Published in final edited form as:

Psychol Addict Behav. 2020 February ; 34(1): 31–39. doi:10.1037/adb0000480.

Working Memory Training and High Magnitude Incentives for Youth Cannabis Use: A SMART Pilot Trial

Catherine Stanger,

Department of Psychiatry, Geisel School of Medicine at Dartmouth

Emily A. Scherer,

Department of Biomedical Data Sciences, Geisel School of Medicine at Dartmouth; Corrora LLC

Hoa T. Vo,

Maryland Treatment Centers; Department of Psychiatry, UT Southwestern Medical Center

Steven F. Babbitt,

Department of Psychiatry, Geisel School of Medicine at Dartmouth; Office of Institutional Research, Tufts University

Ashley A. Knapp,

Department of Psychiatry, Geisel School of Medicine at Dartmouth; Department of Preventive Medicine in Feinberg School of Medicine at Northwestern University

James R. McKay,

Department of Psychiatry, Perelman School of Medicine, University of Pennsylvania

Alan J. Budney

Department of Psychiatry, Geisel School of Medicine at Dartmouth

Abstract

The purpose of this sequential multiple assignment randomization treatment (SMART) pilot study was to examine if (1) adding working memory training to contingency management (CM) for youth with cannabis use disorder (CUD) and (2) switching nonresponding youth to higher magnitude CM incentives boosts outcomes. In Phase 1, youth with CUD ($n = 59$, M age = 16, Male = 71%) attending an intensive outpatient program were randomly assigned to 14 weeks of CM only or CM plus working memory training (WMT). In Week 4, a Phase 2 treatment was assigned. Those with negative urine drug tests (Responders) continued in their Phase 1 treatment. Those who were drug-positive (Nonresponders) were randomly assigned to remain in their Phase 1 treatment or to higher magnitude CM. Zero inflated negative binomial models comparing those assigned to CM vs. CM + WMT indicated no differences in the likelihood of having 1 week of continuous abstinence or longer abstinence duration. Those assigned to WMT showed greater but nonsignificant improvements in working memory ($N=35$; $\beta=.69$, $p=.06$). Working memory improvements were associated with achieving any abstinence (OR [95% CI] = 3.50[1.01, 12.10],

Correspondence concerning this article should be addressed to Catherine Stanger, Ph.D., Department of Psychiatry, Geisel School of Medicine at Dartmouth, 46 Centerra Parkway, Suite 300, HB 7255, Lebanon, NH 03766 catherine.stanger@dartmouth.edu.

The study design and preliminary findings from this study were presented at the annual conventions of The College on Problems of Drug Dependence, Montreal, Canada (2017) and San Diego, CA. (2018).

$p=0.05$). Phase 2 randomization to higher magnitude CM did not boost outcomes. Overall results suggest that WMT appears promising, but the sample size was small, attrition was high, and replication is important. Alternative strategies should continue to be explored to improve outcomes for adolescent substance use disorders, such as different approaches for nonresponders, tailoring to other baseline or response characteristics, or more robust first line interventions.

Keywords

Adolescent; young adult; cannabis use disorder; incentives; working memory training

Cannabis is the most frequently misused substance among youth other than alcohol and has substantial associated consequences (Miech et al., 2018). Recent estimates indicate that 2.3% of adolescents ages 12-17 and 5.0% of young adults ages 18-25 had a cannabis use disorder (CUD) in the past year (SAMHSA, 2017a). Although rates of youth admissions to substance use treatment declined over the past decade, over 75% of adolescent admissions involved cannabis as the primary substance, and it is also the most common primary substance among treatmentseeking young adults ages 18-24 (SAMHSA, 2017b). Overall, youth in treatment for substance use disorders (SUD) have better outcomes than those with an SUD who are not in treatment, and there are multiple interventions that have been identified as “well-established” or “probably efficacious” (Hogue, Henderson, Becker, & Knight, 2018). Contingency management (CM) is one such intervention, with 7 youth SUD trials published since 2010 (Godley et al., 2014; Henggeler, McCart, Cunningham, & Chapman, 2012; Kaminer, Burleson, Burke, & Litt, 2014; Killeen, McRae-Clark, Waldrop, Upadhyaya, & Brady, 2012; Stanger, Ryan, Scherer, Norton, & Budney, 2015; Stanger, Scherer, Babbitt, Ryan, & Budney, 2017; Stewart, Felleman, & Arger, 2015). These interventions demonstrated efficacy across highly diverse settings (school, clinic, juvenile justice, continuing care) when combined with multiple types of platform interventions (e.g., Motivational Enhancement Therapy [MET], Cognitive Behavioral Treatment [CBT]) and with varying types of incentives (fishbowl vs. vouchers) and incentive magnitudes (~\$25 to \$725 total/~\$6 to \$50 per week) (Stanger, Lansing, & Budney, 2016).

Our CM intervention for youth has shown efficacy in three randomized trials (Stanger, Budney, Kamon, & Thostensen, 2009; Stanger et al., 2015; Stanger et al., 2017). However, outcomes achieved with this CM approach leaves much room for improvement regarding early nonresponse and overall rates of long-term abstinence. The current study sought to enhance outcomes in the context of a sequential multiple assignment randomized trial (SMART) (Nahum-Shani et al., 2012), which uses a series of randomizations in a single study to facilitate testing of a first line intervention to boost overall efficacy and evaluation of an adaptive treatment strategy for early nonresponders. Specifically, this design allowed us to test both the overall impact of supplementing CM with cognitive (working memory) training (WMT) at treatment onset and testing higher magnitude incentives for those not abstinent after 1 month of treatment.

