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Decision-Making Deficits Linked to Real-life Social Dysfunction in Crack Cocaine-Dependent Individuals

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Crack cocaine-dependent individuals (CCDI) present abnormalities in both social adjustment and decision making, but few studies have examined this association. This study investigated cognitive and social performance of 30 subjects (CCDI × controls); CCDI were abstinent for 2 weeks. We used the Social Adjustment Scale (SAS), Wisconsin Card Sorting Test (WCST), and Iowa Gambling Task (IGT). Disadvantageous choices on the IGT were associated with higher levels of social dysfunction in CCDI, suggesting the ecological validity of the IGT. Social dysfunction and decision making may be linked to the same underlying prefrontal dysfunction, but the nature of this association should be further investigated. (Am J Addict 2010;20:78–86)

INTRODUCTION

The widespread use of cocaine may be explained by the fact that cocaine is one of the most potent reinforcing drugs of abuse.[1] Although cocaine users initially see cocaine as a possible remediation to personal problems, the reality is that chronic cocaine use is associated with several problems in personal and social domains.[2–4] Crack cocaine-dependent individuals (CCDI) usually present problems at school and with family.[3] Work dysfunction is also frequently observed in adult CCDI: the degree of work dysfunction in CCDI is worse than that of psychiatric patients with panic disorder, depression, or bulimia.[2] Moreover, there are studies reporting that CCDI are more likely to engage in risk-taking behavior[5] and that they may even have a high-rate mortality, due to their poor social adjustment.[6]

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Many studies have shown that specific brain areas, such as the prefrontal cortex (PFC), which play an important role in social behavior, may be affected in CCDI.[7–11] The intermittent dopamine (DA) stimulation that follows cocaine use produces acute changes in the synapses and in dopaminergic neurons associated with pleasure and reward.[12] In the long term, cocaine use may cause structural and functional impairments in certain parts of the brain, including the orbitofrontal cortex (OFC).[8,9,13] The OFC, especially the mesial sector, is the part of the PFC associated with certain executive cognitive functions (ECFs), such as affective decision making and impulse control, as well as emotional control and social behavior.[8,10,14–18] In fact, neurological patients with OFC lesions show marked deficits in social adjustment and personality changes, which result in real-life problems.[14,19] Interestingly, the impaired judgment and poor risk evaluation observed in patients with OFC lesions are somewhat similar to the inability of CCDI to modify their behavior, even when faced with the significant adverse consequences of cocaine use.[8,10,15,18,20] Although CCDI are generally aware of their actions that lead to drug-related problems, they repeatedly fail to demonstrate self-control, and they persist to use cocaine, despite adverse consequences on health and social functioning;[10,15] this is one of the core symptoms of cocaine dependence, according to the DSM-IV-TR.[21]

Although CCDI typically present abnormalities in both social adjustment and decision making, few studies have tried to obtain a direct link between what one finds in the laboratory on decision-making and impulse control tasks, and what actually happens in the real social life of these patients. Some studies of substance abusers have focused on their performance on the Iowa Gambling Task (IGT), as well as on the functional activity of the neural systems subserving decision making using functional neuroimaging techniques.[7,8,20] However, there have been few studies to

date that addressed the relationship between performance on the IGT and the abusers' real-life problems. One study did note a link between IGT performance and the ability to maintain gainful employment,[15] but this observation was not thoroughly addressed. The second study did note an association between more aspects of real-life functioning and performance on IGT,[22] but it was based on a general scale to evaluate addiction-related symptoms and it did not analyze information about financial problems. In addition to the fact that these studies did not use specific measures of social dysfunction, it is relevant to note that they were entirely based on U.S.A. samples, so there is also a need to ask whether the possible association between decision-making deficits and social dysfunction in CCDI would apply to other cultures, especially in developing countries.

Therefore, the primary aim of the current study was to investigate the association between decision-making deficits, as measured by neuropsychological tasks, and social dysfunction, as measured by an instrument that provides objective and detailed measures of social dysfunction, in a sample of CCDI, and compare the results to a matching control group. A secondary aim of this paper was to examine whether the ecological validity of the IGT would extend to other cultures, namely Brazilian culture. It was hypothesized that: (1) the CCDI will have poor decision-making abilities on the IGT when compared with the control group; (2) the decision-making deficits in the CCDI will be correlated with the social adjustment impairments observed in the real life of these patients; and (3) the IGT has an ecological validity even in a very different culture, such as the Brazilian culture.

