

*EFFECT OF REINFORCEMENT PROBABILITY AND PRIZE SIZE ON
COCAINE AND HEROIN ABSTINENCE IN PRIZE-BASED
CONTINGENCY MANAGEMENT*

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Although treatment outcome in prize-based contingency management has been shown to depend on reinforcement schedule, the optimal schedule is still unknown. Therefore, we conducted a retrospective analysis of data from a randomized clinical trial (Ghitza et al., 2007) to determine the effects of the probability of winning a prize (low vs. high) and the size of the prize won (small, large, or jumbo) on likelihood of abstinence until the next urine-collection day for heroin and cocaine users ($N = 116$) in methadone maintenance. Higher probability of winning, but not the size of individual prizes, was associated with a greater percentage of cocaine-negative, but not opiate-negative, urines.

DESCRIPTORS: computer automation, contingency management, methadone, operant conditioning, opiate, substance abuse

Contingency management (CM) has been shown to be an effective treatment for substance dependence (for review, see Lussier, Heil, Mongeon, Badger, & Higgins, 2006). A particularly effective application of the procedure has used a monetary-based escalating reinforcement schedule developed by Higgins et al. (1991) in which a reinforcer is given for every drug-negative urine sample, the value of the reinforcer increases with each consecutive drug-negative urine sample, and drug-positive results reset the value of the reinforcer back to its initial low level. This procedure has been used successfully in a number of clinics (Epstein, Hawkins, Covi, Umbricht, & Preston, 2003; Higgins, Badger, & Budney, 2000; Kirby, Marlowe, Festinger, Lamb, & Platt, 1998; Piotrowski et al., 1999; Robles et al., 2000; Silverman, Higgins, et al., 1996; Silverman, Wong, et al., 1996; Silverman et al.,

2007). Unfortunately, community treatment programs have been slow to adopt CM into standard practice (Amass & Kamien, 2004; Willenbring, Hagedorn, Postier, & Kenny, 2004).

To make CM more accessible and acceptable to community programs by reducing its cost, Petry and colleagues (Petry, Alessi, Marx, Austin, & Tardif, 2005; Petry & Martin, 2002; Petry et al., 2004) investigated a CM procedure in which drug abstinence was reinforced with opportunities to draw for prizes; the draws escalated in number with consecutive negative urine drug screens. For each draw earned, participants drew a chit from a bowl; markings on the chits indicated the size of prize won. Although every drug-negative urine screen was reinforced with one or more draws, not all draws resulted in a material prize. The most frequent prize was verbal encouragement (e.g., “good job”). The other draws gave material prizes that varied in size: small, large, and jumbo worth up to \$1.00, \$20.00, and \$100.00, respectively, with the probability of winning decreasing with increasing prize size. Prize-based CM has been shown to be effective in decreasing drug use in both research treatment and community treatment programs

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(Peirce et al., 2006; Petry & Martin, 2002; Petry et al., 2004; Petry, Peirce, et al., 2005; Roll et al., 2006).

Another direction that researchers have taken is to refine the efficacy of CM treatments and enhance treatment outcome by optimizing the reinforcement schedules. Among the variables that have been investigated are reinforcer magnitude, escalating reinforcer size, contingent resetting of escalating reinforcer size, shaping procedures, abstinence initiation bonuses, and number of target drugs (e.g., see Correia & Benson, 2006; Correia et al., 2003; Dallery, Silverman, Chutuape, Bigelow, & Stitzer, 2001; Lamb, Morral, Galbicka, Kirby, & Iguchi, 2005; Lamb, Morral, Kirby, Iguchi, & Galbicka, 2004; Petry et al., 2004; Preston, Umbricht, Wong, & Epstein, 2001; Robles et al., 2000; Roll & Higgins, 2000; Roll & Shoptaw, 2006; Silverman et al., 1998). Within the context of prize-based reinforcement, Petry et al. (2004) examined the effect of prize size, showing that higher value prizes (\$240.00 expected maximum total) were more effective than lower value prizes (\$80.00 expected maximum total) when the probabilities of winning in the two conditions were equivalent. Studies of reinforcement parameters have important clinical implications for the cost versus efficacy issue of CM in that an ideal arrangement would be to identify a procedure with the lowest cost that also preserves the efficacy of the treatment intervention.

