Reinforcement Schedule Effects on Long-Term Behavior Change

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Abstract *Objective* The primary aim of this study was to determine whether different schedules of contingency management (CM), in conjunction with psychosocial treatment, produced different rates of abstinence and treatment attendance among individuals dependent on methamphetamine. *Methods* Individuals were randomized into 1 of 3 conditions that sought to equate total potential reinforcer magnitude while varying the frequency with which reinforcement was delivered, and comparing these results to those obtained when psychosocial support alone was used. *Results* Results indicate that all 3 CM schedules occasioned more abstinent attendance than the group only receiving psychosocial treatment. However, the 3 CM conditions did not differ in any appreciable way. *Conclusions* These results suggest that treatment providers may be able to decrease the frequency of reinforcer delivery in CM paradigms while retaining efficacy to treat psychostimulant use disorders.

Keywords contingency management · methamphetamine use disorders · substance use disorder treatment · clinical trial · psychostimulants

Contingency management refers to the systematic application of basic principles delineated by workers in the field of the

experimental analysis of behavior to treat the problem behavior of individuals. Primary emphasis is placed on the use of reinforcement and punishment to alter an individual's day-to-day behavior. Contingency management has been used to promote a number of changes in behavior related to the development of healthy lifestyles (e.g., Giuffrida and Torgerson 1997). A number of contingency management procedures have been refined for the treatment of a variety of substance use disorders and related problems (e.g., Higgins et al. 2002; Higgins and Silverman 1999). These procedures have been successful in reducing drug use (e.g., Higgins and Silverman 1999).

Recently, efforts have been undertaken to examine the different components involved in the delivery of contingency management interventions for the treatment of substance use disorders, in order to understand what components of the interventions are needed to maximize treatment success and to attempt to make the interventions more suitable for use in community-based clinics. This study attempted to further our understanding of contingency management by investigating how different reinforcement procedures, used in combination with psychosocial drug abuse treatment, influence the long-term maintenance of abstinence among methamphetamine-dependent individuals.

There is a large body of basic-science research demonstrating that altering behavior via the intermittent delivery of reinforcement produces long-term behavior change relative to behavior that has been modified via continuous reinforcement (e.g., Robbins 1971). This effect may be further enhanced by introducing variability into the delivery of the intermittent reinforcement, that is, by making the delivery of the reinforcement less predictable. We believe this effect might be exploited clinically to promote long-term behavior change. However, understanding the impact of rate of reinforcement is clearly complicated by the presence and rate of other sources (e.g., schedules) of reinforcement (e.g., Nevin 2012) and the context in which reinforcement is delivered (e.g., Grace et al. 2003).

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The use of methamphetamine is a significant public health and criminal justice problem in the United States (Rawson et al. 2002). According to the 2012 National Survey on Drug Use and Health (NSDUH), approximately 1.2 million people (0.4 % of the population) reported using methamphetamine in the past year, and 440,000 (0.2 %) reported using it in the past month (Substance Abuse and Mental Health Services Administration 2013). Methamphetamine-related admissions to federally funded treatment facilities increased dramatically throughout the 1990s and into the 2000s, beginning to stabilize in 2006 and decreasing gradually or remaining stable in subsequent years (Substance Abuse and Mental Health Services Administration [SAMHSA] 2009). Between 2009 and 2011, the rate of emergency department visits involving illicit stimulants increased 68 % (SAMHSA 2011). Additionally, the DAWN report (SAMHSA 2011) indicated there may be an increase in the involvement of illicit drugs. After 5 years of relative stability, an upward trend was observed between 2009 and 2011. Visits involving illicit stimulants, marijuana, and synthetic cannabinoids increased between 2009 and 2011. Involvement of legal stimulants (e.g., CNS stimulants used to treat attention-deficit/hyperactivity disorder) also rose over this period (SAMHSA 2011). The continued manufacturing, distribution, and abuse of methamphetamine represent a serious public health problem in the United States and internationally that remains to be satisfactorily addressed.

