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Relationship of Cognitive Function and the Acquisition of Coping Skills in Computer Assisted Treatment for Substance Use Disorders

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Abstract

Background—Coping skills training is an important component of cognitive behavioral therapy (CBT), yet cognitive impairment and related limitations that are often associated with chronic substance use may interfere with an ability to learn, retain, or use new information. Little previous research has examined the cognitive or neuropsychological factors that may affect substance users' ability to learn new coping skills in CBT.

Methods—Fifty-two substance dependent individuals randomized to receive a computerized version of cognitive behavioral therapy (CBT4CBT) or treatment as usual (TAU) were administered several cognitive and neuropsychological measures, as well as a coping skills measure prior to and upon completing an 8-week treatment period.

Results—Across treatment conditions, participants who scored above the median on a measure of IQ demonstrated greater improvement in the quality of their coping skills than those below the median on IQ (Group $\times$ Time, $F(1,49) = 4.31, p < .05$). Also, IQ had a significant indirect effect on substance use outcomes through an effect on the quality of coping skills acquired, specifically for those who received CBT4CBT.

Conclusion—Individuals with higher IQ at baseline improved the quality of their coping skills more than those with lower IQ, which in turn reduced rates of substance use following treatment. This highlights the impact of substance users' cognitive functioning and abilities on the acquisition of coping skills from CBT, and suggests need for greater awareness and tailoring of coping skills training for those with poorer functioning.

Keywords

Coping Skills; Cognitive Behavioral Therapy; Cognitive Function; Indirect Effects

1. Introduction

Coping skills play an important role in delaying addiction relapse and preventing recurrence of alcohol and other drug use (Carroll, 1996; Chung et al., 2001; Cooper et al., 1992;

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Kadden et al., 1989; Monti et al., 1993). Research has found that individuals are significantly more successful in avoiding relapse if they can demonstrate the ability to appraise situations as risky and implement appropriate coping skills (McKay et al., 1996). Although most prominent in cognitive-behavioral therapy (CBT), a focus on skills to support abstinence or prevent relapse is a component in multiple interventions with substance using populations (Carroll et al., 1994; Moos, 2007; Morgenstern and Longabaugh, 2000; Witkiewitz and Marlatt, 2004). However, the cognitive deficits associated with chronic substance use are substantial (Vik et al., 2004), and very few studies have examined the influence of neurocognitive factors on individuals' ability to acquire effective coping techniques through treatment, even though such skills can be cognitively demanding.

The cognitive impairments and neuropsychological deficits associated with chronic alcohol and drug use are well documented. Neuroimaging studies of long-term users of alcohol and drugs have revealed multiple cognitive changes and deficits (Bolla et al., 2004; Goldstein and Volkow, 2002). It is estimated that more than half of individuals entering treatment for alcohol or substance use disorders show mild to severe neuropsychological impairment, particularly in tasks requiring new learning, memory, executive control, and other fluid cognitive abilities (Bates, 1999; Meek et al., 1989; O'Malley et al., 1992). In poly-substance abusers, evidence has suggested a dose-response relationship between severity of drug use and performance on tests of executive function (Verdejo-Garcia et al., 2005), and a recent meta-analysis on the neurocognitive deficits in cocaine users compared to healthy normal controls found cocaine use had the largest effect on attention and executive functions, such as decision making and mental flexibility (Jovanovski et al., 2005). Coupled with the evidence that substance users often display higher rates of impulsivity and poorer decision making compared to non-substance-using controls (Hanson et al., 2008; Moeller and Dougherty, 2002; Verdejo-Garcia et al., 2007), these issues are likely to present challenges when using interventions that emphasize learning, retaining, and implementing new strategies, such as CBT.

