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Spend today, clean tomorrow: Predicting methamphetamine abstinence in a randomized controlled trial

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Abstract

Objective—This secondary analysis of data from a randomized controlled trial tested two behavioral economics mechanisms (substitutability and delay discounting) to explain outcomes using contingency management (CM) for methamphetamine dependence. Frequency and purchase type (hedonic/utilitarian and consumable/durable) of CM payments were also examined.

Methods—82 methamphetamine-dependent gay/bisexual men randomly assigned to conditions delivering CM received monetary vouchers in exchange for stimulant-negative urine samples in a 16-week trial requiring thrice weekly visits (Shoptaw et al., 2005). At any visit participants could redeem vouchers for goods. A time-lagged counting process Cox Proportional Hazards model for recurrent event survival analysis examined aspects of the frequency and type of these CM purchases.

Results—After controlling for severity of baseline methamphetamine use and accumulated CM wealth, as measured by cumulative successful earning days, participants who redeemed CM earnings at any visit (“*spenders*”) were significantly more likely to produce stimulant-negative urine samples in the subsequent visit, compared to those who did not redeem (“*savers*”) 1.011* [1.005, 1.017], $Z=3.43$, $p<0.001$.

Conclusions—Findings support the economic concept of substitutability of CM purchases and explain trial outcomes as a function of frequency of CM purchases rather than frequency or accumulated total CM earnings. Promotion of frequent purchases in incentive-based programs should facilitate substitution for the perceived value of methamphetamine and improve abstinence outcomes.

Keywords

Contingency Management; Behavioral Economics; Addiction

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Introduction

Although the number of Americans estimated to use methamphetamine in the past 30 days has declined in recent years, methamphetamine dependence continues to be a significant problem in the Western United States and is the leading substance reported among publicly funded drug treatment episodes in California (California Department of Alcohol and Drug Programs, 2012). Gay and bisexual men use methamphetamine at high rates and this use has been associated with elevated risk for HIV infection (Shoptaw & Reback, 2006; Drumright, Gorbach, Little, & Strathdee, 2009; Plankey et al., 2007). Methamphetamine dependence is associated with multiple morbidities including hepatitis, cardiac effects, family disruptions, neurocognitive deficits, and prominent psychiatric consequences (Cruickshank & Dyer, 2009; Gonzales, Mooney, & Rawson, 2010; Scott et al., 2007). Efforts to optimize efficacy of treatment for the disorder have great public health significance.

To date, only behavioral interventions have shown efficacy for treating methamphetamine dependence, with contingency management (CM) showing superiority compared to cognitive behavioral therapy during treatment (Shoptaw et al., 2005; Rawson et al., 2006). Contingency management reflects principles of operant conditioning, reinforcing abstinence from stimulants through delivering increasingly valuable incentives for consecutive urine samples documenting methamphetamine abstinence (see Higgins et al., 1993).

Contingency Management Approaches

Several previous studies have evaluated different manipulations of CM payment schedules to increase effectiveness and address cost-effectiveness concerns including changing the magnitude of reinforcement (Carroll et al., 2002; Petry et al., 2004; Silverman et al., 1999; Sindelar, Olmstead, & Peirce, 2007), the rate of reinforcement (Roll, Higgins, & Badger, 1996), and the relative risk of reinforcement (Petry & Martin, 2002; Petry, Martin, Cooney, & Kranzler, 2000). Overall these studies demonstrate robust effects of CM to affect positive health behavior change under many different situations and reinforcement varieties.

While the success of these approaches is widely recognized, the underlying mechanism is less clear; specifically why CM is more effective during treatment than other forms of behavioral therapy. It is tempting to apply CM in a largely atheoretical manner due to its robust effect; however, to make accurate predictions about behavioral change under a variety of CM reinforcement approaches, it is necessary to understand the theoretical underpinnings of the model.

Applying CM to chronic behavior disorders like methamphetamine dependence is theoretically complex. Creating an association between positive reinforcement and biological markers of drug abstinence instills an active decision-making process on the part of the individual, requiring a balance of executive reasoning and strategies to inhibit desire for drug reinforcement. This report draws on behavioral economic and psychological theory to elucidate mechanisms, which may help advise ways to optimize outcomes when using incentive-based behavior therapy. Further, we studied instances of voucher redemption rather than the typical measure of voucher earning to look more closely at the moment of receiving reward for behavior. Drawing on behavioral economic theory, we examine two contrasting potential mechanisms, substitutability and delay discounting, using patterns of voucher redemption as well as purchase types, in order to explain outcomes of a large trial of CM (Shoptaw et al., 2005) in a sample of methamphetamine-dependent gay and bisexual men in Los Angeles County.

