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Cognitive Function and Treatment Response in a Randomized Clinical Trial of Computer-Based Training in Cognitive-Behavioral Therapy

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Abstract

Cognitive-behavioral therapy (CBT), because of its comparatively high level of cognitive demand, is likely to be challenging for substance users with limitations in cognitive function. However, it is not known whether computer-assisted versions of CBT will be particularly helpful (e.g., allowing individualized pace and repetition) or difficult (e.g., via complexity of computerized delivery) for such patients. In this secondary analysis of data collected from a randomized clinical trial evaluating computer-assisted CBT, four aspects of cognitive functioning were evaluated among 77 participants. Those with higher levels of risk taking completed fewer sessions and homework assignments and had poorer substance use outcomes.

Keywords

addiction; e-therapies; CBT; cognitive functioning; computerized therapies; risk taking

INTRODUCTION

Multiple lines of evidence point to the potential importance of assessing and addressing cognitive functioning in the treatment of substance use disorders. There is now extensive and compelling evidence of the role of cognition (memory, learning, attention, and cognitive control) in the development and maintenance of addiction (Goldstein & Volkow, 2002). A large literature has highlighted the extent to which significant levels of cognitive impairment are found among chronic substance users (Bolla, Funderburk, & Cadet, 2000; DiSclafani, Tolou-Shams, Price, & Fein, 2002; Fals-Stewart & Bates, 2003; Goldstein & Volkow, 2002; Gottschalk, Beauvais, Hart, & Kosten, 2001; Tomasi et al., 2007; Tucker et al., 2004). It is particularly striking that cognitive functions most commonly found to be impaired among substance users (e.g., cognitive flexibility, inhibition, and control; memory, learning, and attention) are precisely those functions that are usually considered to be critical to treatment response. These include functions such as being able to attend to what is discussed in treatment; learning, retaining, and implementing new strategies; monitoring of one's

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behavior; and controlling impulsive responding (Ersche & Sahakian, 2007; Fals-Stewart, Schafer, Lucente, Rustine, & Brown, 1994; Garavan & Hester, 2007).

While there is some evidence that cognitive impairment is associated with poorer treatment and outcome overall (Bates et al., 2004; Bates, Pawlak, Tonigan, & Buckman, 2006; Fals-Stewart et al., 1994; McCrady & Smith, 1986; Passetti, Clark, Mehta, Joyce, & King, 2008) such studies remain rare, and little is known regarding how cognitive functioning may affect response to specific empirically validated therapies. Cognitive-behavioral therapy (CBT) may be a particular challenge for substance-using patients with limitations in cognitive functioning. CBT places a high level of emphasis on complex tasks such as learning and retaining new cognitive and social coping skills and strategies, recognizing and challenging problematic cognitions, attending to cues in the environment that might precipitate craving, inhibiting conditioned responses, and substituting new behaviors. Thus, individuals who have difficulties with attention/concentration and/or inhibiting their behaviors might be expected to have particular problems with CBT.

However, only a handful of studies have evaluated cognitive functioning and CBT outcome. For example, alcohol users with higher levels of neuropsychological impairment had somewhat better outcomes when assigned to a less demanding supportive/interactional therapy than a cognitive behavioral approach (Cooney, Kadden, Litt, & Getter, 1991; Kadden, Cooney, Getter, & Litt, 1989). Similarly, among cocaine-dependent individuals in outpatient treatment, treatment dropouts, as opposed to completers (Aharonovich et al., 2006; Aharonovich, Nunes, & Hasin, 2003), had significantly poorer baseline scores on a number of indices from the computerized MicroCog battery (Powell, Kaplan, Whitla, Catlin, & Funkenstein, 1993), including memory, attention, speed, accuracy, and global cognitive functioning. However, because the Aharonovich studies did not include a comparison condition, it was not clear whether this was a general response to treatment or one that reflects particular challenges for CBT.

In the field of addiction treatment, increasing recognition of the centrality of cognition in addiction and its treatment should bring with it more attempts to identify the type and level of cognitive impairments among treatment samples and their impact on treatment process and outcome, as well as efforts to adapt empirically validated therapies to address the needs of those with cognitive impairments (Ersche & Sahakian, 2007; Fals-Stewart et al., 1994). However, clinicians are likely to overlook or underestimate the level of cognitive impairment in the individuals they treat (Fals-Stewart, 1997) and hence are unlikely to effectively adapt treatments for the needs of their patients who have cognitive difficulties.