Although cognitive and neuropsychological deficits have long been thought to affect addiction treatment outcomes, the empirical evidence of a direct relationship between various cognitive abilities and treatment outcome, particularly substance use and abstinence rates, has been relatively weak (Alterman et al., 1990; Donovan et al., 1984; Fals-Stewart et al., 1994). There is evidence that performance on impulsivity and decision-making tasks are related to treatment dropout rates (Moeller et al., 2001; Passetti et al., 2008), and some research has indicated that poorer cognitive functioning is associated with worse treatment retention in CBT (Aharonovich et al., 2006; Aharonovich et al., 2003). Some studies have suggested that neuropsychological impairments may affect treatment outcome through an effect on therapeutic change mechanisms, with a focus on self-efficacy in particular (Bates et al., 2006; Morgenstern and Bates, 1999). Virtually no research has examined the influence of cognitive and neuropsychological factors, including impulsivity and risk-taking, on the acquisition of coping skills from CBT for substance use.

The purpose of this study was to examine the relationship between cognitive/neuropsychological functioning, the acquisition of coping skills, and treatment outcome, using data drawn from a randomized clinical trial evaluating a computer-assisted version of CBT for substance use as an enhancement to treatment as usual. A previous analysis from this trial indicated that participants who received the computerized CBT demonstrated greater improvement in their coping skills than those who only received treatment as usual, and improvement in coping skills was in turn related to a decrease in substance use (Kiluk et al., in press). The current study sought to extend these findings by exploring cognitive factors that may have affected the acquisition of coping skills during treatment and the

subsequent frequency of substance use following treatment. Our focus was not on the direct relationship between neurocognitive indicators and treatment outcome, which has been evaluated elsewhere (Carroll et al., in press), but rather on a potential indirect relationship through an effect on coping skills. We hypothesized that individuals with poorer cognitive functioning, as well as greater impulsivity and risk-taking, at the time of treatment entry would show fewer increases in their coping skills acquired than those with higher cognitive functioning, which in turn would be associated with higher levels of substance use following treatment.

2. Methods

2.1. Participants

As described in more detail in the main study report (Carroll et al., 2008), participants were 77 individuals seeking treatment for substance abuse at a community based outpatient treatment center. These participants were drawn from a larger pool of 158 individuals screened, and 77 were determined to be eligible for participation in the RCT. Individuals were excluded if 1) they had not used alcohol or illegal drugs within the past 28 days or failed to meet DSM-IV criteria for a current substance dependence disorder, 2) had an untreated psychotic disorder which precluded outpatient treatment, or 3) were unlikely to be able to complete 8 weeks of outpatient treatment due to a planned move or pending court case from which incarceration was likely to be imminent.

2.2. Measures

2.2.1. Substance Use—To assess substance use, the Substance Use Calendar, similar to the Timeline Follow Back (Fals-Stewart et al., 2000) was administered to collect self-reports of drug and alcohol use. Urine toxicology screens (testing for cocaine, marijuana, opiates, amphetamines, and benzodiazepines) and breath samples were obtained at every assessment visit to verify participant self-report of substance use. Two primary outcome measures were used: duration of longest continuous period of abstinence (urine confirmed), and the percentage of urine specimens positive for any type of drug use.

2.2.2. Coping Skills—Coping skills were assessed with the Drug Risk Response Test (DRRT), which involved a series of audio-taped role plays of 6 situations associated with a high risk for drug and alcohol relapse that correspond directly with coping skills taught in CBT. The six situations were played for the participant and a tape recorder was used to record the participant's response. Participants were instructed to imagine themselves in each situation and indicate how they would respond to the situation if it were occurring at that moment. The DRRT was administered at treatment entry (week 0) and at the end of treatment time point (week 8).

A scoring manual was utilized that included clarification of the intent of each scoring dimension, anchor points for Likert scale ratings, and example responses and ratings. Participants' responses to each of the eight situations were scored on the following variables: 1) *latency*, 2) *number of coping responses provided*, 3) *number of activities in each response*, 4) *quality of best coping response* (rated on a 7-point Likert scale ranging from 1- "would definitely use drugs or alcohol" to 7- "excellent response indicated complete confidence, no chance of using"); 5) *quality of overall response*, 6) *type of coping response*, 7) *category of response*, and 8) *specificity* – to assess whether the participant's response was specific to the particular situation, rather than a general, all-purpose response. This was scored dichotomously (yes/no).