This study was developed to further our knowledge about how contingency management can effectively initiate and maintain abstinence from methamphetamine in an outpatient treatment environment. Specifically, the current study examined the effects of the reinforcement procedure (i.e., schedule) with which contingency management is delivered in combination with a psychosocial treatment program in an outpatient setting for the treatment of methamphetamine abuse. The primary aim of the study was to determine if different schedules of reinforcement (i.e., continuous, intermittent predictable, intermittent unpredictable) produce different patterns of abstinence from methamphetamine. Additionally, we examined effects on retention in treatment and abstinence in the year following treatment initiation among methamphetamine dependent individuals.

Method

Study Procedures

Participants Participants were seeking treatment for methamphetamine use disorders. Participants who were randomized into the study must have met all of the following inclusion criteria: (a) 18–65 years of age, (b) met DSM-IV criteria for methamphetamine dependence, (c) were willing and able to comply with study procedures, and (d) were willing and able to provide written informed consent. Exclusion criteria

included (a) a medical condition that, in the study PI's judgment, might interfere with safe study participation, (b) a recent (past 30 days) history of suicide attempts and/or current serious suicidal intention or plan as assessed by the BDI, (c) a history of violent criminal behavior or be on parole, and (d) any other circumstances that, in the opinion of the PI, would interfere with safe study participation.

A total of 120 individuals were eligible for inclusion into the study. After collecting informed consent, completing baseline measures, and receiving clearance for participation, participants were randomly assigned to one of four study conditions: (1) standard, (2) continuous contingency management, (3) intermittent predictable contingency management, and (4) intermittent unpredictable contingency management. Treatment lasted 16 weeks, and participants were expected to provide urine samples on a Monday, Wednesday, Friday schedule throughout the course of treatment. Participants received cognitive behavioral therapy, based largely on the Matrix Model (Rawson et al. 1990). The details of this approach are presented in Roll et al. (2013).

The type of contingency management intervention delivered was voucher-based reinforcement therapy (VBRT), popularized by Higgins and colleagues (e.g., Higgins et al. 1991, 1993, 1994). In this procedure, patients received vouchers for the provision of biological samples (urine or breath) that indicated no recent drug use. More specifically, participants randomly assigned to the contingency management conditions received vouchers for the provision of methamphetamine-negative urine samples, according to the particular schedule to which they were assigned. All three schedules provided reinforcement of abstinence, the magnitude of which escalated with continuous abstinence. Additionally, a methamphetamine-positive urine sample, or failure to test, resulted in a reset of the voucher back to its original magnitude in all three schedules.

Continuous Condition Participants in the continuous condition received a voucher each time they tested negative for methamphetamine. The initial voucher value was set at \$2.50. Each consecutive instance of abstinence (i.e., methamphetamine-negative urine) increased the magnitude of the voucher by \$1.50. Three consecutive abstinences resulted in a \$10.00 bonus. A methamphetamine-positive urine sample, or failure to test, resulted in a reset of the voucher magnitude back to its original level (i.e., \$2.50), which participants earned after the provision of their next methamphetamine-negative test. This is perhaps the most commonly used VBRT protocol for delivering vouchers.

Intermittent Predictable Condition Participants in the intermittent predictable condition earned a voucher when they provided three consecutive methamphetamine-negative urine tests. Individuals in this group were eligible to receive a voucher on

one day a week. They received \$22.00 for the provision of their first three consecutive methamphetamine-negative urine samples, \$35.50 for the provision of their second week of three consecutive methamphetamine-negative urines, \$49.00 for the third week of consecutive drug-free urines, and so forth. There were no bonuses for consecutive abstinences in this group, and methamphetamine-positive urine samples resulted in a reset in the voucher magnitude back to \$22.00 after three consecutive drug-free samples.