This situation thus presents a potential opportunity for technology, e-health, and computer-assisted therapies, that is, to recognize and adapt to better meet the needs of those patients who have limitations in different aspects of cognitive functioning. For example, computerized therapies that make use of multimedia tools, such as interactive games and presentation of material in a variety of formats including videotaped examples, may provide clearer and more compelling means of demonstrating and teaching new skills, particularly for those patients who may have difficulties concentrating on or sustaining attention to demanding tasks. Similarly, in computer-assisted therapies, the ability of the user to modify the pace of material or to repeat material (either within a session or through booster sessions) may provide a more effective means of delivering CBT among users who may have significant difficulties with retaining, organizing, or implementing new information.

On the other hand, it should not be assumed that computerized therapies will convey these benefits among substance users with limitations in executive cognitive functioning. For example, without the interpersonal support offered by a therapist, computer-based therapies may be too demanding for those with limitations in executive functioning, attention and concentration, or inhibitory control. For example, high-risk-taking or impulsive substance abusers[1] may skip through material too quickly to absorb it or may fail to follow through on learning tasks or homework assignments, which are often related to outcome in CBT (Carroll, Nich, & Ball, 2005; Gonzalez, Schmitz, & DeLaume, 2006). Similarly, material presented via computer may have to be simplified or made more entertaining to retain individuals with limited ability to focus their attention for extended periods of time.

Thus, there has been little research to date on the influence of several aspects of cognitive functioning on patient response to empirically supported therapies, and none to date on cognitive functioning and response to treatments delivered in a computer-assisted format. In this article, we present data on the influence of several aspects of cognitive functioning (IQ, attention, visual-motor tracking, and inhibitory control and risk taking) and treatment retention, process, and outcome of a heterogeneous sample of substance abusers enrolled in a randomized clinical trial of a novel computer-assisted version of CBT (Carroll et al., 2008). Our group at Yale has developed a multimedia, computer-assisted version of CBT (called CBT4CBT), which was developed as a strategy both to make CBT more broadly available and to deliver it in a more precise and standardized way for process research.

This article will provide data from a secondary analysis of our randomized clinical trial of CBT4CBT in a community-based setting. In the main study, 77 individuals entering outpatient treatment for substance use disorders were randomized to either standard treatment (weekly individual and/or group sessions) or standard treatment with access to the computer-based training in the CBT program. As described in more detail in a previous work, CBT4CBT was demonstrated to be more effective than standard outpatient therapy (treatment as usual, or TAU) in terms of rates of drug-positive urine samples (34% for CBT4CBT versus 53% for TAU, $d = .46$) and duration of continuous abstinence (22 versus 17 days, respectively, $d = .45$), both within an 8-week treatment period (Carroll et al., 2008) and through a 6-month follow-up evaluation (Carroll et al., 2009).

This article addresses the following research questions: First, what was the extent of limitations in specific areas of cognitive functioning in this sample, and to what extent did several indicators of cognitive functioning (e.g., areas frequently identified as impaired among substance-using populations) influence the primary outcome measures of retention (days in treatment) and outcome (results of urine toxicology screens and self-reported durations of continuous abstinence)? Second, to what extent were the cognitive indicators differentially associated with poorer outcomes in the putatively higher-demand CBT4CBT program? We expected poorer outcome among participants with more problems with attention and concentration. Finally, to what extent do these cognitive functions improve through the course of treatment? Given the brevity of this 8-week trial, we expected small, if any, abstinence-related improvements in cognitive function across time and across conditions.

METHODS

Participants

Participants were recruited from individuals seeking treatment at Liberation Program's Mill Hill clinic, a community-based outpatient substance user treatment provider in Bridgeport, Connecticut. Participants were English-speaking adults who met the Diagnostic and Statistical Manual of Mental Disorders–Fourth Edition (*DSM-IV*) criteria for any current

[1]The journal's style utilizes the category *substance abuse* as a diagnostic category. Substances are used or misused; living organisms are and can be *abused.* Editor's note.

substance dependence disorder, including alcohol, cocaine, opioids, and marijuana. Exclusion criteria were minimized to facilitate recruitment of a clinically representative group of individuals seeking treatment in a community setting. Thus, individuals were excluded only if they (1) had not used alcohol or illegal drugs within the past 28 days or failed to meet the *DSM-IV* criteria for a current substance dependence disorder, (2) had an untreated psychotic disorder that precluded outpatient treatment, or (3) were unlikely to be able to complete 8 weeks of outpatient treatment because of a planned move or pending court case from which incarceration was likely to be imminent. Of the 155 individuals screened for the study, 77 met the inclusion/exclusion criteria, provided written informed consent, and were randomized to treatment (either CBT4CBT plus TAU at the clinic or TAU alone). Of the 73 individuals who initiated treatment, 43% were female; 46% identified themselves as African American, 34% as European American, 12% as Hispanic, and 6% as Native American. Most (78%) were single or divorced; 77% were unemployed; and 75% had completed high school. Over one third (37%) of the sample reported that they were on probation or parole, and 27% indicated their application for treatment had been prompted by the criminal justice system. Most participants (59%) reported cocaine use as their primary substance use problem, followed by alcohol (18%), opioids (16%), and marijuana (7%) use, with multiple types of concurrent substance use being common. Demographic and substance use characteristics by treatment condition are provided in Table 1.