Three experienced independent evaluators blind to treatment assignment rated the participants' DRRT responses. Raters were trained through a didactic seminar that included review of the coding manual and group practice ratings on five tapes until consensus was achieved. Given that these were experienced raters who had participated in multiple previous trials using a similar instrument, a reliability sample of four additional tapes (total of nine tapes) was deemed adequate. Intraclass correlation coefficient (ICC) estimates for the reliability sample of tapes was .86 for the *quality of overall response* variable, and between .85 and .93 for other variables from the DRRT.

Presented elsewhere, analyses from the DRRT indicated that participants assigned to a computerized version of CBT demonstrated a significantly greater increase in the quality of their overall responses (Week 0 Mean = 3.7, $sd=.76$; Week 8 Mean = 4.4, $sd=1.0$) compared with participants assigned to treatment as usual (Week 0 Mean = 3.8, $sd=.80$; Week 8 Mean = 3.8, $sd=.82$) (Group $\times$ Time, $F(1,51) = 6.77, p<.05$), whereas no such differences were evident for the quantity of coping responses, and this increase in the quality of coping was related to the amount of substance use following treatment (Kiluk et al., in press). Therefore, the *quality of overall response* variable was considered the indicator of effective coping skills and was the main variable of interest for the current study. Coping skill ability and acquisition was indicated by the mean quality of overall responses across the six situations from the DRRT, for both the baseline and end-of-treatment time points.

2.2.3. Cognitive Function—Measures utilized to assess aspects of cognitive function found to be impaired in drug users included the Vocabulary and Abstraction subtests of the Shipley Institute of Living Scale (Shipley, 1967; Zachary, 1986), which can then be converted into an estimate of Full Scale IQ from the Wechsler Adult Intelligence Scale (WAIS) by taking into account the age of the respondent. The composite scores from the Shipley correlate well with other measures of intelligence (Zachary, 1986). The test was used in this study as a brief test of intelligence.

The Digit Symbol – Coding subtest of the WAIS-III (Wechsler, 1997) was also included, which can be described as measuring the ability to learn combinations of symbols and numbers and the ability to make associations quickly and accurately. Much of the research to date strongly suggests that speed is the prime determinant of Digit Symbol performance, with memory playing a subsidiary role (Joy et al., 2004). Digit Symbol – Coding is considered a reliable subtest with reliability coefficients at or above .81 at all of the 13 age groups in the standardization sample (Wechsler, 1997).

2.2.4. Attention—The Connors Continuous Performance Test II (CPT-II) (Connors, 2004) is a general measure of sustained attention and provides measures of response time, and two types of error scores (omission and commission). All of the measures of the CPT II are converted to *T*-scores and percentiles. Data from the original standardization sample provided evidence of adequate consistency in terms of split-half reliability (α ranging from .83 to .95) and satisfactory test-retest reliability (r ranging from .55 to .84) (Connors, 2004).

2.2.5. Impulsivity—Impulsivity was measured with the Barratt Impulsiveness Scale Version 11 (BIS-11) (Patton et al., 1995), which is a 30-item self-report questionnaire answered on a 4-point scale designed to assess levels of impulsiveness. Factor analytic work has identified three separate domains/subtraits of impulsivity, which are labeled motor impulsiveness, nonplanning impulsiveness, and attentional impulsiveness. Internal consistency for the BIS-11 total score has been found to be within an acceptable range (Patton et al., 1995), with strong psychometric properties in both psychiatric and non-clinical populations (Spinella, 2007).

2.2.6. Risk-Taking—Risk taking was assessed with The Balloon Analogue Risk Task (BART) (Lejuez et al., 2002), which is a computer-simulated assessment of risk-taking behavior. Research has found the BART to be correlated with measures of sensation seeking, impulsivity, and deficiencies in behavioral restraint, as well as with self-reported occurrence of addictive, health, and safety risk behaviors (Lejuez et al., 2003; Lejuez et al., 2002).

