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Reward-Related Decision-Making Deficits and Elevated Impulsivity Among MDMA and Other Drug Users

Karen L. Hanson[*,1,2,3], **Monica Luciana**[4], and **Kristin Sullwold**[4]

1*University of California San Diego, Department of Psychiatry, San Diego, CA 92193, United States*

2*San Diego State University, Department of Psychology, 92182, United States*

3*VA San Diego Healthcare System, San Diego, CA 92161, United States*

4*University of Minnesota, Department of Psychology, N218 Elliott Hall, 75 East River Road, Minneapolis, MN 55455, United States*

Abstract

Background—The recreational drug, MDMA (3,4-methylenedioxymethamphetamine; 'Ecstasy'), is a synthetic amphetamine derivative and a serotonin neurotoxin. MDMA use is associated with cognitive dysfunction and impulsivity, but since polydrug abuse is common among users it is difficult to attribute these problems specifically to MDMA. Moreover, few studies have examined reward-related cognitive processes. Our aim was to examine reward-related decision-making and impulsivity among MDMA users while controlling for polydrug use via appropriate comparison groups.

Methods—We examined decision-making (Iowa Gambling Task; IGT; Bechara et al., 1994), self-reported impulsivity (Multidimensional Personality Questionnaire – Brief Form [Constraint subscale]; Barratt Impulsiveness Scale; Zuckerman Sensation Seeking Scale), and drug use among 22 abstinent MDMA users, 30 other drug users, and 29 healthy non-drug controls.

Results—MDMA and other drug users showed comparable patterns of decision-making and impulsivity. However, both drug groups demonstrated poorer IGT performance and elevated self-reported impulsivity relative to controls. Poorer decision-making was related to heavier drug use in the past year, heavier weekly alcohol use, and meeting lifetime substance use disorder (SUD) criteria for more drug classes. Elevated impulsivity was associated with heavier drug use, heavier weekly alcohol use, more lifetime SUDs, and higher self-reported depression levels.

Conclusions—These findings contradict the idea that MDMA is specifically associated with deficient decision-making. Drug users, in general, may be at risk for decision-making deficits and elevated impulsivity. Such behaviors may represent trait factors that lead to the initiation of drug and alcohol use, and/or they may represent behavior patterns that are exacerbated by extensive use.

Keywords

MDMA; drug use; alcohol use; executive functions; decision-making; impulsivity

*Corresponding author at: VA San Diego Healthcare System, 3350 La Jolla Village Drive (151B), San Diego, CA 92151, United States. Telephone: 1-858-552-8585 ext. 2663, Fax: 1-858-642-6340, Email: klhanson@ucsd.edu (K.L. Hanson).

1. Introduction

The recreational drug, 3,4-methylenedioxymethamphetamine (MDMA; 'Ecstasy'), is typically used for its hallucinogenic and stimulant properties (Davidson and Parrott, 1997; Liechti et al., 2001; Vollenweider et al., 1998). Animal studies suggest that MDMA elicits an initial upsurge in brain serotonin (5-HT) release and blocks reuptake, followed by a period of diminished release after prolonged use (Battaglia et al., 1987; O'Hearn et al., 1988; Schmidt, 1987). Both rodent and human studies suggest that it is a 5-HT neurotoxin (e.g., Commins et al., 1987; Gerra et al., 2000; Lew et al., 1996; Reneman et al., 2002) that may lead to enduring cognitive and emotional changes (Hatzidimitriou et al., 1999).

Several researchers have compared the cognitive performance of MDMA users to healthy non-drug using controls, revealing dose-related, relatively long-lasting verbal memory deficits (e.g., Curran and Verheyden, 2003; Hanson and Luciana, 2004; Morgan, 1999; Morgan et al., 2002; Rodgers, 2000; Thomasius et al., 2003) and relatively slow processing speeds (e.g., Gouzoulis-Mayfrank et al., 2000; Halpern et al., 2004; McCann et al., 1999). In contrast, attention and vigilance appear to be largely intact (e.g., Gamma et al., 2001; Parrott et al., 1998; Semple et al., 1999).

MDMA users also exhibit a range of executive impairments, including deficient spatial working memory (e.g., Hanson and Luciana, 2004; Wareing et al., 2004), verbal fluency (e.g., Bhattachary and Powell, 2001; Fox et al., 2002; Heffernan et al., 2001), and planning and problem solving (e.g., Dafters et al., 1999; Fox et al., 2001; Schifano et al., 1998). Speed-accuracy tradeoffs suggest that impulsivity may play a role (Halpern et al., 2004; Morgan et al., 2002). Still, other studies report either no observable deficits or failures to replicate (e.g., Back-Madruga et al., 2003; Gouzoulis-Mayfrank et al., 2003; Vollenweider et al., 1998).

Whereas most executive function measures in the above studies are mediated by the dorsolateral prefrontal cortex (e.g., Smith and Jonides, 1999), other processes, such as reward-related decision-making, elicit activation of the ventromedial prefrontal cortex (VMPFC) in functional imaging studies of healthy individuals (e.g., Elliott et al., 1999; 2000). Patients with VMPFC lesions typically show decision-making deficits as measured by the Iowa Gambling Task (IGT: Bechara et al., 1994; 1998; 2000). Using the IGT, Bechara et al (2002) identified subgroups of substance dependent individuals: 1) a subgroup with no detectable deficits; 2) a subgroup that is insensitive to both positive and negative future consequences; and 3) a subgroup that is hypersensitive to rewards. Furthermore, multiple groups of drug users have demonstrated decision-making impairments on the IGT and similar measures requiring decisions based on reward and punishment (e.g., Bechara et al., 2001; Bowden-Jones et al., 2005; Ernst et al., 2003; Grant et al., 2000; Leland and Paulus, 2005; Petry et al., 1998; Rogers et al., 1999; Stout et al., 2005; Verdejo-Garcia et al., 2007). Predictors of poor decision-making include chronic alcohol abuse, shorter duration of abstinence, (Bechara et al., 2001), low IQ (Mazas et al., 2000), male gender (Stout et al., 2005), and elevated impulsivity (Verdejo-Garcia et al., 2007).

