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Predictors of Decision-Making on the Iowa Gambling Task: Independent Effects of Lifetime History of Substance Use Disorders and Performance on the Trail Making Test

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Abstract

Poor decision-making and executive function deficits are frequently observed in individuals with substance use disorders (SUDs), and executive deficits may contribute to poor decision-making in this population. This study examined the influence of lifetime history of an alcohol, cocaine, heroin, or polysubstance use disorder on decision-making as measured by the Iowa Gambling Task (IGT) after controlling for executive ability, demographic characteristics, and current substance use. Participants (131 with lifetime history of SUD and 37 controls) completed the IGT and two neuropsychological tests: the Trail Making Test and the Controlled Oral Word Association Test. Control participants performed significantly better than those with a lifetime SUD history on the IGT, but performance on the neuropsychological tests was comparable for the two groups. A lifetime SUD diagnosis was associated with performance on the IGT after controlling for covariates, and Trail Making Test performance was associated with IGT performance in both SUD and control participants.

Keywords

decision-making; substance use disorder; executive ability; neuropsychological tests; Iowa Gambling Task; Trail Making Test; Controlled Oral Word Association Test

Introduction

Poor decision-making is a characteristic associated with substance use disorders (Allen, Moeller, Rhoades, & Cherek, 1998; Mitchell, Fields, D'Esposito, & Boettiger, 2005). Maladaptive substance use could arise from poor decision-making skills that lead individuals with substance use disorders (SUDs) to ignore long-term negative consequences in the interest of immediate gratification or relief of uncomfortable states (Bechara, 2005). Alcohol and other abused drugs may also contribute to impaired decision-making through acute effects on the nervous system and chronic negative impact on neurotransmitters (Jentsch & Taylor, 1999).

The Iowa Gambling Task (IGT; Bechara, Damasio, Damasio, & Anderson, 1994) is a sensitive measure of decision-making that simulates a real-world decision-making situation requiring evaluation of the magnitude and timing of rewards and punishments under uncertain

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conditions. Higher short-term rewards are associated with larger punishments, making the choice of lower short-term rewards more advantageous in the long-term (Bechara et al., 1994). SUDs are consistently associated with poor performance on the IGT. For instance, poorer performance relative to controls has been observed in patients with dependence on alcohol or stimulants (Bechara et al., 2001), heroin (Petry, Bickel, & Arnett, 1998), marijuana (Whitlow et al., 2004), and polydrugs (Grant, Contoreggi, & London, 2000). The tendency to favor short-term rewards in spite of punishment on the IGT persists in long-term abstinent alcoholics (Fein, Klein, & Finn, 2004). Adverse real life consequences of substance use, including medical and legal problems, and greater severity of alcohol use are associated with poor performance on the IGT among SUD treatment patients (Dom et al., 2006; Verdejo-Garcia, Bechara, Recknor, & Perez-Garcia, 2006).

SUDs are also associated with deficits on neuropsychological tests of executive functions (Bates, Bowden, & Barry, 2002; Fals-Stewart & Bates, 2003; Goldstein et al., 2004; Verdejo-Garcia & Perez-Garcia, 2007). Executive functions are cognitive processes that govern and regulate other abilities and include working memory, alternating and selective attention, self-monitoring, inhibition, cognitive flexibility, novel problem solving, organization, and abstract reasoning. Many of the negative characteristics often attributed to substance abusers, such as low motivation, denial or minimization of problem severity, and poor impulse control, may actually arise in part from executive cognitive deficits (Fals-Stewart, Shanahan, & Brown, 1995; Goldman, 1995). Decision-making can be viewed as a behavioral manifestation of executive cognitive ability. To date, however, empirical research regarding the relationship between performance on the increasingly popular IGT and standard measures of executive function among individuals with SUDs has been limited. They have primarily relied on a single measure, the Wisconsin Card Sorting Test (WCST), and results have been inconsistent, as outlined below.

Bechara et al. (2001) examined group differences on the IGT and three neuropsychological tests among patients with substance (alcohol or stimulant) dependence, patients with lesions to the ventromedial prefrontal cortex (VM), and normal controls. Substance dependent patients performed more poorly than controls, and their performance as a group did not differ from that of patients with VM lesions, who generally exhibit decision-making deficits on the IGT. Substance dependent patients made more preseverative errors on the WCST than either comparison group, suggesting an inability to adapt to changing contingencies. Performance on two other tests of executive ability, the Stroop and Tower of Hanoi, did not differ among groups, and there were no significant correlations among the IGT and the three neuropsychological tests of executive ability (Bechara et al., 2001).