Working memory (WM) is an executive function that involves goal-oriented active monitoring or manipulation of information (Jurado & Rosselli, 2007). WM was targeted in

this trial because it may be important for adolescent substance use risk and progression and may respond to intervention (Khurana, Romer, Betancourt, & Hurt, 2017). Commercially available computerized WMT programs have been developed that aim to improve executive function by strengthening working memory neurocognitive processes through practice, and these programs can reliably enhance cognitive function in diverse populations, including adolescents (Holmes et al., 2010; Klingberg et al., 2005; Lohaugen et al., 2011). Of note, studies of WMT typically include incentives for completing the training. Although not without controversy and limitations (Melby-Lervag, Redick, & Hulme, 2016), WMT reliably improves WM performance and may generalize to enhance performance on other cognitive tasks that have not been trained (Bigorra, Garolera, Guijarro, & Hervas, 2016; von Bastian & Oberauer, 2014). Further, WMT has shown positive effects as an adjunctive intervention among adults in substance use treatment (Hendershot et al., 2018; Houben, Wiers, & Jansen, 2011; Rass et al., 2015). Based on this evidence, WMT was selected for testing as a novel first-line intervention that might improve substance use outcomes when combined with CM.

Post-hoc analyses of our prior youth CM outcome data (Brown, Budney, Thostenson, & Stanger, 2013) indicated that 94% of those with 1 weeks of abstinence had initiated abstinence by the 6th week of treatment. In other words, if a participant did not respond by week 6, s/he was likely not to respond at all. Therefore, we sought to develop an adaptive strategy targeting these early nonresponders. Based on four prior studies showing that adaptive strategies that increase CM magnitude with treatment resistant patients can enhance outcomes (Crowley, MacDonald, Zerbe, & Petty, 1991; Dallery, Silverman, Chutuape, Bigelow, & Stitzer, 2001; Petry, Barry, Alessi, Rounsaville, & Carroll, 2012; Silverman, Chutuape, Bigelow, & Stitzer, 1999), we hypothesized that increasing the magnitude of the CM incentives provided for youth who did not achieve abstinence by the end of the first month of treatment would be an effective strategy for motivating abstinence in these nonresponders.

Primary hypotheses for this trial were: (1) Standard CM plus WMT at treatment onset would be more effective than Standard CM alone; and (2) an adaptive strategy that involved offering week 4 nonresponders Enhanced CM (higher magnitude incentives) would result in higher rates of abstinence than the lowest level nonadaptive intervention (Standard CM, with no WMT).

Methods

Participants

The Institutional Review Board of Dartmouth College approved the study. All youth attended an intensive outpatient community-based treatment program in Baltimore, MD. Inclusion criteria were: (a) age 12 to 26 years, (b) self-report of cannabis use during the previous 30 days or provision of a cannabis-positive urine test and (c) meeting criteria for Diagnostic and Statistical Manual of Mental Disorders (5th ed.; DSM-5) CUD (American Psychiatric Association, 2013). Exclusion criteria included: active psychosis, severe medical or psychiatric illness limiting participation, or pregnant or breast-feeding. Participants meeting DSM-5 criteria for substance use disorders other than CUD (n=30) were also

excluded. Most of those youth (N=20 of 30) were enrolled in an opioid use disorder treatment program and represent a clinically and demographically distinct population whose outcomes were not expected to be comparable to those with CUD only. The additional 10 participants excluded for other SUD met criteria for alcohol (N=4), benzodiazepine (N=4) or opiate use disorder (N=2).

Informed consent/assent was obtained from the youth directly. We attempted to obtain verbal consent from parents of youth ages <18 years; however, we also received a waiver of consent from the IRB if we were unable to reach a parent or guardian after several attempts. Minimum likelihood allocation (Aickin, 1982) was used to randomly assign participants (N=59; see Figure 1) to the initial intervention condition while balancing across conditions on: 1) cannabis-negative urine sample at baseline, 2) T-score >64 on the externalizing scale of the Youth Self-Report or Adult Self-Report (YSR/ASR; Achenbach & Rescorla, 2001, 2003), 3) age > 16, 4) gender, and 5) race (white vs. other). The second randomization of non-responders occurred in Week 4 and was balanced on variables 2-5 above. These two randomizations result in 4 distinct treatment strategies (see Table 1). Youth were enrolled between December 2015 and October 2017, with the final participants completing the intervention in February 2018.

Measures—The DSM-5 version of the Mini International Neuropsychiatric Interview (MINI v.7.0.2) (Sheehan et al., 1998) was used to assess past 6-month substance use and mental health disorders. Past 90-day frequency of substance use was assessed using the Time-Line Follow Back (TLFB; Sobell, Sobell, Litten, & Allen, 1992) at baseline and the end of the 14-week intervention by research assistants not blinded to condition (due to staffing constraints). The percentage of days of cannabis use during the intervention was calculated as the number of reported days of use divided by the number of days for which data were provided. Incomplete data (fewer than 25% of possible days) were coded as missing. Using higher thresholds for non-missing days (e.g., >50% non-missing days) resulted in significantly lower reports of % of days used, essentially excluding those with higher levels of use.

Once-weekly urine testing and alcohol breath tests were performed during treatment. Urine specimens (not directly observed) were tested via onsite rapid drug tests (American Screening Discover Drug Test Card) for cannabis, cocaine, opiates, benzodiazepines, and amphetamines. Invalid specimens (creatinine below 30 mg/dl) required a replacement specimen within 24 hours. Failure to submit a scheduled specimen was treated as a positive result. Weeks of continuous abstinence (WCA) during treatment was derived from these toxicology results.

To assess visual spatial working memory (VSWM), the primary target of working memory training, a computerized task based on Rapport et al. (2008) was administered. This task involved 3 conditions (24-trial sequences of 3, 4, and 6 dots). Participants were asked to replicate a sequence of dots on a 9×9 grid. A ceiling effect was observed on 3- and 4-dot trials, therefore the proportion of correctly replicated sequences on the 6-dot task was used in analyses.

