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The relationship between impulsivity and craving in cocaine- and methamphetamine-dependent volunteers

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ABSTRACT

Impulsivity and craving have been independently hypothesized to contribute to sustained drug use and relapse in addiction. The primary focus of this project was to determine the relationship between impulsivity and craving in 85 cocaine-dependent and 73 methamphetamine-dependent, non-treatment-seeking volunteers. Drug use was assessed with a 14-item, self-report drug and alcohol use questionnaire. Self report instruments utilized included the Barratt Impulsivity Scale (BIS) and the Visual Analog Scale (VAS), which probed "just before your last use of cocaine (for cocaine-dependent participants) or methamphetamine (for methamphetamine-dependent participants), how much craving did you experience?" The groups were similar with respect to recent use of cocaine or methamphetamine, alcohol, nicotine, and marijuana. Analysis of variance (ANOVA) did not reveal significant differences between cocaine and methamphetamine groups for total impulsivity or total craving. Simple linear regression revealed correlations between total impulsivity and total craving in cocaine ($r^2 = 0.05$, $p \leq 0.03$) and methamphetamine users ($r^2 = 0.09$, $p \leq 0.008$). Participants were separated into high impulsivity (HIBIS) or low impulsivity (LOBIS) subgroups using a median split. ANOVA revealed significantly higher craving in the HIBIS group versus the LOBIS group in methamphetamine users ($p \leq 0.02$), but not in cocaine users. For both cocaine and methamphetamine groups, level of impulsivity and craving were found to be related to some drug use variables including years of alcohol use, severity of withdrawal, and craving level following drug use. Taken together, this study shows a marginal relationship between impulsivity and craving, which may further the understanding of motivational factors contributing to ongoing drug use and addiction in psychostimulant users.

1. Introduction

Craving has been hypothesized to play an integral role in sustained drug use and relapse (Anton, 1999; Jellinek, 1955; Pickens and Johanson, 1992; Robinson and Berridge, 2003). Although not specifically listed as a criterion for dependence, the DSM-IV-TR states that craving (defined as the strong subjective drive to use a substance) is likely to be experienced by most substance-dependent individuals. In cocaine-dependent individuals, measures of craving have been shown to predict future drug use. Specifically, high craving individuals had a higher probability of relapse than low craving groups based on self-report measures of craving administered upon discharge from treatment (Bordnick and Schmitz, 1998; Kranzler and Wallington, 1992; Paliwal et al., 2008; Robbins, 1996; Rohsenow et al., 2007; Weiss et al., 2003).

Over the past two decades, studies have shown that craving is only one of many risk factors contributing to the maintenance of addiction and propensity to relapse. For example, impulsivity is considered an important aspect of substance use disorders (Dickman, 1990; Moeller et al., 2001a). In fact, the DSM-IV-TR states that substance use may be characterized by behaviors that are associated with impulsivity, including impaired judgment and risk taking. In addition, Miller and Gold (1994) found in their large-scale cocaine study (1626 participants evaluated 6–12 months after treatment for substance dependence) that the most commonly cited reason for relapse was "impulsive action with no known cause", with only 7% of the relapse group reporting craving as the reason for treatment failure. Also, as a stable trait variable of human personality (Patton et al., 1995), impulsivity may underpin many diagnostic disorders including addiction (Dickman, 1990; Moeller, Barratt et al., 2001a). Continued drug use is characterized not only by intense and involuntary cravings, but also by a lack of impulse control over drug intake and a compulsive pattern of drug-seeking and drug-taking that takes place at the expense of other activities (West, 2006).

Research using stimulant-dependent individuals generally has not examined the relationship between impulsivity and craving. Moeller and colleagues (2001b) found a positive, but not statistically significant, correlation between total impulsivity scores (as measured by the Barratt Impulsiveness Scale, Version 11 (BIS-11)) and cocaine craving scores. In addition, they reported that the BIS-11 motor subscale significantly correlated with craving. In contrast, a recent

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study revealed that cocaine-dependent participants reported significantly greater levels of craving and were more likely to choose cocaine in the laboratory when compared to individuals who met only abuse criteria for cocaine, yet no significant differences were found in BIS scores between these two groups (Walsh et al., 2010).