METHOD

Participants

Thirty subjects participated in this study. The CCDI ($n = 15$) met the DSM-IV-TR criteria[21] for crack-cocaine dependence at the time of admission to the treatment program (cocaine group). The CCDI were recruited from two inpatient units: (1) the Interdisciplinary Group of Studies on Alcohol and Drugs (GREA) at the University of São Paulo (USP); (2) the Association for the Promotion of Prayer and Work (APOT) in Campinas (São Paulo state, Brazil). Exclusion criteria included (1) past or current major DSM-IV-TR diagnosis of psychotic disorders, or a current diagnosis of bipolar disorders; (2) met DSM-IV-TR criteria for opioid dependence; (3) had a history of neurological condition such as head injuries with loss of consciousness for longer than an hour, strokes, and intracranial hemorrhages; (4) had prior diagnosis of learning disorder; (5) had intellectual quotient (IQ) less than 70. The CCDI were all treatment-seeking substance-dependent patients evaluated after at least 2 weeks of inpatient treatment. It was assumed that the CCDI had been abstinent for an average of 2 weeks before their evaluation. The abstinence was verified by self-report and supervised by the clinical staff of the inpatient units (no urine tests were available in both treatment centers at the time of the data collection), since recent cocaine use may mask cognitive impairments in CCDI.[23,24] The neurocognitive performance of the CCDI was compared to a control group which consisted of 15 healthy individuals ($n = 15$), who were volunteers, recruited in the city of São Paulo. The transport costs of the volunteers were reimbursed. The exclusion criteria for the control group were (1) met DSM-IV-TR criteria for any psychoactive substance dependence other than nicotine; (2) the same exclusion criteria of the cocaine group.

Procedures and Ethical Considerations

The data presented in this report were collected between January 2001 and February 2005. The research protocol satisfied the Helsinki Declaration and was approved by the University of Sao Paulo Review Board (CAPPesq). After signing an informed consent, participants were interviewed by either a clinical psychologist or a psychiatrist. The interview questions covered demographics, drug use, and the consequences of drug use on their psychosocial functioning. Investigators obtained initial demographic and clinical information by a semi-structured interview used by neuropsychologists at our research center. The semi-structured neuropsychological interview included basic information such as name, address, gender, age, ethnicity, handedness, educational background, professional activities, socioeconomic level, as well as questions about the medical past and current history, neurodevelopmental history, and neurocognitive complaints associated with cocaine and drug use.[25]

Mood, Anxiety, and Drug Use Evaluation

Psychological and psychiatric symptoms were assessed by the Beck Depression Inventory (BDI)[26] and the State-Trait Anxiety Inventory (STAI).[27] Alcohol, tobacco, and other drug use, as well as the consequences of drug use among the cocaine group, were assessed using the *Cocaine Addiction Severity Test* (CAST) and *Cocaine Assessment Profile* (CAP).[4] The neuropsychological tests, drug use questionnaires, and psychiatric rating scales were administered in a single session, usually in the morning, to avoid the fluctuations, which occur throughout the day. The IQ was estimated based on the scaled scores, provided by the two subtests of the Wechsler Adult Intelligence Scale-Revised (WAIS-R),[28] Vocabulary and Block Design.[29]

Neuropsychological Measures

The Wisconsin Card Sorting Test (WCST)[30]—64 card version,[31] was translated, and validated for use in Brazil.[32] All cards used have a color (blue, red, green, yellow), a geometric shape (star, triangle, cross, circle), and a quantity (number: 1, 2, 3, 4). Four stimulus cards are placed in front of the subject. The participant then receives a deck of 64

cards and is asked to draw a card and match it to one of the 4 stimulus cards. After each trial, the examiner says whether the response is correct or incorrect. The sorting principle (criterion for a correct response) is not revealed to the participant beforehand, meaning that to perform successfully he or she must first deduce the sorting principle from the examiner's feedback and then maintain a consistent pattern of answers. The first sorting principle for correct categorization is color and is maintained until the subject gives 10 consecutive correct answers. The sorting principle is then changed to shape until the subject gives another 10 consecutive correct answers and then to quantity. This sequence of changing of sorting principle is repeated until all 64 cards have been played. The WCST evaluates abstraction ability, mental flexibility, and sustained attention.[10,30,33] Five measures of performance were analyzed: (1) categories: number of sets of 10 correct consecutive matches; (2) total errors; (3) perseverative errors: number of errors that follow an alteration of the sorting principle; (4) nonperseverative errors; (5) failure to maintain set: the number of times the subject, after five or more consecutive correct responses, makes an error before achieving a complete category.