Phase 1 Randomization Intervention Conditions—At the first clinical visit, participants were randomized to receive either STANDARD CM only or STANDARD + Working Memory Training (WMT). The STANDARD CM program included incentives provided by research staff for abstinence, similar to 2 prior trials (Stanger et al., 2009; Stanger et al., 2015) (see Table 2). Financial incentives were provided for documented abstinence once per week defined as a negative urinalysis for all substances, plus negative youth reports of use. Earnings were provided on reloadable credit cards that could not be used to obtain cash. Substance use after abstinence reset the value of the incentive to \$10 and was returned to the prior maximum level after 2 consecutive negative specimens. Specimens were excused if a valid reason was provided (e.g., illness, vacation).

Beginning in week 2, those assigned to STANDARD+WMT received a commercially available WMT program for youth (Cogmed-RM v2, Pearson, Inc) involving 25 sessions (8 training tasks per session). Training was completed in the clinic during intensive outpatient program (IOP) visits, and participants typically attended the IOP 2-3 days per week. Participants earned \$10 for completing a session in a single day and a \$5 bonus for improving or maintaining performance on 50% of training tasks. In addition, in the first 8 weeks of training, weeks with >3 training sessions, or >1 session more than the prior week (minimum of 2 sessions per week) earned a \$15 bonus. Maximum earnings were \$490. Research staff supervised training and provided feedback and motivational support, which is a standard component of Cogmed for youth.

Phase 2 Randomization Interventions—Youth who were abstinent (responders) in week 4 remained in their Phase 1 intervention (STANDARD or STANDARD+WMT) for the remainder of the 14-week intervention. Those who were not abstinent (nonresponders), were randomly assigned to either remain in STANDARD CM or to receive high magnitude (ENHANCED) CM (see Figure 1). Assignment to WMT or no WMT was unchanged in Phase 2.

Statistical Methods—The a priori, primary hypothesis of the study was that youth receiving CM+WMT would have better substance use outcomes than those receiving CM. When comparing the two Phase 1 intervention conditions such analyses are no different from those in a “standard” randomized controlled trial. Zero-inflated negative binomial (ZINB) models compared cannabis use (% days used and weeks of continuous abstinence [WCA]) between conditions during the intervention (Atkins, Baldwin, Zheng, Gallop, & Neighbors, 2013). ZINB models were used because both outcomes were zero-inflated (~22% of youth had 0% of days used cannabis and 47% had 0 WCA), somewhat over dispersed (estimated dispersion parameters: WCA =.69 [95% CI .25, 1.91]; percent days used =.67 [95% CI .36,1.25]).

We also conducted exploratory analyses to identify Phase 1 intervention effects on VSWM and the impact of changes in VSWM on WCA. Intervention effects on VSWM were tested in mixed models comparing baseline vs. end of intervention scores. The impact of changes in VSWM on WCA were tested by adding a VSWM change score (post-pre) to the WCA ZINB model. We also compared mean change score in those who completed at least 20

WMT sessions (Cogmed's criterion for adequate training dosage) and those who completed fewer than 20 sessions via t-test.

Exploratory analyses compared the four treatment strategies embedded in the trial (Table 1). Analysis of the treatment strategies requires additional statistical considerations (e.g., weighting and the use of robust [sandwich] standard errors) which are described in detail in Nahum-Shani et al. (2012). In addition, to compare the four strategies simultaneously, duplicate observations for each responder and for each participant who dropped out before the Phase 2 randomization were added to the dataset and assigned to multiple strategies based on starting condition and response. For example, responders assigned to stay in STANDARD CM are included in strategy 1 (all start in STANDARD CM, all stay in STANDARD CM) and strategy 3 (all start in STANDARD CM, responders stay in STANDARD CM; nonresponders switch to ENHANCED CM). In these analyses, the "lowest" level of treatment (start in STANDARD CM and stay in STANDARD) was the comparison condition.

TLFB models adjusted for baseline TLFB values. A total of 37 of 59 (63%) participants provided TLFB data on at least 25% of the days during treatment. The percentage of non-missing TLFB data did not differ significantly between treatment arms, age, race, intake use, tobacco use status, or CUD severity (data not shown). At post-treatment, 35/59 (59%) completed the VSWM task. There are no missing WCA data because missing specimens are considered not abstinent. A sensitivity analysis was performed using the number of negative samples which treat missing specimens as missing. The same pattern of results was observed. All analyses were performed using SAS version 9.4. All tests were conducted using a 2-sided alpha threshold of .05.

Results

Sample Characteristics

Table 3 shows demographic and substance use data at intake. Overall, the sample was mostly male (71%) and mostly African America (76%) with a mean age of 16.4 (SD=1.8; range 14-25). About ½ received inpatient treatment prior to entering the IOP. About 1/3 met DSM-5 criteria for Mild or Moderate CUD and 2/3 for Severe CUD. Rates of comorbid mental health disorders ranged from 17% for Major Depression to 55% for Oppositional Defiant Disorder+/- Conduct Disorder. About 2/3 had a positive urine specimen for cannabis at intake and reported using an average of about 2/3 of days. Table 4 shows retention rates, Phase 1 CM earnings, and WMT engagement information. In general, engagement was moderate with participants providing on average only about half of the expected urine specimens and about half of those assigned to WMT completing the training. As shown in Figure 1, about 20% dropped out of the intervention prior to the Phase 2 randomization (week 4). In Phase 2, among those assigned to STANDARD CM (includes both Phase 1 responders and nonresponders) mean (SD) CM earnings were \$74 (\$135) of the \$525 maximum. Among those assigned to ENHANCED CM (includes only Phase 1 nonresponders; N=29) mean (SD) CM earnings were \$66 (\$128) of the \$1225 maximum.