Substitutability

In economic theory, as in psychology, reinforcers are fixed stimulus events (e.g., drug use) that can strengthen responses which elicit the desired reinforcement and that over time can lead to dependence (Allison & Timberlake, 1974; Premack, 1965). Some goods act as substitutes for one another and although those goods are not identical (e.g., Coke vs. Pepsi), they can be considered qualitatively the same (Rachlin, Battalio, Kagel, & Green, 1981; Rachlin, Green, Kagel, & Battalio, 1976). Individuals should be willing to exchange one good for another if its influence on the reinforcing relationship is relatively similar (Green & Freed, 1993). Therefore, conceptually a substitute for a drug could be almost anything that an individual would be willing to accept in place of that drug. There may be any number of possible drug substitutes that mimic the desired effects of the drug, including other drugs. An effective substitute that can be implemented in drug dependence treatment is one that does not increase dependency and promotes a healthy, drug free lifestyle. In this research, we propose that vouchers, which correspond to a monetary value, may act as a substitute for methamphetamine by mimicking the hedonic, affective response previously attributed to drug use. While a CM voucher is not a perfect substitute for a drug, we suggest that the act of spending CM vouchers may provide a reinforcing experience that helps individuals elicit a sustained period of abstinence.

Another way to conceptualize substitutability is in terms of cross-price elasticity (Petry, 2001). Good A is often chosen (substitutes for) Good B when the price of Good B increases and the price of Good A does not [e.g., drinking an alternate soda (Pepsi) when the price of the preferred soda (Coke) increases]. Costs for methamphetamine can accrue in two ways. First, the reinforcing effects of the same amount of the drug decrease over time due to tolerance, thereby increasing the financial cost of the drug. Second, experience costs increase with continued use in terms of eroded personal, physical, psychological, and support factors. When applied to methamphetamine dependence, behavioral economics predicts that provision of a good that is experienced as qualitatively similar and comes at a lower cost as the drug should be successful in helping users to switch from their drug to the substitute (CM vouchers). Thus, the efficacy of CM could be explained by the capacity of the vouchers (alone or because of the goods that vouchers purchase) to compete successfully and qualitatively (i.e., to substitute) for the reinforcement from methamphetamine use. From this vantage, it is possible and perhaps likely that individuals who experience a substitution event (i.e., a voucher redemption) will experience an association between the reinforcement of the vouchers and abstinence, thereby predicting better treatment outcomes in the following visit.¹

Based on a substitutability theory of behavior, we would predict that:

H1: If voucher redemptions are acting as a substitute for methamphetamine use, participants who redeem their CM earnings at a visit (*spenders*) will be more likely to have a negative urine result at their next visit compared to participants who do not redeem (*savers*), even when controlling for baseline methamphetamine dependence and cumulative voucher wealth, as measured by cumulative successful earning days.

The success of a CM program can be affected by the reinforcing relationship between the nature of the good acquired through voucher redemption and drug abstinence. The closer the good is to being a substitute for the drug, the more likely the participant is to develop an operant-conditioned reinforcing relationship between the good and abstinence. Drugs are a

¹Receiving a voucher does increase the individual's overall wealth. If participants were to view vouchers as fully fungible with their other wealth, receiving or spending a voucher should increase the availability of participant's personal money to spend on drugs.

hedonic but short-lived experience. While the strength of their hedonic effect diminishes with chronic use (Ahmed, Kenny, Koob, & Markou, 2002; Koob & Le Moal, 2008), each drug intake event is registered in neurological ‘pleasure centers’ (Berridge & Kringelbach, 2008; Kringelbach & Berridge, 2009). A perfectly equitable hedonic substitute for a drug may be another drug that stimulates the reward pathways in the brain. Experiencing CM purchases categorized as hedonic goods may evoke more pleasure and therefore serve as a better substitute than utilitarian goods. As such, with respect to the hedonic nature of the goods purchased with CM payments, we would predict that:

H1b: If the goods purchased via voucher redemption are acting as a substitute for methamphetamine, participants who redeem their CM earnings for more *hedonic* purchases will be more likely to produce a negative urine sample at their next visit compared to participants who redeem their CM earnings for more *utilitarian* purchases, when controlling for baseline methamphetamine dependence and cumulative voucher wealth, as measured by cumulative successful earning days.

