCNPD)

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and gas chromatography/mass spectrometry (GCMS) (Hewlett Packard/Agilent). Blood (1 mL), internal standard (metycaine, 50 μL of a 10 mg/L solution in ethyl acetate), and pH 9 saturated potassium borate buffer (1 mL) were mixed, and extracted with *n*-butyl chloride (3 mL). The organic fraction was back extracted into 3 *M* hydrochloric acid (200 μL), which was then made alkaline with concentrated ammonium hydroxide/ammonium carbonate and re-extracted into chloroform (100 μL), containing the chromatographic standard diphenylamine (2 mg/L solution). A 2 μL aliquot of the chloroform fraction was then injected for analysis. Quantitation was performed from the GCNPD data, and was based on a four-point calibration curve. The method has a limit of quantitation (defined as half the concentration of the lowest standard), of 0.05 mg/L, and a limit of detection of less than that, based on our ability to obtain a mass spectrum consistent with the drug and with the appropriate retention time. Delta-9-tetrahydrocannabinol (THC), and its metabolite THC-11-carboxylic acid were also confirmed by GCMS. Lysergic Acid Diethylamide (LSD) was detected and confirmed by a reference laboratory, using LCMS.

In several cases, a Drug Recognition and Evaluation (DRE) officer evaluated the subject, where parameters such as pulse and blood pressure, pupil size and response, horizontal and vertical gaze nystagmus, muscle tone, and demeanor were evaluated, and the subject was interviewed about their drug use. The arrest or incident reports, and the report of the DRE evaluation when performed, were obtained and reviewed.

## Results and Discussion

The data from the cases we encountered are presented in Table 1. Only three of the 18 drivers were female. The age range was 17 to 30, and the mean age was 21 (median 20). The subjects displayed a variety of driving behaviors that brought them to the attention of the police. Of the 18 drivers identified, five were involved in collisions (various causes), eight displayed erratic driving, usually lane travel (i.e., weaving within the lane), and at least six were speeding. A common feature of these cases, and others reported elsewhere is the presence of multiple drugs and/or alcohol in most cases. Six tested positive for THC or its metabolite, four for alcohol, three for diazepam (although for at least one subject this was likely administered in hospital), and one each for methamphetamine, PCP, ephedrine, and LSD. This pattern of polysubstance use undoubtedly contributes to the overall presentation, but makes the isolation of effects specific to MDMA difficult.

Six subjects tested positive only for MDMA. Blood concentrations in these subjects were <0.05, <0.05, 0.33, 0.36, 0.39, and 0.58 mg/L respectively. As discussed below, these concentrations represent the low to mid range of blood concentrations in recreational MDMA users, consistent with peak concentrations from the use of 50 to 200 mg. This suggests that these subjects are engaging in patterns of typical recreational use, and are not MDMA overdoses. All six subjects appeared cooperative and "laid back," and all but one admitted using ecstasy. Most subjects displayed muscle twitching and body tremors, dilated pupils, elevated pulse, slow reaction to light, and were perspiring profusely. DRE indicators for MDMA use include: horizontal and vertical gaze nystagmus not present; no lack of convergence; dilated pupils with slow reaction to light; elevated pulse rate; elevated blood pressure; and elevated body temperature (10). Observations in the six MDMA only subjects were mostly consistent with these markers, however, indicators such as elevated blood pressure and body temperature were not observed. Five of the six subjects were given field sobriety tests (one leg stand, walk and turn test), and all five performed poorly. There was no clear correlation between the blood concentration and the specific demeanor of the subject. The subject with the highest MDMA concentration (0.58 mg/L) fell asleep in the police car during the arrest. This strongly suggests that the impairing effects experienced by these subjects were a result of normal patterns of recreational use, and they may, in fact, be on the downside, or experiencing the after affects of the use of the drug. The symptomatology in the remaining polydrug subjects was similar, notably the pupil size, attitude and demeanor, elevated pulse, and lack of balance and coordination, overlaid on the symptoms of the other drugs.