Comparisons Based on Phase 1 Assignment

Differences in WCA and percentage days of cannabis use during the 14-week intervention were tested with ZINB models (Table 5). For WCA and frequency of cannabis use, neither the likelihood of any use versus no use nor the mean WCA or percentage of days used among those with any WCA or days used differed between conditions. To explore the impact of WMT on VSWM we compared improvement across Phase 1 treatment arms (Table 6). Those who received WMT showed greater improvement in VSWM than those in STANDARD, however that difference was not significant at $p < .05$ ($p = .06$). However, when the VSWM change score (post-pre) was added to the WCA ZINB model, change in VSWM was a significant predictor of achieving any WCA (odds ratio = 3.50, 95% CI [1.01, 12.10], $p = .05$) but was a not significant predictor of achieving more WCA among those with some WCA (mean ratio = 1.23, 95% CI [0.97, 1.57], $p = .09$). Among those assigned to WMT who completed the follow up VSWM assessment, those who completed at least 20 WMT sessions ($N=11$) had mean (SD) change in VSWM of 1.4 (1.3), whereas those who completed fewer than 20 WMT sessions ($N=6$) had mean (SD) change in VSWM of -0.1 (0.5) ($t(df=14.2) = -3.43$, $p=0.004$).

Comparison of Adaptive Treatment Strategies

Table 7 shows results comparing the 4 treatment strategies on WCA outcomes. Strategy 1 (STANDARD CM with no WMT) was used as the comparison condition, and no significant differences were observed across the four strategies in achieving any abstinence or abstinence duration.

Discussion

This study represents the first use of the novel SMART research design to compare several adaptive treatment strategies for the treatment of youth CUD. Using this design, we tested the impact of both first line randomization to working memory training as well as randomization of nonresponders to high magnitude CM efficiently in a single study. Results did not show significant differences in substance use outcomes when WMT was added to CM as a first-line intervention. Those receiving WMT showed greater improvements in working memory, but those improvements were not significant. However, improvements in working memory were associated with achieving at least a brief period of abstinence. Results also did not suggest any benefit of the adaptive strategy that increased the CM magnitude for nonresponders, youth who had not achieved abstinence by Week 4. Attrition was an overall concern, as almost 20% of participants dropped out of the intervention before the 2nd randomization in week 4, and about 37% of participants did not complete the follow up assessment.

Prior findings for WMT as an adjunctive intervention for participants receiving substance use treatment have been mixed, with some studies showing positive results (Hendershot et al., 2018; Houben et al., 2011; Rass et al., 2015), and some showing negative results (Sweeney et al., 2018; Wanmaker et al., 2018). None of these studies tested relations between WM improvement and substance use outcomes. Retention was challenging across these prior WMT studies, with rates of attrition ranging from 30% to 65%, as it was in the

present study. Further, among those assigned to WMT, $n=5$ (17%) completed 0 Cogmed sessions and additional 5 (17%) completed either 1 or 2 sessions due to IOP treatment dropout. Thus, over 1/3 of the sample assigned to WMT was essentially not exposed to it, making it difficult to assess the impact of WMT given the sample size. Of note, those assigned to WMT who completed at least 20 of the 25 sessions showed significantly more improvement in WM than those who did not. The impact of an adequate dose of WMT on improved VSWM and the positive relation between WM improvement and substance use outcomes is encouraging. A better powered randomized trial with better intervention retention and less missing outcome data would be needed to support both the efficacy of WMT and the role of improved VSWM as a mechanism in improved outcomes.

The failure of higher magnitude incentives to boost abstinence rates in the nonresponders was disappointing, and contextual factors may have contributed to their lack of impact. First, the rate of treatment dropout within the first 4 weeks was significant (~20% of the entire sample and close to 30% of the early nonresponders) and reduced the potential for these adolescents to receive exposure to the larger incentives. The treatment setting was also unique, in that most youth were transported significant distances from their neighborhoods to the treatment center, several days per week. Parents were rarely involved in the program. The sample also experienced higher levels of substance use severity than, for example, the sample in our prior study that was also conducted in an urban setting with a similarly high percentage of African American participants (Stanger et al., 2015). It appears likely that these high-needs youth who showed early nonresponse most likely needed a higher level of care (e.g., inpatient) or a different modality of care for those transitioning from inpatient treatment (e.g., assertive continuing care or home based multisystemic therapy [Godley et al., 2014; Henggeler et al., 2012]). Hence, it warrants emphasis that our negative finding for the higher magnitude incentive nonresponder strategy in this setting does not indicate that offering higher magnitude incentives as a first line intervention or as an adjunct/adaptive strategy combined with a different platform treatment or with a different population would fail. Future studies might explore such alternative models.

This pilot study has several additional limitations, including a lower than expected rate of enrollment resulting in a smaller than planned for sample size. In addition, retention in the clinical program was generally poor. However, the primary analyses were conducted using the complete, intent to treat sample, which was made possible by the collection of weekly urine samples. In addition, this study is the first CM study conducted by the research team that developed this intervention in which implementation was conducted in a community treatment setting with weekly phone supervision by the developers. Another significant limitation was the lack of an attention control comparison condition, which raises the issue that any effects of WMT might have been due to receiving more staff attention or the additional incentive earnings available to those who completed WMT. Although it is currently unclear in the literature whether a minimal or low dose of WMT can improve working memory (Peijnenborgh, Hurks, Aldenkamp, Vles, & Hendriksen, 2016; Soveri, Antfolk, Karlsson, Salo, & Laine, 2017; von Bastian & Eschen, 2016) there is some evidence (Kiluk et al., 2017) that minimal, nonadaptive training is comparable to no training and most likely could be used in future studies as an attention control condition without confounding active training effects.

In summary, results of this initial pilot youth SMART study suggest that first line WMT, when added to CM, did not significantly increase the duration of cannabis abstinence. However, retention was poor in the IOP program resulting in limited exposure to WMT and a small sample size, limiting the ability to draw clear conclusions about the potential efficacy of WMT. There was also evidence that WMT improved VSWM among youth receiving a sufficient training dose and that improvement in VSWM predicted achieving some abstinence, suggesting potential benefits of WMT in this population. Further testing of WMT with a larger sample and in diverse treatment settings would seem warranted. The use of high magnitude CM as a rescue or enhancement strategy for those who had not achieved abstinence in the first month of treatment was not effective. However, significant treatment dropout had already occurred by that time point. In this population at very high risk of poor treatment outcome and in clinical settings where evidence-based counseling interventions are not available, it is possible that higher magnitude CM might have a larger effect as a first line treatment. There is a clear need to continue to explore alternative rescue or tailoring strategies and first line treatments that may be more effective for all youth. SMART research designs offer much promise to efficiently test these important questions.

