Impaired Decision-Making, Higher Impulsivity, and Drug Severity in Substance Dependence and Pathological Gambling

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Objectives: Substance use disorder is characterized by impaired decision making, impulsivity, and risk taking. Pathological gambling shares many of these characteristics, and having both diagnoses may be associated with greater problems than either diagnosis alone. We investigated whether among substance-dependent individuals, comorbid pathological gambling would be associated with worse decision making, greater impulsivity, risk taking, and drug severity.

Methods: Ninety-six substance-dependent individuals were recruited from a residential treatment program and divided into 1 of the 2 groups depending on whether they met *Diagnostic and Statistical Manual of Mental Disorders*, *Fourth Edition*, criteria for pathological gambling (SDPG, n = 26) or not (SD, n = 70). Ninety-two controls were recruited from the community. Participants completed a decision-making task (modified Iowa Gambling Task), measures of impulsivity (Barratt Impulsivity Scale and Delay Discounting), and risk taking (Balloon Analog Risk Task). Decision making was analyzed using a computational model. We tested for group differences using analysis of covariance or Kruskal-Wallis and appropriate post-hoc tests.

Results: The groups differed in decision-making parameters ($P < 0.001$) and self-reported impulsivity ($P < 0.001$). All post-hoc comparisons were significant on these measures, and indicated stepwise changes in controls, followed by SD, followed by SDPG, with SDPG performing worse on decision making and being more impulsive. Compared with SD, SDPG had greater drug severity ($P < 0.001$). No group differences were observed in delay discounting or risk taking.

Conclusions: Compared with individuals with substance dependence without pathological gambling, those with both disorders demonstrated worse decision making and significantly more drug-related symptoms. When evaluating patients with substance dependence, clinicians should consider diagnostic assessments for gambling, as the co-occurrence of both disorders may impact clinical characteristics.

Key Words: computational modeling, decision making, impulsivity, pathological gambling, substance dependence

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Individuals with substance use disorders make poor decisions that involve seeking and taking drugs despite negative long-term consequences. Such patterns of poor decision making can result from elevated impulsivity (Leeman & Potenza, 2012; Tomassini et al., 2012), high levels of risk taking (Lejuez et al., 2003; Crowley et al., 2006), and/or deficits in goal-directed learning (Stout et al., 2004, 2005; Thompson et al., 2012). The Iowa Gambling Task (IGT; Bechara, 2003), a task of decision making under conditions of uncertainty and risk, has been shown to be sensitive to many clinical populations. Compared with controls, people who use substances perform poorly because they persist in making choices that, while yielding large immediate rewards, over time ultimately result in net losses (Bechara, 2003). Computational modeling of behavior on the IGT may identify psychological processes that could account for impaired decisions. For example, Stout et al. (2004) found that, in cocaine users, impaired decision making on the IGT was due to hyposensitivity to loss and response inconsistency. In contrast, patients with ventral medial prefrontal lesions also perform poorly, but their decision-making deficits may be related to impairments in updating expectations (Yechiam et al., 2005).

Poor decisions are also related to impulsivity and risk taking. A vast literature has shown that drug and alcohol addictions are associated with impulsivity (Lejuez et al., 2010; Leeman & Potenza, 2012). One measure of impulsivity, temporal discounting, indicates that individuals with substance use disorders devalue long-term rewards in favor of short-term