Nevertheless, few studies have specifically examined decision-making among MDMA users, and as MDMA users are typically polydrug users, it is difficult to attribute deficits to MDMA versus other drug use. However, Morgan et al. (2006) found risky decision-making among MDMA users relative to polydrug and drug-naïve controls, and Roiser et al. (2006) detected reduced attention to the probability of winning on a risky choices task among MDMA users with the *ss* allele of the 5-HT transporter gene. Furthermore, MDMA users made more disadvantageous choices on the IGT relative to marijuana and non-drug controls, which may be related to poor inhibitory processes (Quednow et al., 2007) and reduced white matter integrity in the anterior corpus callosum (Moeller et al., 2007). Conversely, other studies

reported similar performance among MDMA users and control groups on the IGT or other decision-making tasks, although the impact of marijuana use remains unclear (Fox et al., 2002; Lamers et al., 2006). The effects of acute MDMA administration on decision-making are inconsistent and may depend on the nature of the task (Ramaekers and Kuypers, 2006; Vollenweider et al., 2005). Given the inconsistent findings, further investigation is needed to determine the contribution of MDMA use, other drug use, or additional factors to decision-making processes.

Related to these findings, self-report personality measures have revealed elevated impulsivity and/or novelty/sensation seeking among MDMA users (e.g., Curran and Verheyden, 2003; Butler and Montgomery, 2004; Daumann et al., 2004; Gerra et al., 1998, 2000, 2002; Morgan et al., 2002; Schifano, 2000; Tuchtenhagen et al., 2000; Verkes et al., 2001), which may also impact decision making. Although MDMA use may have led to these elevations (Morgan, 1998; Parrott et al., 2000), impulsivity and novelty/sensation seeking could be pre-existing traits among drug users (Allen et al., 1998; Conway et al., 2002; Mitchell, 1999), perhaps contributing to drug use initiation (Daumann et al., 2004; Dughiero et al., 2001).

The following study was designed to clarify the nature of reward-related decision-making and impulsivity among MDMA users. We examined decision-making, self-reported impulsivity, and drug use in three demographically matched groups of individuals: 1) healthy, non-drug using controls; 2) recreational MDMA users; and 3) other drug users. If MDMA use, specifically, leads to impairments then MDMA users should exhibit poorer reward-related decision-making and elevated impulsivity relative to other drug users and controls. Furthermore, we expected other drug users to demonstrate impairments relative to controls. The associations among reward-related decision-making, self-reported impulsivity, and substance use were also examined.

2. Methods

2.1 Participants

Eighty-one individuals, ages 18 – 35, were studied: (a) recreational MDMA users (n = 22); (b) other drug users with limited or no previous MDMA exposure (n = 30); and (c) individuals with no history of drug use or psychiatric illness (healthy non-drug controls) (n = 29). Forty-one participants (25 controls, 11 other drug users, 5 MDMA users) were recruited from undergraduate psychology courses at the University of Minnesota and received extra credit points for participation. Others (4 controls, 19 other drug users, 17 MDMA users) were recruited via posted advertisements throughout the university and metro communities.

Inclusion criteria included being a native English speaker, having normal or corrected-to-normal vision and hearing, and having no reported history of neurological problems, physical disease, or current pregnancy. Participants were required to be medication-free aside from birth control pills. Healthy non-drug controls were excluded from data analysis if they met current or past DSM-IV (*Diagnostic and Statistical Manual for Mental Disorders – Fourth Edition – Text Revision*; APA, 2000) criteria for any psychiatric disorder. Inclusion criteria for MDMA users consisted of at least 9 occasions of MDMA use, preferably with some use within the last year. Within the MDMA and other drug user groups, a past history of a DSM-IV mood or anxiety disorder was acceptable, but meeting criteria for a current mood disorder was grounds for exclusion. As heavy drug users with no MDMA exposure are rare, the other drug users were required to have limited or no previous MDMA use (i.e., fewer than 9 uses, no past month use). Importantly, the other drug user group consumed MDMA a mean total of only 1.7 times.

All participants agreed to abstain from recreational drug use for at least two weeks and to refrain from alcohol use for at least 48 hours prior to testing. Compliance was measured by self-report.

Participants were permitted to use their typical amounts of tobacco and caffeine. This study was approved by the University of Minnesota's Institutional Review Board. All participants provided informed consent prior to participation.

2.2 Procedure

Eligible participants completed an initial phone screening followed by an in-person demographic and medical screening interview, a semi-structured clinical interview (*Structured Clinical Interview for DSM-IV Axis I Disorders - Patient Edition, Version 2.0*; SCID-I/P; First et al., 1997), an estimate of global cognitive ability, and the Beck Depression Inventory (BDI; Beck et al., 1961). Participants completed the IGT and several self-report personality questionnaires as part of a larger testing battery. Participants answered questions about their drug use histories, including specific questions addressing MDMA use (see Table 2 & Table 3). The average number of alcoholic drinks per week was estimated by multiplying the participants' self-reported average drinking occasions per week and the average number of alcoholic drinks per occasion. The total drug use variables were created by adding together the occasions of use of each class of drugs (including MDMA but excluding alcohol) for the last 30 days, the past year, and lifetime. Hallucinogens do not include MDMA.

2.3 Cognitive Testing

2.3.1 General Intellectual Function—A pro-rated IQ estimate (Sattler, 2001) was obtained via the Wechsler Adult Intelligence Scale, Third edition (WAIS-III; Wechsler, 1997) Vocabulary and Block Design subtests.

2.3.2 Reward-Related Decision-Making—The Iowa Gambling Task (Bechara et al., 1994) is a computerized measure of decision-making under conditions of high versus low risk in the presence of rewards and losses. Participants were instructed to choose cards from one of four decks (A, B, C, or D) presented on-screen. Each choice carried some cost or benefit, either in the form of accrued or lost points. Two decks (C and D) were designated as "good decks," which provided smaller rewards but, also, had less severe losses, resulting in a net gain of points. The other two decks (A and B) were designated as "bad decks," which provided larger rewards but, also, had more severe losses, resulting in a net loss of points. One hundred trials were administered, and within each block of 20 trials, the number of good deck minus bad deck choices was computed. The participants' response patterns over the five blocks of the task provided an index of decision-making. The total good minus bad deck choices was also computed.