2.3. Treatments

All participants were offered standard treatment at the outpatient clinic, which consisted of weekly individual and group sessions of general drug counseling. Participants were randomized to either standard treatment (i.e., treatment as usual: TAU), or standard treatment plus access to an interactive, multimedia computer-based training version of CBT (CBT4CBT). The CBT4CBT program consisted of six lessons based closely on a NIDA-published CBT manual (Carroll, 1998) and is described in more detail in the main study report (Carroll et al., 2008).

2.4. Procedures

Participants who met screening criteria and provided informed consent were scheduled for a baseline assessment that included administration of the above-mentioned neuropsychological and cognitive tests, assessment of substance use during the 28 days prior to randomization, as well as the coping skills assessment. Substance use was then assessed weekly during the treatment period, at the 8-week treatment termination point, and then again at monthly appointments following treatment termination; neuropsychological tests and the coping skills measure were administered again at the treatment termination point as well.

2.5. Statistical Analysis

The various neuropsychological test scores were compared across treatment conditions using Analysis of Variance (ANOVA) tests at the baseline time point in order to identify any baseline differences. Correlations were used to determine the relationship between coping skill ability (as measured by the quality of overall response from DRRT) and the various neuropsychological test scores, and based on these relationships, certain tests were selected for further analyses. Specifically, repeated measures ANOVA were used to assess the relationship of neurocognitive function and coping skills acquired over time (pre-post), with scores on the cognitive/neuropsychological tests dichotomized to represent high and low levels of functioning, using the median of the sample as the cut-off point, similar to prior studies (Aharonovich et al., 2008b; Aharonovich et al., 2003).

To examine the potential indirect effects of neurocognitive function and the acquisition of coping skills on the amount of substance use after treatment, several regression equations were computed for testing indirect effects. The three regression equations were: 1) $Y = i_1 + cX + e_1$; 2) $Y = i_2 + c'X + bM + e_2$; 3) $M = i_3 + aX + e_3$. In these equations, i_1 , i_2 , and i_3 are intercepts, Y is the dependent variable (frequency of substance use), X is the independent variable (neurocognitive test score), M is the mediator (quality of overall response at post-treatment as measured by the DRRT), c is the coefficient relating the direct effect of the independent variable to the dependent variable, c' is the coefficient for the effect of the independent variable to the dependent variable adjusted for the mediator, b is the coefficient relating the effect of the mediator to the dependent variable adjusted for the independent variable, a is the coefficient relating the effect of the independent variable to the mediator, and e_1 , e_2 , and e_3 are residuals (MacKinnon et al., 2007a). The quality of overall response at week 0 was also entered into these equations to control for baseline coping skills.

3. Results

3.1. Participants

Out of the 158 potential participants consented and screened for eligibility, a total of 77 were deemed eligible and randomized to a treatment group, of which 73 initiated treatment in the randomized clinical trial with 4 dropouts before the baseline assessment (CBT4CBT = 35; TAU = 38). The mean age of the sample of these 73 randomized participants was 41 ($SD = 10.3$). ANOVA and chi-square difference tests indicated no significant differences between treatment groups on baseline demographic characteristics, substance use history, or psychiatric diagnoses (see original report for description and analysis of full sample in RCT (Carroll et al., 2008)).

Sixty of the 73 who initiated treatment returned for the end-of-treatment interview (week 8); 52 participants (CBT4CBT = 24; TAU = 28) completed the DRRT at both baseline (week 0) and end-of-treatment (week 8), which were used in the subsequent analyses regarding acquisition of coping skills and cognitive/neuropsychological functioning. No significant differences were found between treatment groups for this sample of 52 participants, using the same baseline variables compared in the main RCT. See Table 1 for comparison of baseline variables between groups.