The IGT[14,15] was translated, adapted, and validated for use in Brazil.[34,35] The IGT is a computer-based test with four decks of cards (A, B, C, and D) appearing on a computer screen in front of the subject. Each participant is lent 2,000 virtual U.S. dollars (in Brazil, we adapted the instructions to Brazilian currency), which are shown on a red bar in the upper left side of the screen. The subject's objective is to win as much money as possible by choosing cards one at a time from the four decks using a mouse until informed to stop (after the selection of the 100th card). The player wins a varying amount of money (a reward) for every card he draws, but some cards also carry a penalty. The rewards obtained from drawing cards from decks A and B are substantially higher than those obtained from decks C and D. However, the penalty amounts are much higher in the high-paying decks (A and B) than in the low-paying decks (C and D) to the extent that A and B are considered "bad decks" (ie, will result in a net loss) and C and D are "good decks" (ie, will result in a net profit). The net outcome score (Netscore) is the number of picks from the "good decks" minus the number of picks from the "bad decks" (Netscore = [C + D] − [A + B]). The evolution of the Netscore over consecutive blocks of 20 picks (trials 1–20, 21–40, 41–60, 61–80, and 81–100) provides a measure of task learning. IGT assesses decision making, impulse control, and the ability to evaluate immediate gains over long-term losses.[8,10,14,35]

Vocabulary from the WAIS-R[28] was translated and adapted for use in Brazil.[36] This test uses a list of 35 words of varying difficulty. The examiner asks the subject to explain the meaning of words from the list one at a time. Each answer is scored 2, 1, or 0, depending on the subject's knowledge of what the word means. The maximum score is 70 points. The Vocabulary subtest of the WAIS-R is considered not only a good measure of verbal ability (vocabulary) and general knowledge but also a reliable estimate of premorbid intellectual functioning.[33]

Block Design from the WAIS-R[28] was translated and adapted for use in Brazil.[36] This test is composed of nine colored cubes whose sides are white, red, or white and red, and nine cards with printed diagrams of arrangements of the cubes. The subject has to use the cubes to produce the nine arrangements in turn. Each of the nine cards has a time limit and a maximum score that varies according to the difficulty of the task. The subject receives bonus points if he builds a given arrangement more quickly. The maximum score is 51 points. According to the norms, the subject is considered to have failed in a task if his construction is faulty or if the construction is not completed within the time limit.

Objective Measurement of the Social Dysfunction

The Social Adjustment Scale Self-Report (SAS-SR)[37] was translated and validated for use in Brazil.[2] The SAS-SR is a 42-item instrument that covers several areas of social functioning such as work, leisure activities, family, marital role, parental role, family unit, and economic aspects. The SAS-SR was used to evaluate the concurrent validity of the Addiction Severity Index (ASI),[38] which is one of the most widely used instruments in the addictions field.[39] The ASI clinical ratings of social problems were significantly correlated with the social functioning as measured by the SAS-SR.[38] The SAS-SR is a more detailed instrument to evaluate social behavior than the ASI. The SAS-SR is a simple and inexpensive method, which use allows a routine assessment of patient adjustment, since no training program and reliability studies between the raters are required; since the SAS-SR is a self-report scale, the interviewer's bias is absent. Moreover, the SAS-SR was adapted from existing scales and had demonstrated both sensitivity and utility with depressed patients, schizophrenics, alcoholics, and CCDI.[2,37] Each item is scored on a five-point scale. One example of these questions for assessing parent role "impaired communication" is: have you been able to talk and listen to your children during the last 2 weeks? Include only children over the age of 2 (1 = I was always able to communicate with them; 2 = I was usually able to communicate with them; 3 = About half the time I could communicate; 4 = I was usually not able to communicate; 5 = I was completely unable to communicate; 6 = Not applicable, no children under the age of 2). An overall score is obtained by summing the individual scores for each item and dividing by the number of items. The higher the score obtained, the greater the impairment of social adjustment (1, normal; 5, severe maladjustment; 6, not applicable). The SAS-SR was initially developed in English.[37] The SAS-SR was translated into Portuguese and validated with a Brazilian sample.[2] Because our clinical sample of CCDI were inpatients in treatment facilities for an average of 2 weeks, and the SAS-SR includes several questions that comprise