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rewards to a greater extent than controls (Petry, 2001; Ledgerwood et al., 2009; Andrade & Petry, 2012; Leeman & Potenza, 2012). Individuals with substance use disorders also take greater risks than controls (Rogers et al., 1999; Lejuez et al., 2003). Impulsivity and risk taking, together, have been shown to increase the probability of initial drug experimentation over either construct alone (Poulos et al., 1995; Dayan et al., 2010; Lejuez et al., 2010). However, poor decision making, impulsivity, and risk taking are not unique to drug use disorders. Individuals who have gambling problems show similar behaviors (Leeman & Potenza, 2012). As with drugs and alcohol, most people can gamble without becoming preoccupied with or jeopardizing their family or professional relationships because of gambling. Prevalence estimates for pathological gambling are more difficult to ascertain than for substance dependence but have been reported in the range of 0.42% to 3% (Petry and Armento, 1999) (National Research Council, 1999) compared with 10% for substance dependence (Miller & Hendrie, 2009). However, both disorders share clinical and biological features that have led to the reclassification of "pathological gambling" from a disorder of impulse control in *Diagnostic and Statistical Manual of Mental Disorders–Fourth Edition* (*DSM-IV*) to a behavioral addiction in the *DSM-V* (5th ed.; *DSM-V*; American Psychiatric Association, 2013). Both disorders are characterized by tolerance, unsuccessful efforts to stop, and continued engagement despite long-term negative consequences (Leeman & Potenza, 2012). In addition, substance use and pathological gambling are highly comorbid.

Compared with controls, individuals with pathological gambling are 5 to 7 times more likely to have alcohol, nicotine, and substance dependence (Petry et al., 2005). Despite high co-occurrence, the clinical impact of having both diagnoses is not clear. Gamblers with substance use disorders show more rapid temporal discounting than gamblers without substance use disorders, suggesting an additive risk on impulsivity (Petry & Casarella, 1999; Andrade & Petry, 2012). Greater impulsivity may have adverse effects on finances, employment, and social relationships, and has been associated with increased legal problems (Ledgerwood et al., 2009). Individuals with both diagnoses may require more intensive management. Suicide attempts were reported to be more common among people who gamble who also had unhealthy alcohol use than among those who did not (Potenza et al., 2005). Individuals with gambling and alcohol problems were more likely to have non–gambling-related arrests compared with individuals with only gambling problems (Potenza et al., 2005).

Previous studies investigating comorbidity of these disorders have recruited participants primarily from centers specializing in gambling problems (Ledgerwood et al., 2009; Andrade & Petry, 2012). As mentioned previously, pathological gambling is significantly less common than substance dependence. Thus, examining the consequences of comorbidity from the perspective of substance use populations would be informative. Moreover, a recent meta-analysis suggested that in drug treatment settings, the prevalence of problem gambling is significantly higher than in the general population (Cowlishaw et al., 2014).

The goal of this study was to investigate decision making, impulsivity, and drug severity in substance-dependent individuals with and without pathological gambling compared with controls. We used a novel computational model to identify mechanisms underlying decision-making performance and then evaluated potential differences in model parameters among the 3 groups.

METHODS

Participants

Patients

Ninety-six drug-abstinent substance-dependent individuals resided for at least 2 months in the University of Colorado Denver's Addiction Research and Treatment Services long-term residential treatment programs. Referrals are mainly through the criminal justice system, and all patients have long-term substance and antisocial behavior problems that prompted criminal justice involvement. The program requires abstinence from drugs, alcohol, and nicotine. On average, these patients have been abstinent from substances for more than 1 year. Once patients are admitted to the treatment program, abstinence is monitored and enforced through close observations and random urinalysis tests. The inclusion criterion was dependence on psychostimulants on the basis of *DSM-IV* criteria. Patients were then subdivided into 1 of the 2 groups: 26 patients met lifetime *DSM-IV* criteria for pathological gambling (SDPG group: 18 males/8 females; mean age = 35.6 years; standard deviation = 6.8 years) and 70 did not (SD group: 38 males/32 females; mean age = 34.3 years; standard deviation = 8.0 years). Self-reported abstinence was, on average, 1.4 years. All patients also met criteria for antisocial personality disorder.

Controls

Ninety-two controls (55 males/37 females; mean age = 33.4 years; standard deviation = 9.3 years) were recruited from the community through newspaper ads, flyers, a marketing company, and a database of community members interested in participating in research. Controls were excluded if they met criteria for pathological gambling or dependence on any drug or alcohol. Smoking was not exclusionary.

