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Decision-making in Long-Term Cocaine Users: Effects of a Cash Monetary Contingency on Gambling Task Performance

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Abstract

Background—The Iowa Gambling task, which typically incorporates hypothetical monetary earnings and losses for performance, has been widely used to measure decision-making in substance abusers. We examined the effects of a cash monetary contingency on Gambling task performance in cocaine abusers and control participants.

Methods—Twenty-two long-term cocaine smokers who met DSM-IV criteria for cocaine dependence and 24 non-cocaine-using control participants completed this study. Both groups were similar in terms of age, executive function, and self-reported alcohol and marijuana use. All participants performed the Gambling task under two counterbalanced conditions: under one condition, earnings and losses were hypothetical, and under the other condition, earnings and losses were in cash.

Results—Condition $\times$ group interactions on card selection and task completion time were noted ($p < 0.05$). Under the hypothetical payment condition, cocaine abusers selected a greater proportion of cards from disadvantageous decks than advantageous decks ($p < 0.05$), but took a similar amount of time to complete the task, relative to control participants. However, under the cash payment condition, no group differences were seen for card selection and cocaine abusers took more time than controls to complete the task ($p < 0.05$).

Conclusions—The application of tangible consequences improved the decision-making and effort of cocaine abusers on the Gambling task, relative to control participants. These findings underscore the importance of considering population-specific factors (e.g., sensitivity to instructional vs. consequential control) when conducting neuropsychological research in substance abusers.

Keywords

Cocaine; Iowa Gambling task; decision-making; contingencies; reinforcement; motivation

1. Introduction

Decision-making, defined as the ability to balance the immediate consequences of choices with their future consequences (Bechara, 2003), has been widely examined in cocaine abusers. This

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concept is of theoretical interest within the field because cocaine-dependent individuals report difficulty in reducing their substance use despite the presence of long-term negative consequences (American Psychiatric Association, 1994). In the laboratory, cocaine abusers have been found to exhibit abnormally steep delay discounting for hypothetical monetary rewards (e.g., Heil et al., 2006), and to have difficulty inhibiting responses on selective attention tasks (e.g., Fillmore & Rush, 2002); cognitive tendencies that may predispose an individual to maladaptive decision-making. Thus, laboratory studies of decision-making in cocaine abusers attempt to provide an empirical bridge between naturalistic behavior and cognitive findings in this population.

Performance on the Iowa Gambling task (Bechara et al., 2000) is hypothesized to model real-life decision-making. During this computerized task, participants repeatedly select cards from four card decks in order to win as much hypothetical money as possible. The decks yield different schedules of earnings and losses that are unknown to the participant. Selection of cards from two of the decks results in consistent small wins (average win per draw = +\$50) and occasional smaller losses (average loss per draw = -\$25), whereas selection from the other two decks results in consistent large wins (average win per draw = +\$100), with occasional larger losses (average loss per draw = -\$125). Exclusive selection from the first two decks leads to overall monetary gains over 100 trials (+\$2500); these decks are considered advantageous. Exclusive selection from the second two decks leads to overall monetary losses over 100 trials (-\$2500); these decks are considered disadvantageous. Hence, the task requires the participant to evaluate these potential gains and losses, with risky decision-making defined as selection of a greater proportion of cards from disadvantageous decks. The Gambling task has been used in a number of studies to assess decision-making in primary cocaine users (Adinoff et al., 2003; Bartzokis et al., 2000; Monterosso et al., 2001; Stout et al., 2004; Tucker et al., 2004; Verdejo-Garcia et al., 2007a, 2007b).

In a study by Stout et al. (2004), the Gambling task was administered to 12 cocaine abusers and 14 nonusers as part of a PET imaging protocol. The results indicated that the cocaine abusers selected fewer cards from advantageous decks than the control participants, and the authors concluded that the cocaine abusers exhibited a deficit in decision-making. This finding has been replicated in cocaine abusers who were also abusing other substances (Verdejo-Garcia et al., 2007b), and is consistent with findings in primary abusers of other substances (e.g., Bechara et al., 2001; Quednow et al., 2007). Stout et al.'s (2004) analysis of the participants' individual responses indicated that the cocaine abusers were less responsive than the control participants to losses that preceded future card selections, which was interpreted as a "motivational" impairment.

However, the use of hypothetical earnings and losses in that study provided no tangible consequences for decision-making, raising the possibility that the cocaine abusers were simply less motivated to maximize hypothetical earnings than the control participants, and thus were less responsive to hypothetical losses. Despite this concern, investigators have largely concluded that cocaine abusers exhibit impaired decision-making ability, characterized by the pursuit of large immediate rewards at the expense of long-term benefit. One way to examine these issues is to provide some tangible consequence for performance, such as real money for Gambling task earnings and losses.