TABLE 1. Demographic variables, psychiatric symptoms, estimated, and premorbid intellectual quotient (IQ) of control group and cocaine group

	Control group ($n = 15$)	Cocaine group ($n = 15$)	P value*
Age, years	26.60 ± 6.62	25.67 ± 6.53	.70
Education, years	11.20 ± 1.66	10.53 ± 2.36	.37
Socioeconomic status	$R\$2,060.00 \pm 1,242.57$	$R\$2,832.00 \pm 2,115.21$	.23
Race, Latin/African Brazilian	14/1	13/2	.50
Handedness (R/L)	14/1	14/1	.75
Estimated IQ (WAIS-R)	100.07 ± 10.61	95.47 ± 10.70	.24
Premorbid IQ (vocabulary)	44.60 ± 6.92	41.60 ± 7.63	.27
Depressive symptoms (BDI)	3.07 ± 3.39	18.71 ± 11.81	$<.01^{\dagger}$
Anxiety traits (STAI/T)	32.87 ± 10.37	49.20 ± 10.59	$<.01^{\dagger}$

Notes: R = right; L = left; IQ = intellectual quotient; BDI = Beck Depression Inventory; STAI/T = state-trait anxiety inventory/trait. Data are presented as means ± standard deviations. Socioeconomic status is represented by the familiar monthly income: values are described in Brazilian currency—each American Dollar (U.S.$1.00) was equivalent to 1.83 Brazilian Reais (R$1.83) at the time of the submission of the article (January 2010). *Student's t-test for independent samples or Fisher exact test; $^{\dagger}(p < .05)$.

assessment of the social adjustment within the last 2 weeks, we decided to adapt the questions that relate to "the last two weeks before the beginning of the addiction inpatient treatment."

Statistical Analyses

Differences in performance on neuropsychological tests were assessed with unpaired t-tests and categorical variables were evaluated using Fisher's exact test. The level of statistical significance was $\alpha = .05$ and all statistical tests were two tailed. Two-way analysis of variance (ANOVA) with repeated measures, with trial blocks (five consecutive blocks of 20 picks) as within-subject factor and subject groups (cocaine users and controls) as between-subject factor were used to compare neurocognitive performance on the IGT. In addition, an analysis considering separated groups was made by repeated measures ANOVA with trial blocks as within-subject factor. Correlation between neuropsychological measures (ie, IGT Netscore), psychiatric symptoms (ie, BDI and STAI scores) and social adjustment (ie, SAS-SR scores) was assessed by the Spearman correlation coefficient (r_S). All statistical analyses were conducted using Statistical Package for the Social Sciences (SPSS) 14.0 for Windows.[40]

RESULTS

Demographic Characteristics, Psychiatric Evaluation, and Intellectual Functioning

The cocaine group and the control group were not significantly different from each other on age, education, socioeconomic status, ethnicity, handedness, or gender (Table 1). All participants from both groups were male, because the inpatient units where the research was conducted did not have any crack-cocaine-dependent women at the time of the data collection. They were from Brazil, and they were native speakers of Portuguese. The estimated IQ (WAIS-R) ranged from 76 to 118 in the cocaine group and from 79 to 117 in the control group. The two subject groups did not differ on the Vocabulary and Block Design subtests of the WAIS-R. On average, the level of depressive symptoms and anxiety traits in the cocaine group were higher than the control group ($p < .01$).