Other studies examined performance on the IGT and the WCST in individuals with SUDs with conflicting results. Some SUD samples perform relatively worse than controls on both the IGT and the WCST (Piratsu et al., 2006), while others perform worse on the IGT but comparably on the WCST (Grant et al., 2000) or vice versa (Piratsu et al., 2006).

Verdejo-Garcia and Perez-Garcia (2007) administered an array of executive tests including the WCST, Stroop, verbal fluency (FAS), Ruff Figural Fluency Test, Letter-Number Sequencing, Arithmetic, Spatial Span, and Similarities from the Wechsler scales, the Category Test, Go/No Go test, and two other interference tests, as well as the IGT and another decision-making test called the Cognitive Bias Task, to abstinent polysubstance users and controls. Factor analysis revealed four factors that the authors described as updating, inhibition, shifting, and decision-making. The IGT was the only test that loaded on the decision-making factor; the other decision-making test loaded on the same factor as tests of fluency, working memory, and reasoning. However, the IGT shared a substantial proportion of variance with other executive tests, suggesting that executive ability may contribute to but not fully account for IGT performance. Abstinent substance users performed more poorly than controls on all four categories of executive ability identified by the factor analysis.

The WCST is considered a test of abstract reasoning and set shifting (Lezak, Howieson, & Loring, 2004). With the exception of the studies by Bechara and colleagues (2001) and Verdejo-Garcia and Perez-Garcia (2007) described above, studies of individuals with SUDs have not examined relationships between the IGT and tests purported to measure other aspects of executive ability. The purpose of this study was to examine whether executive ability as measured by two popular and easily administered tests (Trail Making Test and Controlled Oral Word Association Test) contributes to the relationship between SUDs and decision-making deficits as assessed by performance on the IGT. The Trail Making Test and Controlled Oral Word Association Test (COWA) have been used extensively in studies examining relationships between executive cognitive abilities and SUDs, and SUDs are consistently associated with poorer performance on both tests (e.g., Jovanovski, Erb, & Zakzanis, 2005; Tapert, Granholm, Leedy, & Brown, 2002; Verdejo-Garcia & Perez-Garcia, 2007). The Trail Making Test measures cognitive flexibility, alternating attention, and response inhibition (Kortte, Horner, & Windham, 2002; Strauss, Sherman, & Spreen, 2006), while the COWA is used to assess novel problem solving, organization, and self-monitoring (Struass et al., 2006). We know of no studies examining how the specific executive abilities measured by the Trail Making Test and COWA might contribute to IGT performance in substance users. Decision-making on the IGT relies on multiple cognitive processes, including the ability to respond flexibly to changing contingencies, inhibit a dominant response, identify the solution to a novel problem, and monitor prior responses and their outcomes, processes that are also tapped by the Trail Making Test and COWA. We therefore chose these two tests as our measures of executive ability.

Potential contributions of age, gender, and education were also examined to control for their influence on IGT performance. We predicted that SUDs would be associated with poorer performance on the IGT and that executive ability would contribute to that association.

Method

Participants

Participants were recruited using newspaper advertisements and flyers distributed at substance abuse treatment programs, low-income housing projects, and social service agencies. The SUD group included individuals who met criteria for a lifetime history of alcohol, cocaine, heroin or polysubstance abuse or dependence based on responses to the Structured Clinical Interview for DSM-IV (SCID; First, Spitzer, Gibbon, & Williams, 1997). The control group included individuals who reported no lifetime use of illicit drugs, no lifetime regular use of alcohol, no more than three days of alcohol use in the last 30 days, and no more than two drinks per drinking day. In addition, candidates for the control group were selected based on similarities to the SUD group with respect to age, race, and education. Exclusion criteria for both SUD and control groups included suicidal ideation, psychosis, and, because a purpose of the larger study was to evaluate HIV risk behaviors in HIV negative individuals, HIV positive status.

One hundred and seventy-one people provided informed consent. Data examining the effects of problem gambling on IGT performance in a subset of this sample have been previously published (Petry, 2001), but the effect of executive ability on decision-making was not analyzed in the previous report nor have IGT data from the entire sample been presented. Two participants in the SUD group were excluded from the current analysis because they did not complete all the neuropsychological tests, and one was excluded because of a score discrepancy that appeared to be a data entry error. The final sample included 131 participants in the SUD group and 37 in the control group. All participants who completed the assessment were given

$50, and an additional $10 was given to participants who performed the IGT successfully (see description below).

Assessments

Interview and Drug Testing—Participants were interviewed regarding their substance use using the alcohol and drug sections of the SCID. Prior to testing, participants submitted breath and urine samples to screen for acute alcohol and drug use. Any individuals in the SUD group who were actively using substances and not currently engaged in treatment were given appropriate referrals.