The primary focus of this project was to determine the association between impulsivity and craving in cocaine- and methamphetamine-dependent participants using subjective and retrospective measures of craving (rather than experimental measures that induce craving in vivo) and impulsivity (via a psychometric (trait) instrument rather than an experimental behavioral measurement). Based on Moeller's findings, it was hypothesized that there would be positive correlations between self-reported impulsivity and craving. The secondary focus was to determine if higher scores on overall impulsivity or craving were related to drug use variables, motivation to abstain, withdrawal, and other drug use factors. It was hypothesized that these drug use variables would not be correlated with self-reported measures of impulsivity or craving because there has been no previous literature that has reported that years or use, recent use, etc. have an impact on impulsivity or craving scores. Further, we formed this hypothesis on the basis of our own unpublished findings.

2. Methods

The current study includes data obtained from an archive collected by Drs. Newton and De La Garza at the University of California at Los Angeles (UCLA) from April 2006 through July 2007. Participants included 158 individuals from Los Angeles, CA and the surrounding area, of which 85 were primary crack/cocaine users and 73 were primary methamphetamine users (Table 1).

At the time of the assessment, all individuals were participating in a preliminary screening interview for possible enrollment into one of several inpatient, non-treatment seeking phase I clinical trial studies at UCLA. These studies were sponsored by the National Institute on Drug Abuse (NIDA), and approved by the UCLA Institutional Review Board. All volunteers provided consent after being fully informed about potential risks of study participation.

Participants met all of the following inclusion criteria: (a) regularly used cocaine or methamphetamine, (b) were 18–55 years of age, and (c) were not seeking treatment for cocaine or methamphetamine use. Participants did not meet any of the following exclusion criteria: (a) current Axis I psychiatric disorder or dependence on other drugs of abuse, other than nicotine (DSM-IV-TR, 1994); (b) history of stroke, epilepsy, or brain injury; or (c) history of violent criminal behavior or on parole; or (d) currently pregnant.

Table 1
Demographics and drug use characteristics.

	Cocaine (N = 85)	Methamphetamine (N = 73)	$r^{\#}$
Gender (N)			–
Male	71 (83.5%)	48 (65.8%)	
Female	14 (16.5%)	25 (34.2%)	
Ethnicity (N)			
Caucasian	17 (20%)*	36 (47.3%)	
Hispanic	13 (15.3%)	19 (26%)	
African American	61 (71.8%)*	10 (13.7%)	
Asian	1 (1.2%)	2 (2.7%)	
Native American	2 (2.4%)	5 (6.9%)	
Age (yrs)	43.8 ± 7.4*	35.3 ± 9.8	0.44
Primary Drug Use			
Years of use	17.6 ± 8.3*	11.3 ± 7.7	0.37
^Recent use	17.0 ± 8.5	17.7 ± 9.3	0.03
Nicotine Use (N)	60 (%)	57 (%)	
Years of use	21.6 ± 10.5*	17.2 ± 10.5	0.21
Recent use	25.3 ± 8.9	25.9 ± 10.8	0.03
Alcohol Use (N)	74 (%)	61 (%)	
Years of use	18.8 ± 9.3	16.5 ± 10.5	0.12
Recent use	9.9 ± 9.8	8.4 ± 10.1	0.07
Marijuana Use (N)	55 (%)	50 (%)	
Years of use	18.2 ± 12.2*	13.3 ± 10.0	0.21
Recent use	8.2 ± 11.1	8.4 ± 11.1	0.01

* $p<0.05$ cocaine vs. methamphetamine users; ^recent use indicates number of days of use of primary drug in the 30 days preceding interview. Age, Years of use, and Recent use reflect mean ± S. D.
# Pearson's r (effect size).

2.1. Drug use

Drug use was assessed with a 14-item, self-report drug and alcohol use questionnaire with frequency assessed in terms of date of last use, days used in the past 30, years of use, and method of use (oral, nasal, intravenous, or smoke). In addition to cocaine and methamphetamine, substance use frequency was also assessed for alcohol, cannabis, and nicotine. Participants were asked if they had ever used each drug in their lifetime, how many years they used that drug, and how often they used it in the past 30 days. Recent drug use was assessed via urine toxicology (testing for cocaine, amphetamine, methamphetamine, THC, and opiates).

2.2. Impulsivity

Impulsivity was assessed using the BIS-11 (Patton et al., 1995). The BIS-11 is a 30-item, self-report questionnaire that asks participants to rate how often a series of statements applies to them, based on the following four-point Likert scale: rarely/never, occasionally, often, or always/almost always. The BIS-11 has a three-factor subscale model of impulsivity determined by factor analysis that includes: (a) Motor (MI) — acting without thinking/on the spur of the moment, task persistence and perseverance, (b) Attentional (AI) — the inability to focus on tasks at hand and cognitive instability, and (c) Non-planning (NP) — not thinking carefully, self-control, or cognitive complexity (Patton et al., 1995).