Accordingly, Verdejo-Garcia et al. (2007a) employed a monetary contingency on the Gambling task, comparing the performance of primary cocaine abusers (n=12), primary marijuana abusers (n=11) and healthy control participants (n=14). The drug abusers were administered the task after 25 days of enforced abstinence during an inpatient hospital stay as part of two separate PET imaging studies (Bolla et al., 2003; 2005), and the control participants were administered the Gambling task after three days of inpatient stay. A monetary scaling procedure

was used to administer the cash payment (\$1 of hypothetical money = \$0.01 cash), and the task was administered twice. Similar to the findings of Stout et al. (2004), the cocaine abusers selected a greater proportion of cards from disadvantageous decks over 200 trials, relative to both marijuana abusers and nondrug-using controls. Thus, the cocaine abusers' performance on the Gambling task was disadvantageous even under a monetary contingency, relative to control participants, implying that cocaine abusers' decision-making on the task is not improved by tangible consequences.

However, money has been found to be a potent reinforcer for cocaine abusers in other research paradigms. For example, providing money as an alternative to cocaine in the laboratory has been shown to decrease self-administration of cocaine in nontreatment-seeking cocaine abusers (Hart et al., 2000; Higgins et al., 1994). In treatment-engaged cocaine abusers, a monetary contingency (or its equivalent) has been shown to decrease cocaine-taking (e.g., Higgins et al., 2000), as well as to increase compliance with antiretroviral therapy in HIV-infected individuals (Rigsby et al., 2000), relative to no contingency. Therefore, a monetary contingency has been shown to decrease the frequency of a behavior that increases the risk of long-term negative consequences (cocaine-taking) and to increase the frequency of a behavior that decreases the risk of long-term negative consequences (medication-taking), in cocaine abusers.

Additionally, methodological concerns and differences make it difficult to draw conclusions about the effects of a monetary contingency on Gambling task performance based on a comparison of the results of the Stout et al. (2004) and the Verdejo-Garcia et al. (2007a) studies. Both studies employed small group sample sizes ($n \leq 14$), administered the Gambling task under PET imaging conditions, and did not adequately control for the alcohol and marijuana use of the cocaine abusers. Additionally, in the Stout et al. (2004) study, apparently active cocaine abusers were studied, and were administered 100 trials of the Gambling task; in the Verdejo-Garcia et al. (2007a) study, cocaine abusers were tested after almost a month of substance abstinence and were administered 200 trials of the Gambling task. Finally, the Verdejo-Garcia et al. (2007a) study employed a monetary scaling procedure, which only indirectly linked the onscreen values of earnings and losses to the actual cash payment, perhaps limiting its salience. Thus, the impact of immediate tangible consequences on Gambling task performance in cocaine abusers remains unclear.

Results from studies in healthy college undergraduates (Bowman & Turnbull, 2003; Fernie & Tunney, 2006) generally indicated no differences between groups of participants performing under cash payment conditions and groups of participants performing under hypothetical payment conditions, except when relatively less explicit instructions were given to the participants (Fernie & Tunney, 2006). This suggested that college students' performance was only improved by a monetary contingency when the optimal strategy had to be learned by the participants during the task; it made no difference when the optimal strategy was revealed beforehand (i.e., "stay away from the worst decks"). However, to our knowledge, the direct effects of a monetary contingency on Gambling task performance have never been tested in substance abusers.

The purpose of the current study was to examine Gambling task performance in cocaine abusers and control participants who were similar in their alcohol and marijuana use, under both hypothetical and cash payment conditions. This methodology provides a direct test of competing theories regarding Gambling task performance in cocaine abusers. If cocaine abusers' decision-making on the Gambling task is unaffected by tangible consequences, cocaine abusers' card selection should remain the same, relative to control participants, under both hypothetical and monetary payment conditions. However, if cocaine abusers' decision-making on the Gambling task is responsive to tangible consequences, as we hypothesize, then

the cocaine abusers' card selection should improve from the hypothetical payment condition to cash payment condition, relative to control participants.

2. Methods

2.1. Participants

Participants were recruited by local newspaper, Internet and flier advertisements. They were all native English speakers, screened for color blindness and hearing impairment, and able to view a computer monitor at a comfortable distance. Participants were excluded if they reported any history of head injury or neurological/medical illness (including HIV/AIDS), or developmental disorder (e.g., ADHD, Learning Disability) that could interfere with neurocognitive function. Participants were also excluded if they reported current use of psychoactive medications, and substances other than cocaine, marijuana, alcohol, nicotine or caffeine. Illicit drug use and nonuse was verified by urine toxicology tests during screening and on the day of testing. All participants stated that they were not seeking or engaged in treatment for substance abuse.

No participant met DSM-IV criteria for any current Axis I disorder (besides cocaine dependence for the cocaine abusers), nor for any lifetime psychotic, bipolar or attention-deficit disorder, as assessed by the Structured Clinical Interview for DSM-IV (First et al., 1995) and the Conners' Adult ADHD Diagnostic Interview for DSM-IV (administered when indicated; Epstein et al., 2001). All participants signed a consent form that was approved by New York State Psychiatric Institute Institutional Review Board, completed their participation within one week of screening and were compensated for their time.