Aside from the net gain or loss of points, the contingencies for the *frequency* of losses differed between decks, which allowed for examination of the tendency for harm avoidance. In particular, the tendency to avoid decks with frequent losses (decks A and C) versus decks with infrequent losses (decks B and D) was examined by subtracting the total number of choices from decks B and D (infrequent larger losses) from decks A and C (frequent smaller losses) (Hooper et al., 2004; Overman et al., 2004). Therefore, positive numbers suggest more choices from decks with infrequent losses (i.e., greater harm avoidance) and negative numbers indicate more choices from decks with frequent losses (i.e., less harm avoidance).

2.4 Personality Testing

Participants completed several self-report measures of impulsivity, including the Multidimensional Personality Questionnaire, Brief Form (MPQ-BF; Tellegen, in press; Patrick et al., 2002). Normalized T-Scores from the Constraint subscale were used to measure impulsivity. The Barratt Impulsiveness Scale (BIS; Barratt, 1994) included Nonplanfulness, Motor Impulsivity, and Cognitive Impulsivity subscales. The Zuckerman Sensation Seeking Scale (SSS; Zuckerman, 1979) measures sensation seeking, the tendency to seek out intense

sensory experiences. The SSS Total Score and subscale scores (Thrill and Adventure Seeking, Experience Seeking, Disinhibition, and Boredom Susceptibility) were used for comparison. We generated a Composite Impulsivity Score by z-transforming MPQ Constraint (reverse scored), BIS Total Impulsivity, and SSS Total Score so that high scores represented greater impulsivity. The average of the z-scores was computed and compared between groups. The internal consistency reliability coefficient for the Composite Impulsivity Score was calculated: $\alpha = 0.85$.

2.5 Statistics

Data were analyzed using the Statistical Package for the Social Sciences (SPSS, Inc, Chicago, IL, USA), version 14.0 for Windows. Distributions of all variables were examined prior to analysis, and BDI scores were log 10 transformed to meet the assumptions for parametric analysis. Fisher's Exact Test was used to compare dichotomous variables (gender, handedness distribution). Univariate analysis of variance (ANOVA) assessed for group differences in other demographic characteristics (age, years of education, BDI score). Univariate, multivariate, and repeated measures ANOVAs were used to analyze the IGT and personality measures. Age was entered as a covariate in group comparisons. Our analytic strategy was to first compare MDMA users and other drug users to specifically examine the influence of MDMA use and then (due to similarity between the MDMA and other drug user groups) to combine the drug user groups for comparison to non-drug using controls. Effect sizes will be presented as partial eta-squared (ηp^2, range = 0 to 1). Since some drug use variables did not meet requirements for parametric analysis, even with attempted transformations, the Mann-Whitney procedure was used to compare drug-use characteristics between subsamples. To further examine the associations between MDMA and other drug use characteristics, as well as cognitive and personality measures, Spearman's rho nonparametric correlations were computed.

3. Results

3.1 Demographics

The three groups were similar in years of education, gender and race distributions, proportions of right- versus non-right-handed individuals, and IQs (see Table 1). However, MDMA users were older than controls, and both drug use groups reported higher levels of depression symptoms than controls based on BDI scores, which can range from 0 to 63. Based on recommended interpretive cut-offs (Kendall et al., 1987), the mean scores for all groups fell within the non-clinical range.

3.2 MDMA Characteristics and Other Illicit Drug Use

MDMA use characteristics for the drug-using groups are presented in Table 2. MDMA users reported prior use of several other drugs, consistent with other reports (e.g., Bolla et al., 1998;McCann et al., 1999;Morgan, 1999). In general, individuals in the MDMA group were heavier drug users relative to other drug users, particularly for hallucinogens, sedatives/hypnotics, and cocaine (see Table 3). Controls consumed alcohol significantly fewer times per week (Kruskal-Wallis $X^2 = 29.7$, $p < .001$) and had fewer drinks per occasion of use (Kruskal-Wallis $X^2 = 22.3$, $p < .001$) relative to both MDMA users and other drug users.

Substance use disorder (SUD) criteria were quantified via the SCID for the following categories: alcohol, marijuana, MDMA, cocaine, other stimulants, hallucinogens, sedatives, inhalants, opioids, and other drugs (e.g., over-the-counter drugs). Many MDMA/other drug users met past or current diagnostic criteria for substance abuse/dependence, particularly for MDMA, alcohol, and marijuana, followed by hallucinogens, stimulants, and cocaine. In terms of current SUDs, 32 drug users (61.5%) had no current SUD, 13 (25%) met SUD criteria for one substance, five individuals (9.6%) met criteria for two substances, and two individuals

(3.8%) met criteria for three substances. Co-morbidity was more variable in terms of lifetime SUDs. The lifetime number of substances for which participants met abuse or dependence criteria was totaled, including the ten drug use classes listed above. The total (lifetime) number of substances for which this sample of drug users reported either abuse or dependence, including MDMA, ranged from 0 to 7. MDMA users (mean = 3.6; SD = 1.7) met lifetime SUD criteria for more classes of drugs than the other drug users (mean = 2.2; SD = 1.3) [$F(1,50) = 10.38$, $p < .01$, $\eta p^2 = .17$].

3.3 Co-morbid Psychopathology

Based on the SCID, some MDMA users and other drug users met lifetime criteria for psychological disorders, consistent with other reports (Krystal et al., 1992; Parrott et al., 2001). Other than SUDs, the most common clinical condition observed was unipolar depression, past episode (MDMA Users, $n = 6$; Other Drug Users, $n = 7$). One other drug user also had a comorbid diagnosis of past panic disorder. In addition, one other drug user met criteria for past substance-induced mood disorder. Finally, one MDMA user and one other drug user met criteria for current psychotic disorder not-otherwise-specified; however, these episodes were transient and mild and were possibly related to recent drug use.

3.4 MDMA Users versus Other Drug Users

Our first major question was whether MDMA users and other drug users would show differences in reward-related decision-making and self-reported impulsivity.