Our laboratory has investigated the effects of probability of winning a prize and the effects of manual versus computerized prize drawing on treatment outcome (Ghitza et al., 2007). Participants using cocaine and heroin while enrolled in methadone maintenance were randomly assigned to groups in which the probabilities of winning a prize during a draw were set at 50% (lower probability) or 78% (higher probability) under double-blind conditions. In addition to the difference in probability of winning *any* prize, the higher probability

condition doubled the probability of winning a large or jumbo prize. Results of this study showed that participants in the high-probability contingent group had significantly higher rates of urine specimens negative for cocaine and for both cocaine and opiates than both the low-probability group and noncontingent control groups. Prize-drawing procedure (manual vs. computerized) had no significant effect.

Although, as noted above, treatment outcome in prize-based CM has been shown to depend on reinforcement schedule, the optimal schedule is still unknown. For example, given a set budget for prizes, is it better to give many prizes that are small or increase the prize size and decrease the number of prizes given? Unfortunately, systematic evaluation of all of the possible parameters in randomized clinical trials is cost and time prohibitive. Therefore, we have addressed this question by retrospective analyses of a prospective randomized trial (Ghitza et al., 2007) to separately examine the effect of prize size and reinforcement probability on subsequent abstinence. We asked (a) whether the actual number of draws earned and prizes won on a particular day affected the participant's likelihood of abstinence until the next urine-collection day and (b) whether the size of the largest prize won on a particular day affected the participant's likelihood of abstinence until the next urine-collection day. The answers to these questions should shed light on whether to focus efforts to improve the cost-benefit ratio by increasing the overall number of prizes (of any size) or by increasing the size of the individual prizes.

METHOD

Participants

This study was approved by the local institutional review board for human research. Participants were recruited through advertisements in a variety of local newspapers and television stations. They gave written informed consent prior to participation. Screening in-

cluded medical, psychiatric, and drug use histories; physical examination; standard laboratory screens; and a battery of assessment instruments, including the Addiction Severity Index (ASI; McLellan et al., 1985) and Diagnostic Interview Schedule (DIS-IV; Robins, Cottler, Bucholz, & Compton, 1995). Eligibility criteria used in the present study have been described previously (Ghitza et al., 2007). After enrolling in the study, participants began standard methadone maintenance treatment. All participants received daily methadone and weekly individual counseling without charge throughout the study.

Drug Use Monitoring

Urine specimens were collected under the observation of laboratory technicians three times per week, usually Mondays, Wednesdays, and Fridays. Urine specimens were analyzed by enzyme-multiplied immunoassay technique system that provided qualitative results for benzoylecgonine equivalents (cocaine) and morphine (opiates) with cutoff concentrations for positive set at 300 ng/ml.

Study Timeline and Groups

The study was conducted in three phases: a 5-week baseline of standard treatment during which eligibility for randomization was determined, a 12-week experimental intervention plus standard treatment phase, and an 8-week maintenance postintervention phase. During the maintenance postintervention phase, prize-based reinforcement was discontinued but standard treatment continued. Only data collected in baseline and intervention were used in the current analyses.

At the end of baseline, each participant was randomly assigned to one of four groups, including three contingent conditions and one control condition: lower reinforcement probability with manual prize draws ($n = 20$), lower probability with computerized draws ($n = 36$), higher probability with computerized draws ($n = 20$), or a noncontingent control group ($n =$

40). Participants were eligible for randomization if at least four of 15 urine specimens tested positive for heroin and cocaine (not necessarily on the same days) during the first 5 weeks of treatment (baseline). Stratification of randomization was made by race, sex, employment status, probation status, and frequency of opiate- and cocaine-positive urine specimens during baseline. Participants were not told that they could be assigned to a lower or higher probability group; rather, they were simply given the ranges of probabilities of winning.