### Blood Concentration and Dose

MDMA is metabolized to 3,4-methylenedioxyamphetamine (MDA), which is typically the only metabolite identified in plasma, and is also metabolized to 4-hydroxy-3-methoxymethamphetamine and 3,4-dihydroxymethamphetamine, the latter two of which are glucuronidated prior to excretion in urine (11–13). MDA is further metabolized to 4-hydroxy-3-methoxyamphetamine and 3,4-dihydroxyamphetamine, both of which may be present in the urine but not detectable in the blood. Users typically ingest MDMA orally, and recreational users indicate a preferred dose of 1.76 to 4.18 mg/Kg (mean 2.51 mg/Kg, or about 175 mg in a 70 Kg subject) (14). Other users surveys report a range of doses between 50 to 700 mg in a session, with an average of 120 mg (1), and the Addiction Research Foundation report a normal dose range of 50 to 200 mg (3).

Following oral ingestion of 1.5 mg/Kg (105 mg/70 Kg) doses, average peak serum concentrations of 0.33 mg/L were obtained in two subjects at 120 min (11). The MDA concentration peaked at 380 min and 150 min, and was consistently less than 5% of the parent drug concentration. Verebey et al. (15) report a peak MDMA concentration of 0.106 mg/L in a 74 Kg adult male, 2 h following the ingestion of 50 mg. The MDA concentration peaked at 0.028 mg/L after 4 h.

De la Torre et al. (16) report peak concentrations at 1.5 to 4 h following ingestion of 50 to 150 mg of MDMA. The mean concentrations associated with each dose were as follows (dose (mg)/mean conc. or range (mg/L) (S.D)): 50 mg/0.02 to 0.08 mg/L; 75 mg/0.13 mg/L (0.04); 100 mg/0.21 to 0.19 mg/L; 125 mg/0.24 mg/L (0.06); 150 mg/0.44 to 0.49 mg/L. The authors report that the MDA metabolite concentrations peaked later (4 to 6 h) and never exceeded 5% of the parent concentration.

The half-life of MDMA has been reported as 6.7 hours, however, Fallon et al. (13) note that the pharmacokinetics are nonlinear. This is most likely attributable to stereoselective metabolism of the drug, which in its common form exists as two enantiomeric isoforms, with different affinities for the enzyme responsible for its metabolism. Since the (+)-S enantiomer appears to have greater CNS potency than the (−)-R form, but more rapid elimination, the nonlinear kinetics further complicates the interpretation of blood concentrations and their relationship to effect. The authors report a combined mean peak plasma concentration (both enantiomers) of 0.06 mg/L at 2 to 4 h following the administration of 40 mg of MDMA, which is consistent with earlier references.

Moeller and Hartung (17) have reported serum MDMA concentrations in drivers suspected of impaired driving, in the range 0.001 to 0.514 mg/L (median 0.076 mg/L). These concentrations are consistent with typical recreational doses, perhaps even on the low side, and might suggest some elapsed time since last use. The con-

TABLE 1—*Circumstances and driving behavior in 18 drivers testing positive for MDMA in blood.*