Neuropsychological Measures—The Trail Making Test (Reitan & Wolfson, 1985) is a pencil and paper task that requires individuals to connect a series of circles in order. Part A of the Trail Making Test (Trails A) contains only numbered circles whereas Part B (Trails B) includes both numbered and lettered circles and requires alternation between number and letter while connecting the circles in the correct order. Both parts require visual scanning ability, motor speed and dexterity, and correlate well with other tests of speeded processing, but Part B is also considered a measure of cognitive flexibility, alternating attention, and ability to inhibit a dominant but incorrect response (Kortte, Horner, & Windham, 2002; Strauss et al., 2006).The Trail Making Test is reliable, valid, and sensitive to neurological impairment and brain damage (Giovagnoli et al., 1996; Lezak et al., 2004). Calculating the difference in completion time between Part B and Part A (Trails B –Trails A) is suggested for interpretation of executive deficits and eliminating the influence of visual and motor abilities on performance (Strauss et al., 2006).

The Controlled Oral Word Association test (COWA; Benton & Hamsher, 1976) is a measure of verbal fluency requiring participants to provide words beginning with a series of three specific letters. Participants have one minute to generate as many words as possible for each letter presented. This study used the letters C, F, and L. The COWA is considered a measure of executive ability as it requires novel problem solving, organization, and self-monitoring. Compared to Trails B, however, the COWA relies more heavily on working memory, semantic/episodic memory, and word knowledge (Strauss et al., 2006). The COWA has good reliability (Ruff, Light, Parker, & Levin, 1996) and good validity for identifying executive cognitive impairment and recovery (DesRosiers & Kavanaugh, 1987).

The Shipley Institute of Living Scale (SILS; Zachary, 1986) was administered in order to obtain an estimate of overall intellectual ability. The SILS consists of two subtests, Vocabulary and Abstraction, and the estimated full-scale intellectual quotient (FSIQ) is obtained based on the total score on these two tests. The SILS estimated FSIQ correlates highly with the Wechsler scales among individuals with average intellectual abilility although it tends to underestimate IQ scores under 85 or over 120 (Lezak et al., 2004; Weiss & Schell, 1991; Zachary, 1986).

Iowa Gambling Task—The measure of decision-making was the IGT (Bechara et al., 1994). For this task, participants were asked to select cards from any of four decks labeled A, B, C, and D. Each deck contained a mixture of cards, half with a red circle and half with a blue circle on the underside. Choosing a card that had a red circle on the underside resulted in a win. Choosing a card with a blue circle on the underside resulted in a win but could also result in a penalty. Every card in decks A and B resulted in a $100 win, and every card in decks C and D resulted in a $50 win, but the penalties were higher when blue circle cards were drawn from decks A and B compared to decks C and D. Decks C and D therefore resulted in greater net wins over the course of the task because of the smaller penalties attached to cards with blue circles. An individual choosing ten cards from decks A or B would win $1000 ($100 per card) and lose a total of $1250 resulting in a net loss of $250. In deck A, the loss was distributed across five penalty cards (range −$150 to −$350) per ten cards drawn; in deck B it resulted from one large penalty (−$1250) occurring once per every ten cards drawn on average. Choosing ten cards from decks C and D resulted in $500 in wins and $250 in losses, a net win of $250. Deck C, like deck A, contained five small penalties (range −$25 to −$75) per ten cards drawn, while Deck D contained a single $250 penalty for every ten cards drawn on average.

All participants received standard instructions for the IGT. Briefly, they were told that the object of the task was to win as much as possible and avoid losses by drawing cards, one at a time, from the four decks. They were informed that each card drawn would indicate how much they had won and whether there was also a penalty. They were also informed that some decks were more advantageous than others and that they were free to switch from one deck to another at any time and as frequently as they liked. They were not informed of the schedule of wins and losses in each deck or given advice on how to draw the cards, nor were they told how many cards they would be allowed to draw. The game was stopped after 100 cards were drawn.

One deviation from standard IGT administration was introduced based on observations of inadequate effort and random responding among substance users completing the IGT in a prior study by one of the authors (NP). To encourage good effort, participants were advised that they would receive $10 at the completion of the task if they won more than they lost. Prior research suggests that providing monetary reinforcement on the IGT improves overall performance and reduces performance variability (Bowman & Turnbull, 2003; Fernie & Tunney, 2006).