Of the 73 individuals who initiated treatment, 48 (66%) completed the study (22 in CBT4CBT and 26 in TAU, *ns*). Levels of exposure to the standard counseling services offered in the program were also comparable in both groups, with those assigned to CBT4CBT completing a mean of 39 days and those assigned to TAU completing 41 days of the 56-day protocol. Hence, analyses of the primary substance use outcomes were not constrained by differential rates of attrition nor data availability. Of those who initiated the CBT4CBT program, the mean number of computer sessions completed was 4.3 (*SD*=2.4) of the 6 modules offered. Participants spent an average of 38.3 (*SD* = 8.2) minutes per session working with each module and tended to complete the modules in the order presented. Within CBT4CBT, participants completed an average of three homework assignments, and completion of homework was strongly associated with drug use outcomes in this sample (Carroll et al., 2008).

Treatments

All participants were offered standard treatment[2] at the clinic, which typically consisted of weekly individual and group sessions. Those randomized to the CBT4CBT condition were provided access to the computer program in a small private room within the clinic. A research associate guided participants through their initial use of the CBT4CBT program and was available to answer questions and assist participants each time they used the program. Participants accessed the program through an ID/password system to protect confidentiality. As described in more detail in the report of the randomized trial (Carroll et al., 2008), the CBT4CBT program was intended to be user-friendly, requiring no previous experience with computers and minimally using text-based material. The program consisted of six lessons, or modules, the content of which was based closely on a CBT manual

[2]Treatment can be briefly and usefully defined as a planned, goal-directed, temporally structured change process, of necessary quality, appropriateness, and conditions (endogenous and exogenous), which is *bounded* (by culture, place, time, etc.) and can be categorized into professional-based, tradition-based, mutual-help-based (such as Alcoholic Anonymous and Narcotics Anonymous), and self-help (“natural recovery”) models. There are no unique models or techniques used with substance users—of whatever types and heterogeneities—that are not also used with substance nonusers. In the West, with the relatively new ideology of “harm reduction” and the even newer quality-of-life treatment-driven model there are now a new set of goals in addition to those derived from/ associated with the older tradition of abstinence-driven models. Editor's note.

published by the National Institute on Drug Abuse (Carroll, 1998), used in several previous randomized controlled trials in a range of substance-using populations (Carroll et al., 1994, 2004, 2006). The first module provided a brief explanation of how to use and navigate the program; following completion of the first module, participants could choose to access the modules in any order they preferred and repeat any section or module as many times as they wished. Each module in the CBT4CBT program was structured as follows: First, the key concept for each module was introduced through a brief “movie” using actors and realistic settings depicting situations in which an individual was offered drugs or had to cope with a challenging situation in which substance use was likely. Next, after the narrator explained the key skill covered in that module with graphics and voice-overs, the movie was repeated, this time with a different ending as the same characters applied the skills to change the outcome of the situation so as to avoid substance use (e.g., emphasis was on how individuals could use the CBT skills to “change their story”). Additional videotaped vignettes were used to reinforce the skills taught (e.g., in the “refusal skills” module, the user could click buttons to see additional examples of the characters demonstrating assertive versus aggressive versus passive responding). Next, each module included an interactive assessment followed by a short vignette of an individual explaining how use of each skill had helped him/her avoid substance use and how each CBT principle could be applied to other problems; the intention of this section was to address common areas of resistance in CBT (“Why should I do homework?”) and to emphasize how CBT skills could be generalized beyond substance use issues. Finally, each module concluded with the narrator providing a review of the key points covered, followed by the characters demonstrating how they would complete the “homework” or practice assignment for that module on the basis of the situation depicted in the movie. Participants were then given an identical practice assignment and reminder sheet to take with them. Each module was intended to require about 45 minutes in order to complete, depending on the speed with which the user navigated the program and the amount of material he or she selected to access or repeat.

Assessments

Participants were assessed before treatment, twice a week during treatment, and at the 8-week treatment termination point by an independent clinical evaluator. Participants were administered the Structured Clinical Interview for *DSM-IV* (First, Spitzer, Gibbon, & Williams, 1995) prior to randomization to establish substance use and psychiatric diagnoses. The Substance Abuse Calendar, similar to the Timeline Follow Back (Fals-Stewart, O'Farrell, Freitas, McFarlin, & Rutigliano, 2000; Hersh, Mulgrew, Van Kirk, & Kranzler, 1999), was administered weekly during treatment to collect detailed day-by-day self-reports of drug and alcohol use throughout the protocol. Substance-related problems were assessed at pre-treatment and posttreatment, using the Addiction Severity Index (ASI; McLellan et al., 1992).

