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Altered adaptive but not veridical decision-making in substance dependent individuals

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Abstract

Drug addiction is associated with impaired judgment in unstructured situations in which success depends on self-regulation of behavior according to internal goals (adaptive decision-making). However most executive measures are aimed at assessing decision-making in structured scenarios, in which success is determined by external criteria inherent to the situation (veridical decision-making). The aim of this study was to examine the performance of Substance Abusers (SA, $n = 97$) and Healthy Comparison participants (HC, $n = 81$) in two behavioral tasks that mimic the uncertainty inherent in real-life decision-making: the Cognitive Bias Task (CB) and the Iowa Gambling Task (IGT) (administered only to SA). A related goal was to study the interdependence between performances on both tasks. We conducted univariate analyses of variance (ANOVAs) to contrast the decision-making performance of both groups; and used correlation analyses to study the relationship between both tasks. SA showed a marked context-independent decision-making strategy on the CB's adaptive condition, but no differences were found on the veridical conditions in a subsample of SA ($n = 34$) and HC ($n = 22$). A high percentage of SA (75%) also showed impaired performance on the IGT. Both tasks were only correlated when no impaired participants were selected. Results indicate that SA show abnormal decision-making performance in unstructured situations, but not in veridical situations. (*JINS*, 2006, *12*, 90–99.)

Keywords: Prefrontal cortex, Addictive behavior, Decision-making, Gambling task, Cognitive bias task, Neuropsychological tests

INTRODUCTION

Substance Abusers (SA) usually perform poorly on tests of executive control and decision-making, and they show significant decision-making problems in real-life settings (Bechara et al., 2001). Decision-making constitutes a key component of human drug addiction that is characterized by an intense impulse to use drugs at the expense of other natural reinforcements that can be more advantageous in the short or long term (American Psychiatric Association, 1994). Imaging studies have demonstrated that the decision-making deficits of SA are associated with the abnormal activation of different fronto-striatal systems, including the Dorsolateral (DLPFC) and Ventromedial (VMPFC) portions of the prefrontal cortex (Bolla et al., 2003; Ernst et al., 2002).

Decision-making is defined as the ability to select the most advantageous response from an array of possible behavioral choices (Bechara et al., 2000). In certain situations, one possible choice is correct and others are incorrect. The determination of what is "correct" and "incorrect" is inherent to the situation, which is highly structured and unambiguous, and the individual can resolve it using convergent thinking or veridical decision-making. Whether to add a spoon of salt or sugar to our morning coffee can be an example of a highly structured situation with one correct and one incorrect choice, which can be resolved using veridical decision-making. For a long time, neuropsychological

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studies have focused on these structured-unambiguous situations, and most executive functioning tests are aimed at assessing veridical decision-making (Goldberg & Podell, 2000).

Nonetheless, most everyday situations are more ambiguous and unstructured in that several possible choices are potentially advantageous. Everyday decision-making depends on self-regulation of behavior by ranking and scaling our own priorities in relationship to the characteristics of the situation (Levine et al., 2000). These ambiguous-unstructured situations demand using divergent thinking, or adaptive decision-making, which is the ability to disambiguate the situation and select the best choice for the organism's needs according to internal goals, past experiences, and expectations for the future (Goldberg & Podell, 1999, 2000). Whether to add a spoon of sugar or an artificial sweetener to the above-mentioned coffee requires an adaptive decision-making strategy, since there are no inherently correct or incorrect response options, and our selection is largely dependent on our organism's current necessities and future expectations. Drug use is another clear example of an ambiguous-unstructured scenario. Drug intake is a highly rewarding option for SA, and therefore it is perceived as advantageous as opposed to other choices, even though it can produce significant negative consequences (Bechara et al., 2001; Volkow et al., 2004).

The Iowa Gambling Task (IGT) is sensitive to the detection of decision-making deficits in SA (Bechara et al., 2001; Grant et al., 2000; Verdejo-García et al., 2004). The IGT simulates real-life decisions, in the sense that it involves the simultaneous consideration of competing courses of action in conditions of ambiguity and uncertainty (Bechara et al., 2001). The development of an optimal strategy in this task is highly dependent on the processing of ongoing emotional feedback (Bechara & Damasio, 2002), based on the organism's own preferences, and not on the consideration of external feedback about the correctness/incorrectness of the different choices (which is the case for several tests of executive functioning).