Data Analysis

Demographic characteristics of the control and SUD groups were compared using Chi square tests for nominal variables and analysis of variance (ANOVA) for continuous variables. ANOVA was also used to examine the effect of specific SUD diagnosis on IGT performance in the SUD group and to evaluate the effect of testing positive for acute alcohol or drug use on neuropsychological test and IGT performance. The effects of current use (self-reported use within the last 30 days) and duration of regular substance use in years on IGT performance were evaluated in the SUD group using analysis of covariance (ANCOVA).

ANCOVA was used to examine the influence of group (SUD vs. control) on IGT performance, while controlling for neuropsychological test performance and demographics. The General Linear Model function in SPSS 15.0, which corrects for unbalanced samples using Type III sum of squares, was used for the ANCOVA to correct for the disparity in the size of the SUD and control groups. The dependent variable was the net overall score, that is the number of cards drawn from the advantageous decks (Decks C and D) minus the number drawn from the disadvantageous decks (Decks A and B), on the IGT. The independent variable was group (0 = SUD, 1 = Control). Covariates were the difference between completion times on Trails A and Trails B (Trails B – A), COWA (total number of words provided), age, years of education, and gender (dummy coded, 0 = male, 1 = female). The dependent variable and most continuous independent variables were normally distributed. The exception was the variable created by subtracting completion time for Trails A from completion time for Trails B. A logarithmic transformation resulted in a normally distributed variable that was included in the analysis.

The effect of interactions between group (SUD vs. control) and Trails B – A performance (below vs. above the median) on net IGT performance were examined using factorial ANOVA. Repeated measures ANOVA was used to examine effects of SUD and Trails performance on changes in net IGT scores over five blocks of 20 draws.

Results

Demographic Characteristics

Table 1 shows demographics of the SUD and control groups. The analysis of variance revealed a significant age difference between the two groups with the control group being 3.3 years younger ($F(1,166) = 3.94$, $p < 0.05$). Yearly income was significantly higher in the control group ($F(1,166) = 8.08$, $p < 0.01$). Education, gender composition, ethnic/racial composition, and FSIQ were comparable for the two groups.

Neuropsychological and Decision-Making Measures

Table 1 also shows mean performance on the neuropsychological tests. There were no significant differences between the SUD and control groups on neuropsychological measures, although there was a trend toward the SUD group performing better than the control group on the COWA. A significant between-groups difference emerged on the IGT ($F(1, 166) = 6.95$, $p < 0.01$). Control group participants had higher net IGT scores than participants in the SUD group.

There was no significant association between specific substance use disorder and IGT performance in the SUD group ($F(3, 127) = 1.76$, $p = 0.16$) with mean net IGT scores of 0.79 (SD = 17.21) for alcohol, 0.95 (SD = 18.70) for cocaine, -1.29 (SD = 24.53) for heroin, and 10.04 (SD = 20.35) for polydrugs. Further, there was no effect of current substance use ($F(1,128) = 0.77$, $p = 0.38$) or duration of regular substance use ($F(1,128) = 0.38$, $p = 0.85$) on IGT net score. We therefore included all four substance use disorder groups in the single SUD group for the main analyses and did not categorize members of the SUD group based on current substance use or duration of regular substance use.

Participants who tested positive for alcohol or drugs at the time of testing had significantly lower estimated FSIQ scores ($F(1, 165) = 4.09$, $p < 0.05$). The mean FSIQ score was 95.51 (SD = 18.39) for participants with negative tests and 89.38 (SD = 19.15) for those submitting positive tests. Urine and breath test results did not predict performance on neuropsychological tests or the IGT, with all p values exceeding 0.30. The mean net IGT score was 2.07 (SD = 19.52) for participants with positive breath or urine tests and 5.98 (SD = 22.96) for those submitting negative tests.

Variables Associated with Performance on the Decision-Making Task

As shown in Table 2, performance on the IGT was significantly correlated with group (SUD vs. control), the Trail Making Test measure (log Trails B – Trails A), and estimated FSIQ. SUD group, worse Trails performance, and lower IQ were associated with lower net IGT scores. No other significant correlations between the IGT and independent variables were observed.

Table 3 shows results of the ANCOVA with overall net IGT score as the dependent variable. Substance use disorder status (SUD vs. Control) had a significant association with performance on the IGT after controlling for neuropsychological test performance, age, education, and gender ($F(1, 161) = 7.09$, $p < 0.01$). Performance on the Trail Making Test (log Trails B – Trails A) was the only covariate significantly associated with IGT performance ($F(1, 161) = 4.96$, $p < 0.05$). As expected, the SUD group performed more poorly than the control group on the IGT, and better performance on the Trail Making Test was associated with better performance on the IGT. Although the associations were significant, SUD status and Trail Making Test performance accounted for a relatively small proportion of the total variance in IGT performance, and effect sizes were small.