Participant self-reports of illegal drug use were verified through urine toxicology screens that were obtained at every assessment visit. Of the 578 urine specimens collected during the treatment phase of the study, the majority were consistent with participant self-report in that only 58 (10%) were positive for drugs in cases where the participant had denied recent use during the period the drug's metabolites are typically detectable in urine (3 days for cocaine and opioids, 7 days for marijuana). Breathalyzer samples were also collected at each assessment visit; none indicated recent alcohol use.

Cognitive Measures

Each of the following measures was administered prior to treatment and posttreatment to assess a selected range of functions, emphasizing domains usually impaired among substance users (overall executive functioning, attention and concentration, visual memory, and risk taking/inhibitory control).

Shipley Institute of Living Scale (Shipley, 1967)—This is a self-administered test designed to assess general intellectual functioning in adults and adolescents (Shipley, 1967; Zachary, 1991). It consists of two subtests: a 40-item vocabulary test and a 20-item test assessing abstract thinking. Scores from the vocabulary and abstraction subtests are summed to provide a total raw score, 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. Shipley scores correlate well with other measures of intelligence.

Continuous Performance Test II (CPT; Conners, 2004)—The CPT is a computer-administered, general measure of sustained attention and provides measures of response time (amount of time elapsed between presentation and response) and two types of error scores (omission and commission). Inattention is indicated by high numbers of omissions and long reaction times, while impulsivity is indicated by high numbers of commissions and short reaction times. 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; Borgaro et al., 2003; Conners, 1994, 2004; Sarter, Givens, & Bruno, 2001).

WAIS-III Digit Symbol–Coding (Wechsler, 1997)—The Digit Symbol–Coding subtest of the WAIS-III requires the individual to copy symbols that are paired with numbers by following a key consisting of nine boxes, completing as many symbol copies as possible within 2 minutes. It was included as a measure of visual memory and processing speed (Horner, 1999). 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, Kaplan, & Fein, 2004).

The Balloon Analogue Risk Task (BART; Lejuez et al., 2002)—The BART is a computer-simulated assessment of risk-taking behavior that instructs participants to use the computer mouse to inflate a balloon on the computer screen to a desired level. Each click on the pump inflated the balloon one degree and earned the participant money in a “temporary bank” that would be lost if the balloon “popped.” On the basis of 20 trials, adjusted values were calculated for the average number of balloon pumps, indicating an index of risk-taking behavior (higher scores are associated with more risk taking). The BART has been shown to be associated 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, Aklin, Zvolensky, & Pedulla, 2003; Lejuez et al., 2002). More recent versions of the BART utilize very detailed instructions about the parameters of the task (e.g., information regarding the distribution of explosion points) (Pleskac, Wallsten, Wang, & Lejuez, 2008). However, the original version containing virtually no information was best suited to the current study, as detailed instructions might neutralize any important differences in performance as a function of cognitive deficits.

RESULTS

Cognitive Indicators at Baseline Assessment

Analysis of variance (ANOVA) and chi-square analyses indicated no baseline differences in cognitive functioning by treatment group. These are shown in Table 2. Shipley scores IQ estimates were consistent with average intelligence for the group as a whole (mean estimated age-adjusted IQ was 99.9). The mean score for the sample on the Digit Symbol

Substitution Test was 46.4, which is consistent with the scores reported for the impaired sample in Grohman and Fals-Stewart's (2004) sample of 84 recently detoxified substance users (*M* = 48.9) and markedly below their estimate for the unimpaired sample (*M* = 63.6). For the CPT, rates of commission errors (30%) were consistent with recent work among cocaine users (Gooding, Burroghs, & Boutros, 2008). For the BART, the average adjusted number of pumps for the sample was 26.5, which was consistent with that reported by Lejuez and colleagues in a sample of college students (Lejuez et al., 2002) but lower than that reported for a sample of smokers (Lejuez, Aklin, Jones, et al., 2003).