Intermittent Unpredictable Condition Participants in the unpredictable intermittent condition earned vouchers of the same magnitude as those in the predictable intermittent condition (see above), and at approximately the same rate (i.e., \$22.00 for the provision of their first three consecutive methamphetamine-negative urine samples, \$35.50 for the provision of their second week of methamphetamine-negative urines, etc.). Participants in this group received a voucher for \$22.00 following their first three methamphetamine-negative urine tests. Following that, they were eligible to receive a voucher one day a week if all of their urine tests since the receipt of their last voucher were methamphetamine negative. The day of the week on which the voucher was available was randomly selected for each week, and the participants did not know which day of the week they were eligible to receive a voucher until they provided their urine test. We are aware that for those weeks in which the voucher is eligible on the last day of the week, the participant knew in advance that they were eligible to receive a voucher on that day because they knew that they were eligible to receive one voucher per week, and that the last day of the week was their last opportunity in a given week. We do not believe this diminished the efficacy of the intervention or detracted meaningfully from the variability in the delivery of reinforcement the procedure was designed to introduce. As with the intermittent predictable group, there were no bonuses for consecutive instances of abstinence, and provision of a methamphetamine-positive urine sample, or failure to test, resulted in a reset in the voucher magnitude back to its original level from whence the progression began again.

Standard Condition Participants randomized to the standard treatment condition received no vouchers for the provision of methamphetamine-negative drug tests during the treatment phase of the study.

For the contingency management conditions, vouchers were exchanged for goods or services that would help the patient with activities of daily life (i.e., groceries, department stores, etc.). The maximum cash value of vouchers delivered to participants who remained continuously abstinent from methamphetamine was \$1,155.00 in all three conditions. This is a typical amount of available reinforcement (Higgins et al. 1994; Roll et al. 2013; Silverman et al. 1996) for studies of this type. In all three contingency management conditions,

the amounts of money were adjusted to equate reinforcer magnitudes across conditions. Vouchers were typically available within 1 hour of providing a urine sample. Participants were allowed to accumulate their vouchers or redeem them immediately upon receipt. Once a request was made, it was typically carried out within 1 working day. This short delay is important, as research has demonstrated that delaying the delivery of the reinforcer significantly reduces its effectiveness in curtailing drug use (Roll et al. 2000).

Participants were contacted for follow-up assessments conducted at 6, 8, 10, and 12 weeks after completion of the treatment phase. At each follow-up assessment, urine samples were collected, and participants were asked to complete study questionnaires.

Measures Drug use was measured longitudinally (methamphetamine urine analysis; UA) during the treatment period, (i.e., three times per week for 16 weeks for a total of 48 possible urine analysis submissions). Aside from the primary predictor of treatment arm, other covariates of interest included age, gender, baseline substance use, and Addiction Severity Index (ASI) composite scores (medical, legal, alcohol, drug, employment, family, and psychiatric).

Statistical Analysis For all baseline comparisons of continuous variables across groups, ANOVAs were performed. For all baseline comparisons of categorical variables across groups, chi-square tests were performed. We utilized generalized estimation equations (GEE) to analyze attendance and methamphetamine abstinence during treatment (Twisk 2003). We also conducted GEE analyses to analyze repeated assessments of methamphetamine abstinence and attendance during follow-up.

Missing data were handled by imputing a positive methamphetamine UA for those who dropped out during the 16-week treatment phase. This was done as our variable of interest was attendance and provision of a methamphetamine-negative urine test. Patients were allowed to miss one session of treatment per week for approved reasons (e.g., health or child-care issues), and thus these approved missed visits were not considered missing data and were therefore not imputed. This is a method that has been used consistently in the analysis of trials similar to the one reported here (Peirce et al. 2006; Petry et al. 2005; Roll et al. 2006). Analyses were performed using Stata 12.1 (StataCorp, College Station, TX) and SPSS for Windows 20.0.