Similarly, Goldberg et al. (1994) designed an experimental paradigm known as the Cognitive Bias Task (CB task) aimed at assessing adaptive decision-making in ambiguous-unstructured situations. The main novelty of this task in the assessment of adaptive decision-making is that participants are required to make a response selection based on their own preference without an obvious correct or incorrect response present. The CB task differentiates between two possible decision-making strategies: context-independent and context-dependent decision-making (Aihara et al., 2003; Goldberg & Podell, 2000; Stratta et al., 1999). Context-independent decision-making is based on the organism's preexistent representations, and reflects an attempt to produce the best possible average responses according to these stable representations, without considering the unique features of the situation at hand. By contrast, context-dependent decision-making tries to capture the unique or specific features of the situation, and reflects an attempt to flexibly adapt our previous representations to the situation's characteristics in order to select the best possible choice (Goldberg, 2001; Goldberg & Podell, 1999).

The aim of this study is to examine the decision-making processes of SA using two behavioral paradigms aimed at assessing adaptive decision-making in ambiguous-unstructured situations: the CB task and the Iowa Gambling Task (IGT). Although a number of studies have reported decision-making deficits in SA as measured by the IGT (Bechara et al., 2001; Grant et al., 2000; Monterosso et al., 2001; Verdejo-García et al., 2004), this is the first study to examine the decision-making processes of SA using the CB task, and to analyze the relationship between the two tasks. Since (1) SA have shown defective performance in different cognitive tests of decision-making, including the IGT, (2) chronic exposure to drugs of abuse have been shown to produce damage to the neural substrates of decision-making, and (3) SA real-life behavior is characterized by a fixed preference (often regardless of the current or future consequences or context) for drug-taking at the expense of other natural (context appropriate) reinforcers; we anticipate that SA will present a context-independent decision-making strategy in the CB task.

METHODS

Research Participants

SA were recruited as they joined inpatient rehabilitation programs in the centers "Proyecto Hombre" and "Cortijo Buenos Aires" in Granada (Spain), and "Lopera" in Jaén (Spain). Participants were referred to these centers from outpatient drug centers where they were assessed by expert clinical psychologists for DSM-IV substance dependence and Axis I and II comorbidity. Subjects with Axis I and II disorders are routinely referred to other specific centers addressing dual pathology, so there is no reason to believe that there were subjects with comorbid mood or personality disorders in our target sample. Selection criteria for participants in this study were (1) meeting the DSM-IV criteria for substance dependence, (2) absence of documented comorbid mood or personality disorders, (3) absence of documented head injury or neurological disorders, and (4) minimum abstinence duration of 15 days before testing. Ninety-seven SA (94 males) aged 18 to 54 years (mean 30.99) participated in the study. Drug of choice was cocaine in 38.5%, cocaine/heroin mixture in 27.1%, heroin in 27.1%, and alcohol in 7.3% of participants. Urine analyses for cannabis, benzodiazepines, cocaine, and heroin metabolites were carried out in order to confirm the abstinence period. None of the participants were experiencing withdrawal symptoms before or during neuropsychological testing as assessed by routine medical examination. Smoking was not allowed immediately before or during testing. However, smoking was not restricted before participation. Studies in SA have shown that this is the best strategy to avoid confounds arising from acute nicotine craving or withdrawal, since it has been shown that there are not significant differences in neuropsychological performance between participants allowed *versus* not allowed to smoke during the hours before testing (see Bjork et al., 2004).

Healthy Comparison participants (HC) were recruited through direct verbal advertisement and snowball communication among undergraduate students from the University of Granada. Selection criteria for these comparison group participants were (1) absence of current or past substance abuse excluding social drinking, (2) absence of documented major psychiatric disorders, (3) absence of documented head injury or neurological disorder, and (4) not being familiar with the testing contents and procedures. Eighty-one participants (21 males) aged 17 to 30 years (mean 22.07 years) were included in this comparison group.

All participants provided informed consent stating their voluntary collaboration before beginning the study. The demographic data on the two groups are presented in Table 1.