Rules for earning draws were modeled after those used by Petry and Martin (2002) and were the same for all three contingent groups. Each urine specimen negative for either opiates or cocaine earned one draw; each specimen negative for both drugs earned four draws. Missed specimens counted as positive. The opportunity to draw for prizes was presented immediately after provision of a drug-negative urine sample. Weekly bonus draws were earned and drawn at the end of the week if all specimens that week tested negative for both drugs. The number of bonus draws increased with each consecutive week of abstinence: five the 1st week, six the 2nd week, up to 16 for the 12th week. Positive or missed urine specimens resulted in no bonus draws for the week and reset the following week's bonus draws to five. Participants in the noncontingent control group were yoked to participants in the contingent groups such that they were given opportunities to draw for prizes in the same drawing procedure (manual or computerized) and probabilities of winning as those in the contingent groups. The probabilities that a draw would result in a prize for the lower probability groups were 50% no prize (\$0.00), 43.6% small prize (valued at \$1.00 to \$5.00), 6% large prize (valued at \$20.00), and 0.4% jumbo prize (valued at \$100.00). The corresponding probabilities for the higher probability groups were 22% no prize, 65.2% small prize, 12% large prize, and 0.8% jumbo prize.

The manual and computerized drawing procedures (the automated contingency management system) used in the present study have been described previously (Ghitza *et al.*, 2007; Vahabzadeh *et al.*, 2007). After completing all draws for a given day, participants selected and received any prizes they had won. The maximum possible number of draws was 270. Twelve weeks of continuous abstinence from both cocaine and opiate use would enable a participant to receive total prizes valued at \$788.00 and \$1,391.00 in the lower and higher probability conditions, respectively, which were calculated from mean reinforcement probabilities.

Data Analysis

To examine the effect of reinforcement probability or prize size on subsequent abstinence in the retrospective analyses reported here, data from the three contingent groups were combined. This increased the range of reinforcement probabilities to be used as predictors of abstinence; it also made the presentation of results more manageable. Furthermore, because there was no main effect of prize-draw modality on drug abstinence, combining the computerized and manual prize-drawing groups was justified.

To examine the relation between probability of reinforcement regardless of prize size (expressed as the number of prizes received per draw earned, our operational definition of the terms *probability of winning* and *reinforcement probability*) and subsequent drug abstinence, analyses were conducted using generalized linear mixed models (SAS Version 9.1, SAS GLIMMIX macro). GLIMMIX was used with the logit link function for binary data to perform an analysis that can be functionally described as a repeated measures logistic regression, although the output is more like that of an analysis of variance (including *F* values) with the additional output of covariate-adjusted percentages. For each urine screen day during intervention in

which each participant was negative for cocaine and earned at least one draw (i.e., tested negative for cocaine or cocaine and opiates), we determined the relation between reinforcement probability and the likelihood of a cocaine-negative urine on the following urine-collection day. Similar analyses were performed assessing the relation between reinforcement probability and subsequent opiate abstinence, except that this analysis was conducted for events in which each participant earned at least one prize draw and tested negative for opiate use. Outcome measures were qualitative urinalysis: cocaine-negative urines or opiate-negative urines during the urine-collection day after prize-drawing days. The independent variables were the number of prizes received per prize draw earned (a standardized measure of reinforcement probability taking into account the number of prize draws earned), a covariate for dropout (continuous variable: time in treatment), a covariate for baseline drug use (a known predictor of treatment response; Preston *et al.*, 1998), and the percentage of urine specimens negative for both opiates and cocaine. The term for dropout (operationalized as the number of the last urine specimen corresponding with the number of weeks that the participant remained in the study before dropping out) was included based on the pattern-mixture approach to controlling for the nonrandom nature of missing data (i.e., for the possibility that dropouts differed in some systematic way from study completers; Hedeker & Gibbons, 1997). The percentage was arcsine transformed to correct for heterogeneity of variance (Hogg & Craig, 1995).