Exclusions for all participants were history of head trauma with loss of consciousness exceeding 15 minutes, neurological illness, schizophrenia, bipolar disorder, or major depression, and intelligence quotient (IQ) less than 80 (Wechsler Abbreviated Scale of Intelligence, 2-subtest version; Psychological Corporation).

All subjects were reimbursed US$65 and were paid the same amount. All subjects provided written informed consent approved by the Colorado Multiple Institutional Review Board.

Structured Interviews

All interviews and assessments were administered by trained lay personnel on 2 separate days. On the first day, subjects were given Composite International Diagnostic Interview-Substance Abuse Module (CIDI-SAM), Diagnostic Interview Schedule–Version IV, Barratt Impulsiveness Scale–Version 11 (BIS-11), delay discount task, and Balloon

Analogue Risk Task (BART). On the second day, separated by about 2 weeks, subjects performed the modified IGT.

Composite International Diagnostic Interview-Substance Abuse Module

This computerized structured interview was administered to patients and controls to provide dependence diagnoses on 11 substances (amphetamines, cocaine, marijuana, alcohol, tobacco, hallucinogens, opioids, inhalants, sedatives, club drugs, and phencyclidine) and to ensure that controls did not meet dependence criteria on substances.

Diagnostic Interview Schedule–Version IV

This computerized structured interview provides diagnostic and symptom information about psychiatric diagnoses according to the *DSM-IV*. The module for pathological gambling was used for inclusion/exclusion into the SDPG group. Controls were excluded if they met criteria for pathological gambling. Modules were administered to exclude participants with schizophrenia, bipolar disorder, or current major depression, and to test for the presence of antisocial personality.

Behavioral Tests

Decision Making

Modified Iowa Gambling Task. To measure decision making, we administered the modified IGT (mIGT; Thompson et al., 2012). Data, not including computational parameters, on 31% (58 of the 188) of the participants have been published (Thompson et al., 2012). Participants were shown 4 decks of cards and instructed to win as much money as possible. For each trial, a deck was selected by the computer and the subject chose to "play" or "pass" by pushing 1 of the 2 response buttons. If the subject chose "play," the outcome was a single positive or negative monetary value, along with the running total. If he/she chose "pass," the running total remained the same. The decks were balanced on the frequency and magnitude of wins and losses. The dependent measure of overall performance was the total passes on bad decks (Thompson et al., 2012). To further investigate cognitive processes underlying overall performance, data were analyzed with a computational model of expected valence (Stout et al., 2004). This model estimates 3 parameters: sensitivity to loss relative to win (ω), updating (α), and response consistency (θ). The expectancy valence model has previously been adapted to the modified IGT. Details of the model can be found in Tanabe et al. (2013) and Supplemental Digital Content 1 (http://links.lww.com/JAM/A29).

Impulsivity

Barratt Impulsiveness Scale. The BIS-11 (Patton et al., 1995) is a 30-item self-report questionnaire that measures multiple facets of impulsivity. Participant state how often phrases describing aspects of impulsivity pertain to themselves along a 4-point Likert-like scale. The BIS-11 has been shown to be a reliable measure of impulsiveness (Patton et al., 1995; Stanford et al., 2009).

Delay Discounting. As a measure of temporal impulsivity, participants completed a computerized discounting task in which they chose between a hypothetical $1000 reward at some time in the future and a lesser amount now. There were 7 delays ranging from 1 day to 10 years and 30 possible immediate amounts ranging from $1 to $999 (Green et al., 1996). We considered removing nonsystematic data as recommended by Johnson and Bickel (2008) and determined that 57 participants would be excluded by their criteria. Therefore, to avoid potential bias by omitting or poorly fitting approximately one third of our data, we computed area under the discounting curve (AUC) for each participant's response trajectory. The AUC approach avoids assuming that data are fit by a hyperbolic or other function (Myerson et al., 2001) and has been used in populations similar to ours (Ledgerwood et al., 2009). Secondarily, we estimated and plotted discounting rates from averaging hyperbolic curves fit to each participant.