Results

Demographics and Baseline Comparisons

No significant ($p > .05$) differences were found between the treatment groups on any demographic characteristics at

baseline. The mean age was 35, and approximately 52 % of the sample was male. Table 1 is a complete report of the demographic variables for this sample across the different treatment groups. There were also

no differences in ASI composite scores across treatment group (see Table 2). Thus, the randomization of patients across different treatment groups before the trial began proved effective.

Table 1 Descriptive statistics of patients with methamphetamine use disorders across treatment groups with varying contingency management durations

Characteristic	Standard TAU (<i>N</i> =29)	Continuous (<i>N</i> = 30)	Predictable (<i>N</i> =32)	Unpredictable (<i>N</i> =28)
	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>
Age (years)	34.8 (10.1)	32.5 (10.0)	33.1 (8.2)	30.3 (10.9)
	% (<i>N</i>)	% (<i>N</i>)	% (<i>N</i>)	% (<i>N</i>)
Gender				
Male	51.7 (15)	66.7 (20)	59.4 (19)	71.4 (20)
Female	48.3 (14)	33.3 (10)	40.6 (13)	28.6 (9)
Education				
Grades 1–8	3.5 (1)	3.3 (1)	0.0 (0)	3.6 (1)
Grades 9–11	17.2 (5)	20.0 (6)	28.1 (9)	28.6 (8)
High School	51.7 (15)	53.3 (16)	40.6 (13)	28.6 (8)
Graduate				
Some College	27.6 (8)	16.7 (5)	31.3 (10)	35.7 (10)
College Graduate	0.0 (0)	6.7 (2)	0.0 (0)	3.6 (1)
Race				
Caucasian	41.4 (12)	56.7 (17)	50.0 (16)	39.3 (11)
African American	0.0 (0)	6.7 (2)	0.0 (0)	3.6 (1)
Latino	58.6 (17)	33.3 (10)	46.9 (15)	46.4 (13)
Asian	0.0 (0)	0.0 (0)	3.1 (1)	3.6 (1)
Other	0.0 (0)	3.3 (1)	0.0 (0)	7.1 (2)
Employment				
Employed for Pay	41.4 (12)	26.6 (8)	12.5 (4)	42.9 (12)
Self-Employed	6.9 (2)	3.3 (1)	31.3 (10)	17.9 (5)
Unemployed >1 Yr.	10.3 (3)	16.7 (5)	9.4 (3)	10.7 (3)
Unemployed <1 Yr.	27.6 (8)	43.3 (13)	28.1 (9)	25.0 (7)
Homemaker	6.9 (2)	10.0 (3)	9.4 (3)	3.6 (1)
Unable to Work	6.9 (2)	0.0 (0)	9.4 (3)	0.0 (0)
Income				
\$0–\$9,999	17.2 (5)	26.7 (8)	31.3 (10)	36.0 (10)
\$10,000–\$14,999	20.7 (6)	23.3 (7)	12.5 (4)	7.1 (2)
\$15,000–\$19,999	6.9 (2)	10.0 (3)	3.1 (1)	10.7 (3)
\$20,000–\$24,999	3.5 (1)	16.7 (5)	6.3 (2)	14.3 (4)
\$25,000–\$34,999	6.9 (2)	6.7 (2)	9.4 (3)	14.3 (4)
\$35,000–\$49,999	24.1 (7)	6.7 (2)	15.6 (5)	7.1 (2)
\$50,000–\$74,999	13.8 (4)	6.7 (2)	12.5 (4)	7.1 (2)
\$75,000+	6.9 (2)	3.3 (1)	9.4 (3)	3.6 (1)
Marital Status				
Married	37.9 (11)	23.3 (7)	34.4 (11)	17.9 (5)
Divorced	17.2 (5)	26.7 (8)	9.4 (3)	17.9 (5)
Widowed	0.0 (0)	3.3 (1)	0.0 (0)	3.6 (1)
Never Married	0.0 (0)	3.3 (1)	9.4 (3)	7.1 (2)
Unmarried	20.7 (6)	43.3 (13)	28.1 (9)	39.29 (11)
Relationship Other	24.1 (7)	0.0 (0)	18.8 (6)	14.3 (4)