These results are thus consistent with the presence of mild to moderate limitations in the specific functions assessed in this sample: Overall, 30 of the 77 (39%) participants scored in the impaired range on at least two of the three cognitive measures. That is, using fairly conservative cutoffs, 9 participants had a Shipley estimated IQ below 85; 37 had a Digit Symbol standard score of 8 or below; and 34 had slow reaction times or a high percentage error rate on the CPT. This estimate of the frequency of cognitive problems in this sample is very similar to that reported among other samples of substance users entering treatment (Grohman & Fals-Stewart, 2004; Schrimsher, Parker, & Burke, 2007), as were the types and severity of problems indicated (Ersche, Clark, London, Robbins, & Sahakian, 2006). Table 3 summarizes simple Pearson's correlations among the four behavioral measures of cognition and further summarizes participants' demographic and substance use variables at baseline. There were several statistically significant correlations, notably between participants' age, level of education, and history of previous treatment for substance use and several of the cognitive measures in expected directions. Shipley IQ estimates were significantly correlated with years of education, reported ethnic minority status, and the ASI medical and employment composite scores. Digit Symbol scaled scores were significantly negatively associated with age, gender, education level, and number of arrests. CPT omissions and commissions t-scores were positively associated with ethnic minority status, gender, and previous treatment for a substance use disorder. CPT reaction time was associated with age, days of alcohol use in the 28 days prior to randomization, and number of arrests. The BART mean adjusted average pumps were positively associated with days of heroin use in the 28 days prior to randomization and number of lifetime arrests.

Baseline Cognitive Indicators: Relationship to Retention and Outcome

Simple correlations between these measures and the primary indicators of retention (number of days retained in treatment, number of sessions of standard treatment in the program completed) and outcome (maximum consecutive days abstinent from all drugs within treatment, percentage of urine specimens negative for all drugs) are presented in Table 4 for the full sample and by treatment condition. In general, estimates of general intelligence from the Shipley were not significantly correlated with any primary outcome measure overall or in either treatment condition. Regarding retention (number of sessions completed, total days in treatment) CPT reaction times and BART scores were significantly associated with retention in the CBT4CBT condition but not among those assigned to TAU (with poorer outcomes associated with slower reaction times on the CPT and higher risk taking on the BART).

Within the CBT4CBT condition, participants' performance on the BART was significantly associated with retention in treatment and both primary drug use outcomes (maximum days of consecutive abstinence and percentage of drug-positive urine specimens). Higher risk taking as measured by the BART was also associated with significantly fewer CBT homework assignments completed; CPT reaction time was associated with total days in treatment and number of CBT4CBT modules completed within the CBT4CBT condition. In contrast, there was only one statistically significant relationship between this battery of cognitive assessments and outcome in the TAU condition, where Digit Symbol scores were significantly negatively correlated with total days in treatment. The composite measure of cognitive functioning (scoring in the impaired level on two of three indicators) was not associated with any outcome measure, for the sample as a whole or by treatment condition.

Change in Cognitive Indicators Through the Course of Treatment

ANOVA was used to evaluate change in these measures across time and as a function of participant's attainment of abstinence in treatment as well as possible differential effects of treatment condition. Overall, there were significant improvements across time for only the Digit Symbol Substitution Test ($F = 9.9$, $p < .001$), with no significant treatment condition by time interactions. When abstinence was added as a covariate to the ANOVA models, there were no significant effects for abstinence status by time for any of the cognitive measures.

DISCUSSION

Data from this evaluation of four behavioral measures of cognitive functioning and treatment response from a randomized clinical trial of a computerized cognitive behavioral approach suggested the following: First, data from baseline indicators of memory, speed, attention, risk taking, and overall cognitive functioning were consistent with previous reports, indicating that a substantial proportion of the sample had some difficulties in these areas. As in previous reports (Bates et al., 2004; Fals-Stewart & Bates, 2003), higher age, lower education levels, and a longer history of substance use and treatment were more strongly associated with poorer functioning on several of the measures. Second, while general intelligence did not appear to be strongly associated with retention or drug use outcomes in either condition, participants' pretreatment scores on the BART, a test of risk taking, were consistently associated with outcome for participants in the CBT4CBT condition but not those assigned to TAU. Third, there was only modest evidence for improvement in these measures by the end of the 8-week period of outpatient treatment.

Overall, our findings are consistent with the mixed evidence regarding the impact of cognitive functioning on addiction treatment outcome. Although there was evidence that approximately 40% of this sample scored in the impaired range on two of three of our cognitive measures, neither this composite indicator nor scores on several individual tasks were consistently associated with treatment retention or the primary drug outcomes. The exception was the BART, which was consistently associated with outcome for those assigned to the CBT4CBT condition but not those assigned to standard treatment (TAU). Thus, in terms of the cognitive functioning indicators evaluated here, there were few strong indicators for the level of functioning being an important determinant of treatment engagement or outcome in computerized CBT. Thus, neither standard treatment nor CBT4CBT would appear to be contraindicated, or in need of significant adaptation, for those with limitations in most of the domains evaluated here.