Cocaine, Alcohol, and Other Drug Use

The self-report amounts of cocaine use, as well as other substances, are presented in Table 2. Despite the majority of CCDI from the cocaine group having started their cocaine use by snorting, smoking crack was the main route of cocaine administration in the cocaine group at the time of the study. On average, the CCDI reported that they normally used cocaine 4.6 days a week, taking 17.66 g of cocaine, and that they had been cocaine users for 7.80 years. Mean alcohol use was 5.27 drinks per day and mean marijuana use was less than one joint per day (.66). None reported LSD, ecstasy, or amphetamine use in the past 30 days, and

TABLE 2. Cocaine, alcohol, and other drug use in the cocaine and the control group

	Control group ($n = 15$)	Cocaine group ($n = 15$)
Cocaine		
Days/week	$.00 \pm .00$	4.60 ± 1.88
Grams/week	$.00 \pm .00$	17.66 ± 15.29
Duration (years)	$.00 \pm .00$	7.80 ± 5.17
Abstinence (days)	$.00 \pm .00$	14.73 ± 5.01
Alcohol		
Drinks/day	$.07 \pm .11$	5.27 ± 11.24
Marijuana		
Joints/day	$.00 \pm .00$	$.66 \pm .86$
Tobacco		
20 cigarettes/day (packs)	$.40 \pm 1.29$	$.62 \pm .72$

Note: Data are presented as means ± standard deviations (SD).

TABLE 3. Performance of cocaine and control groups in neuropsychological tests of executive functioning and social adjustment

Neurocognitive functions	Neuropsychological tests		Control group ($n = 15$)	Cocaine group ($n = 15$)	P value*
Executive functioning	WCST (Wisconsin)	Correct	45.07 ± 7.69	43.53 ± 8.99	.62
		Perseverative errors	9.47 ± 4.76	10.40 ± 5.47	.62
		Failures to maintain set	$.47 \pm 0.64$	$.87 \pm .92$	.17
		Categories	3.07 ± 1.22	2.53 ± 1.13	.22
Social behavior‡	SAS-SR (social functions)	Work	$1.14 \pm .18$	$2.42 \pm .92$	.00†
		Studies	$1.00 \pm .00$	3.11 ± 1.32	.21
		Leisure	$1.82 \pm .57$	3.01 ± 1.01	.00†
		Family	$2.54 \pm .67$	$1.43 \pm .39$	.00†
		Marital role	$1.53 \pm .35$	$2.13 \pm .72$	.08
		Parental role	$1.37 \pm .53$	$1.58 \pm .62$	.49
		Finance	$1.25 \pm .43$	2.70 ± 1.63	.00†
		SAS-SR total score	$1.39 \pm .27$	2.71 ± 1.39	.00†

Notes: Results are presented as means ± standard deviations (SDs); WCST = Wisconsin Card Sorting Test; SAS-SR = Social Adjustment Scale-Self Report; *Student's t-test for independent samples; †($p < .05$); ‡The lower the SAS-SR score, the better the social adjustment.

none had ever used heroin or other opiates. They had abstained from cocaine and other drugs (except cigarettes) for an average of 14.73 days. No urine tests were performed, but the patients were voluntarily enrolled in treatment at inpatient facilities at the time of the evaluation, for at least 2 weeks.

Neuropsychological Tests, Decision-Making Evaluation, and Social Dysfunction

Although the WCST variables did not reveal any statistically significant differences between the cocaine group and the control group, the SAS-SR did (Table 3). The SAS-SR total score was significantly higher for the CCDI ($p < .01$), suggesting higher social maladjustment; the SAS-SR areas where differences between the two groups were greatest were work, leisure activities, family life, and financial management ($p < .01$).

In Fig. 1, the Netscore during 100 trials of the IGT for cocaine and control groups is shown. Two-way repeated measures ANOVA revealed differences between trials ($F = 3.672$, df = 4, $p = .008$): 01–20 × 81–100 ($p = .035$), 21–40 × 61–80 ($p = .025$), and 21–40 × 81–100 ($p = .011$). There was no significant effect between groups ($F = 2.516$; df = 1; $p = .125$) and in the interaction between trials and group ($F = 1.078$; df = 4; $p = .371$). Considering both cocaine and control groups separately, there were statistically significant differences in the trial blocks in the control group ($F = 3.470$, df = 4, $p = .014$): the Netscore started below zero and persisted at this level for the two first blocks of 20 trials, but rose above zero in the last three blocks (trials 41–60, 61–80, 81–100). The evolution of the Netscore for the cocaine group differed significantly when compared to the control group: this variable remained negative and stable for almost the entire experiment (trials 1–81) and rose slightly in the last block of 20 trials (81–100). The repeated measures ANOVA did not reveal any statistically significant differences among the trials in the cocaine group ($F = .544$, df = 4, $p = .779$).