2.1.1. Cocaine abusers—Twenty-two active cocaine smokers who met DSM-IV criteria for current cocaine dependence and reported using cocaine for a minimum of 2 days per week ($\geq \$70/\text{wk}$), participated in this study. All cocaine abusers tested positive for cocaine, and marijuana if reported, on urine toxicology tests during screening and on the day of testing.

2.1.2. Control Participants—Twenty-four non-cocaine users, who were recruited to match the cocaine abusers on current use of marijuana and alcohol, participated in this study. No control participant met DSM-IV criteria for current marijuana or alcohol abuse/dependence. All marijuana users tested positive for marijuana on urine toxicology tests during screening as well as on the day of testing. Reported lifetime use of cocaine greater than 10 times was exclusionary.

Demographic and neuropsychiatric characteristics for both groups are presented in Table 1. Continuous variables were analyzed with two-tailed independent-samples t-tests and categorical variables were analyzed with chi-square.

Group differences were seen on several demographic variables. Compared to the cocaine abusers, the controls reported greater than two additional years of education and about twice as much annual income, and a greater proportion of the controls were White ($p < 0.05$). Although the cocaine abusers exhibited greater severity of depressive symptoms ($p < 0.05$), as assessed by the Beck Depression Inventory - Second Edition (BDI-II; Beck et al., 1996), the BDI-II scores for both groups were below the clinically accepted "mild" threshold (Beck et al., 1996). The controls also exhibited higher estimated Full Scale IQs than the cocaine abusers ($p < 0.05$), although both mean IQ scores were in the clinically accepted "average" range.

Self-reported substance use characteristics are presented in Table 2. There were no group differences in the number of participants reporting marijuana use, nor in the reported weekly frequency or amount of marijuana use. Similar observations were noted for alcohol, except

that the cocaine abusers reported drinking alcohol about one more day per week than the controls ($p < 0.05$).

2.2. Design and Procedure

For this single-session outpatient study, participants were instructed not to use any psychoactive substance on the morning of testing except regular caffeine and nicotine. Prior to testing, all participants passed alcohol breathalyzer and field sobriety tests, and spent 30-45 min completing urine toxicology tests and self-report instruments. Additionally, no behavioral signs of intoxication were noted by the experimenter. Thus it is unlikely that any participant was intoxicated during testing. All testing took place in a quiet room that was equipped with both PC and Macintosh computers, as well as a table for manual testing. For computerized tasks, participants were given instructions by the examiner and were then monitored by remote video during performance.

2.3. Measures

2.3.1. Modified Gambling task (Vadhan et al., 2007)—The Gambling task was administered under two conditions to each participant: (1) hypothetical payment (Hypothetical) and (2) cash payment (Cash). Condition order was counterbalanced, and participants were blind to the repeated administration and condition type until just prior to condition onset. Each condition was separated by 3-4 hours, during which the participants performed other tasks.

Cash condition: Four decks of cards (A-D) were displayed on a computer screen. Before performing the task, participants were handed \$10 cash, which was also displayed on an onscreen counter. They were told the game entailed a series of card selections from any of the decks, one card at a time, and that they should select cards until instructed to stop. They were also told that the objective of the game was to win as much money as possible and that some decks were better than others, but no strategy hint was given. They were told that if their net earnings on the task were $> \$0$, they would keep the \$10 and be paid the additional balance. If their net earnings were $\$0 \geq -\10 , they would be required to give back the difference to the examiner from the cash they had been given, but no personal money would be taken if their earnings fell below $-\$10$. This credit system was employed to provide tangible consequences that could be both positive and negative. Participants had been informed during consent that they could earn up to \$35 (\$10 credit plus \$25 task earnings) on a computerized choice task.

Following each card selection, participants were credited with some amount of money, which was accompanied by a sound. Occasionally after a card selection, participants simultaneously won and lost some amount of money, accompanied by a different sound. Total earnings were updated in the counter after each selection. The task was stopped after 100 card selections (participants were not told this information prior to task onset), and there was no time limit. Selection of a card from two of the decks (C and D) paid an average of \$0.50 per card, and was associated with an average loss of \$0.25 per card. Thus, if a participant exclusively selected from these “advantageous” decks, her/his net earnings would be \$25.00. In contrast, selection of a card from the other two decks (A and B) paid an average of \$1.00 per card selection, but these decks were associated with an average penalty of \$1.25 per card. Thus, if a participant exclusively selected from these “disadvantageous” decks, her/his net earnings would be $-\$25.00$. Therefore, the values employed in the task were considerably smaller than in the traditional version of the Iowa Gambling task, but the value proportions were identical. Advantageous and disadvantageous decks were randomly assigned by the computer between decks A-D at the start of each task administration. At the end of each administration, the net earnings were displayed on the computer screen and participants were paid their earnings at the end of the testing session.

Hypothetical condition: This condition was identical to the Cash condition, except participants were told that the task money was not real, and they were not handed any cash.