To examine the relation between prize size and subsequent abstinence, we performed GLIMMIX analyses similar to those described above, except that the independent variable was the size of the largest prize won, coded as 0 = no prize, 1 = at least one small prize but no large or jumbo prizes, 2 = at least one large or jumbo prize. Jumbo and large prizes were

Table 1
Mean (*SD*) Intake Demographic Characteristics and Study Retention

	All participants	By experimental treatment	
		Noncontingent controls	Contingent
<i>N</i>	116	40	76
Age (years)	37.0 (8.4)	36.5 (8.2)	37.9 (8.2)
Male (%)	56	55	57
African American (%)	47	40	50
Years heroin use	10.3 (7.5)	9.0 (5.8)	10.6 (8.2)
Years cocaine use	9.4 (7.4)	9.1 (7.2)	8.0 (6.5)
Days heroin use ^a	29.0 (4.3)	29.7 (0.9)	29.2 (3.3)
Days cocaine use ^a	17.4 (10.2)	17.1 (10.6)	17.5 (10.0)
Estimated IQ	92.7 (8.1)	92.9 (7.4)	92.6 (8.4)
Years of education	11.4 (1.3)	11.5 (1.4)	11.3 (1.3)
Monthly income (\$)	453	406	478
Study retention (weeks)	21.3 (6.4)	22.0 (5.7)	21 (6.8)
Completed 25 weeks (%)	69	73	68

^a Number of days used in last 30 before admission to treatment.

grouped together because few jumbo prizes were won. Because the number of draws affected the probability of winning a large or jumbo prize (i.e., more draws increased the likelihood that a larger prize would be won) and more draws were earned with longer durations of abstinence, the prize-size data were also analyzed with total number of prize draws earned on each occasion as a covariate. Controlling for the number of draws is important because the number of draws earned reflects the duration of prior abstinence, and prior abstinence is an independent predictor of future abstinence (Higgins et al., 2007; Preston et al., 1998).

In all GLIMMIX analyses, pairwise differences between least squares means were analyzed by *t* tests with Tukey-Kramer adjustment (via the PDIFF option in the LSMEANS statement of the SAS GLIMMIX macro), maintaining familywise Type I error rate at an alpha level of .05.

Participants in the noncontingent control group were not included in these analyses because their receipt of prizes was not contingent on drug use but was yoked to the drug use of the other participants. Separate analyses of data from noncontingent control participants (pooled into a single group) were conducted as a follow-up to the analyses described above to

determine whether contingent reinforcement of drug abstinence was necessary for the effects.

Alpha level for all analyses was .05 (two tailed).

RESULTS

Participant Characteristics

Table 1 lists the demographic characteristics for all participants and for those in the noncontingent ($n = 40$) and contingent ($n = 76$) groups. Pearson χ^2 and ANOVA analyses revealed that demographic, ASI, and DIS-IV characteristics at intake did not differ significantly between groups.

Prizes

The contingent reinforcement group received comparable prizes per prize draw (62.2% of draws were winners) as the noncontingent control group (62.4%). The mean total prize amounts received per group over the 12-week intervention period were \$191.00 for the contingent reinforcement group and \$171.00 for the noncontingent control group. The higher probability contingent reinforcement group received more prizes per draw ($M = 78\%$ draws were winners; range, 62.5% to 100%) than the lower probability contingent

reinforcement group ($M = 50\%$; range, 0% to 100%). The mean total prize amounts received per group over the 12-week intervention were \$286.00 for the higher probability contingent reinforcement group and \$157.00 for the lower probability contingent reinforcement group.

Relation Between Prize-Draw Ratio and Subsequent Abstinence

Figure 1 (top) shows the relation between prize-draw ratio and cocaine abstinence on the urine-collection day following the prize drawing, averaged across prize sizes won, for each participant in a contingent group. Participants who won prizes on a higher proportion of draws during occasions when they were negative for cocaine were significantly more likely to be abstinent from cocaine during the subsequent urine collection day than those participants who were less likely to win a prize, $F(1, 135) = 5.56$, $p < .05$. This relation was significant only in participants in the contingent reinforcement groups; there was no relation between prize-draw ratio and subsequent abstinence among participants in the noncontingent control group, $F(1, 53) = 0.07$, $p > .05$ (data not shown).

Figure 1 (bottom) shows the relation between prize-draw ratio and opiate abstinence on the urine-collection day following the prize drawing, averaged across prize sizes won, for each participant in a contingent group. Unlike for cocaine, the relation was not statistically significant, $F(1, 135) = 0.21$. The relation was also not significant in the noncontingent group, $F(1, 53) = 1.35$ (data not shown).