Correlation between Anxiety, Depression, Decision Making, and Social Adjustment

Despite higher anxiety and depressive symptoms rates, we did not find any statistically significant correlation of the IGT with either BDI ($p = .63$) or STAI/trait (STAI-T) ($p = .98$). Figure 2 shows that there was no correlation between IGT and SAS-SR in the control group ($p = .59$). However, in the cocaine group, we found a statistically significant correlation between the IGT and SAS-SR ($r_S = -.55$; $p = .04$).

DISCUSSION

In this study, we have compared several neuropsychological measures and social adjustment from a group of Brazilian CCDI, to a comparison (control) group matched in age, gender, education, socioeconomic level, ethnicity, handedness, as well as IQ. Despite not having found statistically significant differences between the two groups on the WCST, we found that the CCDI made more disadvantageous choices on the IGT. Thus, the CCDI demonstrated problems in learning to choose advantageously on the IGT, reflected by a certain *myopia* for the future consequences of their choices. In addition, it was shown using the SAS-SR that the CCDI had higher levels of social dysfunction, in several areas of the social domain, including work, leisure, family, and finances. A statistical analysis suggested that the latter two results were correlated; specifically, it indicates a negative correlation between decision making and an objective measure of social dysfunction (ie, worse decision making was associated with worse social functioning).

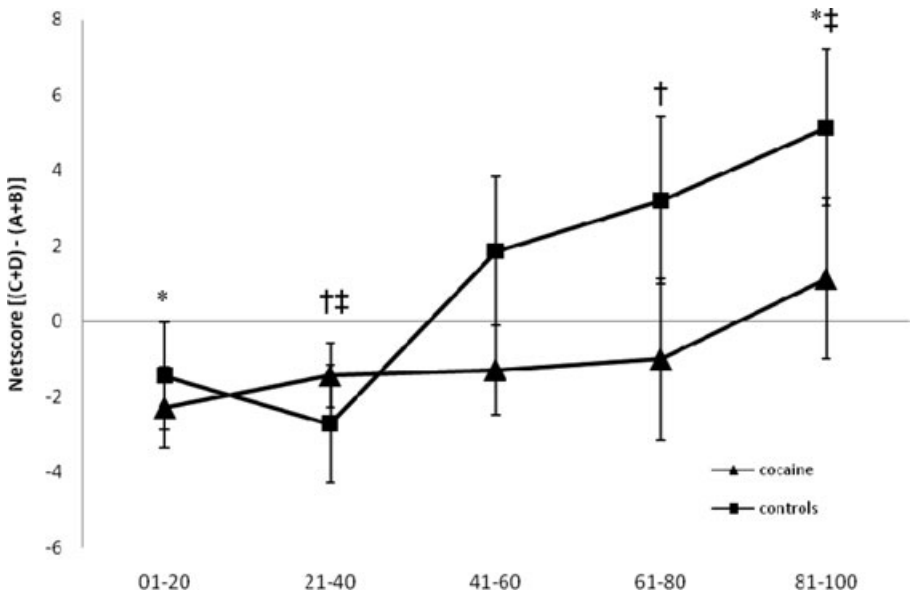

FIGURE 1. Evolution of Netscore ([C + D] − [A + B]) over five consecutive blocks of 20 picks (trials 1, 2, 3, 4, and 5) in the IGT. *Note*: The differences between trials 01–20 × 81–100 ([*] $p = .035$); 21–40 × 61–80 ([†] $p = .025$), and 21–40 × 81–100 ([‡] $p = .011$) were statistically significant in the control group. There were no statistically significant differences between trials in the cocaine group.