These findings differ from those of Aharonovich and colleagues, who reported that cognitive deficits were associated with poorer retention within a group of cocaine users receiving traditional clinician-delivered CBT. In the current study, which extends the work of Aharonovich by including outcome data from a control as well as a CBT condition, there was little indication that cognitive impairment was strongly associated with retention or outcome. It should be noted, however, that there were multiple differences between these studies, particularly in the specific cognitive indicators and measures evaluated. Nevertheless, there was little in our data to suggest strong or consistent relationships between general indicators of cognitive functioning and outcome in this form of CBT. It is possible that in contrast to the clinician-delivered format in the Aharonovich studies (Aharonovich et al., 2003, 2006), the computer-delivered format of CBT4CBT, which allowed participants to go through the material at their own pace and repeat it as needed and provided concrete, visual examples of individuals demonstrating the skills, was more engaging and easily comprehended among those with specific cognitive limitations.

The exception to the lack of strong relationships between cognitive indicators and outcome was the BART, where higher numbers of pumps, an indication of higher risk taking, were consistently associated with poorer retention, less homework completion, and poorer drug use outcomes for those assigned to the CBT4CBT condition but not to TAU. Thus, risk taking, as measured by the BART, may be a moderator of outcome in CBT4CBT. This finding thus adds to the growing literature pointing to the significance of risk taking as indicated by behavioral measures such as the BART to addiction (Crowley, Raymond, Mikulich-Gilbertson, Thompson, & Lejuez, 2006; Lejuez, Aklin, Jones, et al., 2003; Lejuez, Aklin, Zvolensky, et al., 2003; Lejuez et al., 2002) and extends these findings to treatment outcome. Thus, while preliminary and based on a single, small, and heterogeneous sample, our data suggest that substance users who are more impulsive and prone to risky behavior may benefit less from this format of CBT. While our data do not address how risk taking negatively influenced CBT outcome, it is possible that individuals who are more prone to risk taking may be less likely to learn cognitive and behavioral skills or may be less able to implement skills and strategies when opportunities for drug use arise. Similarly, risk takers may be less willing to persist in treatment or take the time to learn new strategies for behavior change. Those with higher scores on the BART completed significantly fewer homework assignments, a strong indicator of outcome within both this computerized version of CBT (Carroll et al., 2008) and traditional clinician-delivered CBT (Carroll et al., 2005; Gonzalez et al., 2006; Kazantzis, Deane, & Ronan, 2000). Thus, it may be important to emphasize and encourage patients with higher levels of risk taking to complete homework assignments or to monitor homework completion more closely for these individuals.

Finally, there were only a few indicators of improvement over time in the cognitive indicators overall or within each treatment condition or of abstinence being associated with greater improvement in these measures. On the other hand, this was only an 8-week trial, and longer periods of treatment or abstinence may be needed for meaningful improvements in functioning to emerge. Bates and colleagues (1994) found significant, but small, recovery of function after 15 months among alcohol-using individuals enrolled in Project MATCH. Sustained abstinence over longer periods of time, with direct attention or targeting of cognitive functioning, may be needed for clinically significant improvements in cognitive functioning (Ersche & Sahakian, 2007; Fals-Stewart, 1994; Grohman, Fals-Stewart, & Donnelly, 2006).

STUDY'S LIMITATIONS

Limitations of this study include a modest sample size, which was also somewhat variable because of some participants' failure to complete some tasks. Moreover, the tasks used here, while widely used and validated measures selected on the basis of their ability to accurately assess functions commonly impaired in substance-using samples (memory, attention, speed, risk taking), did not constitute a comprehensive cognitive or behavioral assessment. Moreover, participants varied in their duration of abstinence prior to completing the tasks. On the other hand, strengths of this trial included drawing data from a well-controlled clinical trial with comparatively high rates of retention and posttreatment assessment, as well as inclusion of a comparison group and a novel computer-assisted version of an empirically validated therapy. Moreover, they underscore, as do the other articles in this Special Issue, the emerging promise of computerized therapies and e-therapies for a range of problems.

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GLOSSARY

Cognitive-behavioral therapy	A manualized intervention, focusing on changing behavior and thought patterns, as well as building skills to successfully reduce harmful substance use, that has been shown to be effective, in multiple clinical trials, for multiple types of substance use
Cognitive functioning	Measures of an individual's capacities with respect to memory, attention, learning, planning, ability to control impulses, and other goal-directed behavior
Computer-assisted therapy	Exposure to a form of treatment that is provided via computer, rather than through an interaction with a clinician.