Relation Between Prize Size and Subsequent Abstinence

Figure 2 (top) shows the percentage of cocaine-negative urine specimens on the days following occasions when participants earned at least one prize draw for being cocaine negative and the highest value prize won was none, small, or large or jumbo. Data were analyzed with and without controlling for the number of

prize draws at each occasion. In analyses in which number of draws was not controlled, there was a positive relation between prize size and subsequent cocaine abstinence, $F(2, 41) = 3.24$, $p < .05$. Adjusted percentages (mu values from a SAS GLIMMIX random-effects mixed-regression model), controlling for baseline drug use and for days in treatment, were as follows: no prize, 36% negative; small prize, 51% negative; large or jumbo prize, 56% negative. Post hoc Tukey-Kramer tests revealed that negative urines were more likely to occur after receipt of a large or jumbo prize than after receipt of no prize ($t = 2.52$, $df = 41$, $p < .05$). In a similar analysis in the noncontingent control group, there was no significant relation between prize size and subsequent cocaine abstinence, $I(2, 17) = 0.42$, $p > .05$. However, in analyses controlling for the total number of prize draws earned, the relation between prize size and subsequent cocaine abstinence was no longer significant, $F(2, 41) = 2.17$.

Figure 2 (bottom) shows the percentage of opiate-negative urine specimens on the days following occasions when participants earned at least one draw for being opiate negative and the highest value prize won was none, small, or large or jumbo. There was no relation between prize size and subsequent opiate abstinence with, $F(2, 69) = 1.06$, or without, $F(2, 69) = 0.88$, inclusion of total number of prize draws earned as a covariate. Adjusted percentages (mu values from a SAS GLIMMIX random-effects mixed-regression model), controlling for baseline drug use and for days in treatment, were 74% negative after no prize, 77% negative after a small prize, and 79% negative after a large prize.

DISCUSSION

An important unresolved issue in CM research is how to optimize the use of an intermittent reinforcement approach to decrease cost in a manner that optimizes clinical effectiveness. In these analyses, we addressed this issue by examining whether multiple-drug