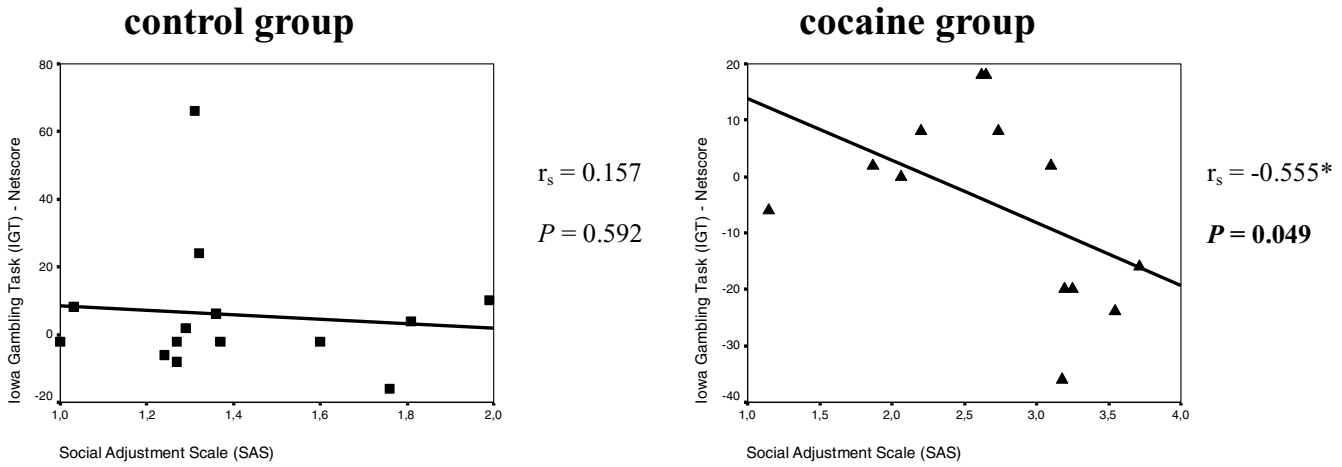

FIGURE 2. Correlation between decision making and social adjustment among the control group and the cocaine group. *Notes*: r_s: Spearman correlation coefficient; $^*P$ value $< .05$.

Our data confirm the ecological validity of the IGT even in a different culture, such as the Brazilian culture.

Considering that recent studies have shown that CCDI present with signs of OFC dysfunction, and that they have strong difficulties in controlling their drug use despite rising negative consequences, it is plausible to suggest that the social maladjustment detected in these patients is associated to an underlying OFC dysfunction. In this study, it is unlikely that the social environment was the precursor of the expressed social problems of the CCDI, because these subjects were from the same geographical regions and socioeconomic and ethnic groups as the subjects of the control group. A possible explanation is that the OFC dysfunction would be a predisposing factor that may have led to the poor decision making as well as the social dysfunction among the CCDI. This dysfunction can be the by-product of an interaction between genes and the environment. For instance differences in certain serotonergic or dopaminergic circuits and gene products could influence the functional activity of the neural circuits involved in decision

making. Another possible explanation is that OFC dysfunction could be induced or even exacerbated by cocaine use. In fact, recent studies suggest that chronic cocaine use induces persistent changes in gene expression with potential negative impact on synaptic functioning in the OFC.[41] Therefore, cocaine-related OFC dysfunction could lead to a variety of negative social consequences, such as unemployment, legal problems, financial debts, abandonment by friends, spouse, and family members, which could, therefore, be manifested by poor scores on the SAS-SR.

The present results agree with findings of other neuropsychological studies that have demonstrated decision-making impairments and OFC dysfunction in CCDI.[7–10,13,15,20] It is noteworthy that the CCDI showed decision-making deficits somewhat similar to those observed in neurological patients with OFC lesions.[14] One possible explanation of such decision-making deficits is the particularly high degree of crack-cocaine dependence found among the CCDI. Another is the associated use of other substances such as tobacco and alcohol, which are also known to be harmful to decision making and the PFC.[12,13,15,42,43]

Considering that the WCST was designed to assess mental flexibility,[30] and that addicts persist with drug use despite its adverse consequences, one might expect an excessive number of perseverative errors among the CCDI. Several studies in the literature have found deficits on the WCST among cocaine abusers.[15,44–48] However, the present investigation did not find differences between CCDI and the control group in the WCST. This is consistent with several other studies that failed to detect impairment on the WCST.[10,20,25,49–53] The question of why the WCST yield inconsistent results remains to be studied further. One possibility that explains the inconsistency is the type of addicts that are being tested. It is possible that patients who seek treatment voluntarily, remain in treatment, and are relatively more functional, express impairments on only more sensitive OFC tasks, such as the IGT, but not on more dorsolateral prefrontal cortex (DLPFC) tasks, such as the WCST. However, addicts with more severe problems and who are less functional are more likely to show impairments on the IGT as well as the WCST. Also, in the WCST, the subject has to make a decision immediately after the examiner's feedback, meaning that analysis of future consequences is not a prerequisite as is the case in the IGT.