Comparison of the baseline cognitive/neuropsychological test scores across treatment group indicated a difference on the BIS-11 *Non-planning* impulsiveness scale ($F(1, 45) = 9.14, p < .05$), with slightly higher mean scores for those assigned to TAU compared to CBT4CBT (30.4 vs. 27.7). Sample sizes varied slightly for some of the tests due to non-administration of certain measures at baseline. No other differences were found on the baseline cognitive/neuropsychological tests. As a group, the participants had a mean IQ of 99.1 ($sd = 13.7$), WAIS-III Digit Symbol scaled score of 7.6 ($sd = 2.6$), CPT-II *T* scores of Omissions = 59.5 ($sd = 25.2$), Commissions = 47.4 ($sd = 11.4$), and Reaction time = 60.8 ($sd = 11.8$). Scores on these tests are similar to those reported in other samples of substance users (Gooding et al., 2008; Grohman and Fals-Stewart, 2004). Scores on the BIS-11 *Attentional* impulsiveness = 18.2 ($sd = 4.1$), and *Motor* impulsiveness = 24.5 ($sd = 4.3$) are consistent with those found in stimulant users (Leland and Paulus, 2005), and BART mean scores of 24.5 ($sd = 13.6$) and 3.7 ($sd = 2.6$) for average number of pumps and explosions, respectively, are consistent with samples of college students and healthy control participants (Ledgerwood et al., 2009; Lejuez et al., 2002). Although some of the cognitive/neuropsychological measures were not repeated at the end-of-treatment time point (e.g., IQ, WAIS-III Digit Symbol), there were significant positive correlations between baseline and end-of-treatment performance on the CPT-II, BART, and BIS-11, with magnitude ranging from $r = .55, p < .01$ for CPT-II Omissions, to $r = .77, p < .001$ for the BART mean number of pumps.

3.2. Cognitive/Neuropsychological Functioning and Coping Skills

Pearson Product Moment correlations revealed several significant relationships between the various cognitive/neuropsychological scores and coping skills (as measured by the quality of the overall coping responses from the DRRT) at both baseline and end-of-treatment. See Table 2 for results. Again, sample sizes for the correlations vary slightly due to non-administration of certain measures at baseline. At both time points, IQ was related to the quality of the overall coping responses ($r = .29, p < .05$) and ($r = .53, p < .01$), respectively. Relationships were also noted at both the baseline and end-of-treatment time points for the BIS-11 *Motor* impulsiveness and the quality of coping responses ($r = -.33, p < .05$) and ($r = -.41, p < .01$), respectively, as well as for the BIS-11 *Non-planning* impulsiveness scale ($r =$

$-.38, p < .01$) and ($r = -.38, p < .01$), respectively. Also, the average number of pumps from the BART was related to the quality of the overall responses at baseline ($r = .33, p < .05$).

To further investigate the relationship between the various cognitive/neuropsychological test scores and the acquisition of coping skills (mean quality of overall coping responses from week 0 to week 8), several repeated measures ANOVAs were conducted. For these analyses, each cognitive/neuropsychological test score was divided according to a median split (e.g., above vs. below), which was entered as the between-subjects factor in the repeated measures ANOVAs. Results indicated significant group by time effects for the mean quality of coping response according to a median split of IQ (Group $\times$ Time, $F(1,49) = 4.31, p < .05$). These results are illustrated in Figure 1, demonstrating that those who scored above the median IQ improved the quality of their overall coping responses greater than those with lower IQ scores. No group by time effects were present for any other cognitive/neuropsychological test score. Treatment group was entered as an additional between-subjects factor in subsequent repeated measures ANOVAs, and resulted in significant treatment group by time effects for the mean quality of coping responses according to a median split of the BIS-11 *Attentional* impulsiveness (Treatment Group $\times$ Median Split $\times$ Time, $F(1,43) = 4.29, p < .05$), and the median split of the CPT-II Omissions score (Treatment Group $\times$ Median Split $\times$ Time, $F(1,37) = 4.19, p < .05$). However, this method considerably reduced the sample within each group ($n < 12$), limiting the interpretability of these results.