The BIS-11 is structured to assess long-term patterns of behavior by asking participants to answer questions about the ways they act and think without relation to a specific time period (item scores range from 1 to 4). Cumulative scores range from 30 (low in trait-impulsivity) to 120 (high in trait-impulsivity). BIS-11 subscale score ranges include: Attentional 8–32, Motor 10–40, and Non-planning 12–48. The BIS-11 has been normed on a variety of sample populations, including college students, inpatient substance abusers, and prison inmates (Patton et al., 1995). The BIS-11 has been shown to be reliable in both clinical and community samples, with Cronbach's alpha coefficients ranging from .79 to .83 (Patton et al., 1995). The BIS-11 has been validated in psychostimulant abuse and dependency populations and studies have demonstrated a relationship between impulsivity and drug use (Coffey et al., 2003), withdrawal, treatment dropout (Moeller et al., 2001b), and age of first drug use (Moeller et al., 2004).

2.3. Craving

In this study, craving was defined as a strong or intense desire (DSM-IV-TR, 2004) and was assessed using a modified version of the Visual Analog Scale (VAS). Participants were asked to rate their level of craving immediately prior to, and after the last time they engaged in drug use. In the opinion of the investigators, self-reports of craving *before* drug use is a measure of desire for the drug that may have contributed to drug use, whereas measuring craving *after* drug use is likely an indicator of the drug's effect on craving level (satiation or intensification). The VAS is a reliable self-report instrument for assessing levels of craving at specific points in time, indicated on a scale from 0 (no craving) to 100 (most severe craving possible) (Drobes and Thomas, 1999). The VAS has been used in hundreds of published studies of cocaine and methamphetamine addiction.

2.4. Assessment of withdrawal

The Amphetamine Withdrawal Questionnaire (AWQ; Srisurapanont et al., 1999) was used to measure cocaine and methamphetamine withdrawal. Based on DSM-IV-TR criteria for amphetamine withdrawal, the AWQ is a 10-item, self-completed instrument designed to measure the domains of craving, dysphoria, anhedonia, increased appetite, fatigue, agitation, anxiety, increased sleep, vivid, unpleasant dreams and slowing of movement. Items were scored on a Likert scale, from 0 (not at all) to 4 (very much).

2.5. Assessment of motivation to abstain

The Motivation to Abstain (MTA) instrument is a seven-item self-report questionnaire developed by our laboratory. The MTA was structured to assess participants' motivation to abstain from their primary drug of abuse at the time of the assessment, as well as to answer questions about previous attempts to stop their drug use in the last month, the last 6 months, the last year, and total instances in their lifetime. The MTA incorporated 2-items designed to measure the level of motivation to stop drug use in the present moment, and quantified the previous attempts to stop using their primary drug of choice. Motivation to abstain was measured using a 100-mm VAS scale range from 0 (not at all motivated) to 100 (very motivated) and was relative to each participant's individual experience.

2.6. Screening interview

Screening interviews were conducted at the UCLA Medical Center by trained bachelor's and master's level research assistants. After signing the informed consent, the research assistant collected substance use data through the administration of a series of questionnaires, including the Demographic Information Form, BIS-11, VAS, MTA, AWQ, and Multiple Drug Use Questionnaire. The screening interview concluded with a urinalysis drug screen and $25 voucher payment for participation.

2.7. Statistical analyses

Chi square was used to evaluate differences in demographic variables between cocaine and methamphetamine users. The correlation between total BIS-11 scores, BIS-11 subscale scores and craving scores was determined using Pearson product-moment correlations. Analysis of variance (ANOVA) was used to determine differences between cocaine and methamphetamine users for total impulsivity (or total craving) versus primary drug, gender, and urine state. High versus low impulsivity subgroups were separated based on median split scores. Group comparisons between high versus low impulsivity versus total craving were determined using ANOVA. The relationship between impulsivity (or craving) scores and drug use variables in cocaine and methamphetamine users was determined using ANOVA.