Measures

Decision-making testing was operationalized by using two behavioral tasks: the Cognitive Bias Task (Goldberg et al., 1994) and the Iowa Gambling Task (Bechara et al., 1994). The Cognitive Bias Task (CB, see Goldberg et al., 1994; Goldberg & Podell, 2000) consists of stimuli portraying simple geometric designs each characterized along five binary dimensions: color (red/blue), contour (outlined or filled with a homogenous color), number (one/two), shape (circle/square), and size (larger/smaller). This allows for a total of 32 possible geometric designs. As such, any two designs can be compared for the number of concordant dimensions, creating a "similarity range" from 0–5.

Each trial consisted of three stimuli being presented: one target and two possible choices vertically aligned below it. The target was presented alone for two seconds, followed by the simultaneous presentation of the two choices below the target (see Figure 1).

The participant sat in front of the computer and was instructed to look at the target card, then to select one of the two choices. Two different conditions can be administered in this task. In the *preference* condition (administered to all SA and HC participants) the participant was asked to look at the target and select one of the two choices that they "liked the best. There is no correct or incorrect choice." This condition was aimed at assessing *adaptive decision-making*. In the *control* conditions (administered to a subsample of 34 SA and 22 HC, all of them males) the participant was asked to look at the target and then select one of the two choices that was either "most similar to" or "most different from" the target card. The administration of *control* conditions was counterbalanced across participants, but always administered after the *preference* condition. These *control* conditions were aimed at assessing *veridical decision-making*.

There are 60 fully counterbalanced independent trials. All trials were designed in such a way that the similarity indices between the target and each of the two choices are never equal; thus the subject must make a choice that is either more similar to, or more different from, the target.

The CB task was fully counterbalanced in terms of frequency representation of each binary dimension, similarity indices, and presentation order. For presentation order, all possible trial pairwise combinations were used. This yielded a combination of 15 possible trials (0/1, 0/2, 0/3, 0/4, 0/5, 1/2, 1/3 . . .) that were called blocks. The blocks were counterbalanced for top and bottom stimuli, choice cards being the more similar or more different choice. The order of presentation of blocks A and B were randomly determined and blocks C and D were presented in the mirror reverse fashion of A and B, respectively.

Table 1. Demographics of participants in the substance dependent individuals (SDI) and healthy comparison groups

Characteristic	Group SA (97)		Group HC (81)		*p*
	Males	Females	Males	Females	
Gender	94	3	29	52	<.001
	Right	Non-Right[a]	Right	Non-Right[a]	
Handedness	83	14	67	14	ns
	Mean	SD	Mean	SD	
Age (years)	30.99	7.17	22.07	2.84	<.001
Education (years)	9.61	2.72	15.90	1.71	<.001

[a]Participants were considered right-handed if their individual score on the standardized handedness questionnaire was 41 or greater, out of a possible 48 (Goldberg & Podell, 2000).

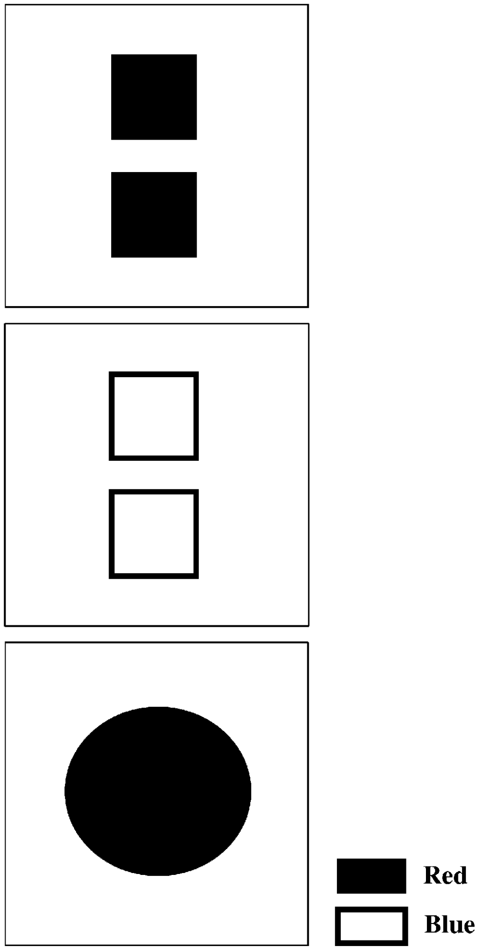

Fig. 1. Sample trial from the Cognitive Bias Task.