To determine whether the influence of Trail Making Test performance on IGT performance differed between the SUD and control groups, a dichotomous variable based on the median split of the Trails B minus Trails A scores was created (see Figure 1). We then tested the main effects of group (SUD vs. control) and Trails performance (below vs. above the median), and the interaction of group and Trails performance, with net IGT score as the dependent variable, to ascertain if the effects of Trails performance differed by SUD status. Main effects of both group ($F(1, 164) = 6.91$, $p < 0.01$) and Trails performance ($F(1, 164) = 6.06$, $p < 0.05$) remained, but the interaction was not significant ($F(1, 164) = 0.93$, $p = 0.34$).

Figure 2 shows the number of cards selected from the advantageous decks (C and D) minus the number chosen from the disadvantageous decks (A and B) across five blocks of 20 cards for SUD and Control participants performing below vs. above the median score for Trails B minus Trails A. All four groups started out choosing primarily from the disadvantageous decks. Both control groups and the SUD group with better Trails performance switched to a preference for the advantageous decks between draws 21 and 40. Only the Control group with better Trails performance maintained a strong preference for the advantageous decks for the remainder of the test. IGT net scores for the SUD group with better Trails performance and the Control group with poorer Trails performance declined somewhat across the five blocks. The SUD group with poorer Trails performance never developed a clear preference for the advantageous decks, with IGT net scores close to zero on each block.

Repeated measures ANOVA with block as the within subjects independent variable, group (SUD vs. control) and Trail Making Test performance (below vs. above the median) as the between subjects independent variables, and net score as the dependent variable revealed significant main effects for block ($F(3.79, 159) = 6.74$, $p < 0.01$), group ($F(1, 159) = 6.20$, $p < 0.05$), and Trails performance ($F(1, 159) = 6.45$, $p < 0.05$), but no significant block by group ($F(3.79, 161) = 0.49$, $p = 0.73$) or block by Trails ($F(3.79, 159) = 1.02$, $p = .39$) interaction after correcting for departure from sphericity.

Discussion

Having a lifetime history of SUD reduced the likelihood of choosing more cards from the advantageous versus the disadvantageous decks on the IGT in this sample of participants. Performance on the Trail Making Test (Trails B minus Trails A) was also associated with IGT performance, regardless of whether one had a SUD history. Performance on the COWA was not associated with IGT performance, nor were demographic characteristics, including age, gender, and education. Specific SUD diagnosis, current substance use, and duration of regular substance use did not influence IGT performance within the SUD group.

These results are consistent with previous studies finding a negative effect of current SUDs on decision-making as assessed by the IGT. Because our sample included a subset of individuals who had a lifetime history of SUD but were not currently using substances, we were able to examine the effect of current use. The fact that current substance use was not associated with performance on the IGT within the SUD group suggests that decision-making deficits endure into remission. This finding presents multiple possibilities. Decision-making deficits could be stable traits that increase the odds of developing problematic substance use, or heavy substance use could cause enduring neurotoxic damage that interferes with decision-making even during periods of abstinence. SUD participants performed more poorly on the IGT regardless of the specific substance used or the duration of regular substance use, lending support to the first hypothesis, since the different pharmacological effects of various substances could be expected to lead to differing degrees of neurotoxic damage, and longer histories of substance use could be expected to cause more severe damage.

Despite relatively poorer performance by the SUD group, the mean net score of both groups was positive. Participants in the SUD group may have failed to consistently employ the advantageous decision-making strategy of choosing from Decks C and D, but as a group they did not display an overall tendency to *favor* the more risky decks, Decks A and B. In fact, the mean number of cards drawn from the advantageous decks (Decks C & D) was not in the defective range (< 50 cards) defined by Bechara and colleages (Bechara, Damasio, Tranel, & Anderson, 1998). This finding suggests that decision-making among substance users may not be qualitatively different from that of controls, it may simply be less efficient. It also raises the possibility that individuals in the SUD group were less motivated to perform effectively, despite the $10 incentive to perform the task successfully.

The Trail Making Test and COWA, although both considered tests of executive functions, require different aspects of executive ability. The Trail Making Test measures cognitive flexibility, alternating attention, and behavioral inhibition, while the COWA assesses verbal productivity, organization, self-monitoring, and perseveration. In addition to executive functions, the COWA also requires word knowledge and long-term semantic memory. Although our tests of executive function were correlated with one another, only the Trail Making Test was significantly associated with the measure of decision-making (IGT).