3. Results

The present sample consisted of 158 study participants, including 85 who were primary cocaine users and 73 who were methamphetamine users (Table 1). Methamphetamine users were more likely to be Caucasian ($\chi^2_{1,71} = 7.49$, $p \leq 0.01$) whereas cocaine users were more likely to be African American ($\chi^2_{1,83} = 21.87$, $p \leq 0.001$). Relative to methamphetamine users, cocaine users were significantly older ($F_{1,156} = 37.92$, $p \leq 0.0001$), used their primary drug for a greater number of years ($F_{1,156} = 24.36$, $p \leq 0.0001$), and reported more years of nicotine use ($F_{1,115} = 5.10$, $p \leq 0.03$), and marijuana use ($F_{1,103} = 4.90$, $p \leq 0.03$). No significant differences were found between groups for any other demographic or drug use variables.

The relationship between total impulsivity and craving among cocaine and methamphetamine users is shown in Table 2. Analysis of variance (ANOVA) did not reveal significant differences between cocaine and methamphetamine users for total impulsivity and total craving. In addition, no significant differences were found between males and females for total impulsivity and total craving. Similarly, no significant differences were found between negative and positive urine states for total impulsivity and total craving. Despite considerable heterogeneity in responses among participants, simple linear regression revealed that total impulsivity was significantly correlated with total craving in cocaine users (Fig. 1, $p \leq 0.03$) and methamphetamine users (Fig. 2, $p \leq 0.008$); however, the r^2 values were very small (0.05 for cocaine and 0.09 for methamphetamine) demonstrating that there was a considerable amount of variability in each of the samples.

To further explore differences in impulsivity between cocaine and methamphetamine groups, participants were separated into high impulsivity (HIBIS) or low impulsivity (LOBIS) subgroups using a median split, which is similar to the analytical approach adopted by Moeller and colleagues (2001b) and Semple et al. (2005). For cocaine and methamphetamine users, the median impulsivity split yielded significantly different HIBIS and LOBIS subgroups for cocaine users ($F_{1,83} = 156.9$, $p < 0.0001$) and methamphetamine users ($F_{1,71} = 150.4$, $p < 0.0001$) (Table 3). An ANOVA revealed that cocaine users with HIBIS scores did not differ significantly with regard to level of craving before last drug use from those with LOBIS scores ($F_{1,83} = 2.86$, $p = 0.09$), whereas an ANOVA revealed that methamphetamine users with HIBIS scores reported higher levels of craving than those with LOBIS scores ($F_{1,83} = 5.59$, $p = 0.02$).

We also investigated whether impulsivity was related to drug use in cocaine and methamphetamine users (Table 3). Among cocaine users, ANOVA did not indicate significant differences between the HIBIS or LOBIS subgroups with regard to years of cocaine use ($F_{1,83} = 2.82$, $p = 0.10$), recent cocaine use ($F_{1,83} = .30$, $p = 0.59$), nicotine use ($F_{1,58} = 1.87$, $p = 0.18$), or marijuana use ($F_{1,53} = 2.62$, $p = 0.11$). ANOVA revealed a significant difference between HIBIS or LOBIS subgroups for years of alcohol use ($F_{1,72} = 4.23$, $p \leq 0.04$). Among methamphetamine users, there were no significant differences between HIBIS or LOBIS subgroups for years of methamphetamine use ($F_{1,71} = 0.11$, $p \leq 0.74$), recent methamphetamine use ($F_{1,70} = 3.53$, $p = 0.99$), nicotine use ($F_{1,55} = 0.88$, $p = 0.35$), marijuana use ($F_{1,48} = 1.41$, $p = 0.24$), or alcohol use ($F_{1,59} = 0.09$, $p = 0.77$).

In addition, we evaluated whether impulsivity was related to drug use variables in cocaine and methamphetamine users (Table 3). HIBIS and LOBIS subgroups differed with regard to severity of withdrawal symptoms in both cocaine ($F_{1,83} = 6.26$, $p \leq 0.01$) and methamphetamine users ($F_{1,70} = 10.49$, $p \leq 0.002$). For cocaine users, ANOVA revealed a trend toward differences between HIBIS and LOBIS subgroups in craving after cocaine use ($F_{1,83} = 3.68$, $p = 0.059$). No other significant differences were found between HIBIS and LOBIS subgroups for drug use variables including motivation to abstain ($F_{1,82} = 0.99$, $p = 0.32$) or

Table 2
Total impulsivity and craving among cocaine and methamphetamine users.