Additionally, individuals who abuse drugs tend to discount drugs more steeply than money (for review see Bickel & Marsch, 2001) and moreover, they discount other consumables, such as food to a similar level as drugs when compared to money (Odum & Baumann, 2007). Individuals who abuse drugs and have steeper discounting rates for other consumable goods may consider a good that can be consumed quickly (i.e., more similar in consumption rate to methamphetamine) a better substitute compared to one with a long lifespan (i.e., a computer). Therefore, *consumable* goods rather than *durable* goods may serve as qualitatively better substitutes for drugs. Individuals can show domain-specific levels of delay discounting, having similar discount rates for goods they personally find tempting, compared to others (Tsukayama & Duckworth, 2010). Individuals in this study were given the freedom to choose their purchases, provided the purchase promoted a healthy/pro-social lifestyle (e.g., rent, music, dry cleaning), according to their desires or needs. With respect to the consumable nature of the goods purchased with CM vouchers then, we would predict that:

H1c: If the goods purchased via voucher redemption are acting as a substitute for methamphetamine, participants who redeem their CM earnings for more *consumable* purchases will be more likely to give a negative urine sample at their next visit compared to participants who redeem their CM earnings for more *durable* purchases, when controlling for baseline methamphetamine dependence and cumulative voucher wealth, as measured by cumulative successful earning days.

Delay discounting

Individuals with drug dependence tend to value immediate rewards more than distant future rewards, compared to those without drug dependence (review by Bickel & Marsch, 2001). This greater degree of *delay discounting* explains the difficulty of establishing sustained, long-term abstinence. Drug-dependent individuals must make repeated choices between the immediate reinforcing effects of methamphetamine and the distant health, psychological, and social benefits of not using methamphetamine. Those who can delay reward (i.e., successfully resolve the delay discount regarding abstinence) may be more successful in response to a CM intervention. Specifically, individuals who successfully resolve the delay discount, accrue voucher earnings, and make fewer voucher redemptions when money is available (*savers*), may experience generalized effects that can result in successful drug abstinence during treatment. Based on a differential delay discounting theory of behavior, we would predict that, in contrast to H1:

H2: Individuals who delay purchasing over a greater number of consecutive visits (*savers*), will be more likely to produce negative urine results on any given subsequent visit than those who make purchases, even when controlling for baseline methamphetamine dependence and cumulative voucher wealth, as measured by cumulative successful earning days.

Method

Participants

Study participants were 162 methamphetamine-dependent gay and bisexual men who provided voluntary informed consent (reviewed by Friends Research Institute West Coast IRB) and were appropriate for outpatient treatment. Participants in this analysis included those randomly assigned to conditions that provided contingency management and who were able to earn any incentives (n=82; see Figure 1).

Procedures

Consented participants entered a 2-week screening period in which they were required to attend clinic and provide a urine sample a minimum of four out of six available times to be eligible for study participation. Eligible participants were randomized to one of four behavioral therapy conditions: CM only (n=42), cognitive behavioral therapy only (n=40), CM plus cognitive behavioral therapy (n=40) and a gay-specific cognitive behavioral therapy (n=40) and attended clinic three days per week for 16 weeks to provide urine samples, receive treatment, and complete study measures. Outcomes from the study are described elsewhere (Shoptaw et al., 2005).