Under both conditions, the primary dependent measure for decision-making was card selection (number of cards selected from advantageous decks), with higher values indicating more advantageous decision-making and lower values indicating less advantageous decision-making. The dependent measure for task effort was time spent to complete the task (sec), with slower times indicating greater effort and faster times indicating lesser effort. Money earned on the task (\$) was also examined.

2.3.2. Wechsler Adult Intelligence Scale - Third Edition (WAIS-III) Block Design and Vocabulary subtests (Wechsler, 1997)—These manually-administered tasks require the participant to copy increasingly difficult geometric patterns using colored blocks, and to define increasingly difficult words, respectively. They were administered to estimate intellectual functioning (Ringe et al., 2002).

2.3.3. Wisconsin Card Sorting Task (WCST; Heaton, 2005)—This computerized task requires the participant to match cards with different designs on them to four sample cards by pressing keys that matched the samples. The rules that govern the matching (color, shape and number) are unknown to the participant, must be learned based on feedback (correct/incorrect), and covertly shift after 10 consecutive correct matches (category). The primary performance variable was the number of categories completed over 128 trials, which is a measure of categorization ability and cognitive flexibility.

The WAIS-III subtests and the WCST were administered for descriptive purposes and no monetary contingency was applied to these tasks.

2.4. Data Analyses

Participants' individual data were first examined to assess task completion and adequate deck sampling; i.e., at least one choice from each deck. One participant did not meet the deck sampling requirement and his data were replaced with that of a new participant who adequately sampled all four decks under each condition. All other participants completed 100 trials under each condition and met the deck sampling requirement. To assess the impact of modifications to the Gambling task (i.e., lower money values, deck order randomization), we first calculated the mean earnings per selection from each deck under each condition, and compared their relative values (the values for Decks A and B should be lower than Decks C and D). Next, we examined Pearson correlations between card selection and net earnings under each condition (card selection and earnings should be positively correlated).

Task performance was examined as a function of group and payment condition (cocaine abusers vs. controls under the Cash vs. Hypothetical conditions) by mixed (condition $\times$ group) repeated measures Analyses of Variance (ANOVA); one ANOVA was conducted for each dependent measure. Significant interactions were probed for group differences under each condition by two-tailed independent-samples t-tests. To examine the effects of condition order on task performance, condition order (Hypothetical first vs. Cash first) was inserted as a second between-group factor in the above ANOVA model, and the main effects of condition order on task performance were examined. Only p-values < 0.05 were considered statistically significant.

3. Results

3.1. Mean Gambling task deck earnings (Table 3) and intercorrelations

Mean deck earnings per selection were in the expected directions under each condition (i.e., Decks A and B < Decks C and D). Additionally, moderate correlations between card selection and money earned under each condition were seen (Hypothetical condition, $r=0.36$; Cash condition, $r=0.32$, all $p's < 0.05$). This indicates that under each condition, those participants who selected a relatively greater number of advantageous cards earned more money than those who selected relatively fewer advantageous cards. Together, these results demonstrate that despite modifications to the Gambling task, the relative deck values and interrelationships between dependent measures were in expected directions in this sample.

3.2. Card selection (Figure 1, upper panel)

There was no main effect of condition, but there was a main effect of group on card selection ($F_{1,42} = 6.53$, $p < 0.05$), with the cocaine abusers selecting less cards from advantageous decks than the control participants overall. There was a condition $\times$ group interaction on card selection ($F_{1,42} = 5.78$, $p < 0.05$). Under the Hypothetical condition, the cocaine abusers selected about 14 less cards from advantageous decks than the control participants ($t_{40} = 3.75$, $p < 0.05$). In contrast, under the Cash condition, no group differences were observed. Thus, the cocaine abusers selected less advantageously than control participants only under the hypothetical monetary contingency. There was no main effect of condition order on card selection.

3.3. Money earned (Figure 1, middle panel)

There was a main effect of condition on money earned, with both groups earning more money under the Cash condition than the Hypothetical condition ($F_{1,42} = 4.39$, $p < 0.05$). There was no main effect of group, nor any condition $\times$ group interaction on card selection, indicating that both groups earned similar amounts of money overall and within each condition. There was no main effect of condition order on card selection.

3.4. Task completion time (Figure 1, lower panel)

There was a main effect of condition on task completion time, with slower performance for both groups under the Cash condition, relative to the Hypothetical condition ($F_{1,42} = 25.93$, $p < 0.05$). There was a main effect of group on task completion time, with cocaine abusers taking longer to complete the task than the control participants overall ($F_{1,42} = 7.75$, $p < 0.05$). There also was a condition $\times$ group interaction on task completion time ($F_{1,42} = 4.61$, $p < 0.05$). Under the Hypothetical condition, no group differences were observed. In contrast, under the Cash condition, the cocaine abusers took about 75 seconds longer to complete the task than the control participants ($t_{29} = -3.06$, $p < 0.05$). Thus, the cocaine abusers took more time than the control participants to complete the task only under the cash monetary contingency. There was no main effect of condition order on card selection.