3.4.1 Reward-Related Decision-Making—The total good ("advantageous") minus bad ("disadvantageous") deck choices for each of the five IGT blocks was computed and entered into a repeated measures ANOVA with block (5 levels) as the within subject factor and group (MDMA users vs. other drug users) as the between subjects factor (see Figure 1). Controlling for age, no group difference [$F(1,48) = 0.02$, *NS*, $\eta p^2 = .00$] or group by block interaction [$F(4,45) = 0.98$, *NS*, $\eta p^2 = .08$] was found between MDMA users and other drug users. However, there was a significant main effect of block [$F(4,45) = 10.75$, $p < .001$, $\eta p^2 = .50$]; participants made significantly more advantageous choices from blocks 2 to 3 ($p < .01$), and marginally more from blocks 1 to 2 ($p < .10$) and from blocks 4 to 5 ($p = .06$) indicating a general improvement throughout the task. The groups showed no differences in their biases towards infrequent versus frequent punishment deck choices [$F(1,48) = 0.33$, *NS*, $\eta p^2 = .01$].

3.4.2 Impulsivity—A univariate ANOVA revealed that, controlling for age, MDMA users reported marginally higher impulsivity relative to other drug users [$F(1,45) = 2.91$, $p < .10$, $\eta p^2 = .05$].

3.4.3 Secondary Analysis—Drug users with a history of unipolar depression ($n = 13$) were compared to those with no depression history ($n = 38$). No significant group differences or interactions were found.

3.5 Controls versus Combined Drug Groups

Due to the similarity between the two drug-using groups, our second question concerned whether the combined group of drug users differed from non-drug using controls.

3.5.1 Reward-Related Decision-Making—Controlling for age, this analysis (Figure 2) revealed a main effect of group [$F(1,77) = 5.51$, $p < .05$, $\eta p^2 = .07$], a main effect of block [$F(4,74) = 25.89$, $p < .001$, $\eta p^2 = .58$], and a group by block interaction [$F(4,74) = 4.98$, $p = .001$, $\eta p^2 = .21$]. Controls made relatively more advantageous choices compared to combined drug users. Follow-up univariate ANOVAs showed differences between groups on block 1 [$F(1,77)$

= 5.88, $p < .05$, $\eta p^2 = .07$], block 2 [$F(1,77) = 6.31$, $p < .05$, $\eta p^2 = .08$], and block 4 [$F(1,77) = 11.65$, $p = .001$, $\eta p^2 = .13$] and a marginally significant difference on block 3 [$F(1,77) = 3.01$, $p < .10$, $\eta p^2 = .04$]. Controls made more advantageous choices in blocks 2, 3, and 4, while combined drug users made more advantageous choices in block 1. Overall, participants made better choices from blocks 1 to 2 ($p < .001$) and from 2 to 3 ($p = .001$). A univariate ANOVA showed no group differences in bias towards infrequent versus frequent punishment deck choices [$F(1,77) = 0.04$, *NS*, $\eta p^2 = .00$].

3.5.2 Measures of Impulsivity—Univariate analysis of the Composite Impulsivity Score, controlling for age, revealed a significant group difference, with drug users scoring higher than controls (see Table 4 for *F* values, *p*-values, and ηp^2). Follow-up analyses of the individual measures showed that combined drug users scored lower in MPQ Constraint signifying higher impulsivity, and they scored higher than controls on the BIS Total Score and the three BIS subscales. Drug users also scored higher than controls in total sensation seeking, as well as the Experience Seeking, Disinhibition, and Boredom Susceptibility subscales.

3.6 Relationships between Drug Use, Decision-Making, and Personality/Mood Factors Among MDMA Users, Other Drug Users, and Controls

Spearman's rho non-parametric correlations (Table 5) showed that poorer reward-related decision-making was associated with having more occasions of combined drug use in the past 30 days and the past year, a higher number of lifetime SUDs, and more alcoholic drinks per week. Follow-up correlations with individual drug use variables (Table 6) showed that IGT performance was associated with more occasions of stimulant and hallucinogen use in the past 30 days; more occasions of cocaine, other stimulant, hallucinogen, inhalant, and marijuana use in the past year; and more occasions of intranasal MDMA use.

The impulsivity, combined substance use, and mood variables were moderately to strongly associated with each other (*rho* = .32 to .93), as seen in Table 5. Follow-up correlations (see Table 6) showed that the Composite Impulsivity Score was significantly correlated with use of multiple individual drug use variables, including recent, past year, and lifetime use. In addition to lifetime and past year MDMA use, the total occasions of oral MDMA ingestion was associated with impulsivity. As expected, this variable was also strongly associated with total MDMA use (*rho* = .96, $p < .001$), since most MDMA users in this sample ingested pills orally (see Table 2).

4. Discussion

This study examined reward-related decision-making among MDMA users, other drug users, and healthy controls using the Iowa Gambling Task (Bechara et al, 1994), while considering the relationship of decision-making with self-reported impulsivity and drug use characteristics. Consistent with previous studies of MDMA users (e.g., Croft et al., 2001; Hanson and Luciana, 2004; Morgan et al., 2002), this college and community sample exhibited general intellectual functioning in the high average range. The first major finding is that MDMA users did not demonstrate differences in reward-related decision-making or self-reported impulsivity relative to other drug users. Given the similarity between the two drug use groups, they were combined into a single group of drug users and compared to healthy controls. The second major finding is that the combined group of drug users demonstrated poorer reward-related decision-making and scored significantly higher on measures of self-reported impulsivity/sensation seeking relative to controls.

4.1 Reward-Related Decision-Making

The examination of reward-related decision-making among MDMA and other drug users is an important contribution of the current study. While controls made fewer advantageous choices during the initial IGT trials, when participants were theoretically ascertaining which decks have greater losses versus rewards, drug users made fewer advantageous choices than controls on subsequent trials, consistent with previous studies that have assessed decision-making among MDMA users (Moeller et al., 2007) and other drug users (e.g., Bartzokis et al., 2000; Bechara et al., 2001; Grant et al., 2000; Ernst et al., 2003; Petry et al., 1998; Petry, 2001; Stout et al., 2005; Verdejo-Garcia et al., 2007). This pattern implies that once controls learned the contingencies of the decks, they began to avoid the decks with greater long-term losses and chose from the more advantageous decks, despite smaller short-term rewards. Drug users, however, may have been more strongly influenced by the large, occasional rewards from the disadvantageous decks and had more difficulty changing their behavior despite the resulting long-term losses.