The fact that there was no correlation between the IGT and SAS-SR in the control group, presumably because the subjects in this group had a good social functioning (the SAS-SR variability among the control group was very low), strongly indicates that the negative correlation of these tests in the CCDI is explained by cocaine use. Thus, this study reveals a link between decision making (IGT) and an objective measure of social dysfunction (SAS-SR) in CCDI. Also, the present study demonstrates that the IGT, and presumably other decision-making tasks that measure the same construct,[54] have good ecological validity, which may be extended to developing countries and other cultures, namely Brazilian culture, since their results are associated with real-world decision making.[17] We suggest that such tasks may be used as indicators, of how well the CCDI will perform in real life, after an initial detoxification and drug abstinence period.

Despite the important strengths, some limitations of this study need to be highlighted. First, the present study included a small sample size and it was unable to detect more significant interactions. However, the results are in line with our initial hypothesis. Second, our sample was limited to male individuals. Although social dysfunction and risk-taking behavior are common in both males and females addicted to cocaine,[55] males do have distinct behavioral, hormonal, and neuroimaging patterns.[56–58] Third, since the present data are cross-sectional, it was not possible to determine whether the cognitive impairments observed were antecedents or consequences of cocaine use.[47] It is very difficult to determine to what extent the drug per se, through its influence on brain functioning, leads to behavioral alterations such as increased risk taking, decision-making impairments, and social dysfunction. The possibility that the unusual social environment of drugs users also influences behavior should also be born in mind. Controlled studies of both animals and humans have strongly suggested that cocaine use leads to OFC dysfunction.[8,13,18,41] Indeed, even brief periods of exposure to cocaine use may lead to long-lasting functional and structural deficits in the OFC.[18] Therefore, the argument that the OFC dysfunction may precede the crack-cocaine dependence and social dysfunction must be received with caution. We also have to consider that crack-cocaine use may induce or exacerbate OFC dysfunction and poor social functioning. Fourth, the present study was based on self-reported cocaine and other drug use, for both the CCDI and the control group. However, the CCDI were predominantly inpatients, they were under the supervision of the clinical staff, and there has been significant evidence that self-reported drug use has been shown be valid.[59] Fifth, it was not possible to determine the reversibility of decision-making deficits and social maladjustment, because the abstinence period was too short. Decision-making deficits may be attenuated by abstinence,[20] but other authors have found that even longer periods of abstinence (6 months to 3 years) are not sufficient to improve decision making in alcoholics.[60] Although several studies show recovery in neuropsychological functioning after a period of abstinence, it appears that this recovery seems to apply only to "cold" cognitive tasks such as the WCST, but not to "hot" decision-making tasks, such as the IGT. This corroborates that poor decision making, as captured by the IGT, may represent a predisposing factor, which is brought about by either genetic factors, or early environmental factors (eg, chronic emotional stress), which may impact the normal development of the PFC, which in turn leads to poor decision making, which heightens the risk for acquiring addictive

disorders and poor social function. The crack-cocaine and other drug use would have an additional negative impact on OFC functioning in these subjects, but further studies are needed to investigate the nature of this association.

CONCLUSION

The current study provides evidence that CCDI show marked decision-making deficits when compared to a control group and that these cognitive impairments are associated to social adjustment impairment. This suggests a possible link between the OFC and decision-making dysfunction that may constitute a plausible explanation for the significant deficits in social behavior and tendencies toward risk taking and personality alteration typically seen in CCDI. Also, it emphasizes the ecological validity of the IGT, even in a different culture. These findings may have some implications, not only on research into the neurobiology of cocaine dependence, but also on clinical decision-making and substance-use prevention efforts.

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Declaration of Interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this paper.

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