4. Discussion

This data indicated that relative to control participants, cocaine-dependent individuals selected fewer cards from advantageous decks on a modified Gambling task under hypothetical payment conditions, but selected a similar number of cards from advantageous decks under cash payment conditions. Additionally, cocaine abusers spent more time than controls to complete the task under the cash payment condition. To our knowledge, this was the first direct comparison of Gambling task performance under hypothetical and cash payment conditions in the same participants. This was also the first study of Gambling task performance in cocaine

abusers that incorporated a control group that was similar in terms of reported alcohol and marijuana use.

The finding that the cocaine abusers' card selection was similar to the control participants under the Cash condition supports our hypothesis that cocaine abusers' performance would benefit from the cash monetary contingency, and is consistent with studies demonstrating the reinforcing efficacy of money in cocaine abusers (e.g., Hart et al., 2000). This finding was striking given that the cocaine abusers had reported using cocaine for most of their adult lives, and might not have been expected to perform similarly to the control participants under any condition. Since the control group included a number of light-to-moderate users of marijuana and alcohol, the performance data under the Hypothetical condition replicates and extends the results of previous studies (Stout et al., 2004; Verdejo-Garcia et al., 2007b) that employed exclusively non-substance-using controls.

The lack of group differences on card selection under the Cash condition contrasts with prior findings that long-term cocaine abusers exhibited less advantageous card selection on the Gambling task than marijuana abusers or healthy controls, when tested under exclusively cash payment conditions (Verdejo-Garcia et al., 2007a). However, the groups of participants in the Verdejo-Garcia et al. (2007a) study were tested during an inpatient stay that was greater in length for the drug abusers (25 days) than the controls (three days), which may have altered the perceived value of the monetary contingency.

In the current study, the cocaine abusers reported less than half as much annual income as the control participants, on average. As such, the cocaine abusers may have perceived a greater value for the money earned on the task than the controls, and were correspondingly more motivated to earn the task money. This interpretation is supported by the finding that the cocaine abusers spent more time completing the Gambling task under the Cash condition than the control participants, which suggests greater effort or care (see Clark et al., 2006; Dickman and Meyer, 1988) on the part of the cocaine abusers' when real money was at stake. Since the participants were tested on an outpatient basis, this value-based financial contingency was likely more proximate for them than for the inpatient participants in the Verdejo-Garcia et al. (2007a) study, who were presumably living expense-free for the duration of the study. Additionally, the cocaine abusers in the Verdejo-Garcia et al. (2007a) study spent a longer time as inpatients prior to testing than the controls, making this contingency even less proximate for the cocaine abusers. In contrast, Stout et al. (2005) administered the Gambling task with exclusively cash payment to mixed substance abusers (n=66) and healthy control participants (n=58) under identical outpatient testing conditions, and found no overall group differences on card selection. These observations are consistent with a role for the value function of task earnings on task performance and effort for substance abusers, although there may have been an inverse effect of lower education as well (e.g., Evans et al., 2004).

Though all participants increased their money earned from the Hypothetical condition to the Cash condition, and there were no group differences on money earned on the Gambling task under either condition, the chance to earn real money under the Cash condition surprisingly appears to have engendered a riskier card selection strategy for the control participants and a more conservative strategy for the cocaine abusers. Evidence from between-participants studies (Bowman & Turnbull, 2003; Fernie & Tunney, 2006) in college undergraduates did not suggest that card selection would become riskier under the monetary contingency for non-drug abusers. Since the control participants in the current study likely had more disposable income than the cocaine abusers, it is possible that the controls felt more comfortable with riskier selections under the Cash condition, akin to games of chance in the natural ecology. This issue remains the subject of future research.

Although it has been suggested that cocaine abusers exhibit a decreased sensitivity to monetary incentive relative to control participants (e.g., Goldstein et al., 2007a; 2007b), the results of the current study demonstrated that a monetary contingency improved cocaine abusers' decision-making on a laboratory task, relative to control participants. The monetary contingency also slowed the decision-making of cocaine abusers; having patients engage in more deliberate decision-making is a goal of cognitive-behavioral therapies for cocaine abuse (Carroll & Rawson, 2005). In sum, these findings suggest that incentives that are tangible and relatively immediate can promote adaptive decision-making in cocaine abusers, consistent with the results of clinical treatment studies in cocaine abusers (Higgins et al., 2000; Rigsby et al., 2000). The role of improved decision-making as a mechanism by which reinforcement-based behavioral treatments might decrease drug use is an interesting notion and requires further investigation.

There are several limitations to the current study. A number of group demographic and clinical differences were observed, such as lower reported education and estimated IQ levels, and greater depressive symptoms, in the cocaine abusers relative to the controls. These differences could potentially explain the disadvantageous card selection of the cocaine abusers in the current study under the Hypothetical condition. However, the results of several previous studies employing hypothetical earnings on the Gambling task are inconsistent with this notion. Bechara et al. (2001) found that neither education¹ nor IQ were associated with card selection on the Gambling task in substance abusers. Additionally, studies in substance-abusing participants (Hanson et al., 2008) and partially-remitted depressive participants (Westheide et al., 2007) found no association between depressive symptoms² and card selection. Therefore, group differences in these demographic/clinical variables may not have significantly influenced Gambling task performance for hypothetical earnings in the current study.