If drug users have less sensitivity to punishments and/or greater sensitivity to rewards (Bechara et al., 2002; Petry et al., 1998), they may have difficulty changing their behavior in the face of drug-related rewards or problems and may be vulnerable to risk-taking. Consistent with Damasio's (1994) somatic marker hypothesis, impaired decision-making among substance dependent individuals has been linked to inadequate somatic signals within the VMPFC, which may lead to hypersensitivity to rewards without regard to future consequences and which might underlie the conversion from casual substance use to dependence (Bechara and Damasio, 2002). We do not believe that the group difference is an issue of motivation since drug users performed similarly to controls on aspects of a larger test battery reported on elsewhere (Hanson, 2007).

Since MDMA users and other drug users performed similarly, the current results do not suggest that MDMA has a specific association with reward-related decision-making abilities, which is consistent with previous reports (Fox et al., 2002; Lamers et al., 2006). Nevertheless, other researchers reported risky decision-making among MDMA users compared with other drug users (Morgan et al., 2006; Quednow et al., 2007), which may be associated with genetic polymorphisms of the 5-HT transporter (Roiser et al., 2006). Possible reasons for this discrepancy include differences in sample characteristics (e.g., degree and recency of MDMA or other drug use) or methodologies (e.g., task-related factors, different aspects of decision-making). Other characteristics that elevate vulnerability for drug use or risky decision-making should be explored in future research.

We also found that poorer reward-related decision-making was associated with generally heavier drug use in the past 30 days and the past year, as well as higher weekly alcohol use, more occasions of intranasal MDMA use, and meeting lifetime substance use disorder criteria for more classes of drugs. However, no particular drug class clearly emerged as being most strongly associated with decision-making deficits.

In general, this pattern suggests a dose-response relationship between heavier and more pathological drug use (particularly within the past year) and poorer decision-making, which is in concordance with Bechara et al.'s (2001) report that years of abuse, duration of abstinence, treatment episodes, and relapses are associated with poorer decision-making. The association of poorer decision-making with heavier weekly alcohol use is also consistent with Goudriaan et al.'s (2007) report of disadvantageous decision-making in heavy binge-drinking college students. Taken together, these studies suggest that heavier, more pathological, and more chronic substance use are associated with decision-making problems. The specific role of MDMA use in reward-related decision-making is, therefore, questionable since MDMA users tend to be individuals who exhibit heavier patterns of drug use in general.

4.2 Impulsivity

Although MDMA users and other drug users reported similar levels of impulsivity, when combined they showed markedly higher levels of impulsivity and sensation seeking relative to controls. Previous studies also found that MDMA users and polydrug users reported similar levels of impulsivity or sensation seeking (Butler and Montgomery, 2004; Dafters et al., 2004; Daumann et al., 2001; Morgan, 1998; Morgan et al., 2002; Tuchtenhagen et al., 2000), although other evidence suggests higher impulsivity specifically among MDMA users (Daumann et al., 2001; Parrott et al., 2000; Tuchtenhagen et al., 2000; Verheyden et al., 2002). Elevated impulsivity may be a reflection of low 5-HT activity in the frontal lobe (Hoyenga and Hoyenga, 1988), and it may be a general characteristic of drug users in this age group (Allen et al., 1998; Conway et al., 2002; Mitchell, 1999). If so, it might be conceptualized as a premorbid distinction that is not significantly influenced by MDMA use (Daumann et al., 2004; Hanson and Luciana, 2002; Parrott et al., 2000).

Upon closer examination, we found that higher impulsivity was significantly associated with more extensive drug use, as well as abuse or dependence of more types of substances, heavier weekly alcohol use, and higher self-reported depression levels. When individual drug classes were examined, greater lifetime uses of multiple types of drugs was associated with higher impulsivity, rather than a specific drug. In addition to other types of drugs, greater lifetime and past year MDMA use and occasions of oral MDMA ingestion were related to elevated impulsivity, but other MDMA use characteristics (e.g., duration of use, time since last use, dosage) were not correlated with personality measures. Other studies also found that heavier MDMA use was associated with higher impulsivity (Morgan, 1998; Parrott et al., 2000), although cannabis use has been implicated (Daumann et al., 2001). Our previous study did not suggest a dose-response relationship between MDMA use and impulsivity/sensation seeking, although higher impulsivity and sensation seeking were associated with meeting lifetime SUD criteria for more types of drugs and generally heavier drug use, especially of hallucinogens and opiates (Hanson and Luciana, 2002). Discrepancies between studies may be due to differences in sample characteristics or methodology. It remains unclear whether impulsivity and sensation seeking pre-dated drug use (Daumann et al., 2004).

The relationship between behavioral and self-report measures of impulsivity is also of interest. Consistent with previous research, self-reported impulsivity was not correlated with decision-making (e.g., Goudriaan et al., 2007; Morgan, 1998; Morgan et al., 2002). The lack of association between these measures suggests they are measuring distinct constructs of impulsivity (e.g., cognitive impulsivity *versus* behavioral impulsivity) (Morgan, 1998; Morgan et al., 2002). Indeed, the construct of impulsivity is multifactorial and various aspects of impulsivity likely have distinct biological mechanisms (see Evenden, 1999).

4.3 Limitations

Drug use research poses certain methodological, ethical, and interpretive complexities (Curran, 2000; Morgan, 2000). Prospective studies may help to resolve whether cognitive deficits and impulsivity predated drug use. However, the measurement of functioning prior to drug use initiation is challenging due to legal and practical limitations, and ethical concerns limit administration of MDMA to humans in a controlled environment. Thus, naturalistic and retrospective reports predominate in human drug use research, and confirmation that MDMA or other drug use led to cognitive or personality changes is difficult to obtain.

Other drugs are sometimes found in ‘ecstasy’ pills, such as 3,4-methylenedioxyamphetamine (MDA), amphetamines, ketamine, hallucinogens, or other chemicals (Curran, 2000). Although doses of MDMA found in ecstasy pills depend on the source, earlier reports suggest that most pills (85–90%) contain approximately 100–150 mg of MDMA (Schifano et al., 1998). A two-

week period of abstinence from drugs and a 48-hour period for alcohol were required of participants in the current study to minimize the effects of acute substance intoxication or withdrawal. Information regarding substance use was gathered via self-report, since financial constraints limited verification of abstinence with biological assays. While not ideal, self-report typically corresponds with urine or hair analysis (Schifano et al., 1998; Thomasius et al., 2003).