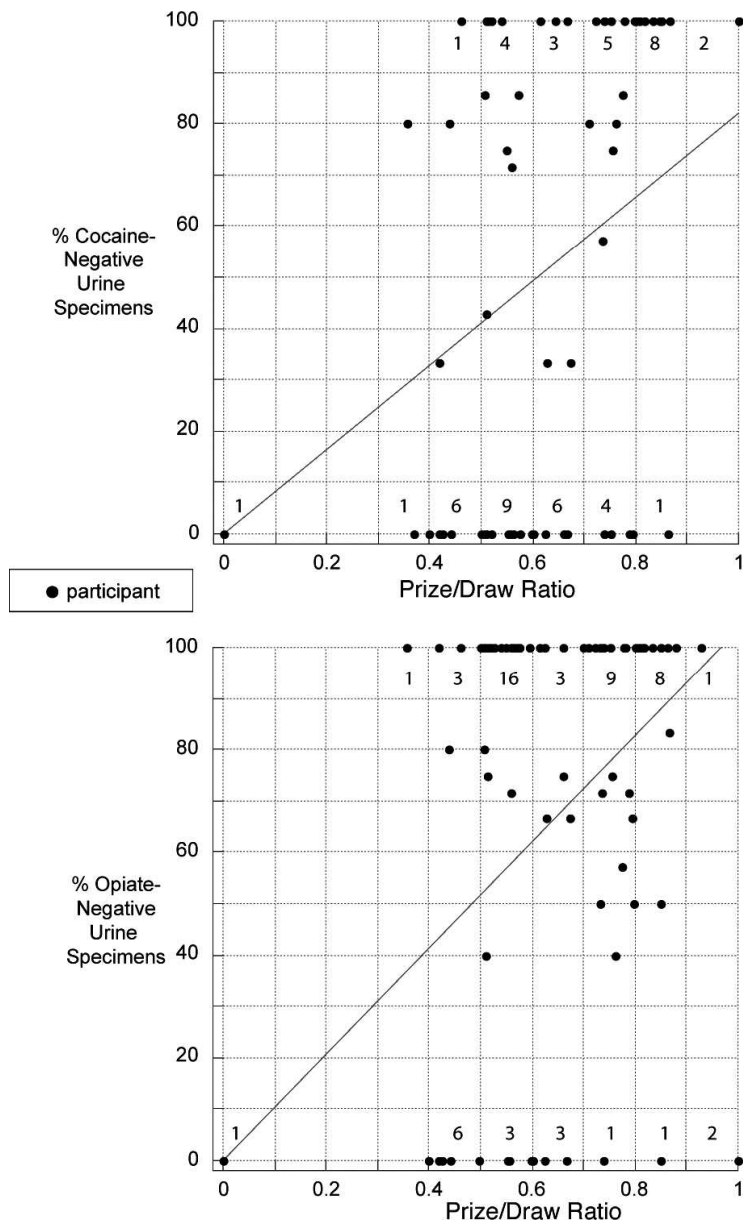


Figure 1. Relation between prize–draw ratio (actual prizes won divided by draws earned) and percentage of cocaine-negative (top) or opiate-negative (bottom) urines at the next urine-collection day. Each circle represents data from an individual participant in the contingent reinforcement group, averaged across all occasions in which that individual earned at least one prize draw for testing negative for cocaine or opiates. Numbers within the graph indicate the number of participants in each decile interval for 0% negative and 100% negative. The regression lines were calculated within the graphing software (Kaleidagraph) and were forced to go through the origin in order to avoid negative intercept terms, which would have been theoretically uninterpretable for these data. Forcing the intercept through the origin also produced a better fit to the data in terms of the standard errors for the regression coefficients, suggesting that this approach was appropriate (Eisenhauer, 2003).