Table 2 Addiction Severity Index composite scores for patients with methamphetamine use disorders across treatment as usual with varying contingency management reinforcement schedules

Measures	Standard TAU (<i>N</i> =29)	Continuous (<i>N</i> =30)	Predictable (<i>N</i> =32)	Unpredictable (<i>N</i> =28)
	<i>M</i> (<i>SD</i>)	<i>M</i> (<i>SD</i>)	<i>M</i> (<i>SD</i>)	<i>M</i> (<i>SD</i>)
ASI Medical	0.104 (0.24)	0.140 (0.27)	0.106 (0.20)	0.029 (0.10)
ASI Employment	0.397 (0.32)	0.498 (0.30)	0.496 (0.27)	0.390 (0.26)
ASI Alcohol	0.081 (0.17)	0.089 (0.13)	0.044 (0.08)	0.064 (0.11)
ASI Drug Use	0.188 (0.11)	0.168 (0.10)	0.171 (0.11)	0.170 (0.12)
ASI Legal	0.117 (0.21)	0.030 (0.10)	0.085 (0.20)	0.027 (0.07)
ASI Family/Social	0.154 (0.21)	0.195 (0.25)	0.215 (0.25)	0.092 (0.15)
ASI Psychological	0.189 (0.19)	0.104 (0.17)	0.191 (0.21)	0.099 (0.15)

Longitudinal Analysis of Attendance and Methamphetamines Use During Treatment

We used GEE to analyze attendance and methamphetamine abstinence during the four months of treatment. Overall session attendance rates for each study group were as follows: standard treatment=46.12 %, continuous=64.51 %, intermittent predictable=67.58 %, intermittent unpredictable=59.82 %. Compared to the standard treatment group, those in the intermittent predictable CM treatment group were about 2.5 times more likely to attend treatment appointments (odds ratio [OR]=2.38, $p<0.05$). No other CM treatment groups were significantly less or more likely to attend treatment. While many other covariates were tested (i.e., age, gender, race, education, income, number of amphetamines used in last 30 days), none were significant.

GEE was also used to investigate whether there was a change in methamphetamine abstinence over time (i.e., a total of 48 possible UAs submitted during 16 weeks of treatment trial) and across treatment conditions. The results revealed that, compared to the standard treatment condition, those in continuous CM condition were almost two times more likely to submit a negative methamphetamine UA (OR=1.98, $p<0.05$), the intermittent predictable CM condition was 2.4 times more likely to submit a negative methamphetamine UA (OR=2.40, $p<0.05$), and the intermittent unpredictable CM condition was about 1.7 times more likely to submit a negative methamphetamine UA (OR=1.72, $p<0.05$). Post hoc pairwise tests of the predicted ORs revealed that none of CM conditions' OR were significantly ($p<0.05$) different from one another. We also performed this analysis without imputing any of the values. The results were somewhat similar to the previous analysis in direction (continuous OR=0.77; intermittent predictable OR=1.02; intermittent unpredictable OR=1.36), but none of these ORs were significantly different from the standard treatment condition. This is likely due to significantly decreased statistical power for our primary outcome of methamphetamine UA (i.e., very few methamphetamine positive samples were submitted). Again, we tested multiple covariates

(i.e., age, gender, race, education, income, number of amphetamines used in last 30 days), but none were significant. See Fig. 1 for a pictorial description of the effect of time and CM group.

Last, an ANOVA revealed significant differences across CM conditions for the number of consecutive days of methamphetamine abstinence; $F(3, 115)=3.34$, $p>.05$. Bonferroni adjusted follow-up tests revealed that each treatment schedule was significantly different from the standard treatment group with the exception of the intermittent unpredictable group, and the treatment groups were not significantly different from one another.