| Case | Sex/Age | MDMA (mg/L) | Other Drugs | Conc. (mg/L)† | HGN | VGN | Pupils | Temp. (*F) | B.P. (mmHg) | Pulse (bpm) | Reaction to Light | Circumstances/Impairment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MDMA and Other Drugs | | | | | | | | | | | | |
| 1* | M/18 | <0.05 | MDA | 0.08 | yes | no | dilated | … | elevated | … | none | Single car collison—hit freeway barrier |
| | | | ethanol | 0.11 | | | | | | | | Smelt of intoxicants and marijuana; profuse sweating |
| | | | carboxy-THC | 15 | | | | | | | | Cooperative; jittery; mood swings; poor coordination |
| | | | | | | | | | | | | Poor SFSTs; lack of balance; obvious impairment |
| | | | | | | | | | | | | DRE opinion: CNS stimulant and cannabinoids |
| 2 | M/17 | 0.12 | ethanol | 0.08 | … | … | … | … | … | … | … | Left roadway midspan on bridge; female passenger drowned |
| | | | diazepam | 0.03 | | | | | | | | Subject transported to hospital |
| | | | nordiazepam | 0.03 | | | | | | | | Smelt of intoxicants; admitted ecstasy use |
| 3* | F/30 | 0.13 | ethanol | 0.08 | yes | no | dilated | 98.2 | 142/68 | 90–98 | slow | Stopped for speeding |
| | | | THC | <5 | | | | | | | | Smelt of intoxicants and marijuana |
| | | | carboxy-THC | 44 | | | | | | | | Cooperative; bloodshot eyes; body sways and tremors |
| | | | | | | | | | | | | Varied coordination; lack of balance |
| | | | | | | | | | | | | DRE opinion: CNS depressants and cannabinoids |
| 4 | F/29 | 0.15 | ethanol | 0.10 | … | … | … | … | … | … | … | Speeding, then collided with another vehicle |
| | | | diazepam | 0.32 | | | | | | | | Strong odor of intoxicants on breath |
| | | | nordiazepam | <0.05 | | | | | | | | Subject ejected from vehicle |
| | | | | | | | | | | | | Subject not able to respond to questions; taken to hospital |
| | | | | | | | | | | | | Officer suspected CNS stimulant and cannabinoids |
| 5* | M/18 | 0.15 | LSD | 0.46 | no | no | dilated | 96.7 | 140/90 | 104–116 | slow | Stopped for speeding |
| | | | | | | | | | | | | Odor of intoxicants in car; green tongue; bloodshot eyes |
| | | | | | | | | | | | | Cooperative and laid back, then nervous and slight paranoia |
| | | | | | | | | | | | | Impaired perception of time and distance |
| | | | | | | | | | | | | Lack of balance; uncoordinated; poor SFST's |
| | | | | | | | | | | | | Hand fidgeting; body tremors; dazed appearance |
| | | | | | | | | | | | | Incomplete thought process; memory loss |
| | | | | | | | | | | | | Lack of smooth pursuit; lack of convergence |
| | | | | | | | | | | | | Admitted use of acid, marijuana and ecstasy |
| | | | | | | | | | | | | DRE opinion: CNS stimulant, hallucinogen and cannabinoids |
| 6 | M/18 | 0.17 | THC | 3 | no | yes | dilated | … | … | … | … | Stopped for minor traffic infraction |
| | | | carboxy-THC | 24 | | | | | | | | Cooperative; appeared sleepy and slow to respond |
| | | | | | | | | | | | | Bloodshot eyes; body sways |
| | | | | | | | | | | | | Poor coordination and balance; obvious impairment |
| | | | | | | | | | | | | Poor performance in FSTs |
| | | | | | | | | | | | | In possession of marijuana, and admits to recent use |
| 7 | M/21 | 0.23 | MDA | pos | … | … | varied | … | 143/77 | 92–112 | … | Crossed center line striking other vehicle |
| | | | ephedrine | pos | | | | | | | | Subject transported to hospital |
| | | | | | | | | | | | | Admitted ingestion of "mini-thin" tablets |
| | | | | | | | | | | | | Pupils normal then constricted |
| 8* | M/18 | 0.24 | carboxy-THC | 8 | no | no | dilated | 98.2 | 130/92 | 60–68 | normal | Stopped for speeding |
| | | | | | | | | | | | | In possession of marijuana pipes; admitted marijuana use |
| | | | | | | | | | | | | Cooperative; slow coordination; body and eyelid tremors |
| | | | | | | | | | | | | Bloodshot eyes; lack of convergence; green tongue |
| | | | | | | | | | | | | Poor performance on Walk and Turn test |
| | | | | | | | | | | | | DRE opinion: cannabinoids |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MDMA and Other Drugs cont. | | | | | | | | | | | | |
| 9 | M/18 | 0.46 | carboxy-THC | 35 | yes | yes | dilated | … | … | … | … | Stopped for lane travel<br>Smelt of marijuana in vehicle; cooperative<br>Performed poorly on Walk and Turn test<br>Fidgety; continually scratching arms and legs<br>In possession of marijuana and ecstasy<br>Admitted ecstasy use |
| 10 | M/25 | 0.60 | MDA<br>diazepam<br>nordiazepam | <0.05<br>0.05<br><0.05 | … | … | … | … | … | … | … | Speeding and erratic driving, then single car rollover<br>Transported to hospital; cooperative and subdued<br>Had attended a RAVE party and admitted ecstasy use<br>Indicated he felt the effects of the drug as he drove |
| 11 | M/25 | 0.74 | methamphetamine<br>carboxy-THC | 0.05<br>45 | … | … | dilated | … | … | … | … | Stopped for lane travel<br>Green tongue; poor FST's; eyes could not track object<br>Officer suspected hallucinogen and cannabinoids |
| 12 | M/19 | 1.89 | phencyclidine | 0.04 | … | … | … | … | … | … | … | Stopped for lane travel<br>Admitted ecstasy use |
| MDMA only | | | | | | | | | | | | |
| 13* | M/24 | <0.05 | … | … | no | no | dilated | 98.9 | 178/90 | 110-116 | slow | Stopped for a traffic violation<br>Cooperative; shaky coordination; profuse sweating<br>Twitchy shoulders and fingers; leg tremors; body sways<br>Performed poorly on SFST's<br>Subject admitted ecstasy use<br>DRE opinion: CNS stimulants |
| 14* | M/25 | <0.05 | … | … | no | no | dilated | 97.9 | 140/80 | 54 | slow | Stopped for speeding<br>Smelt of marijuana; profuse sweating<br>Slight body sway; calm, relaxed attitude; dazed appearance<br>No balance tests performed due to knee problems<br>Subject admitted ecstasy use<br>DRE opinion: hallucinogen/ psychedelic amphetamine |
| 15* | F/22 | 0.33 | … | … | no | no | dilated | 99.2 | 150/70 | 128–134 | slow | Stopped for driving the wrong way on one-way street<br>Cooperative; very relaxed and mellow; dazed appearance<br>Perspiring; fidgety; body and leg tremors; body sway<br>Stated she had a heart condition and was taking Lanoxin<br>Subject admitted ecstasy use<br>DRE opinion: hallucinogen |
| 16* | M/22 | 0.36 | … | … | no | no | dilated | 98.6 | 145/80 | 84–111 | slow | Stopped for erratic lane usage<br>Smelt of intoxicants in car<br>Laid back and cooperative; appeared dazed; perspiring<br>Lack of convergence; fidgety; body sway; leg tremors<br>Subject admitted ecstasy use<br>DRE opinion: hallucinogen |
| 17* | M/19 | 0.39 | … | … | no | no | dilated | 98.1 | 130/60 | 80–100 | slow | Stopped for minor infraction<br>Cooperative; very relaxed and mellow; perspiring<br>Lack of convergence; slurred speech; fidgety; leg tremors<br>Poor coordination; lack of balance; body sway<br>Performed poorly on SFST's<br>Subject admitted ecstasy use<br>DRE opinion: hallucinogen (ecstasy) |