Risk Taking

Balloon Analogue Risk Task. The BART (Lejuez et al., 2002) is a computerized task in which participants earn hypothetical money by incrementally increasing the size of a balloon. If the balloon "pops," earnings for that balloon are lost. Each trial requires a decision between increasing earnings and "collecting" money already earned. The dependent variable was an average number of pumps, excluding balloons that popped (Lejuez et al., 2002).

Drug Use Severity

The CIDI-SAM assesses 4 abuse and 7 dependence symptoms for each of the 11 substances tested. Drug severity was determined using a dimensional approach by adding abuse and dependence symptom counts across all drugs (Gelhorn et al., 2008; Hartman et al., 2008).

Data Analysis

Dependent variables were inspected for normality. For normally distributed variables, one-way analysis of covariances (ANCOVAs), adjusted for education (which differed between controls and patients but not between SD and SDPG), were performed with post-hoc comparisons between each 2-group combination (eg, SD vs SDPG) when indicated by a significant group effect. Categorical variables were analyzed with χ^2-square and Fisher exact tests, as recommended (Campbell, 2007). For variables that were not approximately normally distributed, Kruskal-Wallis tests were performed, and when the group effect was significant, post-hoc comparisons between each 2-group combination were conducted with Mann-Whitney *U* tests. When normally distributed variables demonstrated nonhomogenous variability, a reciprocal transformation was performed.

We compared drug severity between SD and SDPG using an independent *t* test. Drug severity was correlated with other variables using Pearson *r* for parametric and Spearman ρ for nonparametric variables. Analyses were conducted using SPSS 20 (IBM SPSS Statistics for Windows, Version 20.0, Armonk, NY: IBM Corp).

TABLE 1. Means and Standard Deviations for Demographic Data, Drug Dependence, and Abstinence

	Controls (N = 92)	SD (N = 70)	SDPG (N = 26)	*P*
Sex, male/female	55/37	38/32	18/8	NS
Age, yrs	33.4 ± 9.3	34.3 ± 8.0	35.6 ± 6.8	NS
Education*	14.1 ± 1.9	12.2 ± 2.1	11.3 ± 1.9	<0.001
IQ*	108.0 ± 12.5	101.2 ± 10.1	101.1 ± 10.0	<0.001
Stimulants	0 (0%)	70 (100%)	26 (100%)	NS
Amphetamines	0 (0%)	53 (76%)	24 (93%)	NS
Cocaine	0 (0%)	41 (59%)	20 (77%)	NS
Tobacco	15 (16%)	53 (76%)	22 (85%)	NS
Alcohol	0 (0%)	40 (57%)	16 (62%)	NS
Cannabis	0 (0%)	19 (27%)	15 (58%)	<0.05
Opioids	0 (0%)	13 (19%)	9 (35%)	NS
Hallucinogens	0 (0%)	3 (4%)	4 (15%)	NS
Club drugs	0 (0%)	3 (4%)	3 (12%)	NS
Sedatives	0 (0%)	2 (3%)	0 (0%)	NS
PCP	0 (0%)	1 (1%)	0 (0%)	NS
Inhalants		0 (0%)	0 (0%)	NS
Abstinence, yrs		1.2 ± 0.9	1.7 ± 1.7	NS

*Controls differ from SD and SDPG. No difference between SD and SDPG.
IQ, intelligence quotient; NS, nonsignificant; PCP, phencyclidine; SD, substance-dependent individuals; SDPG, substance-dependent individuals with pathological gambling.