Methamphetamines Urine Analysis and Attendance During the Follow-Up Period

We used GEE to investigate change in methamphetamine abstinence (i.e., provision of a negative methamphetamine UA) during the follow-up period. There was a significant effect of treatment completion such that those who completed the 16 weeks of treatment were significantly more likely to submit a negative methamphetamine UA during follow-up (OR=21.79, $p<0.05$). There were no significant differences between the CM conditions and the standard treatment group in their likelihood of submitting a negative methamphetamine UA. The post hoc comparisons also evidenced no significant differences between the CM conditions. None of the covariates of interest were significant predictors of abstinence during follow-up.

Discussion

These results provide further support for the use of contingency management in treating psychostimulant use in general (Higgins et al. 2008) and methamphetamine use in particular (e.g., Roll et al. 2006). This bolsters the notion that drug use is an operant behavior that is modifiable via the juxtaposition of

Fig. 1 Methamphetamine use across 4 months among patients receiving standard treatment with or without contingency management

salient alternative sources of reinforcement delivered, contingent on abstinence. When possible, clinicians should attempt to arrange abstinence-based contingencies as an adjunct to other types of therapeutic approaches when treating substance use disorders.

The finding that attendance was roughly equivalent between the various schedules is notable. All three CM conditions occasioned greater rates of attendance than the condition without CM, although the difference was only significant for the continuous condition. This was likely the result of low power levels in the statistical testing procedure. Nonetheless, the data provide some indication that CM enhances attendance, and certainly that it does nothing to negatively impact attendance.

All three CM groups were associated with more abstinence than the group without CM; however, no differences in rates of abstinence were observed between the CM conditions. This is a potentially important finding, which suggests that as long as you preserve the essential elements of the voucher-based reinforcement procedure—escalation in reinforcer magnitude for consecutive instances of abstinence and a reset to a low magnitude of reinforcement following a failure to abstain (e.g., Roll and Higgins 2000)—the frequency of reinforcer delivery can potentially be decreased. This may have important clinical ramifications as delivery of reinforcement is a time-consuming process that represents a significant expenditure to clinicians' already taxing schedules. If, as these early results suggest, the delivery of reinforcement can occur less frequently while retaining procedural efficacy, it could help to increase the acceptability of CM-based interventions to clinicians who desperately need pragmatic strategies to enhance

treatment retention and abstinence when treating individuals with substance use disorders. Additionally, providing reinforcement less frequently may have economic benefit (i.e., less expensive to implement and maintain CM reinforcement), which would make implementation into a clinic setting more likely.

It is interesting that no between-group differences for the CM procedures were observed with regard to rate of abstinence given work showing the effects of intermittent reinforcement. One likely difference between basic science studies of this topic and the present investigation is the rate of behavior. In many basic science protocols, organisms are presented with multiple opportunities to behave during a relatively short time period. In this protocol, persons have relatively fewer opportunities to engage in the behavior, for instance, drug taking—or abstaining—and the behavior is distributed over time.

In this study, no effect of treatment group on follow-up drug use was detected. However, a potentially important observation was made suggesting that those individuals who remained in treatment for the duration of the intervention were more likely to provide a negative drug test at follow-up. This has potential clinical relevance as it suggests that maximal effort needs to be directed toward keeping individuals in treatment so they can receive a full dose of the intervention.

Additional work on reinforcement schedules and how they impact the initiation and maintenance of abstinence is warranted. This study again demonstrates the exquisite sensitivity of human behavior to manipulation by contingent consequences. In addition, it suggests that a refinement to CM procedures in which reinforcers are disbursed less frequently

may be a pragmatic approach for use in community-based clinics that have limited resources. Finally, the results underscore the clinical significance of trying to retain individuals in treatment for the duration of the intervention.

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