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TABLE 1

Baseline demographic variables and substance use by treatment condition

	CBT4CBT, *n* = 35		TAU, *n* = 38		Total, *n* = 73				
Variable	**n**	**%**	**n**	**%**	**n**	**%**	χ^2	**df**	**p**
Number (%) female	15	42.9	16	42.1	31	42.5	0.00	1	.95
Ethnicity									
African American	18	46.2	17	44.7	35	45.5	1.02	3	.80
European American	10	28.6	15	39.5	25	34.2			
Latin American	5	14.3	4	10.5	9	12.3			
Native American	2	5.7	2	5.3	4	5.5			
Married or in stable relationship	9	25.7	7	18.4	16	21.9	0.57	1	.45
Employed, full or part time	7	20.0	10	26.3	17	23.3	0.41	1	.52
Completed high school education	25	71.4	30	78.9	55	75.4	0.55	1	.46
Primary substance use problem									
Cocaine	20	57.1	23	60.5	43	58.9	2.32	3	.51
Alcohol	8	22.9	5	13.2	13	17.8			
Marijuana	3	8.6	2	5.3	5	6.8			
Opioids	4	11.4	8	21.1	12	16.4			
On probation or parole	11	31.4	16	42.1	27	37.0	0.89	1	.35
DSM-IV diagnoses, from SCID interviews									
Lifetime alcohol abuse or dependence	30	85.7	28	73.7	58	79.4	1.62	1	.20
Current alcohol dependence	15	42.9	14	36.8	29	39.7	0.28	1	.60
Lifetime cocaine abuse or dependence	28	80.0	35	92.1	63	86.3	2.26	1	.13
Current cocaine dependence	19	54.3	26	68.4	45	61.6	1.54	1	.22
Lifetime marijuana abuse or Dependence	29	82.8	30	78.9	59	80.8	0.18	1	.67
Current marijuana dependence	4	11.4	4	10.5	8	11.0	0.02	1	.90
Lifetime opioid abuse or dependence	13	37.2	21	55.3	34	46.6	2.40	1	.12
Current opioid dependence	7	20.0	8	21.1	15	20.5	0.01	1	.91
Any lifetime depressive disorder	17	48.6	13	34.2	30	41.1	1.55	1	.21
Any lifetime anxiety disorder	9	25.7	10	26.3	19	26.0	0.00	1	.99
Antisocial personality disorder	9	25.7	6	15.8	15	20.5	1.10	1	.29

	CBT4CBT, n = 35		TAU, n = 38		Total, n = 73				
Variable	**n**	**%**	**n**	**%**	**n**	**%**	χ^2	**df**	**p**
Continuous variables, mean and SD							*F*	*df*	*p*
Age	40.6	12.0	42.5	8.4	41.6	10.2	0.68	1, 71	.41
Days any substance use in the past 28 days	9.6	7.8	9.9	8.4	9.7	8.1	0.03	1,71	.86
Days of alcohol use in the past 28 days	4.8	7.2	5.5	7.7	5.2	7.5	0.14	1,71	.71
Days of cocaine use in the past 28 days	3.8	5.7	6.1	8.0	5.0	7.0	1.90	1,71	.17
Days of marijuana use in the past 28 days	2.7	6.6	2.4	6.1	2.5	6.3	0.05	1,71	.83
Days of opioid use in the past 28 days	1.3	3.8	1.2	4.6	1.3	4.2	0.01	1,71	.94

Note: SCID, Structured Clinical Interview for *DSM-IV*. For substance use variables, participants designated a primary substance (drugs or alcohol) of abuse, but multiple concurrent substance use was common.

TABLE 2

Baseline scores on measures of neurocognitive functioning by treatment group

	CBT4CBT			TAU			Total			Statistic		
Variable	**Mean**	**SD**	**n**	**Mean**	**SD**	**n**	**Mean**	**SD**	**n**	**F**	**p**	**df**
Shipley estimated IQ, age adjusted	100.0	13.1	39	99.8	13.1	37	99.9	13.0	76	0.01	.94	74
Digit Symbol scaled score	7.4	2.7	30	7.7	2.6	31	7.5	2.6	61	0.17	.68	59
CPT omissions t-score	56.3	22.0	31	66.0	36.5	31	61.1	30.3	62	1.60	.21	60
CPT commissions t-score	50.0	13.0	31	48.1	11.3	31	49.0	12.1	62	0.36	.55	60
CPT reaction time t-score	57.0	14.1	31	59.6	10.7	31	58.3	12.5	62	0.67	.42	60
BART adjusted average pumps	28.2	16.2	30	25.0	11.7	31	26.5	14.0	61	0.80	.38	59

Note: 77 individuals were randomized to condition; 73 were exposed to treatment; and 60 completed a posttreatment interview. Sample sizes vary because of failure of some participants to complete assessments

TABLE 3

Correlations between baseline demographic and drug use measures and baseline cognitive function measures