One unexpected finding of this study was the comparable performance of SUD and control groups on the neuropsychological tests. Although several studies have found significantly poorer performance on tests of executive ability among samples of individuals with SUDs relative to controls (e.g. Bechara et al., 2001; Dao-Castellana, et al., 1998; Ratti, Bo, Giardini, & Soragna, 2002; Tapert et al., 2002; Verdejo-Garcia & Perez-Garcia, 2007), others have found comparable performance in SUD and control groups (e.g., Prosser et al., 2006), and examination of a large (N=8521), heterogeneous sample of patients receiving SUD treatment revealed that most performed within normal limits on the Trail Making Test (Roberts & Horton, 2001). Our SUD and control groups were fairly similar demographically, while control group participants in some studies have been significantly more educated than participants with SUDs (Bechara et al., 2001; Dao-Castellana et al., 1998), which could partly explain discrepant findings.

The IGT was developed to identify decision-making deficits in patients with damage to the ventromedial portion of the orbitofrontal cortex. Imaging studies have revealed reduced grey matter volume in the prefrontal cortex of drug abusers (Liu, Matochik, Cadet, & London, 1998), particularly in the orbitofrontal cortex (London, Ernst, Grant, Bonson, & Weinstein, 2000). Animal studies indicate changes in functional activity in the orbitofrontal cortex, including reductions in glucose metabolism, that correspond to increased duration of exposure to drugs (Porrino & Lyons, 2000). These findings suggest that substance use can lead to orbitofrontal dysfunction, perhaps reflected in relatively poor IGT performance by individuals with SUDs in this and numerous other studies.

Executive ability is also primarily governed by the frontal lobes, but most evidence supports the importance of the dorsolateral rather than orbitofrontal regions. Disruption of circuitry between the dorsolateral prefrontal cortex and subcortical structures leads to impairments of reasoning, mental flexibility, and other abilities generally classified as executive functions, including performance on Trails B (Stuss et al., 2001; Tekin & Cummings, 2002). Although the IGT has been considered an orbitofrontal task, recent research suggests that dorsolateral prefrontal cortex is also involved in decision-making on the IGT (Fellows & Farah, 2005). In our sample, SUD status may reflect activity of the orbitofrontal pathway, and Trails B – Trails A could represent the activity of the dorsolateral pathway in the decision-making process. Our findings suggest that the two pathways may operate relatively independently, a conclusion supported by the Fellows and Farah (2005) study in which patients with discrete damage to either area were more likely than a control group to have difficulty on the IGT.

The orbitofrontal lobes may also contribute to Trail Making Test performance as suggested by other findings by Fellows and Farah (2005). In their study, participants with ventromedial orbitofrontal (VMF) damage made more errors on Trails B than participants with dorsolateral frontal (DLF) damage. The authors also tested the hypothesis that reversal learning, the ability to revise reinforcement associations as contingencies change, is a key element of the decision-making process required for the IGT. The first few cards of the standard IGT provide rewards without penalties in all decks, making Decks A and B initially more rewarding. Once the penalties start appearing in the decks, it is necessary to abandon a previously rewarding strategy and adopt a new one, a change that requires cognitive flexibility. To eliminate the need for reversal learning from the IGT, Fellows and Farah offered an alternative IGT with “shuffled” decks that gave participants an early experience with the penalties, thus preventing them from developing an initial preference for the more risky decks. VMF participants performed as well as controls on the alternative IGT, while DLF participants continued to perform relatively poorly. These findings suggest that reversal learning is an important component of decision-making on the standard IGT, and that reversal learning, or the cognitive flexibility required for it, is governed at least in part by the ventromedial orbitofrontal cortex.

Nevertheless, executive abilities other than reversal learning must contribute to IGT decision-making, since DLF participants were not aided by the elimination of the reversal learning component. Response inhibition, an ability also required for effective Trail Making Test performance, is one potential contributor, as the dominant response of choosing high rewards yields negative outcomes on the IGT.

Although neuroimaging studies using phonemic verbal fluency tasks similar to the COWA have found brain activation in dorsolateral prefrontal cortex (Gaillard et al., 2000), activity is predominantly in the left hemisphere. Other brain regions including the left inferior frontal cortex (Broca’s area) also show increased activity, consistent with the verbal production demand of the task. The significant contribution of brain regions other than the frontal lobes may explain our failure to find an association between the COWA and the IGT.