Acknowledgments

This work was supported by NIH Grants R01DA015186, T32DA037202 and P30DA029926. Cogmed and Cogmed Working Memory Training are trademarks, in the U.S. and/or other countries, of Pearson Education, Inc. or its affiliate(s).

References

- Achenbach TM, & Rescorla LA (2001). Manual for aseba school-age forms and profiles. Burlington, VT: University of Vermont, Research Center for Children, Youth, and Families.
- Achenbach TM, & Rescorla LA (2003). Manual for the aseba adult forms & profiles. Burlington, VT: University of Vermont, Research Center for Children, Youth & Families.
- Aickin M (1982). A program for balancing the allocation of subjects in a clinical trial. *Computers and Biomedical Research*, 15, 519–524. doi:10.1016/0010-4809(82)90014-3 [PubMed: 6897627]
- American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Washington, DC: Author.
- Atkins DC, Baldwin SA, Zheng C, Gallop RJ, & Neighbors C (2013). A tutorial on count regression and zero-altered count models for longitudinal substance use data. *Psychology of Addictive Behaviors*, 27(1), 166–177. doi:10.1037/a0029508 [PubMed: 22905895]
- Bigorra A, Garolera M, Guijarro S, & Hervas A (2016). Long-term far-transfer effects of working memory training in children with adhd: A randomized controlled trial. *European Child & Adolescent Psychiatry*, 25(8), 853–867. doi:10.1007/s00787-015-0804-3 [PubMed: 26669692]
- Brown PC, Budney AJ, Thostenson J, & Stanger C (2013). Initiation of abstinence in adolescents treated for marijuana use disorders. *Journal of Substance Abuse Treatment*, 44, 384–390. [PubMed: 23085041]
- Crowley TJ, MacDonald MJ, Zerbe GO, & Petty TL (1991). Reinforcing breath carbon monoxide reductions in chronic obstructive pulmonary disease. *Drug Alcohol Depend*, 29(1), 47–62. [PubMed: 1797517]
- Dallery J, Silverman K, Chutuape MA, Bigelow GE, & Stitzer ML (2001). Voucher-based reinforcement of opiate plus cocaine abstinence in treatment-resistant methadone patients: Effects of reinforcer magnitude. *Experimental and Clinical Psychopharmacology*, 9(3), 317–325. [PubMed: 11534542]
- Godley MD, Godley SH, Dennis ML, Funk RR, Pasetti LL, & Petry NM (2014). A randomized trial of assertive continuing care and contingency management for adolescents with substance use

disorders. *Journal of Consulting and Clinical Psychology*, 82(1), 40–51. doi:10.1037/a0035264 [PubMed: 24294838]

- Hendershot CS, Wardell JD, Vandervoort J, McPhee MD, Keough MT, & Quilty LC (2018). Randomized trial of working memory training as an adjunct to inpatient substance use disorder treatment. *Psychol Addict Behav*, 32(8), 861–872. doi:10.1037/adb0000415 [PubMed: 30475014]
- Henggeler SW, McCart MR, Cunningham PB, & Chapman JE (2012). Enhancing the effectiveness of juvenile drug courts by integrating evidence-based principles. *Journal of Consulting and Clinical Psychology*, 80(2), 264–275. doi:10.1037/a0027147 [PubMed: 22309470]
- Hogue A, Henderson CE, Becker SJ, & Knight DK (2018). Evidence base on outpatient behavioral treatments for adolescent substance use, 2014–2017: Outcomes, treatment delivery, and promising horizons. *J Clin Child Adolesc Psychol*, 47(4), 499–526. doi:10.1080/15374416.2018.1466307 [PubMed: 29893607]
- Hollingshead AB (1975). Four factor index of social status Department of Sociology, Yale University New Haven, CT.
- Holmes J, Gathercole SE, Place M, Dunning DL, Hilton KA, & Elliott JG (2010). Working memory deficits can be overcome: Impacts of training and medication on working memory in children with adhd. *Applied Cognitive Psychology*, 24(6), 827–836. doi:10.1002/acp.1589
- Houben K, Wiers RW, & Jansen A (2011). Getting a grip on drinking behavior: Training working memory to reduce alcohol abuse. *Psychological Science*, 22(7), 968–975. doi:10.1177/0956797611412392 [PubMed: 21685380]
- Jurado MB, & Rosselli M (2007). The elusive nature of executive functions: A review of our current understanding. *Neuropsychology Review*, 17(3), 213–233. doi:10.1007/s11065-007-9040-z [PubMed: 17786559]
- Kaminer Y, Burleson JA, Burke R, & Litt MD (2014). The efficacy of contingency management for adolescent cannabis use disorder: A controlled study. *Substance Abuse*, 35(4), 391–398. doi:10.1080/08897077.2014.933724 [PubMed: 25010430]
- Khurana A, Romer D, Betancourt LM, & Hurt H (2017). Working memory ability and early drug use progression as predictors of adolescent substance use disorders. *Addiction*, 112(7), 1220–1228. doi:10.1111/add.13792 [PubMed: 28206689]
- Killeen TK, McRae-Clark AL, Waldrop AE, Upadhyaya H, & Brady KT (2012). Contingency management in community programs treating adolescent substance abuse: A feasibility study. *Journal of Child and Adolescent Psychiatric Nursing*, 25(1), 33–41. doi:10.1111/j.1744-6171.2011.00313.x [PubMed: 22299805]
- Kiluk BD, Buck MB, Devore KA, Babuscio TA, Nich C, & Carroll KM (2017). Performance-based contingency management in cognitive remediation training: A pilot study. *J Subst Abuse Treat*, 72, 80–88. doi:10.1016/j.jsat.2016.08.003 [PubMed: 27590364]
- Klingberg T, Fernell E, Olesen PJ, Johnson M, Gustafsson P, Dahlström K, ... Westerberg H. (2005). Computerized training of working memory in children with adhd—a randomized, controlled trial. *J Am Acad Child Adolesc Psychiatry*, 44(2), 177–186. doi:10.1097/00004583-200502000-00010 [PubMed: 15689731]
- Lohaugen GCC, Antonsen I, Haberg A, Gramstad A, Vik T, Brubakk AM, & Skranes J (2011). Computerized working memory training improves function in adolescents born at extremely low birth weight. *Journal of Pediatrics*, 158(4), 555–561. doi: 10.1016/j.jpeds.2010.09.060 [PubMed: 21130467]
- Melby-Lervag M, Redick TS, & Hulme C (2016). Working memory training does not improve performance on measures of intelligence or other measures of “Far transfer”: Evidence from a meta-analytic review. *Perspectives on Psychological Science*, 11(4), 512–534. doi: 10.1177/1745691616635612 [PubMed: 27474138]
- Miech R, Johnston L, O’Malley P, Bachman J, Schulenberg J, & Patrick M (2018). Monitoring the future national survey results on drug use, 1975–2017: Volume i, secondary school students. In. Ann Arbor: Institute for Social Research, The University of Michigan.
- Nahum-Shani I, Qian M, Almirall D, Pelham WE, Gnagy B, Fabiano GA, ... Murphy SA (2012). Experimental design and primary data analysis methods for comparing adaptive interventions. *Psychological Methods*, 17(4), 457–477. doi:10.1037/a0029372 [PubMed: 23025433]