	Shipley estimated IQ	Digit Symbol scaled score	CPT omissions t-score	CPT commissions t-score	CPT reaction time t-score	BART adjusted average pumps
	r	r	r	r	r	r
Age	.08	**−.46***	.10	−.12	**.32***	−.21
Ethnic minority (1 = no, 2 = yes)	**−.48***	−.06	−.26	−.26	−.05	−.09
Gender (1 = male, 2 = female)	−.14	**.38***	**.31***	**.37***	−.19	.02
Years of education	**.64***	−.27	.24	.17	−.01	−.02
Employment status (employed vs. not employed)	−.10	−.02	.12	−.09	.02	−.10
No. of times treated for substance abuse	−.21	−.15	**.37**	.27	.11	−.15
Years of primary drug use	.18	−.17	−.01	−.05	.02	.03
Days of alcohol use in the past 28 days	.01	−.08	.07	.05	.27	−.16
Days of heroin use in the past 28 days	.00	.21	−.03	−.15	−.02	.26
Days of cocaine use in the past 28 days	−.17	−.01	.13	.16	.11	−.14
Days of cannabis use in the past 28 days	−.20	.06	.11	.26	−.14	−.01
Total number of arrests in lifetime	−.16	−.25	.09	−.11	.27	−.25
Total months incarcerated in lifetime	−.21	−.25	−.02	−.20	.20	−.18
ASI medical composite score	−.25	−.16	−.18	−.15	.05	−.16
ASI employment composite score	**−.35***	.09	.01	.06	−.22	−.19
ASI family composite score	.14	.21	−.02	.00	−.01	−.08
ASI psychological composite	−.03	−.11	.12	.20	.12	.03
ASI legal composite score	−.11	−.10	**.41***	.12	.24	.04

Note: Numbers in bold indicate statistically significant relationships.

TABLE 4

Relationships of primary outcome measures and cognitive measures by treatment group, treatment exposed sample

	Total no. of sessions completed			Total days in treatment			Maximum continuous days of abstinence			Percentage of positive urine samples			CBT4CBT process measures: No. of CBT homeworks completed			CBT4CBT process measures: No. of CBT4CBT modules completed		
	r	p	n	r	p	n	r	p	n	r	p	n	r	p	n	r	p	n
All participants (*N* = 72)																		
Shipley estimated IQ, age adjusted	−.10	.42	71	.02	.84	72	.09	.43	72	−.21	.09	71						
Digit Symbol scaled score	−.04	.78	58	−.23	.08	58	**−.27**	**.04**	57	.25	.06	58						
CPT omissions t-score	−.09	.50	59	−.12	.36	59	−.13	.33	58	**.28**	**.03**	59						
CPT commissions	−.08	.57	59	−.23	.09	59	.06	.67	58	−.06	.64	59						
CPT reaction time	.05	.73	59	**.30**	**.02**	59	.13	.33	58	.03	.82	59						
BART adjusted average pumps	**−.35**	**.01**	58	−.11	.40	58	**−.26**	**.05**	58	.24	.07	58						
CBT4CBT only (*N* = 35)																		
Shipley estimated IQ, age adjusted	−.01	.95	34	.10	.55	35	.20	.26	35	−.30	.09	34	.13	.49	28	.27	.11	35
Digit Symbol scaled score	−.01	.96	27	−.12	.54	27	−.26	.20	26	.34	.08	27	−.30	.16	23	−.18	.36	27
CPT omissions t-score	.06	.78	28	.16	.41	28	−.12	.56	27	.20	.32	28	.12	.59	24	.06	.75	28
CPT commissions t-score	−.03	.89	28	−.34	.08	28	.00	.99	27	−.09	.64	28	−.22	.29	24	−.31	.11	28
CPT reaction time t score	.08	.67	28	**.47**	**.01**	28	.21	.29	27	−.17	.38	28	.27	.20	24	**.40**	**.04**	28
BART adj avg pumps	**−.48**	**.01**	27	−.16	.42	27	**−.40**	**.04**	27	**.45**	**.02**	27	**−.41**	**.05**	24	−.31	.12	27
TAU only (*N* = 37)																		
Shipley estimated IQ, age adjusted	−.21	.22	37	−.08	.66	37	−.04	.83	37	−.14	.42	37						
Digit symbol scaled score	−.07	.70	31	**−.35**	**.05**	31	−.29	.11	31	.17	.37	31						
CPT omissions t score	−.22	.24	31	−.33	.07	31	−.11	.55	31	.30	.10	31						
CPT commissions t-score	−.13	.48	31	−.12	.54	31	.13	.48	31	−.05	.80	31						
CPT reaction time t-score	−.01	.95	31	.07	.71	31	.03	.87	31	.24	.19	31						
BART adjusted average pumps	−.16	.39	31	−.06	.74	31	−.15	.43	31	.10	.59	31						

Note: Numbers in bold indicate statistically significant relationships.