	Total Impulsivity (BIS)	Total Craving (VAS)	$r^{\#}$
Primary Drug of Use			
Cocaine (54)[&]	71.95 ± 12.48	70.0 ± 24.64	0.04
Methamphetamine (46%)	73.32 ± 13.03	64.93 ± 28.34	0.18
Gender			
Male (75%)	72.19 ± 12.86	68.24 ± 25.99	0.10
Female (25%)	73.64 ± 12.38	65.90 ± 28.07	0.17
Urine State			
Positive (70%)	72.27 ± 12.04	67.40 ± 36.70	0.08
Negative (30%)	73.80 ± 14.61	68.48 ± 25.21	0.13

[&] Percentage of total sample size.
[#] Pearson's *r* (effect size).

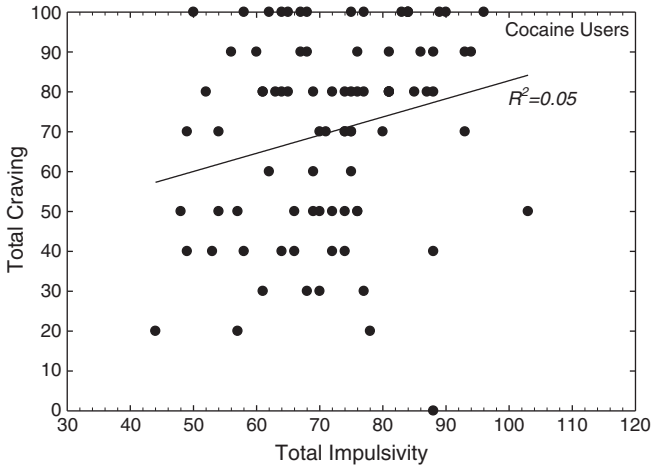

Fig. 1. Simple linear regression demonstrating the association between total impulsivity and total craving in cocaine users (n = 85).

number of attempts to quit cocaine use ($F_{1,72} = 0.08$, $p = 0.78$). Likewise for methamphetamine users, ANOVA revealed no significant differences between HIBIS and LOBIS subgroups in motivation to abstain from methamphetamine use ($F_{1,63} = 0.07$, $p = 0.79$), number of attempts to quit using methamphetamine ($F_{1,62} = 1.79$, $p = 0.19$), or craving after methamphetamine use ($F_{1,71} = 2.22$ $p = 0.14$).

4. Discussion

The primary goal of this report was to determine the relationship between impulsivity and craving in cocaine- and methamphetamine-dependent volunteers. The results confirmed the primary hypothesis revealing a statistically significant relationship between total impulsivity and total craving; however, the magnitude of the relationship was small, indicating that approximately 90–95% of variance was accounted by unknown factors. This report is unique from data already published in that it provides a direct assessment between impulsivity scores using a validated measure and their corresponding craving scores based upon the participants craving before their last use of their stimulant of choice. Since the participants were asked specifically about their craving just before their last use, we were able to investigate how craving influenced recent drug taking behavior.

The marginal relationship between total impulsivity and total craving could be due to the fact that craving is just one of several reward processes that promote drug use. According to de Wit and Richards (2004), in addition to craving, reward-related influences include individual differences in sensitivity to reward, the degree of euphoria from drug taking, the strength of positive drug memories, the direct effects of drug use that are reinforcing, and the environmental stimuli associated with drug use that have acquired positive motivational properties. The de Wit and Richards model of addiction identifies reward and impulsivity as processes that can function independently or combine together to influence drug use. De Wit and Richards further identify the major determinants of drug use maintenance are the rewarding effects produced by the drug use combined with the inability to refrain from using drugs.

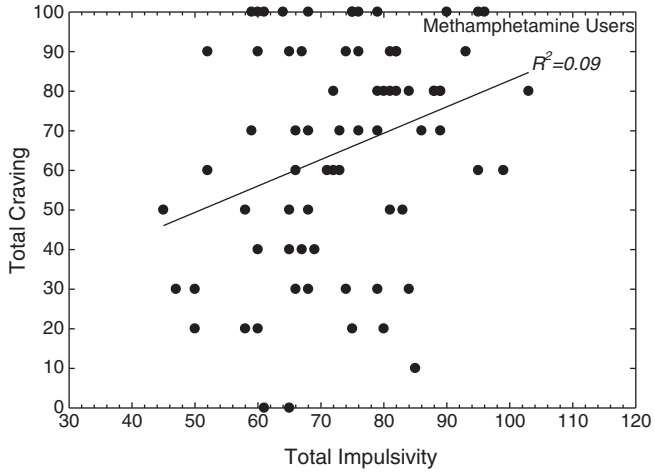

Fig. 2. Simple linear regression demonstrating the association between total impulsivity and total craving in methamphetamine users (n = 73).