- Peijnenborgh JC, Hurks PM, Aldenkamp AP, Vles JS, & Hendriksen JG (2016). Efficacy of working memory training in children and adolescents with learning disabilities: A review study and meta-analysis. *Neuropsychol Rehabil*, 26(5-6), 645–672. doi: 10.1080/09602011.2015.1026356 [PubMed: 25886202]
- Petry NM, Barry D, Alessi SM, Rounsaville BJ, & Carroll KM (2012). A randomized trial adapting contingency management targets based on initial abstinence status of cocaine-dependent patients. *J Consult Clin Psychol*, 80(2), 276–285. doi:10.1037/a0026883 [PubMed: 2229758]
- Rapport M, Alderson R, Kofler M, Sarver D, Bolden J, & Sims V (2008). Working memory deficits in boys with attention-deficit/hyperactivity disorder (adhd): The contribution of central executive and subsystem processes. *Journal of Abnormal Child Psychology*, 36(6), 825–837. doi:10.1007/s10802-008-9215-y [PubMed: 18317920]
- Rass O, Schacht RL, Buckheit K, Johnson MW, Strain EC, & Mintzer MZ (2015). A randomized controlled trial of the effects of working memory training in methadone maintenance patients. *Drug Alcohol Depend*, 156, 38–46. doi:10.1016/j.drugalcdep.2015.08.012 [PubMed: 26404954]
- SAMHSA. (2017a). Key substance use and mental health indicators in the united states: Results from the 2016 national survey on drug use and health (hhs publication no. Sma 17-5044, nsduh series h-52). Retrieved from Rockville, MD: Substance Abuse and Mental Health Services Administration, Center for Behavioral Health Statistics and Quality website: <https://www.samhsa.gov/data/sites/default/files/cbhsq-reports/NSDUHFFR2017/NSDUHFFR2017.pdf>
- SAMHSA. (2017b). Treatment episode data set (teds): 2005-2015. National admissions to substance abuse treatment services. BHSIS series s-91, hhs publication no. (sma) 17-5037 (BHSIS Series S-71, HHS Publication No. (SMA) 14-4850). Retrieved from Rockville, MD: Substance Abuse and Mental Health Services Administration, Center for Behavioral Health Statistics and Quality website: http://www.samhsa.gov/data/sites/default/files/TEDS2012N_Web.pdf
- Sheehan DV, Lecrubier Y, Sheehan KH, Amorim P, Janavs J, Weiller E, ... Dunbar GC (1998). The mini-international neuropsychiatric interview (m.I.N.I.): The development and validation of a structured diagnostic psychiatric interview for dsm-iv and icd-10. *J Clin Psychiatry*, 59 Suppl 20, 22–33; quiz 34–57.
- Silverman K, Chutuape MA, Bigelow GE, & Stitzer ML (1999). Voucher-based reinforcement of cocaine abstinence in treatment-resistant methadone patients: Effects of reinforcement magnitude. *Psychopharmacology (Berl)*, 146(2), 128–138. [PubMed: 10525747]
- Sobell LC, Sobell MB, Litten R, & Allen J (1992). In *Timeline follow-back: A technique for assessing self-reported alcohol consumption* (pp. 41–72). Totowa, NJ: Humana Press.
- Soveri A, Antfolk J, Karlsson L, Salo B, & Laine M (2017). Working memory training revisited: A multi-level meta-analysis of n-back training studies. *Psychon Bull Rev*, 24(4), 1077–1096. doi:10.3758/s13423-016-1217-0 [PubMed: 28116702]
- Stanger C, Budney AJ, Kamon JL, & Thostensen J (2009). A randomized trial of contingency management for adolescent marijuana abuse and dependence. *Drug and Alcohol Dependence*, 105(3), 240–247. doi:10.1016/j.drugalcdep.2009.07.009 [PubMed: 19717250]
- Stanger C, Lansing AH, & Budney AJ (2016). Advances in research on contingency management for adolescent substance use. *Child and Adolescent Psychiatric Clinics of North America*, 25(4), 645–659. doi:10.1016/j.chc.2016.05.002 [PubMed: 27613343]
- Stanger C, Ryan SR, Scherer EA, Norton GE, & Budney AJ (2015). Clinic- and home-based contingency management plus parent training for adolescent cannabis use disorders. *Journal of the American Academy of Child & Adolescent Psychiatry*, 54(6), 445–453. doi:10.1016/j.jaac.2015.02.009 [PubMed: 26004659]
- Stanger C, Scherer EA, Babbitt SF, Ryan SR, & Budney AJ (2017). Abstinence based incentives plus parent training for adolescent alcohol and other substance misuse. *Psychology of Addictive Behaviors*, 31(4), 385–392. doi:10.1037/adb0000279 [PubMed: 28414474]
- Stewart DG, Felleman BI, & Arger CA (2015). Effectiveness of motivational incentives for adolescent marijuana users in a school-based intervention. *Journal of Substance Abuse Treatment*, 58, 43–50. doi:10.1016/j.jsat.2015.06.002 [PubMed: 26231697]
- Sweeney MM, Rass O, DiClemente C, Schacht RL, Vo HT, Fishman MJ, ... Johnson MW (2018). Working memory training for adolescents with cannabis use disorders: A randomized controlled