Education was used as a proxy measure of overall intellectual ability in our main analysis because the SILS estimated FSIQ correlated highly with both education and the neuropsychological measures of executive ability, suggesting significant shared variance with both. By including education as a covariate rather than FSIQ, we could assess the influence of general cognitive ability and specific executive abilities relatively independent from one another. Furthermore, in our sample, FSIQ was the only measure associated with a positive alcohol or drug screen, making it impossible to determine whether a relationship between FSIQ and IGT performance was attributable to a stable trait of intellectual ability or an unstable state induced by acute substance use. Bechara et al. (2000) state that performance on the gambling task is not related to education, but little data exist regarding the influence of education on IGT performance. Data generally do not support a relationship between education and IGT performance (Cavedini et al., 2002; Lawrence et al., 2006), although one study found that higher education predicted *poorer* performance (Evans, Kemish, Turnbull, 2004). Education did not predict IGT performance in our sample.

A strength of this study was sufficient sample size to simultaneously examine the influence of lifetime SUDs, executive ability, and other potential predictors of IGT performance. Previous studies have examined group differences in performance on the IGT and tests of executive cognitive ability (Grant et al., 2000; Piratsu et al., 2006) or identified correlations between the IGT and various neuropsychological tests (Bechara et al., 2001), but have not had sufficient sample size to examine the role of executive functions in group differences due to SUDs. Although we found no significant group differences on our executive tests, we were able to show that some component of executive ability, possibly characterized as cognitive flexibility or response inhibition, influences IGT performance, and does so at least partly independently of SUD history. Another strength is inclusion of individuals with both current and lifetime histories of SUDs, which allowed us to examine the effect of current use.

A limitation of this study is its inclusion of only two tests of executive ability. Had we included additional tests that evaluate components of executive ability that overlap with those assessed by the Trail Making Test, it could have helped to further specify which components of executive ability influence IGT performance. For instance, including the Stroop, a measure of selective attention and response inhibition, could have helped to isolate which aspects of executive ability tapped by the Trail Making Test are most likely to influence decision-making. The uneven size of the samples is another weakness, as it may have prevented them from being as tightly matched for demographic features as would have been desired. Despite efforts to match the two groups, significant differences in age and yearly income were noted.

In summary, it appears that at least one component of executive ability contributes to IGT performance, both in individuals with a lifetime SUD history and those with no history of problematic substance use. Future research examining other cognitive processes that contribute to the relationship between SUD history and decision-making are needed to shed light on the mechanisms underlying that relationship. Additional research is also needed to ascertain the temporal relationship between decision-making and the development of SUDs and to elucidate the neurological pathways underlying that relationship. The association between SUDs and poor decision-making has implications for treatment outcomes, since being able to anticipate and account for long term consequences when making decisions facilitates recovery. Identifying executive deficits that further compromise decision-making may be particularly important when developing treatment plans for individuals with SUDs.

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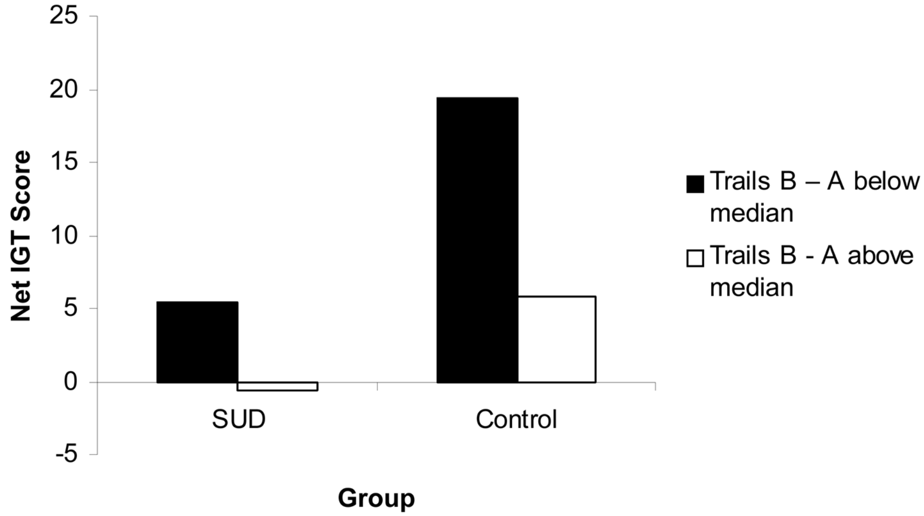

Figure 1.
Mean Iowa Gambling Task net scores for participants scoring below vs. above the median difference between completion times on Trail Making Test Parts A and B. Larger differences between Parts A and B indicate more impaired performance.