RESULTS

Demographics

Demographic data are shown in Table 1. Sex and age did not differ by group, but education ($F[2,186] = 30.3$; $P < 0.001$) and IQ ($F[2,186] = 8.5$; $P < 0.001$) did. Controls had more education than SD (controls, 14.1 ± 1.9; SD, 12.2 ± 2.1; $P < 0.001$) and SDPG (SDPG, 11.3 ± 1.9; $P < 0.001$). There was no difference in education between SD and SDPG ($P = 0.11$). Controls had higher IQ than SD (controls, 108.0 ± 12.5; SD, 101.2 ± 10.1; $P < 0.001$) and SDPG (SDPG, 101.1 ± 10.0; $P = 0.02$). There was no difference in IQ between SD and SDPG ($P = 1.00$). Because of these group differences, education was entered as a covariate in the analyses that included the control group (ie, ANCOVAs), whereas IQ was not because it strongly correlated with education.

Decision-Making Performance

One-way ANCOVA on *passing on bad decks* revealed a significant difference across all groups ($F[2,156] = 6.78$; $P = 0.002$). Post-hoc analysis revealed that controls passed on bad decks more than SD (controls, 42.01 ± 18.3; SD, 33.30 ± 15.1; $P = 0.01$) and SDPG (SDPG, 26.85 ± 11.2; $P < 0.001$). SD passed more on the bad decks than SDPG ($P = 0.04$).

Decision-Making Computational Parameters (ω, θ, and α)

The Kruskal-Wallis test revealed a significant group differences ($H[2,157] = 17.63$; $P < 0.001$) in *sensitivity to loss* (ω). Post-hoc analysis revealed significant differences between controls and SD (controls, 0.29 ± 0.28; SD, 0.19 ± 0.27; $P = 0.01$), between controls and SDPG (SDPG, 0.06 ± 0.14; $P < 0.001$), and between SD and SDPG ($P = 0.03$). Controls were most sensitive to loss, followed by SD, and then followed by SDPG. The Kruskal-Wallis test revealed a significant group difference ($H[2,157] = 16.01$; $P < 0.001$) in *response consistency* (θ). Post-hoc analysis revealed significant differences between controls and SD (controls, −0.01 ± 1.1; SD, −0.39 ± 0.53; $P = 0.02$), between controls and SDPG (SDPG, −0.63 ± 0.23; $P < 0.001$), and between SD and SDPG ($P = 0.03$). Controls had the highest response consistency, followed by SD, then followed by SDPG. No significant group differences were found in the update parameter (α).

Barratt Impulsiveness Scale

ANCOVA revealed a significant group difference ($F[2,185] = 56.59$; $P < 0.001$) on the BIS. Post-hoc analysis revealed controls reported less impulsivity than both SD (controls, 58.97 ± 7.3; SD, 70.89 ± 10.8; $P < 0.001$) and SDPG (SDPG, 77.23 ± 10.3; $P < 0.001$). SD reported significantly less impulsivity than SDPG ($P = 0.01$) (Table 2; Fig. 1).

Delay Discounting

AUC did not differ by group ($F[2,185] = 7.57$; $P = 0.09$), but the trend suggested that controls (0.41 ± 0.27) discounted less than either SD (0.28 ± 0.24) or SDPG (0.25 ± 0.21). Comparing all substance users (SD + SDPG) with controls showed that substance users discounted at a more rapid rate ($P = 0.03$, adjusting for education). Figure 2 shows discounting curves for each group, estimated from averaging hyperbolic curves fit to each subject.

Balloon Analogue Risk Task

There were no significant group differences in an average number of pumps, excluding balloons that popped (controls, 35.1 ± 14.3; SD, 37.0 ± 13.9; SDPG, 39.4 ± 13.7; $P = 0.17$) (Table 2; Fig. 1).

Drug Severity and Correlation With Dependent Variables

Compared with SD, SDPG had significantly greater drug severity (SDPG, 35.27 ± 12.4; SD, 25.49 ± 10.9; $P < 0.001$; Table 2). Across all substance users, drug severity correlated significantly with BIS-11 scores ($r = 0.27$; $P = 0.01$; Fig. 3). Drug severity did not correlate with other variables (ie, BART, Delay Discount, ω, α, and θ).