The current sample reflects the challenge of recruiting MDMA users and other drug users matched for previous exposure to other drugs. We found that the more heavily individuals used MDMA, the more heavily they used other drugs. Although the groups were comparable in their previous exposure to alcohol, marijuana, and opiates, the MDMA users consumed multiple types of drugs more heavily. Furthermore, the MDMA users had not used MDMA in the past month and had minimal past year use, which may reflect a possible downward trend in the prevalence of MDMA use. Nevertheless, this is a limitation of the present study, and a sample with more recent or heavier MDMA use may have produced different results. We also had difficulty recruiting other drug users without previous MDMA exposure, which was further reason to combine the two drug groups and perform correlation analyses.

4.4 Conclusions

In conclusion, this study of MDMA users, other drugs users, and healthy controls revealed similar reward-related decision-making and impulsivity profiles between MDMA users and other drug users, suggesting that MDMA use does not lead to long-term impairments above and beyond generally heavy drug use. Drug users, as a whole, showed a pattern of reward-related decision-making deficits that were similar to other groups of drug users. Further, poorer reward-related decision-making was associated with heavier drug use, as well as meeting substance abuse or dependence criteria for more drug classes, emphasizing the importance of a thorough assessment of substance use disorders. Finally, drug users reported elevated levels of impulsivity and sensation seeking, which were associated with heavier lifetime drug and alcohol use, as well as more pathological drug use and depression. Perhaps impulsivity and sensation seeking, along with reward-related decision-making deficits, place individuals at risk for drug use, and drug use may lead to further cognitive and psychological problems.

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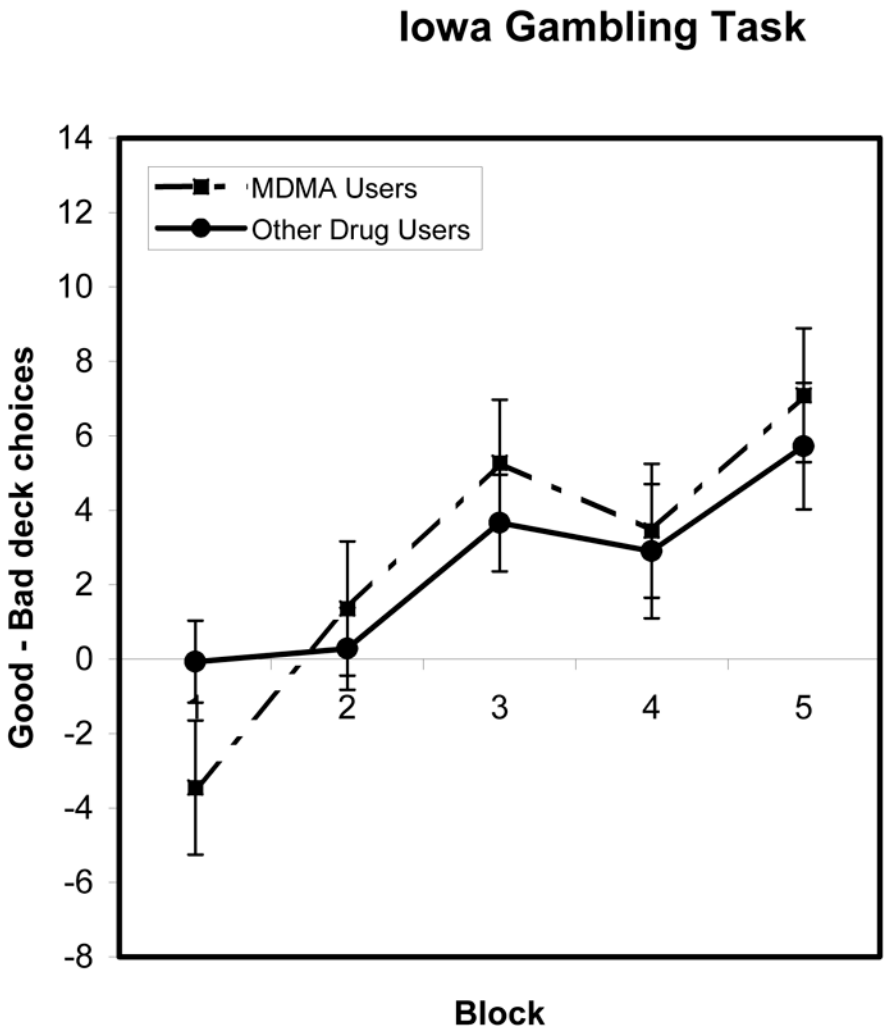

Figure 1.

Reward-Related Decision Making in MDMA Users versus Other Drug Users Note. Figure shows good minus bad deck choices for each of 5 consecutive blocks with 20 trials each. Negative numbers signify more bad (disadvantageous) deck choices and positive numbers signify more good (advantageous) deck choices. Error bars depict the standard error of measurement.