*continues*

TABLE 1—*Continued.*

| Case | Sex/Age | MDMA (mg/L) | Other Drugs | Conc. (mg/L)† | HGN | VGN | Pupils | Temp. (*F) | B.P. (mmHg) | Pulse (bpm) | Reaction to Light | Circumstances/Impairment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 18* | M/18 | 0.58 | … | … | no | no | dilated | 98.4 | 132/92 | 110–114 | normal | Stopped for lane travel and erratic driving<br>Feel asleep in patrol vehicle<br>Cooperative; overly relaxed; blank stare<br>Poor coordination; lack of balance<br>Leg tremors; hand twitching; body sway<br>Performed poorly on SFST's; obvious impairment<br>DRE opinion: hallucinogen (ecstasy) and cannabinoids |

Conc: concentration; pos: positive.
THC: tetrahydrocannabinol; LSD: lysergic acid diethylamide.
HGN: horizontal gaze nystagmus; VGN: vertical gaze nystagmus.
CNS: central nervous system; B.P.: blood pressure (mmHg); pulse in bpm.
* Cases that underwent Drug Recognition Evaluation (DRE)/Standard Field Sobriety Tests (SFSTs) (10).
† Ethanol concentrations in g/100 mL; LSD, THC, and carboxy-THC concentrations in ng/mL.
NOTE: "normal" body temperature 98.6 +/− 1 *F; B.P. systolic 120 to 140, diastolic 70 to 90 mmHg; pulse 60 to 90 bpm; pupil size 3.5 to 6.0 mm in all light conditions (10).

centrations are certainly not suggestive of overdoses. Mueller and Korey (18) have noted that most cases of MDMA toxicity appear idiosyncratic and are not associated with massive overdose, making adverse reactions with effects on driving possible, following even limited use.