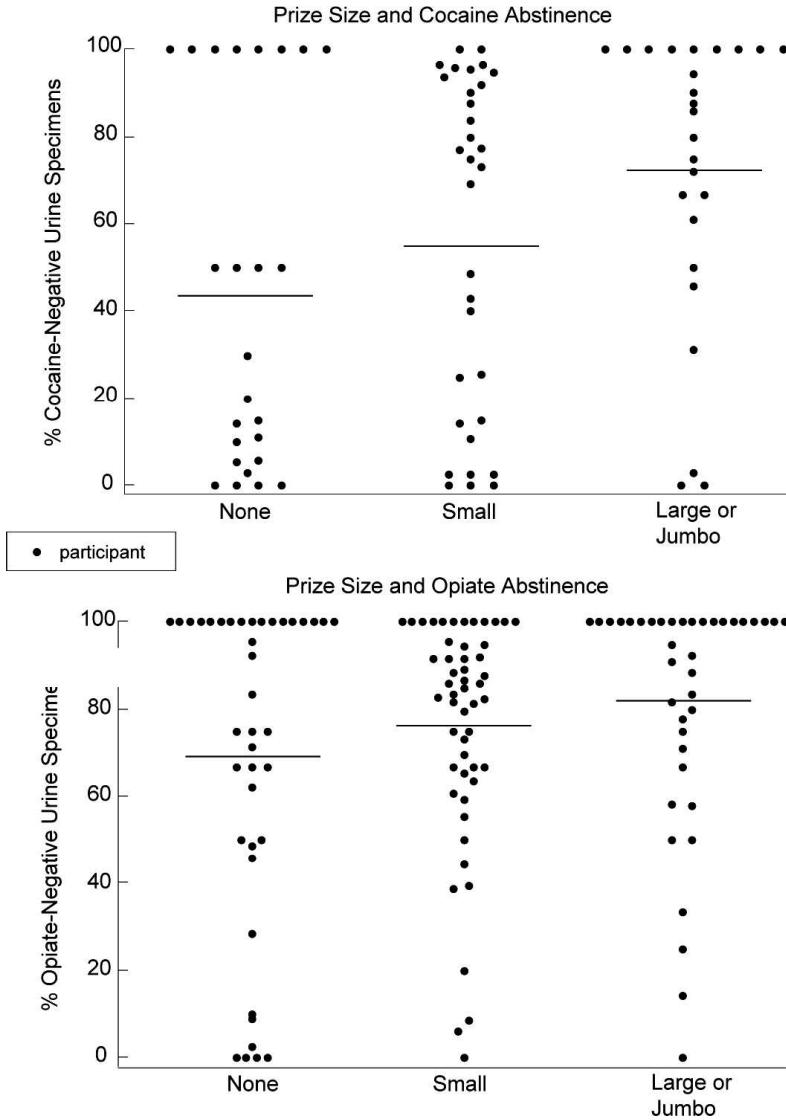


Figure 2. Relation between largest prize won and percentage of cocaine-negative (top) or opiate-negative (bottom) urines at the next urine-collection day. Each circle represents data from an individual participant in the contingent reinforcement group, averaged across all occasions in which that individual earned at least one prize draw for testing negative for cocaine or opiates and won none, small, or large or jumbo prizes. Jumbo and large prizes were grouped together because few jumbo prizes were earned. More participants are represented for opiates (bottom) because a larger proportion of participants tested negative for opiates at least once. Unadjusted means across participants are denoted by horizontal lines.

users, having already earned prize draws contingent on abstinence, would be more likely to remain abstinent when their prize draws resulted in tangible winnings. We further assessed whether such an effect would become

more prominent when the overall likelihood of winning was greater or when the size of the largest prize won was greater. Our results showed that the overall likelihood of winning was a clearer predictor of subsequent abstinence

than the size of the largest prize won. The important clinical implication of this finding is that clinicians may optimize the clinical and cost effectiveness of an intermittent reinforcement system by enhancing the overall likelihood of winning a prize rather than by increasing the size of the individual prizes.

This finding reached statistical significance only for cocaine, not opiates, and only in participants whose prize draws were contingent on prior abstinence. The absence of an enhancement of opiate abstinence probably reflects a ceiling effect (e.g., see Figure 2) attributable to methadone. The absence of an effect in the noncontingent condition shows that enhancement of abstinence is not an inherent consequence of winning prizes; rather, the prizes reinforce abstinence when abstinence is the response required for access to prizes.

The relation between overall likelihood of winning and subsequent abstinence is consistent with the principle that leaner reinforcement schedules produce behavior that is less resistant to change, and that as the schedule approaches continuous reinforcement, responding becomes more robust (Nevin & Grace, 2000). Continuous reinforcement schedules are used in voucher-based CM. Our results suggest that the use of prize-based CM to decrease cost may lead to a trade-off between savings and clinical effectiveness. This needs to be tested empirically in studies with a wider range of probabilities, including a continuous reinforcement schedule (i.e., a one-to-one prize-to-draw condition), to determine the optimal arrangement. What seems clear, however, is that the winning of tangible prizes, above and beyond the earning of the draws that made winning possible, was a key determinant of continued responding (i.e., subsequent abstinence). The relation between prize size and subsequent abstinence is less clear. Although our results showed that winning a larger prize predicted abstinence on the following day, the effect was no longer significant when we controlled for the number of draws earned on

that day. We believe that the latter finding reflects the true nature of the relation between size and outcome because we based the analysis on the largest prize won on each occasion. The more draws a participant earned on a single day, the greater the probability of winning at least one large or jumbo prize, and number of draws was linked to abstinence through escalating bonus draws. Furthermore, previous studies have shown that abstinence predicts subsequent abstinence (Higgins et al., 2007). Our statistical analyses allowed us to determine the independent impact of the size of the earned prize on subsequent abstinence by controlling for number of prize draws as well as other potential confounding effects, such as abstinence rate and study dropout. It should be noted, however, that studies of voucher-based CM have clearly shown a positive relation between abstinence and reinforcer magnitude (Lussier et al., 2006). In our study, the lack of effect of prize size may have been due to the intermittent nature of the schedule or to the fact that our study was not designed to examine the effects of prize size. Therefore, further work is needed to confirm this finding.

Our findings extend previous research demonstrating that prize-based reinforcement in methadone-maintained patients promotes abstinence from illicit drug use (Peirce et al., 2006; Petry, Alessi, Marx, Austin, & Tardif, 2005; Petry & Martin, 2002; Petry et al., 2004) and to our knowledge, are the first to show a rapid effect of a given day's winnings on subsequent days' abstinence. An important determinant of the effect seemed to be a higher likelihood of receiving a tangible reinforcer (prize) following an occasion of drug abstinence. This finding has clinically significant implications for the design and dissemination of CM treatment procedures that are both affordable and effective.

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