TABLE 2. Behavioral and Cognitive Measures*

	Controls	SD	SDPG	*P*
Impulsivity				
BIS-11†	57.8 ± 7.8	70.5 ± 11.4	77.1 ± 11.0	<0.001
Delay discount	0.41 ± 0.27	0.28 ± 0.24	0.25 ± 0.21	0.09
Risk taking				
BART	35.1 ± 14.3	37.0 ± 13.9	39.4 ± 13.7	0.17
Drug severity‡	–	25.49 ± 10.9	35.27 ± 12.4	<0.001
Decision making				
Pass bad†	42.01 ± 18.3	33.30 ± 15.1	26.85 ± 11.2	0.02
ω†	0.29 ± 0.28	0.19 ± 0.27	0.06 ± 0.14	<0.001
α	0.12 ± 0.15	0.12 ± 0.14	0.13 ± 0.13	0.40
θ†	−0.01 ± 1.1	−0.39 ± 0.53	−0.63 ± 0.23	<0.001

*All *P* values are adjusted for education.
†All pair-wise groups differ significantly.
‡SD and SDPG differ significantly.
BART, Balloon Analogue Risk Task; BIS-11, Barratt Impulsiveness Scale–Version 11; SD, substance-dependent individuals; SDPG, substance-dependent individuals with pathological gambling.

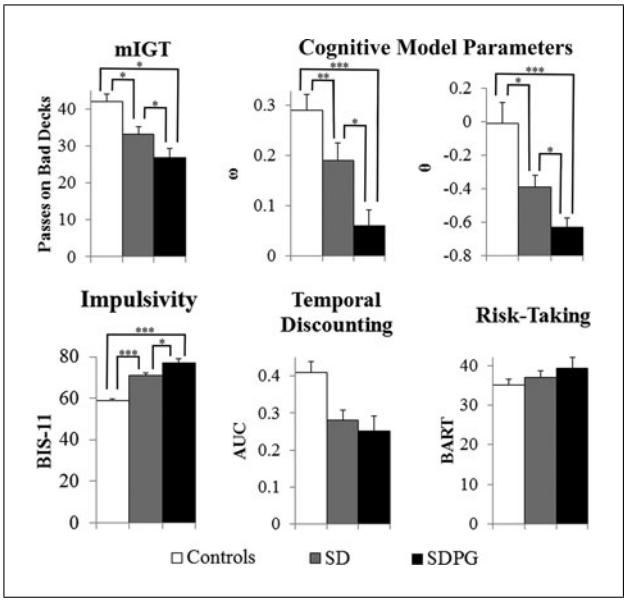

FIGURE 1. Behavioral and cognitive measures across all groups (*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$).

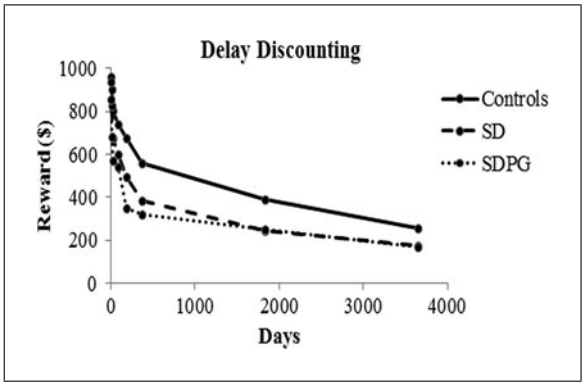

FIGURE 2. Delay discounting curves for controls, SD, and SDPG. SD indicates substance-dependent individuals; SDPG, substance-dependent individuals with pathological gambling.

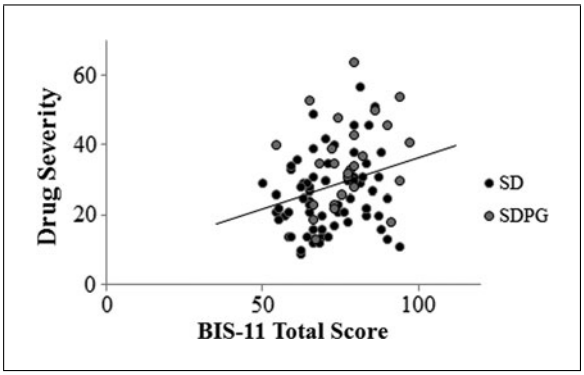

FIGURE 3. Correlation between drug severity and BIS-11 in all substance users ($r = 0.27$; $P = 0.01$). BIS-11 indicates Barratt Impulsiveness Scale–Version 11.