For all trials in the different conditions, a similarity index between the participant's choice and the target (ranging from 0 to 5) can be computed. The sum of the similarity indexes across trials provides a CB raw score ranging from 80 to 220, representing the degree of dimensional concordance between the subject's choice relative to the target. A converted score can be computed from the CB raw score. This CB converted score is the absolute deviation of the CB raw score from the raw score midpoint, 150. The CB converted score (absolute value of CB raw −150, ranging from 0 to 70) was used as the primary dependent measure for this task.

It is postulated that the target provides a cognitive context that the subject will use to make his response. We were especially interested in the degree to which the subject chose to use this cognitive context to make a choice given the absence of external constraints. In the *preference* condition (tapping on adaptive decision-making), low CB converted scores indicates that the participant shows a context-independent decision-making pattern (not using the target as context), whereas high CB converted scores indicates that the participant shows a context-dependent decision-making pattern (consistently choosing similar or different, indicating guidance by the properties of the target). In the *control* conditions (most similar and most different), low scores represent poor accuracy in deciding the choice between most similar to or most different from the target, whereas high scores represent good accuracy in deciding the choice between most similar to or most different from the target.

The Iowa Gambling Task (Bechara et al., 1994) has been proposed to be sensitive to real-life decision-making deficits. We used a computerized version of this task (Bechara et al., 2001). The task involves four decks of cards labeled A', B', C', and D'. Decks A' and B' gave an average reward-payoff greater than decks C' and D', but they also led to harsher penalties, producing an overall loss over repeated selection. Participants are required to make a series of 100 card selections, trying to win as much play money as possible. Good performance on the IGT implies choosing more cards from decks C' and D' (advantageous decks: lower immediate gain but smaller future loss) than from decks A' and B' (disadvantageous decks: high immediate gain but larger future loss). Participants did not receive actual money as a function of their performance on IGT. Studies have shown that this variable is not relevant for accurate IGT performance (Bowman & Turnbull, 2003). The primary dependent measure for this task was the difference in the number of cards selected from the advantageous *versus* the disadvantageous decks: [(C + D) − (A + B)]. The IGT was administered only to the SA group.

Procedure

This study was approved by the Human Subjects Committee of the University of Granada and by the Drug Dependence Committee of the "Junta de Andalucía." All SA and HC participants provided written informed consent. The testing protocol, including the IGT, the CB task, and a standardized handedness questionnaire, was administered in a single session that lasted approximately 45 minutes. All tasks were administered using a 15-inch Compaq lap-top computer. IGT and CB task presentation sequence was counterbalanced across subjects.

RESULTS

All statistical analyses of the data presented next were conducted using the software SPSS 12.0 for Windows. We established an alpha level below .05 for statistical significance in all comparisons.

Preliminary Analyses on Demographic Characteristics

The SA and HC groups were matched in handedness distribution. However, the groups were not closely matched in gender ($\chi^2 = 77.19$, $p < .01$), age [$F(1,176) = 110.70$,

$p < .01$], and years of education [$F(1,176) = 325.79$, $p < .01$] (see Table 1). To address the gender differences, we carried out a t test on the converted CB-preference scores of males and females in the comparison group. Results showed no significant differences as a function of gender in CB-preference performance ($t = 0.676$, $p = .501$). No gender differences were found in the SA group either ($t = -0.427$, $p = .671$). Therefore all males and females in the SA group ($n = 97$) and the HC group ($n = 81$) were included in the CB-preference comparisons. The CB-veridical control conditions were only administered to a subgroup of male SA ($n = 34$) and HC participants ($n = 22$).

We conducted correlation analyses to examine the effect of age and education on CB-preference performance in each group separately. Pearson correlation analyses showed that age was not correlated with CB-preference performance in the SA ($r = -.156$, $p = .129$) or the HC group ($r = -.002$, $p = .987$). Therefore we excluded this variable from subsequent analyses. Pearson correlation analyses also showed that education was not correlated with CB-preference performance in the SA ($r = .121$, $p = .240$) or the HC group ($r = -.184$, $p = .100$).