### *Effect Profile of MDMA*

MDMA in low to moderate doses (50 to 200 mg) produces mild intoxication, euphoria, an increase in physical and emotional energy, a great sense of pleasure, increased sociability and closeness, mild visual disturbances, nystagmus, pupillary dilation, and blurred vision. Muscular effects are prominent, including instability and incoordination in gait, in finger-to-nose testing, enhanced jaw clenching, and deep tendon reflexes. Although the above effects were generally gone 24 h after use, users reported prolonged physical and psychological problems, most frequent among which were muscle tension in the jaw, fatigue, depression, anxiety and insomnia. Insomnia, fatigue, mandibular muscle pain, loss of balance, and headache may persist into the next day, and some users report confusion, depression, and anxiety lasting several weeks after a single dose. Higher doses produce possible neurotoxicity, and distortion of perception, thinking, or memory (1–3,5,14,19,20).

Siegel (1) reported a survey of 44 experienced MDMA users. Typical initial doses were around 100 mg (range 50 to 390 mg), with the total dose in a given session being 120 mg (50 to 700 mg). The intoxication effects noted included the following: changes in feelings and emotions (80%), enhanced communication, empathy or understanding (68%), changes in cognitive or mental associations (68%), euphoria or ecstasy (63%), and changes in perception (44%). Undesirable effects included muscle tension (100%), increased sweating (91%), blurred vision (77%), and ataxia (77%). Several subjects reported illusory or hallucinatory experiences, although these are typically associated with higher doses. Many subjects had attentional dysfunction, manifested as difficulty in maintaining attention during complicated tasks, focusing instead on inner personal experience, and preoccupation with personal problems. Those subjects who reported changes in perception noted increased light sensitivity, blurred vision, and difficulty in focusing, which is also of concern.

There is mounting evidence of persistent neurological deficits in MDMA users, even when the subject has been drug free for a period of time. This is believed to be associated with damage to serotonergic neurons, resulting in lowered endogenous brain serotonin production. These changes result in poor memory recall (6), flashbacks, depersonalization, panic attacks, and psychosis (21). Persistent performance decrements in a number of measures of complex task performance such as selective attention, divided attention (9), sustained attention, and complex attention tasks (8) have been reported. These changes are associated with lower cerebrospinal fluid levels of the serotonin metabolite 5-hydroxyindoleacetic acid (5-HIAA), providing further evidence that MDMA is neurotoxic to brain serotonergic neurons, resulting in long term cognitive deficits (22). Morgan (23) reports that there is evidence of enhanced impulsivity in recreational users of MDMA, and notes that this is also consistent with reduced levels of serotonergic function.

When taken in a setting involving strenuous activity, such as all night dancing, fatigue, exhaustion, dehydration, sympathetic hyperactivity, increased pulse and blood pressure, and tachyarrythmias, secondary to the use of the drug may occur which can further complicate the effect profile. Typically at elevated doses, MDMA will cause excessive hyperthermia (>107°) with muscular rigidity,

disseminated intravascular coagulation, rhabdomyolysis, hyponatremia, hyperkalemia, acute renal failure, coma and death (19,24–26). The hyperthermic effects of MDMA result from disruption of central neurotransmitter mediated thermoregulatory control. Serotonergic hyperstimulation (serotonin syndrome) has been implicated in some ecstasy deaths (18,27), and is characterized by the presence of at least three of the following: behavioral changes (confusion, agitation, hypomania, or coma), alteration of muscle tone (incoordination, shivering, tremor, hyperreflexia, myoclonus, rigidity), autonomic instability (diaphoresis, tachycardia, hypertension, hypotension), hyperthermia, and diarrhea (28,29).

There have been sufficient case reports now of fatalities and toxidromes associated with use of MDMA to conclude that it is potentially a very dangerous drug (5,18,24,30–34). In addition, many subjects under the influence of MDMA have been brought to the emergency room following car crashes or related incidents, and the specific reported effects of this drug which relate to driving are considered below.