trial. *J Child Adolesc Subst Abuse*, 27(4), 211–226. doi:10.1080/1067828x.2018.1451793 [PubMed: 30524179]

von Bastian CC, & Eschen A (2016). Does working memory training have to be adaptive? *Psychol Res*, 80(2), 181–194. doi:10.1007/s00426-015-0655-z [PubMed: 25716189]

von Bastian CC, & Oberauer K (2014). Effects and mechanisms of working memory training: A review. *Psychol Res*, 78(6), 803–820. doi:10.1007/s00426-013-0524-6 [PubMed: 24213250]

Wanmaker S, Leijdesdorff SMJ, Geraerts E, van de Wetering BJM, Renkema PJ, & Franken IHA (2018). The efficacy of a working memory training in substance use patients: A randomized double-blind placebo-controlled clinical trial. *J Clin Exp Neuropsychol*, 40(5), 473–486. doi:10.1080/13803395.2017.1372367 [PubMed: 28933254]

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

Figure 1.

CONSORT diagram. *n = 1 Phase 1 responder assigned to ENHANCED CM in error and therefore excluded from Phase 2 analyses. IOP = Intensive outpatient program; CM = contingency management; SUD = substance use disorder; WMT = working memory training.

Table 1.

Treatment strategies

Treatment Strategy	Phase 1 Treatment	4-week status	Phase 2 Treatment	Type of Strategy
1	STANDARD CM	Abstinent	STANDARD CM	Start in STANDARD CM, stay in STANDARD CM
		Not Abstinent	STANDARD CM	
2	STANDARD CM +WMT	Abstinent	STANDARD CM +WMT	Start in STANDARD CM+WMT, stay in STANDARD CM+WMT
		Not Abstinent	STANDARD CM +WMT	
3	STANDARD CM	Abstinent	STANDARD CM	start in STANDARD CM; if abstinent stay in STANDARD CM; if not abstinent switch to ENHANCED CM
		Not Abstinent	ENHANCED CM	
4	STANDARD CM +WMT	Abstinent	STANDARD CM +WMT	Start in STANDARD CM+WMT; if abstinent stay in STANDARD CM+WMT; if not abstinent switch to ENHANCED CM+WMT
		Not Abstinent	ENHANCED CM +WMT	

Note: CM=contingency management; WMT=working memory training.

Table 2.

Maximum incentive earnings in STANDARD CM and ENHANCED CM

Week	Weekly Incentive	2 Weeks of Abstinence Bonus	Weekly Total	Grand Total	Weekly Incentive	2 Weeks of Abstinence Bonus	Weekly Total	Grand Total
PHASE 1 – All in STANDARD CM								
1	\$10.00	-----	\$10.00	\$10.00				
2	\$10.00	-----	\$10.00	\$20.00				
3	\$10.00	-----	\$10.00	\$30.00				
4	\$15.00	\$20.00	\$35.00	\$65.00				
PHASE 2 STANDARD CM								
5	\$20.00	-----	\$20.00	\$85.00	\$25.00	-----	\$25.00	\$25.00
6	\$25.00	\$20.00	\$45.00	\$130.00	\$40.00	\$60.00	\$100.00	\$125.00
7	\$30.00	-----	\$30.00	\$160.00	\$55.00	-----	\$55.00	\$180.00
8	\$35.00	\$20.00	\$55.00	\$215.00	\$70.00	\$60.00	\$130.00	\$310.00
9	\$40.00	-----	\$40.00	\$255.00	\$85.00	-----	\$85.00	\$395.00
10	\$45.00	\$20.00	\$65.00	\$320.00	\$100.00	\$60.00	\$160.00	\$555.00
11	\$50.00	-----	\$50.00	\$370.00	\$115.00	-----	\$115.00	\$670.00
12	\$55.00	\$20.00	\$75.00	\$445.00	\$130.00	\$60.00	\$190.00	\$860.00
13	\$60.00	-----	\$60.00	\$505.00	\$145.00	-----	\$145.00	\$1,005.00
14	\$65.00	\$20.00	\$85.00	\$590.00	\$160.00	\$60.00	\$220.00	\$1,225.00

Note: CM=Contingency Management

Table 3.

Sample characteristics for each Phase 1 treatment condition

	STANDARD CM N = 30	STANDARD CM + WMT N = 29	X ² or t	p-value
	N/(%) or M (SD)	N/(%) or M (SD)		
Male	21 (70.0%)	21 (72.4%)	0.04	0.84
Race				
White	4 (13.3%)	8 (27.6%)	0.03 *	0.18
African American	24 (80.0%)	21 (72.4%)		
More than one race	2 (6.7%)	0 (0.0%)		
Ethnicity				
Hispanic	2 (6.7%)	3 (10.3%)	0.32 *	0.67
Non-Hispanic	28 (93.3%)	26 (89.7%)		
Mean SES	4.9 (1.8)	4.5 (1.9)	0.82	0.42
Mean Age	16.7 (2.13)	16.0 (1.45)	1.40	0.17
Inpatient Referral	11 (37%)	16 (55%)	2.04	0.15
Tobacco user	17 (56.7%)	16 (55.2%)	0.01	0.91
Intake cannabis positive specimen	24 (80.0%)	21 (72.4%)	0.47	0.49
Mean intake proportion of days used cannabis in past 30	.60 (.38)	.67 (.37)	-0.70	0.49
DSM Cannabis Use Disorder			0.07 *	1.00
Mild	5 (16.7%)	4 (13.8%)		
Moderate	6 (20.0%)	5 (17.2%)		
Severe	19 (63.3%)	20 (69.0%)		
DSM non-substance disorder				
ADHD	8 (27.6%)	15 (51.7%)	0.03 *	0.06
CD/ODD	16 (53.3%)	17 (58.6%)	0.19 *	0.79
Major depression	5 (16.7%)	5 (17.2%)	0.27 *	1.00
Anxiety disorder (any)	8 (26.7%)	5 (17.2%)	0.76	0.38
PTSD	1 (3.3%)	1 (3.4%)	0.51 *	1.00
VSWM dots correct (of 6)	3.18 (1.25)	2.81 (1.21)	1.14	0.26