However, due to previous evidence suggesting that educational level may have an effect on decision-making (Evans et al., 2004), and considering the categorical difference between groups in educational attainment, we dichotomized this variable using a median split procedure and we included it as an additional independent variable in subsequent analyses. Thus, we classified individuals with 12 or less years of education as a "lower education subgroup," and individuals with more than 12 years of education as a "higher education subgroup."

Comparison Between SA and HC in Adaptive Decision-Making

To analyze possible differences between SA and HC in their *adaptive* decision-making skills we conducted a 2 [Group: SA ($n = 97$) *vs.* HC ($n = 81$)] × 2 (Educational Attainment: Lower education *vs.* Higher education) univariate ANOVA on the converted CB-preference scores. Educational attainment was dichotomized based on a median split on years of education. In this way, we classified individuals with 12 or less years of education as the "lower education subgroup" (SA, $n = 72$; HC, $n = 21$), and individuals with more than 12 years of education as the "higher education subgroup" (SA, $n = 25$; HC, $n = 60$). Results showed a main effect for Group, SA showing significantly lower CB-preference scores than HC, but no effects for Educational Attainment or Group × Educational Attainment interaction (see Table 2). SA showed a more pronounced context-independent decision-making pattern in the CB preference condition, whereas HC showed a more pronounced context-dependent pattern in this task. Debriefing of the data and further descriptive analyses showed that SA responses were based on fixed sensory preferences independent of the target (see Goldberg et al., 1994).

Testing Adaptive Decision-Making in Right-Handed Males

Despite the fact that the two groups (SA and HC) showed no significant differences on CB performance as a function of gender, we carried out additional tests including only a subsample of right-handed males. We performed these analy-

Table 2. CBT means, standard deviation scores, and F-tests in SDI and healthy comparison participants on veridical and adaptive decision-making skills

			Group			
N	Dependent variable		SA	HC	*F*	*p*
All subjects SA = 97, HC = 81	Adaptive decision-making	Lower education Higher education	24.12 (21.23) 27.83 (23.83)	40.29 (24.02) 33.93 (24.87)	Group: 7.736 Education: .109 Gr. × Ed.: 1.580	Group: .006** Education: .742 Gr. × Ed.: .210
Only right-handed males SA = 81, HC = 25	Adaptive decision-making	Lower education Higher education	22.26 (20.26) 26.20 (22.91)	37.78 (24.59) 35.85 (29.63)	Group: 4.866 Education: .031 Gr. × Ed.: .264	Group: .030* Education: .860 Gr. × Ed.: .609
Only subjects who also performed control conditions SA = 34, HC = 22	Adaptive decision-making	Lower education Higher education	20.25 (17.22) 24.20 (25.58)	40.28 (24.01) 62 (–)	Group: 6.032 Education: 1.188 Gr. × Ed.: .569	Group: .017* Education: .281 Gr. × Ed.: .454
	Veridical decision-making	Lower education Higher education	62.92 (4.49) 62.40 (5.50)	64.90 (2.86) 68 (–)	Group: 2.797 Education: .323 Gr. × Ed.: .634	Group: .100 Education: .572 Gr. × Ed.: .430

Note: $*p < .05$, $**p < .01$

ses because (1) the two groups were not comparable in gender composition (SA group was composed of a higher proportion of males), (2) previous studies using the CB have detected differential performance as a function of gender and handedness in HC (Goldberg et al 1994; Goldberg & Podell, 1999, 2000), and (3) most previous studies using the CB in different clinical samples have focused only on right-handed males (Aihara et al., 2003; Stratta et al., 1999). Participants in our sample were considered right handed if their individual score on the Briggs and Nebes (1975) handedness questionnaire was 41 or greater, out of a possible 48 (Goldberg et al., 1994; Goldberg & Podell, 2000). We conducted a 2 (Group: SA, $n = 81$ *vs.* HC, $n = 25$) × 2 (Educational Attainment: Lower Education *vs.* Higher Education) univariate ANOVA on the converted CB-preference scores in this subsample. Results also showed significant differences in adaptive decision-making as a function of Group, with SA scoring lower than HC, in this subsample of participants. We did not find effects of Educational Attainment or Group × Education interaction in this subsample of participants (see Table 2).