*MDMA and Driving*

Several workers have commented specifically on concerns regarding the detrimental effects of MDMA consumption on driving, and the associated increase in risk of accident involvement.

Acute changes in cognitive performance in users before, during and after a Saturday night dance where the drug was self-administered, were evaluated by Parrott and Lasky (6). These authors note that MDMA markedly impairs information processing ability, and they emphasize the dangers of undertaking *skilled activities like car driving* when under its influence (our italics). Downing et al. (14) whose work was reviewed above, concluded, based on impairment in cognitive performance, that tasks requiring significant coordination and concentration should not be performed while under the influence of MDMA, *especially operating a motor vehicle* (our italics).

DeWaard et al. (35) tested subjects using an advanced driving simulator after they had self administered MDMA (average dose 56 mg). This is a modest dose compared to normal reported use patterns of 120 mg. Under these conditions, there were only moderate effects on vehicle control compared to the same subjects when sober, however as noted elsewhere, the persistent cognitive impairment associated with frequent use of this drug brings into question the validity of using each subject as their own control. This study did show that the subjects acutely under the influence of MDMA, were prepared to accept higher levels of risk, than when in the control condition. This is an issue that has been raised with respect to methamphetamine (36–38), and Morgan (23) has also noted that recreational use of MDMA is associated with increased impulsivity, which raises concerns about judgment and appropriate decision making while under the influence of the drug.

Giroud et al. (39) report three cases of drivers under the influence of MDMA with whole blood MDMA and MDA concentrations, of 0.121 and 0.008, 0.078, and 0.005, and 0.141 mg/L and undetectable, respectively. The authors cite the psychotropic properties of the drug as being incompatible with the safe operation of an automobile. They also note that in the case of a positive urine drug test alone, even in the absence of MDMA in the blood, the ability to drive may be heavily compromised until the driver has recovered after an evening of partying, and from the secondary effects of the drug.

Schifano (40) reports a series of case reports of five drivers referred for neuropsychiatric assessment. Between them they were responsible for 11 serious accidents while under the influence of MDMA. Specific behavioral changes that led to the crashes included speeding (numerous mentions), jumping red lights, hallucinations/delusions, and a sense of detachment or distance from the real world. Patterns of use most frequently mentioned involved daily doses of 200 mg, although the upper limit ranged from 600 to 1500 mg/day. No blood drug concentrations were available.

Bost (41) reported two cases of intoxicated drivers with MDMA in their blood, and five cases of MDEA, although concentrations were not reported for the former. One driver had alcohol present also (0.06 g/100 mL). The other case where MDMA was the only substance reported, the driver had abruptly changed lanes resulting in an accident. He admitted to using what he thought was MDEA 2.5 h earlier. The author drew no specific conclusions about the nature of the impairment produced by the drug.

Moeller and Hartung (17) have reported serum concentration of MDMA in eighteen impaired drivers. They report a median MDMA concentration of 0.076 mg/L (range 0.001 to 0.514 mg/L), and a median MDA concentration of 0.013 mg/L (range 0.001 to 0.067 mg/L) in 23 cases as a metabolite of either MDMA or MDEA. They also note a very high incidence (83%) of combined use of MDMA or MDEA and marijuana in Germany. However, other than noting that twelve of the eighteen MDMA drivers were involved in accidents, they give no details of the specifics of the driving involved.

Omtzigt et al. (42) lists blood drug concentration data in a series of nine impaired driving cases involving MDMA. The mean $\pm$ SD MDMA concentration was 0.18 $\pm$ 0.14 mg/L, and the range was 0.04 to 0.38 mg/L. The median concentration was 0.19 mg/L. Alcohol and/or other drugs were present in seven of the nine cases, and included ethanol (range 0.02 to 0.11 g/100 mL), amphetamine, MDEA, cocaine or benzoylecgonine, and cannabinoids. Specific behaviors noted included disturbance of equilibrium, confused speech, disorientation to time and place, aggressive behavior, dilated pupils, slow reactions, and drowsiness. The metabolite MDA was not detected in any of the cases. The authors cite reckless driving, disturbance of equilibrium, and impaired tracking ability as the primary effects resulting in the accidents from which these cases arose.