Note: CM=contingency management; WMT=working memory training; SES=Hollingshead's 9-step socioeconomic status (Hollingshead, 1975); DSM=Diagnostic and Statistical Manual 5; ODD=Oppositional Defiant Disorder; CD=Conduct Disorder; ADHD=Attention-Deficit/Hyperactivity Disorder; PTSD=Post Traumatic Stress Disorder; VSWM=visual spatial working memory task (6 dots condition)

* Fisher's exact test used because expected cell count < 5, and table probabilities are given in the test statistic column

Table 4.

Participation, retention and earnings for each Phase 1 treatment condition.

	STANDARD CM (<i>n</i> = 30)	STANDARD CM+WMT (<i>n</i> = 29)	X ² or <i>t</i>	p-value
	N/(%) or M (SD)	N/(%) or M (SD)		
Mean urine samples provided (of 14 expected)	7.40 (4.55)	7.93 (5.01)	.43	.67
Phase 1 teen incentive earnings (of \$65 maximum)	\$25 (11)	\$25 (14)	.16	.87
N (%) completing 20 WMT sessions (of 25 maximum)	NA	13 (45%)		
Mean WMT sessions/week ^a	NA	2.07 (0.47)		
Mean % WMT tasks improved ^a	NA	4% (18%)		
Mean WMT earnings (of \$490 maximum)	NA	\$284 (\$176)		

Note: WMT=Working Memory Training.

^aFive participants (17%) of those assigned to WMT dropped out of the intervention before completing any WMT sessions. Mean WMT sessions per week and tasks improved exclude these five participants.

Table 5.

Zero-inflated negative binomial models of effects of Phase 1 treatment condition (STANDARD vs. STANDARD+WMT) on weeks of continuous abstinence and Percent days used cannabis across the 14-week intervention period.

	Weeks of Continuous Abstinence (WCA)		Days Used Cannabis	
	STANDARD	STANDARD+WMT	STANDARD	STANDARD+WMT
N	30	29	19	18
N(%) >0 WCA/N(%) >0% days used cannabis use	18 (60.0%)	13 (44.8%)	14 (73.7%)	11 (61.1%)
Mean(SD) WCA if >0/Mean(SD) % Days Use if >0	4.88 (4.35)	7.15 (4.63)	24.5% (23.3%)	32.5% (31.0%)
Odds Ratio (95%CI) for >0 WCA vs. 0 WCA/>0% days used vs. 0% days used	0.42 (.11,1.56) $\chi^2(1)=1.63$, $p=.19$		0.93 (0.18,4.82) $\chi^2(1)=0.03$, $p=.87$	
Ratio of Means (95% CI) for WCA/% Days Used	1.56 (0.79,3.07) $\chi^2(1)=1.63$, $p=.20$		0.92 (.33,2.54) $\chi^2(1)=0.03$, $p=.87$	

Note: WMT= Working memory training, CI= Confidence Interval; ZINB=Zero Inflated Negative Binomial. The days used cannabis analysis adjusted for percent days used at intake.

Table 6.

Mixed models of effects of time (pre vs. post), Phase 1 treatment condition (STANDARD CM vs. STANDARD CM+WMT), and time $\times$ treatment condition on visual spatial working memory (VSWM) (N=35).

Terms in Model	β (SE)	p-value
Intercept	3.18 (.25)	<.0001
Time (pre vs. post)	0.18 (.24)	.46
Treatment Condition (STANDARD CM+WMT VS STANDARD CM)	-.37 (.35)	.30
Time (pre vs. post) * Treatment Condition (STANDARD CM+WMT VS STANDARD CM)	.69 (.35)	.06

Note: CM=contingency management; WMT=working memory training;

Zero-inflated negative binomial models comparing the four treatment strategies on weeks of continuous abstinence across the 14-week intervention period.

Table 7.

	Strategy			
	1	2	3	4
N	21	21	21	24
N(%) >0 WCA	12 (57.1%)	12 (57.1%)	14 (66.7%)	11 (45.8%)
Mean(SD) WCA if >0	6.17 (4.73)	7.42 (4.74)	5.29 (4.43)	7.82 (4.75)
Odds Ratio (95% CI) for >0 WCA vs. 0 WCA		1.04 (.45, 2.45) p=.92	2.29 (.84, 6.20) p=.10	0.51 (0.23, 1.13) p=.09
Ratio of Means (95% CI) for # WCA		1.21 (0.76, 1.92) p=.42	0.76 (0.49, 1.18) p=.22	1.33 (0.83, 2.15) p=.24

Note: CI= Confidence Interval; WCA=weeks of continuous abstinence; CM=contingency management; WMT=working memory training; Strategy 1: start in STANDARD CM, stay in STANDARD CM;
Strategy 2: start in STANDARD CM+WMT, stay in STANDARD CM+WMT; Strategy 3: start in STANDARD CM, responders stay in STANDARD CM; nonresponders switch to ENHANCED CM;
Strategy 4: start in STANDARD CM+WMT, responders stay in STANDARD CM+WMT; nonresponders switch to ENHANCED CM+WMT.