3.3. Indirect Effect on Substance Use

Results of the regression equations for testing indirect effects were computed using the sample of participants who completed the DRRT at both baseline (week 0) and end-of-treatment (week 8) time points and had substance use data collected during a follow-up period ($n = 48$). In these regression equations, IQ as measured by the *Shipley Institute of Living Scale* was the independent variable, the duration of longest continuous period of abstinence during a 56-day period following treatment was the dependent variable, and the mean quality of overall response from the DRRT at post-treatment was the mediator. As mentioned in the statistical analysis section, the quality of overall response at week 0 was entered into these equations to control for baseline coping skills. Results are demonstrated in Figure 2, which were replicated in separate regression analyses that also controlled for frequency of substance use during the month prior to entering treatment.

Although baseline IQ did not have a direct effect on the amount of substance use following treatment, indirect effects can still be present even in the absence of a significant direct effect (Hayes, 2009; MacKinnon et al., 2007a). One method for testing the significance of an indirect effect is the difference in coefficients method (Freedman and Schatzkin, 1992), which is equal to the reduction in the IV effect on DV when adjusted for M, and is calculated by: $[(c - c') / (s.e. c - s.e. c')]$. This resulted in $z = -19.00$, which falls in the range of significance when compared to a standard normal distribution ($z > \pm 1.96$). Additionally, the product of coefficients method (MacKinnon, 2000), which is another test to determine if the indirect effect is significantly different from zero, was calculated by: $[(a * b) / (s.e. a * s.e. b)]$. This resulted in $z = 8.55$, which is again significant at the .05 level based on a standard normal distribution ($z > \pm 1.96$). Other methods to test whether the indirect effect is significantly different from zero include the Sobel test (Sobel, 1982), which resulted in $z = 2.07, s.e. = 0.15, p < .05$, the Aroian test (Aroian, 1947), which resulted in $z = 2.01, s.e. = 0.15, p < .05$, and the Goodman test (Goodman, 1960), which resulted in $z = 2.13, s.e. = 0.14, p < .05$. Finally, confidence limits for the mediated effect were computed based on the distribution of the product of the coefficient method using the computer program PRODCLIN (MacKinnon et al., 2007b; MacKinnon et al., 2004). This resulted in upper and lower confidence intervals of 0.64 and 0.07, respectively, which are consistent with a statistically significant indirect effect because they do not contain zero.

To address the potential for bias due to the reduced sample size used in the mediation analyses ($n = 48$), we also performed the tests for mediation using the full information maximum likelihood approach (FIML), which is a model-based imputation method that utilizes the full data set of 73 randomized participants who have at least one data point on any of the three variables in the model (e.g., IQ, quality of coping response from DRRT, or substance use during a 56-day follow-up period). Results demonstrated nearly identical beta weights as our initial regression model that utilized a listwise deletion method (displayed in Figure 2). For instance, the corresponding regression path beta weights from the FIML approach were: $a = 0.04$ ($se = 0.01$); $b = 11.31$ ($se = 3.21$); $c = 0.17$ ($se = 0.21$); $c' = -0.22$ ($se = 0.22$). As was true using listwise deletion, both the a and b paths were significant at the $p < .01$ level. Results of the methods for testing the significance of an indirect effect noted above were also replicated using the coefficients produced from the FIML approach.