Comparison Between SA and HC in Veridical Decision-Making

To examine possible differences between SA and HC in their *veridical* decision-making skills we conducted a 2 (Group: SA, $n = 34$ *vs.* HC, $n = 22$) × 2 (Educational Attainment: Lower Education *vs.* Higher Education) univariate ANOVA on the converted CB-control scores in this subsample. Results showed no significant effects of Group, Education, or Group × Education interaction on veridical decision-making as measured by the control conditions of the CB task (see Table 2).

SA Performance on Decision-Making as Measured by the IGT

We did not administer this task to HC due to time constraints. Ninety-five SA performed the IGT. We used a cut-off net score of 10 (Bechara et al., 2001) to determine advantageous performance in this task (i.e., SA scoring below 10 were classified within the impaired range). Based on this criterion, 71 out of 95 (75%) SA scored within the impaired range (disadvantageously) in the IGT ($\chi^2 = 92.35$, $p < .01$). A descriptive summary of IGT performance on both subgroups is presented on Figure 2. We conducted a one-way ANOVA to examine possible effects of educational attainment (low education subgroup vs high education subgroup) on SA's performance on the IGT. Results showed no effects of educational attainment on IGT performance in SA, $F(1,92) = .013$, $p = .908$.

Relationship Between Veridical and Adaptive Decision-Making as Measured by the CB and Decision-Making Skills as Measured by the IGT in SA

Results showed no significant correlations between CB-preference (adaptive decision-making) and CB-control (veridical decision-making) scores and IGT net scores (see Table 3). Since a significant proportion of SA performed within the impaired range in the IGT (below a cut-off score of 10, Bechara et al., 2001), we hypothesized that the relationship between CB and IGT scores may differ for SA included in the impaired *vs.* unimpaired range in the IGT. To study this possibility we carried out two independent correlation analyses for the SA who performed within the impaired range (IGT-impaired subgroup, $n = 71$) and the

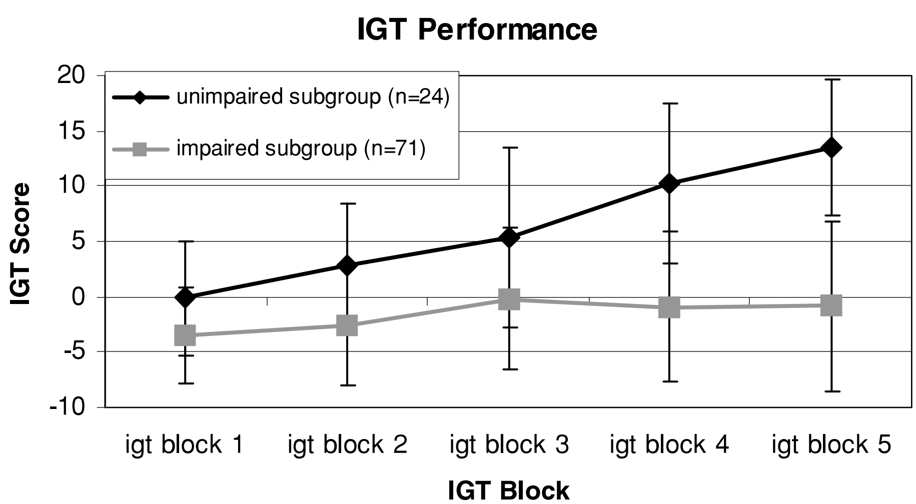

Fig. 2. Mean (and Standard Errors) for each block of 20 card choices on the IGT by SDI impaired and unimpaired subgroups.

Table 3. Pearson correlations on the relationship between decision-making performance in the CBT and the IGT in all SDI, and in SDI subgroups classified according to their (good/bad) IGT scores

Variables examined	Veridical decision-making (CBT-control scores)	Adaptive decision-making (CBT-preference score)
IGT-all SDIs	.07	.09
IGT-impaired subgroup (n = 71)	−.03	.12
IGT-unimpaired subgroup (n = 24)	−.16	.47*

Note. *p = 0.02.

SA who performed within the unimpaired range (IGT unimpaired subgroup, $n = 24$). Results showed a significant correlation between CB-preference scores and IGT net scores in the IGT-unimpaired subgroup ($r = .47$, $p < .05$), but not in the IGT-impaired subgroup. There were no significant correlations between IGT net scores and CB control scores (veridical decision-making) in the IGT-unimpaired or the IGT-impaired subgroups (see Table 3).