Research conducted by our group (Newton et al., 2009) is in line with the outcomes reported in the current investigation. In that study, a majority of methamphetamine-dependent participants (56%) indicated using methamphetamine because they enjoyed it and wanted to get "high". In contrast, only 27% identified impulsivity, 25% reported habit, and 19% cited craving as reasons for ongoing drug use; indicating that these are minor factors. Similar outcomes were obtained in a sample of cocaine users (Haile et al., 2010).

The current data are also in agreement with two other reports. In cocaine dependent users, Moeller and colleagues (2001b) found a relationship between total impulsivity and total craving, though unknown factors accounted for 92% of the variance. Similar findings can also be inferred from a study conducted by Walsh et al. (2010). In their report, cocaine dependent participants reported significantly greater levels of baseline craving compared to a group of participants who only met criteria for cocaine abuse, but no significant differences were found between groups with regard to impulsivity (assessed using the BIS). Though not stated as such, the findings by Walsh suggest that factors other than impulsivity must account for the distinct patterns of cocaine use reported between groups.

The current study also explored the association between total craving and scores on impulsivity subscales of Attention, Motor and Non-Planning. Our findings are largely in agreement with the data by Moeller et al. (2001b) who also showed no correlation between total craving and scores on impulsivity subscales of Attention and Non-Planning. The current report differs from that of Moeller with regard to motor impulsiveness (i.e. acting without thinking, lack of perseverance). Participants in the research conducted by Moeller included treatment seeking cocaine dependent users, and in the current study, participants were identified as non-treatment seeking, which may account for the disparity between findings. Perhaps the relationship between craving and motor impulsiveness is stronger during initial treatment when addicts are experiencing withdrawal symptoms or stress during the early stages of abstinence.

The secondary focus of the current study was to explore the relationship of impulsivity and craving scores to amount of drug use (poly-substance use, years of use, recent use) and other drug use variables (withdrawal symptoms, motivation to abstain). With the exception of years of alcohol use, levels of impulsivity were not related to amount of drug use or other drug use variables, which implies that other factors must contribute to drug seeking and serve as motivational factors for cocaine or methamphetamine use. Results from the current study reveal that severity of withdrawal and craving after use were significantly elevated and may therefore serve as motivational factors contributing to drug use.

In the present study, more impulsive cocaine users exhibited more severe withdrawal and greater years of alcohol use. Research has shown that severity of cocaine withdrawal is a predictor of treatment retention and subsequent relapse in cocaine dependent users (Kampman et al., 2001; Mulvaney et al., 1999). Severity of withdrawal among more impulsive cocaine users may also be influenced by alcohol use. Many individuals who use cocaine also abuse alcohol in order to increase euphoric effects or to decrease dysphoria associated with drug withdrawal (Gawin and Kleber, 1986; McCance-Katz et al., 1998). In a study investigating the combined effects of alcohol and cocaine on

Table 3
Relationship between impulsivity and drug use variables for cocaine and methamphetamine users.