In contrast, Hanson et al. (2008) did report correlations between the frequency of self-reported substance use, including cocaine, marijuana and alcohol use, and card selection. Notably, at least one study (Verdejo-Garcia et al., 2007a) that employed cash payment for Gambling task performance in cocaine abusers found a similar pattern, whereby card selection was correlated with reported substance use, but not IQ. These findings support our choice to focus on controlling for other substance use in the current study. However, due to the relatively small sample size (albeit larger than previous studies of Gambling task performance in cocaine users), we were unable to statistically account for the influence of these various participant characteristics. It should also be pointed out that even if the cocaine abusers' lower intellectual functioning and increased depressive symptoms decreased their performance under the Hypothetical condition, the group similarities in performance under the Cash payment condition only emphasized the robust motivational nature of the monetary contingency's effect in cocaine abusers. It would be interesting to examine whether the monetary contingency has a similar impact in cocaine abusers relative to controls with similar demographic and clinical characteristics.

Another limitation was that the \$10 credit system for the Cash condition did not require participants to pay for losses out of personal funds, so it is likely that the negative consequences were not as salient as the positive consequences. This limitation could be addressed by requiring the participants to use a portion of their study compensation to pay for their losses; similar procedures have been used effectively in other studies examining behavioral choice in cocaine abusers (e.g., Hart et al., 2007). Related to this, it is unknown how different magnitudes of earnings and losses would have influenced the pattern of results (e.g., van den Bos et al., 2006), since this was not manipulated in the current study. Further research is needed to fully

¹Mean education levels of both the substance abusers and controls in this study were similar to participants in the current study.

²Mean BDI-II scores of both substance abusers and controls in these studies were similar to participants in the current study.

characterize the demographic, clinical and financial influences on Gambling task performance in cocaine abusers.

References

- Adinoff B, Devous MD Sr, Cooper DB, Best SE, Chandler P, Harris T, Cervin CA, Cullum CM. Resting regional cerebral blood flow and gambling task performance in cocaine-dependent subjects and healthy comparison subjects. *Am J Psychiatry* 2003;160:1892–1894. [PubMed: 14514509]
- American Psychiatric Association. Diagnostic and Statistical Manual of Mental Disorders. American Psychiatric Association; Washington, DC: 1994. T
- Bartzokis G, Lu PH, Beckson M, Rapoport R, Grant S, Wiseman EJ, London EE. Abstinence from cocaine reduces high-risk responses on a gambling task. *Neuropsychopharmacology* 2000;22:102–103. [PubMed: 10633497]
- Bechara A. Risky business: emotion, decision-making, and addiction. *J Gambl Stud* 2003;19:23–51. [PubMed: 12635539][Review] [71 refs]
- Bechara A, Dolan S, Denburg N, Hindes A, Anderson SW, Nathan PE. Decision-making deficits, linked to a dysfunctional ventromedial prefrontal cortex, revealed in alcohol and stimulant abusers. *Neuropsychologia* 2001;39:376–389. [PubMed: 11164876]
- Bechara A, Tranel D, Damasio H. Characterization of the decision-making deficit of patients with ventromedial prefrontal cortex lesions. *Brain* 2000;123:2189–2202. [PubMed: 11050020]
- Beck, AT.; Steer, R.; Brown, G. BDI-II Beck Depression Inventory Manual. Harcourt Brace & Company; San Antonio, TX: 1996.
- Bolla KI, Eldreth DA, London ED, Kiehl KA, Mouratidis M, Contoreggi C, Matochik JA, Kurian V, Cadet JL, Kimes AS, Funderburk FR, Ernst M. Orbitofrontal cortex dysfunction in abstinent cocaine abusers performing a decision-making task. *Neuroimage* 2003;19:1085–1094. [PubMed: 12880834]
- Bolla KI, Eldreth DA, Matochik JA, Cadet JL. Neural substrates of faulty decision-making in abstinent marijuana users. *Neuroimage* 2005;26:480–492. [PubMed: 15907305]
- Bowman CH, Turnbull OH. Real versus facsimile reinforcers on the Iowa Gambling Task. *Brain Cogn* 2003;53:207–210. [PubMed: 14607149]
- Carroll, KM.; Rawson, RA. Relapse Prevention for Stimulant Dependence. Maintenance strategies in the treatment of addictive behaviors. In: Marlatt, G Alan; Donovan, Dennis M., editors. Relapse prevention. Vol. 2nd. 2005. 2005
- Clark L, Robbins TW, Ersche KD, Sahakian BJ. Reflection impulsivity in current and former substance users. *Biological Psychiatry* 2006;60:515–522. [PubMed: 16448627]
- Dickman SJ, Meyer DE. Impulsivity and speed-accuracy tradeoffs in information processing. *Journal of Personality & Social Psychology* 1988;54:274–290. [PubMed: 3346814]
- Epstein, JN.; Johnson, DE.; Conners, CK. Conner's Adult ADHD Diagnostic Interview for DSM-IV (CAADID). Multi-Health Systems, Inc.; North Tonawanda, New York: 2001.
- Evans CEY, Kemish K, Turnbull OH. Paradoxical effects of education on the Iowa Gambling Task. *Brain & Cognition* 2004;54:240–244. [PubMed: 15050783]
- Fernie G, Tunney RJ. Some decks are better than others: the effect of reinforcer type and task instructions on learning in the Iowa Gambling Task. *Brain Cogn* 2006;60:94–102. [PubMed: 16271818]
- Fillmore MT, Rush CR. Impaired inhibitory control of behavior in chronic cocaine users. *Drug Alcohol Depend* 2002;66:265–273. [PubMed: 12062461]
- First, MB.; Spitzer, RL.; Gibbon, M.; Williams, JBW. Structured Clinical Interview for DSM-IV Axis I Disorders-Patient Edition (SCID-I/P, version 2.0). Biometrics Research Department, New York State Psychiatric Institute; New York: 1995.
- Goldstein RZ, Alia-Klein N, Tomasi D, Zhang L, Cottone LA, Maloney T, Telang F, Caparelli EC, Chang L, Ernst T, Samaras D, Squires NK, Volkow ND. Is decreased prefrontal cortical sensitivity to monetary reward associated with impaired motivation and self-control in cocaine addiction? *Am J Psychiatry* 2007a;164:43–51. [PubMed: 17202543]see comment
- Goldstein RZ, Tomasi D, Alia-Klein N, Cottone LA, Zhang L, Telang F, Volkow ND. Subjective sensitivity to monetary gradients is associated with frontolimbic activation to reward in cocaine abusers. *Drug Alcohol Depend* 2007b;87:233–240. [PubMed: 16997508]