DISCUSSION

This is the first study to report on SA decision-making performance in the CB task. One of the unique features of the CB task is that it elicits the subject's response selection preference along the context-dependent *vs.* context-independent continuum. Extreme context-independent response selection is expressed as making choices on the basis of a fixed, unchanging perceptual attribute regardless of the context or changing nature of the stimuli presented during different trials. It is driven by the subject's preference for a simple perceptual property regardless of the overall cognitive context of the trial. By contrast, extreme context-dependent response selection is expressed as making choices on the basis of the relationship between the target and the other two stimuli in the trial, which we call "cognitive context." The subject's response selection is a reflection of this relationship, which results in reliance on different perceptual characteristics on every trial.

Consistent with our hypothesis, SA showed a more pronounced context-independent decision-making strategy in the CB task's preference condition, measuring adaptive decision-making. By contrast, no significant differences were found between SA and HC in the CB task's control conditions, measuring veridical decision-making. With respect to the IGT, although we did not administer this task to HC, the results were congruent with previous findings showing a high proportion of SA scoring within the impaired range in this task (75%). Interestingly, we found significant correlations between both tasks when we selected those SA not scoring within impaired range in the IGT, but not when selecting the SA scoring within the IGT impaired range.

Although previous studies using the CB task had reported gender differences in the preference condition (Goldberg, 2001; Goldberg et al., 1994; Goldberg & Podell, 2000; Stratta et al., 1999), , we did not find significant differences between healthy males and females in adaptive decision-making. Despite the inclusion of both males and females, the descriptive CB preference scores in our comparison group were very similar to the scores obtained by previous studies including only male comparison participants (Stratta et al., 1999). However, when we performed additional analyses including only right-handed males we still found significant differences between SA and HC. These results indicate that the context-independent pattern observed in SA is consistent and independent of gender and handedness distribution.

The context-independent decision-making pattern observed in SA has been previously observed in patients with specific damage to the left prefrontal cortex (Goldberg & Podell, 2000), patients with schizophrenia (Stratta et al., 1999), and young children (the context-dependent pattern emerged during adolescence) (Aihara et al., 2003). A recent imaging study has demonstrated that context-dependent decision-making as measured by the CB relies importantly on the functioning of the DLPFC in right-handed males (Shimoyama et al., 2004). Therefore, SA's context-independent decision-making pattern may be associated with the detrimental effects of several drugs of abuse on different prefrontal systems including the DLPFC.

Neuropsychological studies have consistently shown poorer performance of SA in different DLPFC-dependent executive functioning measures, including working memory and mental flexibility tests (Bechara & Martin, 2004; Goldstein et al., 2004; Mintzer & Stitzer, 2002). For example, it is been observed that SA usually make more perseverative errors than HC in the Wisconsin Card Sorting Test (WCST), although they achieve a similar number of categories (Bechara et al., 2001). The CB results in our SA group were congruent with this pattern of higher WCST perseverative error rate, since both tasks depend on the ability to flexibly modify behavior in response to the unique features of the situation at hand. SA does not have the ability to adopt or switch to different cognitive contexts and as such get "stuck-in-set" and have a higher perseveration rate. Obviously the difference between the WCST and CB is that in WCST the context is external, given by the examiner, while in CB it is self-generated (see Podell et al., 1995).

The hypothesis of prefrontal alterations in substance abuse is supported by the findings of neuroimaging studies. These studies have shown that substance abuse can produce damage to different prefrontal pathways, including the DLPFC, involved in different aspects of decision-making (Adinoff et al., 2003; Franklin et al., 2002; Goldstein et al., 2004; Laakso et al., 2002; Liu et al., 1998). Activation of the left DLPFC has been consistently associated with the craving response of SA to drug cue-exposure (Daglish et al., 2001; George et al., 2001; Tapert et al., 2004), while left DLPFC hypoactivation has been frequently reported during abstinence (Franken et al., 2004; Pezawas et al., 2002). Additionally, recent studies have demonstrated that the abnormal activation of VMPFC and DLPFC circuits is associated with the decision-making deficits of SA in different behavioral paradigms, including the IGT (Bolla et al., 2003; Paulus et al., 2003).