Crifasi and Long (43) report a case of a traffic fatality attributed to MDMA impairment, in which the driver suddenly veered off the roadway, and rolled over an embankment. The MDMA concentration in preserved whole blood was 2.14 mg/L, and the MDA was less than 0.25 mg/L. Urine and vitreous MDMA concentrations were 118.8 mg/L and 1.11 mg/L respectively. Marijuana metabolites were present in the urine but were not detected in the blood. The authors note the difficulty in assessing the relationship between the drug use, which in this case clearly results from overdosage, and the causation of the accident.

Hooft et al. (44) have reported the case of a death, in which the decedent fell from the roof of a moving vehicle. They attribute this bizarre and reckless behavior to the use of MDMA, based on the history and the toxicology data. The MDMA concentration in blood was 0.63 mg/L, and ethanol was also detected at a concentration of 0.123 g/100 mL.

Davies et al. (45) report their experience in treating 16 ecstasy abusers over a three month period, all of whom had been injured in road traffic accidents. They note that reckless driving had been the cause of all sixteen, and note that impaired neurological function resulting from use of the drug complicated the assessment of the patients for purposes of treatment.

Cadier and Clarke (46) report a case of severe burns in an individual who had been using in ecstasy and amphetamine, in which a gasoline container in a vehicle ignited, although the exact circumstances were unclear.

Dowling et al. (32) reported five deaths in subjects testing positive for MDMA or MDEA. One of these was of a man who was fatally injured in a traffic accident after his truck hit a curb, then a utility pole. His injuries were minor and the cause of death was determined to have resulted from ASCVD; however, his postmortem toxicology revealed 0.95 mg/L of MDEA, and 0.8 mg/L of butalbital.

Henry et al. (34) reported on a series of deaths and intoxications resulting from MDMA use, including five road traffic accidents (three drivers, a passenger, and one pedestrian). The authors attribute the accidents, in part, to the use of the drug and the associated behavioral disturbances.

Morland (47) reviews some of the above reports and notes that epidemiologically there are not as many incidences of MDMA related traffic fatalities as might be expected given the extent of its use. A possible explanation for this could be that the population of MDMA users is relatively young, and accordingly may perform less driving.

Brookhuis' work (48) also suggests that impairment to the extent where an accident is inevitable may only occur in exceptional circumstances. Two examples would be where the adverse effects are so profound, either because of overdosing or idiosyncrasy, and secondly where the demands on driving are such that even mild impairment may make the difference between a crash and no crash.

## Conclusions

The relationship between the use of MDMA and driving impairment is complex. Empirically, many of the anticipated and adverse effects of the drug discussed above are clearly incompatible with safe driving. In addition, it is evident that MDMA is frequently used with other drugs, or alcohol, making isolation of the specific effects of the drug itself very difficult, and complex drug interactions likely. Coupled with this, the drug is often used in a setting where the subject may experience exhaustion, fatigue, dehydration, and sleep loss, which may produce impairments independent of, but additive to those of the drug itself. The above factors, together with considerations of sensitization and tolerance, the intoxication/withdrawal course of the effects, idiosyncratic responses, and the persistent cognitive deficits even after periods of abstinence, make any dose-response predictions in experienced drug users difficult, and a quantitative relationship between blood concentrations and a specific degree or constellation of effects, impractical.

Chemical tests of urine do little more than confirm prior use of the drug, and with the drugs' relatively long half life, urine could test positive for two to three days following moderate use. Chemical tests of blood, however, have some additional value in that they do allow assessment of toxicity, or excessive use beyond what is considered a normal recreational use, and may provide evidence of the subject being in the post acute intoxication phase.

In assessing future cases of alleged impaired driving resulting from MDMA or related compounds, useful information can be obtained at the time of the arrest from a structured medical, or drug recognition (DRE) evaluation of the subject. In any event conclusions about the relationship between the use of this or any drug to driving impairment must be based on all available information, including driving behavior, the subjects demeanor and appearance, their statements, witness statements, observations of police officers, and specially trained observers together with toxicology results.

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