DISCUSSION

Compared with SD, SDPG had poorer decision making driven by low sensitivity to loss and response inconsistency. Second, compared with SD, SDPG reported greater impulsivity and greater drug severity. These results suggest that among substance users, a co-occurring diagnosis of pathological gambling may be a marker for greater deficits in decision making and more drug-related symptoms.

We found significant differences between all 3 groups on decision-making performance. There was a stepwise increase in passing on bad cards on the mIGT in SDPG, SD, and controls, respectively. Prior work has shown impaired passing on bad decks in substance-dependent individuals compared with controls (Thompson et al., 2012). We extend that work by showing for the first time that co-occurring PG further impairs performance. A caveat is that these samples partially overlapped. The current sample size of 188 participants has greater power to examine the effect of PG compared with the prior study of 58 participants.

To evaluate the cognitive processes that underlie decision making, we implemented a computational model of the IGT (Stout et al., 2004) and found that the groups differed significantly on sensitivity to loss relative to gain. Controls were the

most influenced by losses followed by SD, followed by SDPG who were the least influenced by losses. This same pattern was observed for response consistency, which indicates the extent to which an individual's responses reflect his/her expectations over time. Controls showed the greatest response consistency, followed by SD, and followed by SDPG. In contrast, no group difference was found on the third parameter, α, which reflects updating expectancies on the basis of prior trials. Our results are consistent with Stout et al. (2004) who reported lower sensitivity to loss and less consistent responses, whereas updating did not differ, in cocaine users compared with controls (Stout et al., 2004, 2005). We extend those results and suggest that compared with substance dependence alone, those with co-occurring pathologic gambling are even less sensitive to loss and less consistent in their decision-making choices.

We found significant differences between all 3 groups on self-reported impulsivity, increasing in score from controls to SD to SDPG, consistent with some (Petry & Casarella, 1999; Andrade & Petry, 2012) but not all prior studies (Tanabe et al., 2007; Ledgerwood et al., 2009; Stea et al., 2011). The most notable difference between our study and those that found no difference is in the criteria for gambling and substance use problems. Previous work utilized the South Oaks Gambling Screen, which is a 16-item self-report questionnaire. Although widely used and easily administered, the South Oaks Gambling Screen is a screening tool and not a diagnostic instrument, and therefore may result in false positives (Lesieur & Blume, 1987; Gambino, 1997). Our findings of increased impulsivity in SDPG may be related to greater specificity of *DSM-IV*.

Drug severity was measured using a dimensional approach (Gelhorn et al., 2008; Hartman et al., 2008) by calculating total symptom count across drugs. Compared with SD, SDPG had significantly greater drug severity, although, except for cannabis, dependence diagnoses were not significantly different between the groups. In addition, impulsivity correlated with drug severity and is consistent with the notion that greater impulsivity is associated with a worse clinical course. Although our study cannot determine causality (eg, impulsivity may lead to greater drug severity and pathological gambling; alternatively greater drug exposure may induce more impulsivity and lead to pathological gambling), our SD and SDPG patients had been abstinent from drug use for a prolonged period, approximately 1.4 years. This indicates that regardless of the causal relationships, high levels of impulsivity are likely to persist even with sustained full remission in a controlled environment. Our data support a recommendation to assess for comorbid pathological gambling in substance abuse treatment populations, given the very high rates of comorbidity and because SDPG individuals differ from SD patients in clinically meaningful ways. A co-occurring diagnosis of pathological gambling should raise the clinician's concern for very high levels of impulsiveness that may require more intensive intervention. As new treatments to improve forms of impulsiveness are developed, this patient population may particularly benefit.