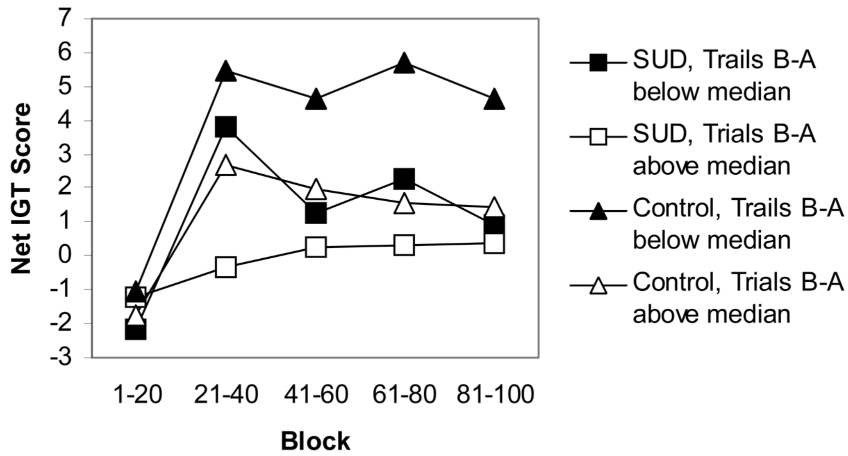

Figure 2.

Mean Iowa Gambling Task net scores on each of five blocks of 20 draws. Data are presented separately for participants with substance use disorders performing below vs. above the median difference between completion times on Trail Making Test Parts A and B and for Control participants performing below vs. above the median. Larger differences between Parts A and B indicate more impaired performance.

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Table 1

Demographic Characteristics and Performance on Neuropsychological Tests and Iowa Gambling Task by Group

Characteristic	Substance Use (N = 131)	Control (N = 37)	χ^2	F	*p*
Age	39.9 ± 8.6	36.6 ± 10.2		3.94	.049
Education	12.4 ± 2.1	12.5 ±1.3		.105	.747
Gender (% male)	67.9	67.6	.002		.966
Race/Ethnicity (%):			9.02		.108
White	53.4	54.1			
African American	32.8	35.1			
Hispanic/Latino	11.5	5.4			
Other	2.3	5.4			
Yearly Income	$7247 ± 9388	$12364 ± 9124		8.08	.005
Specific Substance Use Disorder (%)					
Alcohol	26.0				
Cocaine	32.1				
Heroin	21.4				
Polysubstance	20.6				
Self-Reported Use in Past 30 Days (%)	72.5				
Years of Regular Substance Use	14.38 ± 10.61				
Tested Positive for Alcohol/Drugs (%)	44.3	0	24.4		<.001
Estimated Full Scale IQ	92.6 ± 19.5	96.6 ± 16.0		1.32	.253
Trails B – Trails A	57.4 ± 44.3	54.4 ± 35.0		.140	.709
Controlled Oral Word Association Test (CFL Version)	38.0 ± 11.4	34.4 ± 9.7		3.01	.085
Iowa Gambling Task Net Score[a]	2.3 ± 20.2	12.8 ± 25.2		6.95	.009

[a]Number of cards drawn from Decks C and D minus number of cards drawn from Decks A and B.

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Table 2

Correlations Among Demographic Characteristics, Neuropsychological Test Results and Iowa Gambling Task Results

	Group	**Trails B – Trails A**	**Controlled Oral Word Association**	**Age**	**Gender**	**Education**	**Estimated Full-Scale IQ**	**Iowa Gambling Task**
Group (0 =Substance Use, 1 = Control		−.009	−.133	−.152*	.003	.025	.089	.200**
Trails B – Trails A	−.009		−.339*	.370**	−.187*	−.271**	−.451**	−.184*
COWA	−.133	−.339*		−.143*	.030	.248**	.373**	.081
Age	−.152*	.370**	−.143*		−.160*	−.020	.011	−.027
Gender (0 = male, 1 = female)	.003	−.187*	.030	−.160*		−.016	−.001	−.011
Education	.025	−.271**	.248**	−.020	−.016		.416**	.083
Estimated Full-Scale IQ	.089	−.451**	.373**	.011	−.001	.416**		.172*
Iowa Gambling Task	.200**	−.184*	.081	−.027	−.011	.083	.172*	

* $p < 0.05$,

** $p < 0.01$

Note. N = 168

Table 3

Results of Analysis of Covariance (ANCOVA) Showing Effects of Substance Use, Demographic Characteristics, and Neuropsychological Test Performance on Iowa Gambling Task Performance

	Iowa Gambling Task		
Predictor Variable	**F**	***p***	**Partial η^2**
Group (0 = Control, 1 = Substance Use)	**7.090**	**.006**	**.047**
Trail Making Test (Trails B – Trails A)	**4.955**	**.027**	**.030**
Controlled Oral Word Association	.411	.522	.003
Age	.952	.331	.006
Education	.023	.881	.000
Gender (0 = Male, 1 = Female)	.228	.634	.001

Note. N = 168