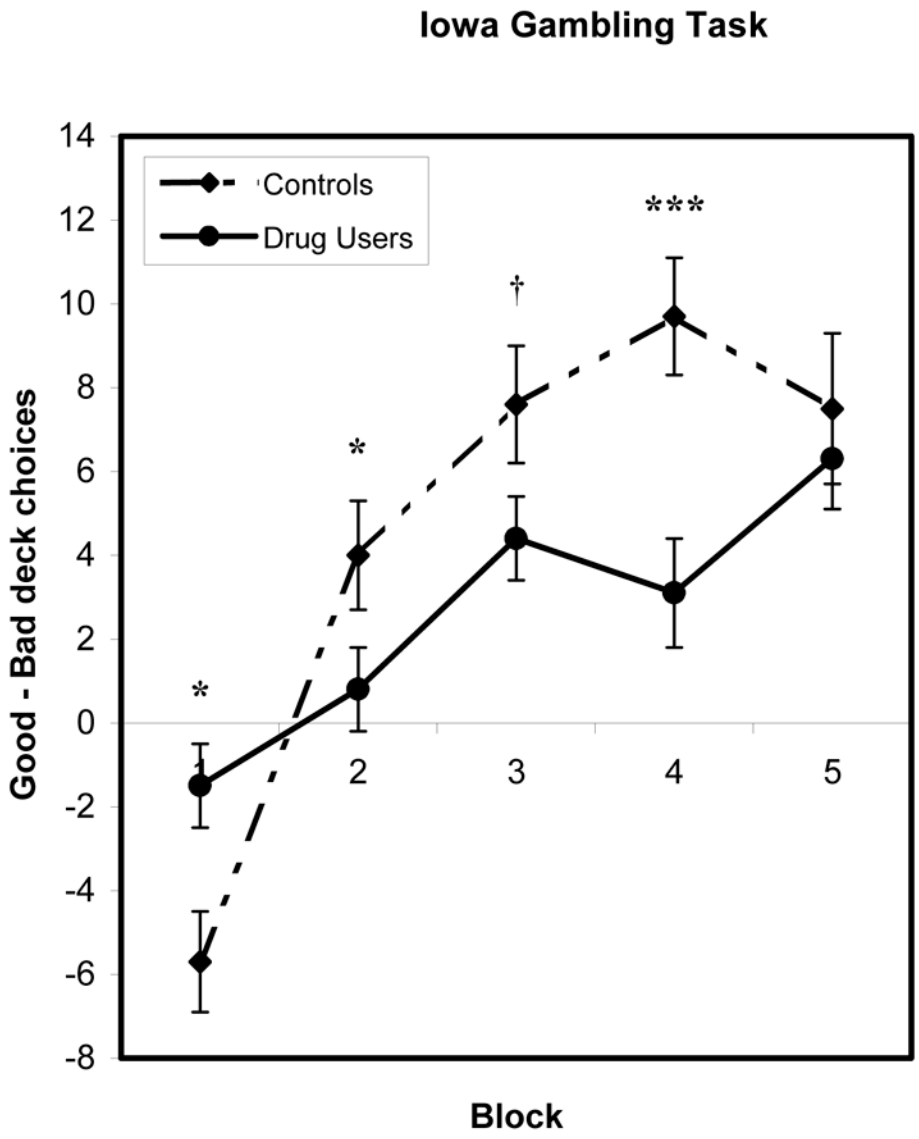

Figure 2.

Reward-Related Decision Making in Controls versus Combined Drug Users Note. Figure shows good minus bad deck choices for each of 5 consecutive blocks with 20 trials each. Negative numbers signify more bad (disadvantageous) deck choices and positive numbers signify more good (advantageous) deck choices. Error bars depict the standard error of measurement. † $p < .10$, * $p < .05$, *** $p = .001$.

Table 1

Demographic Characteristics of Control Participants, Other Drug Users, and MDMA Users

	Controls (*n* = 29)	**MDMA Users (*n* = 22)**	**Other Drug Users (*n* = 30)**	***F* or *Fisher's Exact***	***Effect Size* ηp^2**
Age	19.8 (2.0)	22.5 (4.6)	20.9 (2.9)	4.61*	.11
Gender ratio (male : female)	17 : 12	16 : 6	16 : 14	2.05	na
Race (% Caucasian)	75.9%	77.3%	73.3%	11.42	na
% right handed	86.2%	90.9%	90.0%	0.41	na
Beck Depression Inventory Total Score	2.4 (3.6)	5.0 (4.2)	5.2 (4.7)	5.96**	.13
Years of education	13.4 (1.0)	13.9 (1.5)	13.5 (1.3)	1.30	.03
Estimated Full Scale IQ	117.6 (11.7)	118.7 (12.3)	118.2 (11.4)	0.05	.00
Vocabulary Standard Score	13.1 (2.6)	13.7 (2.4)	13.9 (2.2)	0.82	.02
Block Design Standard Score	13.0 (2.6)	12.7 (3.3)	12.4 (2.5)	0.35	.01

Notes. Values are means (and standard deviations), except where otherwise indicated.

* $p < .05$

** $p < .01$

Table 2

MDMA Use Characteristics

	Combined Drug Groups		MDMA Users	Other Drug Users	
	Mean (SD)	**Range**	**Mean (SD)**	**Mean (SD)**	***U***
Total number of occasions of MDMA use[a]	17.1 (27.4)	0 – 150	38.0 (32.0)	1.7 (2.5)	0.0***
Number of occasions of use in past month[a]	0.1 (0.2)	0 – 1	0.1 (0.4)	0.0 (0.0)	285.0*
Number of occasions of use in past year[a]	3.1 (6.1)	0 – 30	6.6 (8.0)	0.5 (1.4)	99.0***
Number of occasions MDMA ingested orally[a]	15.7 (24.2)	0 – 125	35.0 (27.2)	1.6 (2.5)	0.0***
Number of occasions MDMA ingested intranasally[a]	3.0 (9.6)	0 – 60	6.8 (14.1)	0.2 (0.7)	124.5***
Duration of use (months)[b]	31.4 (25.1)	0 – 102	40.8 (25.2)	14.1 (12.9)	46.0**
Time since last use (weeks)[b]	50.9 (61.9)	2 – 245	31.7 (42.1)	86.2 (77.5)	79.0†
Average number of pills per session[b]	1.7 (1.1)	1 – 6	1.9 (1.3)	1.3 (0.4)	87.0†
Maximum number of pills ever taken in one session[b]	3.3 (3.3)	1 – 17	4.3 (3.7)	1.6 (0.6)	28.0***
Number of occasions multiple MDMA doses taken[b]	11.5 (25.3)	0 – 135	18.3 (30.7)	0.9 (1.5)	26.0***

Notes. Mann-Whitney U's were computed between MDMA Users and Other Drug Users.

[a]These variables included all drug users (n = 22 MDMA Users; n = 30 Other Drug Users).

[b]These variables included only those drug users who ever ingested MDMA (n = 22 MDMA Users; n = 12 Other Drug Users).