- Hanson KL, Luciana M, Sullwold K. Reward-related decision-making deficits and elevated impulsivity among MDMA and other drug users. *Drug & Alcohol Dependence* 2008;96:99–110. [PubMed: 18384979]
- Hart CL, Haney M, Foltin RW, Fischman MW. Alternative reinforcers differentially modify cocaine self-administration by humans. *Behav Pharmacol* 2000;11:87–91. [PubMed: 10821213]
- Hart CL, Haney M, Vosburg SK, Rubin E, Foltin RW. Gabapentin does not reduce smoked cocaine self-administration: employment of a novel self-administration procedure. *Behav Pharmacol* 2007;18:71–75. [PubMed: 17218799]
- Heaton, RK. Wisconsin Card Sorting Test--Computer Version 4--Research Edition--"English". Psychological Corporation; San Antonio, TX: 2005.
- Heil SH, Johnson MW, Higgins ST, Bickel WK. Delay discounting in currently using and currently abstinent cocaine-dependent outpatients and non-drug-using matched controls. *Addict Behav* 2006;31:1290–1294. [PubMed: 16236455]
- Higgins ST, Bickel WK, Hughes JR. Influence of an alternative reinforcer on human cocaine self-administration. *Life Sci* 1994;55:179–187. [PubMed: 8007760]
- Higgins ST, Wong CJ, Badger GJ, Ogden DE, Dantona RL. Contingent reinforcement increases cocaine abstinence during outpatient treatment and 1 year of follow-up. *J Consult Clin Psychol* 2000;68:64–72. [PubMed: 10710841]
- Monterosso J, Ehrman R, Napier KL, O'Brien CP, Childress AR. Three decision-making tasks in cocaine-dependent patients: do they measure the same construct? *Addiction* 2001;96:1825–1837. [PubMed: 11784475]
- Quednow BB, Kuhn KU, Hoppe C, Westheide J, Maier W, Daum I, Wagner M. Elevated impulsivity and impaired decision-making cognition in heavy users of MDMA ("Ecstasy"). *Psychopharmacology* 2007;189:517–530. [PubMed: 16425060]
- Rigsby MO, Rosen MI, Beauvais JE, Cramer JA, Rainey PM, O'Malley SS, Dieckhaus KD, Rounsaville BJ. Cue-dose training with monetary reinforcement: pilot study of an antiretroviral adherence intervention. *J Gen Intern Med* 2000;15:841–847. [PubMed: 11119180]see comment
- Ringe WK, Saine KC, Lacritz LH, Hynan LS, Cullum CM. Dyadic short forms of the Wechsler Adult Intelligence Scale-III. *Assessment* 2002;9:254–260. [PubMed: 12216782]
- Stout JC, Busemeyer JR, Lin A, Grant SJ, Bonson KR. Cognitive modeling analysis of decision-making processes in cocaine abusers. *Psychon Bull Rev* 2004;11:742–747. [PubMed: 15581127]
- Stout JC, Rock SL, Campbell MC, Busemeyer JR, Finn PR. Psychological processes underlying risky decisions in drug abusers. *Psychol Addict Behav* 2005;19:148–157. [PubMed: 16011385]
- Tucker KA, Potenza MN, Beauvais JE, Browndyke JN, Gottschalk PC, Kosten TR. Perfusion abnormalities and decision making in cocaine dependence. *Biol Psychiatry* 2004;56:527–530. [PubMed: 15450790]
- Vadhan NP, Hart CL, van Gorp WG, Gunderson EW, Haney M, Foltin RW. Acute effects of smoked marijuana on decision making, as assessed by a modified gambling task, in experienced marijuana users. *J Clin Exp Neuropsychol* 2007;29:357–364. [PubMed: 17497559]
- van den Bos R, Houx BB, Spruijt BM. The effect of reward magnitude differences on choosing disadvantageous decks in the Iowa Gambling Task. *Biol Psychol* 2006;71:155–161. [PubMed: 16095798]
- Verdejo-Garcia A, Benbrook A, Funderburk F, David P, Cadet JL, Bolla KI. The differential relationship between cocaine use and marijuana use on decision-making performance over repeat testing with the Iowa Gambling Task. *Drug Alcohol Depend* 2007a Sep;90:2–11. [PubMed: 17367959]20072-11
- Verdejo-Garcia AJ, Perales JC, Perez-Garcia M. Cognitive impulsivity in cocaine and heroin polysubstance abusers. *Addict Behav* 2007b;32:950–966. [PubMed: 16876962]
- Wechsler, D. The Wechsler Adult Intelligence Scale. Vol. Third. The Psychological Corporation; San Antonio, TX: 1997.
- Westheide J, Wagner M, Quednow BB, Hoppe C, Cooper-Mahkorn D, Strater B, Maier W, Kuhn KU. Neuropsychological performance in partly remitted unipolar depressive patients: focus on executive functioning. *Eur Arch Psychiatry Clin Neurosci* 2007;257:389–395. [PubMed: 17629730]