	Cocaine			Methamphetamine		
	HIBIS (n = 42)	LOBIS (n = 43)	$r^{\#}$	HIBIS (n = 37)	LOBIS (n = 36)	$r^{\#}$
BIS score	82.05 ± 7.25**	61.98 ± 7.52	0.81	83.84 ± 7.47**	62.50 ± 7.40	0.82
Craving before use	74.52 ± 23.81	65.58 ± 24.91	0.18	72.43 + 25.76*	57.22 + 29.14	0.27
Age	44.83 ± 5.98	42.74 ± 8.54	0.14	35.97 ± 9.48	35.03 ± 10.12	0.05
Gender[1]	35 M, 7 F	36 M, 7 F	–	24 M, 13 F	24 M, 12 F	–
Ethnicity						
African American	23 (54%)	32 (76%)	–	3 (7%)	4 (10%)	–
Caucasian	10 (24%)	3 (7%)		18 (43%)	14 (33%)	
Hispanic	7 (17%)	6 (14%)		9 (21%)	10 (24%)	
Asian/Pacific Islander	0 (0)	0 (0)		3 (7%)	2 (5%)	
More than 1	2 (5%)	1 (2%)		1 (2%)	1 (2%)	
Did not report	0 (0)	1 (2%)		3 (7%)	5 (12%)	
Years of coc/meth use	19.10 ± 6.84	16.12 ± 9.31	0.18	11.72 ± 7.91	10.96 ± 7.71	0.05
Recent coc/meth use[2]	16.54 ± 8.43	17.55 ± 8.73	0.06	17.83 ± 9.92	17.88 ± 8.87	0.00
Years of nicotine use	23.28 ± 10.14	19.61 ± 10.63	0.17	19.65 ± 10.42	15.75 ± 9.70	0.19
Recent nicotine use[2]	26.41 ± 8.06	23.98 ± 9.81	0.13	27.79 ± 10.38	25.71 ± 9.08	0.11
Years of marijuana use	20.73 ± 14.09	15.48 ± 9.44	0.21	14.79 ± 1.39	11.43 ± 9.30	0.24
Recent marijuana use[2]	9.07 ± 11.84	7.20 ± 10.36	0.08	6.48 ± 9.82	11.00 ± 12.32	0.20
Years of alcohol use	20.95 ± 8.72*	16.58 ± 9.52	0.23	16.85 ± 9.99	16.04 ± 11.32	0.04
Recent alcohol use[2]	10.32 ± 9.84	9.49 ± 9.91	0.04	8.59 ± 9.85	8.25 ± 10.49	0.02
Withdrawal Symptoms	16.36 ± 7.63*	12.26 ± 7.48	0.26	20.08 ± 10.25*	13.11 ± 7.86	0.36
Quit Attempts	4.33 ± 5.64	4.95 ± 11.82	0.03	5.09 ± 9.54	2.61 ± 4.40	0.16
Motivation to Abstain	40.61 ± 37.45	32.44 ± 37.94	0.10	38.03 ± 34.71	40.31 ± 34.78	0.03
Craving After Use	76.67 ± 27.47	64.88 ± 29.14	0.20	61.35 ± 36.68	50.00 ± 27.67	0.17

Data reflect mean ± S.D. or N (%).
* $p \leq 0.05$ HIBIS vs. LOBIS; ** $p < 0.0001$ HIBIS vs. LOBIS.
[1] M = males, F = Females.
[2] days used in the last 30.
[#] Pearson's r (effect size).

neurobehavioral performance, Bolla et al. (2000) found that functional impairment and more impulsive responding were related to prefrontal cortical dysfunction. In that trial, participants used cocaine for eight years, and alcohol for fifteen years on average, similar to the cocaine users in the current study. Deficits in executive function and impulsivity could make it more difficult to discontinue or change inappropriate behaviors such as drug taking, and these individuals may have more difficulty resisting the urge to engage in drug use when experiencing withdrawal symptoms.

In the current study, craving before drug use was significantly correlated with total impulsivity, years of alcohol use, severity of withdrawal, and craving after use. The results imply that drug use may not have altered craving after use (i.e., result in craving satiety), suggesting that craving may drive drug use through incentive salience, as proposed by Robinson and Berridge (1993). Research by Walsh et al. (2010) corroborates the current findings showing that cocaine craving among dependent users remained unchanged after cocaine exposure in the laboratory, implying that a lack of craving satiety could contribute to ongoing drug use.

Of particular interest, craving and impulsivity scores did not differ between participants who were assessed during stimulant "positive" versus "negative" conditions. One would expect those individuals who are positive for cocaine or methamphetamine to be more impulsive, but their responses on the BIS and the VAS did not reflect this (Table 2). These data coincide with the primary outcomes.

These findings validate the de Wit and Richards (2004) model of drug use, which integrates operant reinforcement, craving as a reward process, and impulsivity. For users who are impulsive and experience elevated levels of craving prior to drug use, the intensity of craving may continue to be pronounced due to the lack of satiation after drug use, cue induced craving in the environment, and unremitting withdrawal symptoms. A common environmental stimulus associated with cocaine use is alcohol consumption. Intense craving coupled with the impulse to avoid the negative effects of withdrawal, and the association with alcohol use may combine to maintain ongoing drug taking and drug seeking behavior. These findings are consistent with research in cocaine users that indicate craving increases during early abstinence when withdrawal is prominent (Coffey et al., 2000; Weddington et al., 1990), and craving intensifies upon discharge from treatment where users return to their environments, which contain cocaine related stimuli (Bordnick and Schmitz, 1998).