Volkow et al. (2004), recently proposed that the motivational choices of SA become fixed as a consequence of drug consumption. While in healthy subjects the value of different reinforcers differs and this value changes as a function of the context (reflecting a context-dependent strategy), in SA the difference between the drug and the other reinforcers is so large that the option of drug taking becomes fixed (reflecting a context-independent strategy). This proposal supports the role of drug-induced brain changes in the context-independent decision-making pattern of SA. This hypothesis merits future study to analyze the relationship between the context-independent pattern exhibited by SA in the preference conditions of the CB and the functioning of different prefrontal systems.

Alternatively, the context-independent strategy of SA may be associated with personality traits predating the onset of drug abuse (Stratta et al., 1999). The results obtained by Aihara et al. (2003) in young children and adolescents suggested that frontal cortical control of behavior changes from the right to the left hemisphere as cognitive contextual reasoning develops during adolescence. However, frontal maturational disorders like ADHD (Barkley, 2001) have been frequently associated with substance dependence, and may be related to the context-independent pattern of adult SA.

In any instance, the marked context-independent strategy observed in SA may negatively affect their decision-making strategies in real-life settings, in which the majority of situations, including those related to drug use, are primarily ambiguous and unstructured. Although adaptive decision-making depends on the flexible alternation of context-dependent and context-independent strategies (Goldberg, 2001), we hypothesize that marked context-independent reasoning may be associated with higher behavioral rigidity, fixed preference for a narrow set of reinforcers, and lower cognitive flexibility in the ability to appropriately respond to a wide variety of everyday situations. In this sense, the SA context independent orientation could be a correlate of SA decision-making problems in real-life settings.

A different finding from our study was the absence of significant correlations between SA's scores on the two decision-making tests: the CB and the IGT. Interestingly, when we divided the SA group according to their scores in the IGT, significant correlations (although only 27% common variance) between IGT and CB scores emerged in the nonimpaired subgroup, but not in the impaired subgroup. These results seem to suggest that both tasks are taxing different mechanisms of decision-making. Decision-making performance on the IGT has been associated with the affective evaluation of rewards and punishments (Bechara et al., 2003), processing of ongoing emotional feedback (Bechara & Damasio, 2002), and higher rates of delay discounting (Monterosso et al., 2001), and it is associated with the functioning of the VMPFC predominantly in the right hemisphere (Schutter et al., 2004; Tranel et al., 2002). By contrast, CB decision-making performance is associated with executive control, planning, and mental flexibility skills (Stratta et al., 1999), and it is associated with the functioning of the DLPFC predominantly in the left hemisphere (Goldberg & Podell, 2000, Shimoyama et al., 2004). A related discrepancy between both tasks is that IGT is shaped to develop responding in the future. CB task does not do that and is based on the here and now and how one handles the current situation. The presence of significant direct correlations between both tasks in nonimpaired SA seems to indicate that these two decision-making systems can operate in an integrated fashion in the less impaired participants. This is not true for the SA who scored within the impaired range in the IGT, since impaired performance in this task does not necessarily imply a context-independent pattern in the CB. Similar results were reported by Bechara et al. (2001), who found that SA performed poorly in the IGT (relying on the VMPFC) despite normal scores on a number of executive functioning tests relying on the DLPFC.

This is the first study to report a typical context-independent decision-making pattern in a clinical SA population. Our results may have important implications for the design of treatment and relapse prevention strategies in SA. From the standpoint of rehabilitation, it may be interesting to address the possibility of differential decision-making strategies in abusers of different drugs. Further research including larger subgroups of SA abusing different drugs will be required to analyze this possibility. Additionally, future research in the identification of specific decision-making patterns in healthy subjects and recreational drug users may be of enormous interest for the design of prevention and early intervention strategies against drug use. This is also the first study to report on a behavioral dissociation between decision-making as measured by two widely used tests: the IGT and the CB task. Future studies are warranted to further explore the neural and cognitive underpinnings of these dissociated processes. Among the limitations of our study, it is worth mentioning that groups were not matched in age and years of education. Although correlational analyses did not support a significant effect of these variables on adaptive decision-making in SA or HC, and we specifically addressed the issue of educational attainment by including it as a fixed variable in all analyses, we cannot totally discard the possibility that group differences may be partially accounted for by these variables. However, initial studies found little association of CB performance with age or education (Podell, 1992). Nevertheless, future studies should address this caveat, by examining decision-making performance in more homogeneous groups of SA and HC.

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