Figure 1.

Gambling task performance by group under Hypothetical and Cash conditions; card selection (upper panel), money earned (middle panel), time spent (lower panel); each error bar represents one SEM; *indicates a between-group difference ($p < 0.05$)

Table 1

Demographic and clinical characteristics

	COCAINE ABUSERS			CONTROLS			Test value	p value
	M	SD		M	SD			
Age (yrs)	40.3	4.4		36.9	7.8		$t_{37} = -1.9$	0.07
Education (yrs)	13.1	1.8		15.4	1.7		$t_{44} = 4.4$	0.001
Annual income (\$)	19,733	18,513		39,971	25,894		$t_{44} = 2.8$	0.008
BDI-II	9.1	8.7		1.8	3.2		$t_{26} = -3.7$	0.001
WAIS-III FSIQ (est.)	92.1	8.9		103.2	12.9		$t_{44} = 3.4$	0.002
WCST Categories	5.75	1.6		4.9	1.8		$t_{44} = -1.6$	0.12

Race ^a	Black	%	n	%	n	$\chi^2 = 9.8$	0.002
	Hispanic	86.4	19	41.7	10		
	White	4.5	1	12.5	3		
	Other	9.1	2	41.7	10		
		0.0	0	4.2	1		
Sex	Male	86.4	19	87.5	21	Fisher's exact = 1.00	
	Female	13.6	3	12.5	3		

^a comparison based on Black vs. not Black

Table 2

Substance use

Cocaine	COCAINE ABUSERS		CONTROLS		Test Value ^a	P value
	n=22 users		n=0 users			
	M	SD	M	SD		
Days of use/week	4.1	1.4				
\$ spent/week	294.6	195.9				
Most recent use (hrs prior to testing)	32.7	26.9				
Most recent use (\$)	95.1	89.6				
Years of regular use	20.5	5.0				
Marijuana	n=12 users		n=8 users		$\chi^2 = 2.1$	0.15
	M	SD	M	SD		
Days of use/week	2.5	2.3	3.6	2.2	$t_{18} = 1.1$	0.30
\$ spent/week	27.3	39.1	30.6	22.9	$t_{18} = 0.2$	0.83
Alcohol	n=18 users		n=14 users		$\chi^2 = 3.0$	0.08
	M	SD	M	SD		
Days of use/week	3.2	1.9	1.9	1.2	$t_{29} = -2.2$	0.04
SDUs/week ^b	15.4	15.6	7.0	7.1	$t_{29} = -1.9$	0.07
Both marijuana and alcohol	n=11 users		n=8 users		$\chi^2 = 1.3$	0.25

^a df for all chi-square tests = 1

^b standard drink units (i.e., 12-oz beer, 4.5-oz wine, 1.25-oz liquor)

Table 3

Mean deck earnings (\$)

	Hypothetical		CONDITION	
	<u>M</u>	<u>SD</u>	<u>Cash</u> <u>M</u>	<u>SD</u>
Deck A	-0.34	0.34	-0.38	0.51
Deck B	-0.42	0.58	-0.23	0.67
Deck C	0.24	0.07	0.24	0.07
Deck D	0.22	0.12	0.17	0.20