In this study, more impulsive methamphetamine users experienced increased craving and greater withdrawal symptoms as compared to methamphetamine users who reported low impulsivity. Craving that accompanies withdrawal may be a factor involved in the maintenance of drug use by triggering the impulse to use the primary drug. Research conducted by our group (Newton et al., 2004) and McGregor et al. (2005) supports this since these findings reveal that prominent withdrawal symptoms occur within 1–3 days of abstinence, and in the current study recent use was reported 16 out of 30 days. In other words, all participants evaluated in the current study had used their primary drug very recently and were either recently intoxicated (70% urine positive) or in short term withdrawal (30% urine negative). Highly impulsive users who endure intense craving are likely to experience negative effects associated with withdrawal, which could maintain ongoing drug taking and could drive drug seeking behavior. The findings in the current study are also in agreement with data by Moeller et al. (2001b), which revealed relationships between total impulsivity and craving, self-reported cocaine use, and withdrawal symptoms. Findings by Moeller imply that reacting to internal stimuli such as craving or withdrawal without regard to the consequences is important in drug use. As found with cocaine users, baseline craving scores for methamphetamine users in the current study were significantly associated with impulsivity and craving after use. Those who experienced higher craving were also more impulsive and more sensitive to the rewarding effects of methamphetamine, which could further motivate drug-taking and perpetuate ongoing drug use.

An important question is what is the role of impulsivity in ongoing use versus relapse? For the role of impulsivity as it relates to use, the answer can readily be deduced from the data on urine state (positive versus negative; Table 2) and recent cocaine/methamphetamine use (Table 3). In both instances, HIBIS and LOBIS groups did not differ

suggesting that impulsivity does not influence ongoing use. These findings coincide with our recent report (Newton et al, 2009) showing that self-reported impulsivity ("Do you impulsively take drugs?") was endorsed as the principle cause for drug use in only 27% of methamphetamine-dependent respondents. A similar outcome has been shown in cocaine-dependent participants (Haile et al, CPDD, 2010).

With regard to relapse, the answer can be surmised from the data on withdrawal symptoms, motivation to abstain, and craving after use (Table 3). HIBIS and LOBIS groups did not differ on motivation to abstain and craving after use, but HIBIS cocaine and methamphetamine users were significantly more likely than their LOBIS counterparts to self-report increased withdrawal symptoms. Inasmuch as withdrawal symptoms may precipitate relapse to drug use (the negative reinforcement theory of addiction), then these data would indicate a role of impulsivity in relapse. Yet, the absolute values reported were very low (~20 on a scale of 100) and while statistically different, we are not convinced that this low level of self-reported withdrawal symptoms would result in increased probability of relapse. This conclusion is bolstered by our previous work showing that self-reported negative reinforcement ("Do you relapse mostly to make bad feelings go away") was endorsed as the principle reason by only 26% of methamphetamine-dependent respondents (Newton et al, 2009); again this finding is similar for cocaine-dependent participants (Haile et al, CPDD, 2010).

Despite the detailed and informative outcomes presented, some methodological limitations should be noted. The correlational and cross-sectional nature of the current study does not specifically address the issue of cause and effect. Another limitation is that the research design relied solely on self-report instruments, although self-reports have been shown to be reliable in research contexts where confidentiality is ensured (Babor et al., 1990). This study also used only one measure to assess each of the variables (impulsivity and craving) and others may be needed to validate the findings. Additionally, craving was assessed using a non-standardized, but very widely used, measure and it was limited to two items. This instrument is unlikely to provide information about the multiple elements that can define the craving experience and internal consistency could not be determined. Also, previous research has shown that impulsivity is a multi-faceted construct, which is not easily measured with a single self-report questionnaire. This research may have benefited by utilizing an additional craving measure that provided a composite craving score based on a multidimensional conceptualization of craving, such as the Cocaine Craving Questionnaire (Tiffany et al., 1993). Although craving has been extensively researched in the literature, there is no consensus about its measurement. An alternate research design could also involve the use of behavioral measures of impulsivity since research has found that behavioral and self-report impulsivity measures may not necessarily correlate (Lane et al., 2003). Another limitation is that the report of craving since last use may be distorted due to memory decay and/or drug-induced high, which may have impacted the interpretation of the craving responses. Finally, it would have been interesting to obtain data to investigate whether education or socioeconomic status influence impulsivity or craving responses.

Despite the limitations listed above, this research contributes to the understanding of impulsivity and craving as potential factors in the development and maintenance of cocaine and methamphetamine addiction. These findings, although exploratory, may have relevant implications for future research, treatment planning, and clinical management.

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