Additional sets of regression equations were computed using the same variables, to further examine this indirect effect according to treatment assignment (CBT4CBT = 23; TAU = 25). Results indicated the mediator had a significant effect on the outcome for those assigned to CBT4CBT ($b = 12.63$, $s.e. = 4.57$, $t = 2.76$, $p < .05$), but not for those assigned to TAU ($b = 9.30$, $s.e. = 6.72$, $t = 1.38$, $p = 0.18$). See Figure 3 for illustration of results. Computed z -scores based on the product of coefficients methods listed above (Aorian, 1947; Goodman, 1960; Sobel, 1982) indicated an indirect effect significantly different than zero ($p < .05$) for those assigned to CBT4CBT, but not for those assigned to TAU. This would suggest that, in the CBT4CBT condition, IQ had an indirect effect on the amount of substance use following treatment through an effect on the quality of overall coping responses at week 8, whereas no such indirect effect was present in the TAU condition. However, results of this analysis are limited by the small sample in each condition, as well as a significant relationship between baseline quality of overall coping response and the quality of overall coping response at week 8 in the TAU condition ($\beta = .46$, $t = 2.90$, $p < .01$), but not in the CBT4CBT condition ($\beta = .10$, $t = 0.48$, $p = .64$).

4. Discussion

This is one of the first studies to investigate the relationship between cognitive functioning and the acquisition of coping skills following a computerized version of cognitive behavioral therapy for substance use disorders (CBT4CBT). The main finding was that individuals scoring above the median on a measure of IQ improved the quality of their coping responses to audio-taped role plays greater than those who scored below the median, regardless of their treatment assignment. Also, baseline IQ was indirectly related to the amount of substance use during a follow-up period through an effect on the quality of coping responses. In other words, those with higher baseline IQ scores demonstrated greater improvement in the quality of coping skills acquired, which was in turn associated with higher levels of abstinence following treatment. This indirect effect was present for those assigned to CBT4CBT, but not for those assigned to a standard treatment as usual (TAU) condition. These findings shed light on some of the cognitive and neuropsychological factors that may affect individuals' ability to improve their coping skills, and hence their ability to benefit from CBT.

Coping skills training requires various cognitive demands, and findings from this study point to the potential of cognitive/neuropsychological factors, such as IQ, impacting the acquisition of coping skills and hence response to cognitively complex therapies like CBT. Our results are congruent with prior research suggesting cognitive impairments influence substance abuse treatment outcomes through an effect on treatment retention (Aharonovich et al., 2006; Aharonovich et al., 2003), as well as change processes, such as self-efficacy and commitment to abstinence (Bates et al., 2006; Morgenstern and Bates, 1999), and may

highlight a possible mechanism of poorer response to CBT for those with cognitive impairment or difficulties. Therefore, the current finding that baseline IQ scores affected changes in the quality of coping responses over the course of treatment, and that IQ had an indirect effect on substance use outcomes through the quality of coping responses, highlight the need to examine the role of cognitive and neuropsychological factors in this potential change process. It also underscores the importance of neuropsychological evaluation within substance use treatment settings, due to the potential impact of cognitive functioning on treatment response and outcome in CBT. It should be noted, however, because our sample of participants were actively using drugs upon treatment entry (i.e., met dependence criteria within the 30 days prior to treatment), the withdrawal effects of chronic substance use may have affected scores on baseline cognitive measures, such as IQ, which may have inflated the impact of IQ on this change process. However, additional analyses revealed a significant indirect effect after controlling for the frequency of participants' drug use in the month prior to treatment entry, and correlation analyses demonstrated little change on the cognitive/neuropsychological measures between pre- and post-treatment.