† $p < .10$

* $p < .05$

** $p < .01$

*** $p < .001$.

Table 3

Drug Use Characteristics

	Controls (*n* = 29)	MDMA Users (*n* = 22)	Other Drug Users (*n* = 30)	*U*
Occasions of Alcohol Use per Week	0.6 (0.8)	2.5 (2.0)	2.5 (1.8)	297.0
Drinks per Occasion of Use	2.1 (2.1)	5.4 (3.5)	5.2 (2.7)	322.0
Occasions of Drug Use: Past 30 days	0.0 (0.2)	13.2 (21.8)	17.9 (23.6)	203.5*
Occasions of Drug Use: Past Year	0.3 (1.1)	670.7 (1195.6)	557.2 (680.2)	226.0†
Occasions of Drug Use: Lifetime	1.2 (2.0)	4307.1 (6835.3)	2620.9 (3761.3)	275.0
Marijuana	1.2 (2.0)	2807.2 (4007.0)	2121.9 (3168.4)	287.0
Cocaine	0.0 (0.0)	894.1 (3160.6)	97.5 (341.6)	200.0*
Other Stimulants	0.0 (0.0)	215.6 (594.4)	270.8 (1028.8)	188.5**
Hallucinogens	0.0 (0.0)	102.8 (245.4)	23.5 (81.8)	140.0***
Inhalants	0.0 (0.0)	21.9 (37.9)	23.7 (93.8)	191.0**
Opiates	0.0 (0.0)	26.4 (27.6)	19.1 (30.9)	270.5
Sedatives / Hypnotics	0.0 (0.0)	22.4 (52.1)	2.6 (6.5)	175.0**
Other Drugs	0.0 (0.0)	60.5 (202.3)	60.3 (211.4)	270.5

Notes. Values are means (and standard deviations). Aside from alcohol use characteristics, means represent estimated number of occasions of use for each time period or drug. Mann-Whitney U's were computed between MDMA Users and Other Drug Users.

† $p < .10$

* $p < .05$

** $p < .01$

*** $p < .001$.

Table 4

Self-report Impulsivity Scores between Controls and Combined Drug Users

Personality Trait Measures	**Controls (*n* = 29)**	**Combined Drug Users (*n* = 52)**	***F***	***Effect Size* ηp^2**
Composite Impulsivity Score	−0.65 (0.7)	0.41 (0.7)	33.08***	.31
MPQ Constraint	45.7 (7.8)	34.4 (8.3)	31.14***	.29
Barratt's Impulsiveness Scale Total Score	41.2 (17.2)	55.1 (16.9)	10.35**	.12
Nonplanfulness	16.3 (7.4)	23.0 (8.1)	9.36**	.11
Motor Impulsiveness	14.2 (6.7)	18.6 (6.5)	7.79**	.09
Cognitive Impulsiveness	10.7 (5.1)	13.5 (5.3)	5.90*	.07
Zuckerman Sensation Seeking Scale Total Score	17.8 (4.8)	26.5 (5.5)	43.74***	.38
Thrill and Adventure Seeking	7.1 (2.6)	7.8 (2.2)	2.39	.03
Experience Seeking	4.9 (2.2)	7.9 (1.7)	39.45***	.34
Disinhibition	3.4 (2.1)	6.8 (2.0)	50.90***	.40
Boredom Susceptibility	2.7 (1.8)	4.0 (2.4)	4.55*	.06

MPQ = Multidimensional Personality Questionnaire.

* $p < .05$

** $p < .01$

*** $p \leq .001$.

Table 5

Associations between Reward-Related Decision Making, Impulsivity, Drug Use, and Mood in MDMA Users, Other Drug Users, and Controls

	1	2	3	4	5	6	7	8
1. IGT: Total Good minus Bad Deck Choices	--							
2. Composite Impulsivity Score	−.14	--						
3. Occasions of Drug Use: Last 30 Days	−.26*	.36**	--					
4. Occasions of Drug Use: Past Year	−.26*	.49***	.84***	--				
5. Occasions of Drug Use: Lifetime	−.19	.54***	.77***	.93***	--			
6. Lifetime # of Drug Use Diagnoses	−.24*	.54***	.64***	.79***	.85***	--		
7. Estimated # of Alcoholic Drinks per Week	−.24*	.53***	.55***	.62***	.62***	.62***	--	
8. Beck Depression Inventory Total Score	−.11	.38***	.32**	.38***	.43***	.40***	.34**	--

Note. Numbers in the top row correspond with the numbered variables. Values are Spearman's rho nonparametric correlations. IGT = Iowa Gambling Task; Bechara et al., 1994: Total Good minus Bad Deck Choices.

* $p < .10$

** $p < .05$

*** $p < .001$.

Table 6

Associations between Reward-Related Decision Making, Impulsivity, and Use of Various Drug Classes among MDMA Users, Other Drug Users, and Controls

	IGT: Total Good minus Bad Deck Choices	Composite Impulsivity Score
Occasions of Use in Past 30 Days		
Marijuana	−.21†	.31**
Cocaine	−.07	.31**
Other Stimulants	−.23*	.16
Hallucinogens	−.23*	.09
Occasions of Use in Past Year		
MDMA	−.18	.41***
Marijuana	−.25*	.44**
Cocaine	−.33**	.25*
Other Stimulants	−.31**	.28*
Hallucinogens	−.30**	.39***
Inhalants	−.26*	.24*
Opiates	−.10	.48***
Sedatives/Hypnotics	−.13	.39**
Other Drugs	−20†	.19
Occasions of Lifetime Use		
MDMA	−.09	.51***
Marijuana	−.19†	.52***
Cocaine	−.19†	.51***
Other Stimulants	−.22†	.48***
Hallucinogens	−.12	.52***
Inhalants	−.17	.46***
Opiates	−.07	.56***
Sedatives/Hypnotics	−.01	.37**
Other Drugs	−.17	.35**
Other MDMA Use Characteristics		
Occasions of Oral Use	−.16	.32*
Occasions of Intranasal Use	−.37*	.19

Note. Values are Spearman's rho nonparametric correlations. Aside from the correlations listed above, no other significant correlations were found between decision-making, impulsivity, and the above drug use characteristics. IGT = Iowa Gambling Task; Bechara et al., 1994: Total Good minus Bad Deck Choices.

† $p < .10$

* $p < .05$

** $p < .01$

*** $p < .001$.