We demonstrate 2 negative findings that require comment. Although other studies have shown higher discounting of delayed rewards in substance users and/or pathological gamblers compared with controls (Petry & Casarella, 1999; Leeman & Potenza, 2012), our results demonstrated only a nonsignificant trend for group differences in AUC. The lack of a statistical difference across the 3 groups may reflect differences in demographics. Education and IQ were well matched between our SD and SDPG groups. Petry and Casarella (1999) did not adjust for a 15-point difference in IQ between nonproblem gamblers with and without substance abuse. If we do not adjust for education, our group difference in AUC is significant ($P = 0.001$), suggesting that education is an important factor in discounting. Moreover, a comparison of controls to all substance users (eg, SD + SDPG) revealed significantly lower discounting by controls ($P = 0.03$). Inconsistent results may reflect differences in delay discounting tasks and analyses (Reynolds, 2006). Previous studies compared groups by fitting hyperbolic curves to estimate discounting rates. This analysis assumes that the data fit a hyperbolic curve, though this assumption is not necessarily true. Johnson and Bickel (2008) devised a method for removing data that violated this assumption. This method would have excluded nearly one third of our data, suggesting that discounting in our participants did not meet this assumption. Thus, our primary analysis measured AUC, which does not assume the data are hyperbolic. Ledgerwood et al. (2009) also found no difference between individuals with substance use and gambling compared with individuals with gambling problems using AUC (Ledgerwood et al., 2009).

We found no group differences on the BART, a measure of risk taking. Other studies have also shown mixed results using this task in patients with substance use disorders (Lejuez et al., 2003; Crowley et al., 2006) and pathological gambling (Ledgerwood et al., 2009). Not providing real monetary rewards for behavior on the BART may have reduced the sensitivity of this task.

Patients with substance dependence and pathological gambling share symptoms of tolerance, withdrawal, repeated attempts to stop, and continued engagement despite long-term negative consequences (Leeman & Potenza, 2012). Here, we show that patients with both diagnoses demonstrate even greater decision-making impairment, impulsiveness, and drug use severity. The decision-making impairment may be driven by greater insensitivity to loss and choice inconsistency. It is possible that both disorders are manifestations of an underlying behavioral disinhibitory trait. Traits such as antisocial behavior, impulsivity, risk taking, and issues in personality and temperament may signify an overall problem in behavioral control. For example, early problems with behavioral control have predicted adult SD risk (Moffitt et al., 2011), and undercontrolled temperament in children has been shown to predict gambling problems later in life (Slutske et al., 2012).

Our study was limited by the lack of a group with pathological gambling without substance dependence. The SDPG group was relatively small compared with the other groups; however, it is representative of gambling disorders in patients with substance dependence. Pathological gambling is relatively common among substance-dependent patients in treatment, 27% in this study, slightly lower than 38% as reported by some (Petry et al., 2005; Agrawal et al., 2007; el-Guebaly

et al., 2012) and much more common than 3% in the general population (Committee on the Social and Economic Impage of Pathological Gambling et al., 1999; Petry et al., 2005; Topf et al., 2009). Unequal group size can affect the homogeneity of the sample. To prevent violating assumptions for parametric analyses, nonparametric analyses were utilized when necessary and variables were transformed to homogenize variability among groups. Welch F tests were also calculated, though this did not change the results at all.

CONCLUSIONS

Individuals with substance dependence and pathological gambling have poorer decision making, driven by low sensitivity to loss and response inconsistency, than substance-dependent individuals without pathological gambling. These characteristics are measurable in the laboratory, seem to persist even after years of abstinence, and suggest targets at which to direct treatment. Furthermore, pathological gambling is prevalent among substance-dependent individuals in treatment and associated with more drug-related symptoms. Our results suggest that when evaluating patients with substance use, clinicians should also consider diagnostic assessments for gambling problems.

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