Additional limitations of this study include a relatively small sample size, statistical issues with the median split method, the subjectivity of coping skill measurement, and the lack of a comprehensive neuropsychological assessment battery. As noted above, different sample sizes were present for many of the analyses conducted due to assessment measure additions after the start of the trial, which may have limited power and/or produced a biased sample. Also, only 52 participants of the 73 who initiated treatment completed the DRRT at both the baseline and end of treatment time point, which considerably reduced the sample size available for use in analyses of indirect effects according to treatment condition. However, results indicated similar cognitive/neuropsychological scores and outcomes for the sample of participants completing the DRRT and the full sample of participants in the trial. In addition, mediation results were replicated using a model-based imputation method that utilized the full sample of participants (FIML), and several different methods to test the significance of any indirect effect were computed to compensate for the reduced power associated with small sample sizes. Second, the dichotomization of continuous variables, such as IQ, based on the median split method has been criticized for loss of information about individual differences (MacCallum et al., 2002), although it has been used in prior studies examining the effect of cognitive function on treatment outcome (Aharonovich et al., 2008b; Aharonovich et al., 2003). Third, the acquisition of coping skills were assessed through ratings on a role play measure, which is an indirect measure of actual coping skills and may differ from an ability to utilize such skills *in vivo*. Also, higher IQ may have been associated with better verbal reports of coping, rather than the actual use of coping skills. Nevertheless, role-play assessments are not uncommon in research and our raters were blind to treatment assignment and demonstrated good inter-rater reliability. Fourth, due to the practical limitations of conducting a randomized clinical trial at a community outpatient treatment facility, we did not utilize a comprehensive neuropsychological assessment battery and thus some constructs were not measured. Yet, we did measure many cognitive/neuropsychological constructs related to substance abuse, such as attention, impulsivity, and risk-taking, and our findings do suggest significant effects of a brief measure of intelligence, which likely negate the need for a more comprehensive measure of intelligence. Finally, it should be noted the intervention in this study was a computerized version of cognitive behavioral therapy, which may have required a higher level of cognitive capacity than traditional therapist-delivered CBT, and as such our findings on the effect of cognitive/neuropsychological functioning may be somewhat distorted.

In conclusion, the findings presented here offer some support to the notion that cognitive and neuropsychological factors may indirectly affect substance use outcomes through an effect on substance users' ability to acquire coping skills through cognitive-behavioral

therapy. This is consistent with emerging literature regarding the impact of cognitive impairment on change processes and mechanisms of change (Aharonovich et al., 2008a; Bates et al., 2006; Morgenstern and Bates, 1999). Although our findings may have been altered due to the use of a computerized version of cognitive-behavioral therapy, these results highlight the importance of examining the role of cognitive function on treatment processes, particularly as more interventions are developed that incorporate digital technology. Future research might investigate the differential impact of cognitive function on change processes, such as acquisition of coping skills, between standard therapist-delivered treatments and newer technology-incorporated treatments for substance use.

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Figure 1. Changes in DRRT mean quality of overall response by time according to median split of IQ, as measured by the Shipley Institute of Living Scale. [Group $\times$ Time ($F(1,49) = 4.31, p < .05$)].

Figure 2.

Quality of coping response at end of treatment (week 8) as a mediator of the effect of IQ on the consecutive days of abstinence during a 56-day follow-up period, controlling for quality of coping response at baseline (N = 48).

* $p < .05$. ** $p < .01$.

TAU (n = 25) **CBT4CBT (n = 23)** **Figure 3.**

Quality of coping response at end of treatment as a mediator of the effect of IQ on the consecutive days of abstinence during a 56-day follow-up period, controlling for quality of coping response at baseline. Analyses presented with the sample divided according to treatment assignment (TAU = 25; CBT4CBT = 23).

* $p < .05$. ** $p < .01$.

Between Groups Comparisons for Baseline Variables

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TABLE 2

Relationship between Baseline Cognitive/Neuropsychological Scores and Coping Skills

Cognitive/Neuropsychological Measures	DRRT Quality of Overall Coping Response	
	Pre-Treatment (Week0)	Post-Treatment (Week 8)
	r (n)	r (n)
CPT-II		
Omission <i>T</i>	-.08 (41)	-.29 (41)
Commissions <i>T</i>	-.07 (41)	-.02 (41)
Reaction time <i>T</i>	-.25 (41)	-.08 (41)
IQ (age-normed)	.29* (51)	.53** (51)
BART		
No. of Pumps	.33* (41)	.15 (41)
No. of Explosions	.26 (41)	.04 (41)
BIS-11		
Attentional	.01 (47)	-.11 (47)
Motor	-.33* (47)	-.41** (47)
Non-planning	-.38** (47)	-.38** (47)
WAIS-Digit Symbol	.09 (39)	-.04 (38)

* indicates $p < .05$ ** indicates $p < .01$