Interventions

Contingency Management—Participants received voucher-based reinforcement therapy with rapid reset after relapse (Higgins et al., 1993). Vouchers were provided for urine samples testing negative for metabolites of methamphetamine starting at \$2.50 for the first sample and increasing by \$1.25 for successive metabolite-negative urine samples (i.e., \$3.75 for the second negative sample; \$5.00 for the third). Every third consecutive negative urine sample earned a \$10.00 bonus voucher. The maximum that could be earned during the study for providing 100% negative urine samples was US \$1,277.50. Vouchers earned could be redeemed for goods or services that promoted a healthy/pro-social lifestyle, such as groceries, gas, utility bills, travel, movies, or music. Participants could redeem at any study visit if they had a positive balance in their account, regardless of their urine result at that visit. They could: (1) choose from a set of voucher certificates at the clinic that could be redeemed at specific stores and entertainment venues (e.g., grocery stores, gas stations, movie theaters), (2) choose any payee by providing a bill to the clinic staff who would write a check, or (3) be accompanied by a clinic staff member to a store to directly purchase the desired good. When requests were made for staff to accompany participants to make purchases, requests were typically fulfilled within a 24-hour period. Only vouchers were provided. No cash was provided.

Cognitive behavioral therapy—Roughly half of the participants (n=37) in these analyses who received contingency management also received Matrix Model cognitive behavioral therapy (Rawson, et al., 1995). This method uses education in a group format to provide education and skills related to recovery from methamphetamine dependence.

Measures

Spending Measures—The frequency and magnitude of purchases made with the contingency management payments were collected during the study. Categorization of participants into *spenders* or *savers* was based on a median split on frequency of purchasing behavior. For specific voucher certificate purchases, the retailer and amount were recorded. When participants received payments of bills or other invoices, copies of the bills and invoices were kept as well as copies of the checks that were written and a description of the purchase was recorded. Using these records, purchases were categorized into the following non-exclusive groups: *hedonic/utilitarian* and *consumable/durable*. Goods were categorized as hedonic if their use was deemed pleasurable or entertaining (e.g., movie tickets, music) and utilitarian if the good was deemed practical or necessary (e.g., gas, prescriptions). Goods were categorized as consumable if they were used completely or became useless in a short period of time (e.g., groceries) and durable if their period of usefulness was longer term (e.g., bicycle). An exhaustive list of goods purchased can be found in Appendix A. Purchase categorizations were determined independently by the first two authors and reliability analyses demonstrated high inter-rater reliability (.90 and .96 for the respective categorizations).

Drug Use Measures—Baseline methamphetamine dependence was measured by self-report of days of methamphetamine use within the past 30 days at baseline. Current use was assessed with urine drug screening tests. Observed urine samples were collected at each clinic visit and analyzed immediately on-site for metabolites of methamphetamine and cocaine to prevent “stimulant switching.” If participants provided samples that were positive for either stimulant they did not receive a voucher credit. This was also true for participants who failed to attend the clinic visit or refused to provide a urine sample.

Statistical analysis

The Counting Process version of the Cox Proportional Hazards model for recurrent event survival analysis was used. This method improves upon a cross-sectional approach (e.g. Poisson regression) in which the directionality between payment and urine results is unclear (i.e. payment could cause negative urine results or vice versa). Using the Cox Proportional Hazards model, the probability of a negative urine sample at each point is predicted by the covariates from a previous point and therefore each current negative urine sample is solely predicted by past covariates, such as cumulative spending to date. This method rules out the chance that negative urine samples themselves are causing any model covariate effects found².

Further, study visits occurred Mondays, Wednesdays, and Fridays, increasing the likelihood that behaviors on one visit (i.e., voucher redemption) affect the behavior (i.e., interim methamphetamine use) recorded at the next visit. The time horizon for the urine analysis to detect metabolites of methamphetamine or cocaine is within the time elapsed between visits.

²It is important to note that while The Cox Proportional Hazards model does rule out reverse causality, it does not rule out the possibility of a common cause of both the DV and the covariates. This model holds that the probability of having a positive urine sample is a function of the overall risk of a positive urine sample for all participants at baseline level of covariates (the hazard function), multiplied by a set of covariates that can change this risk. This multiplicative (proportionality) assumption allows one to determine whether each covariate changes the risk of having a positive urine sample without regard to the unknown hazard function. Parameters for each covariate are estimated by seeing whether a positive urine sample occurs at different levels of covariates for each event aggregating across all participants but ignoring possible within-participant correlations. The Counting Process model assumes that the order of events does not matter and models each period separately by fitting a Cox PH model to the entire dataset (Andersen & Gill, 1982; Therneau & Lumley, 2009; Twisk, et al., 2005). The standard errors of parameters are then calculated to adjust for within-participant clustering by using a grouped jackknife estimate that repeatedly drops one participant from the statistical analysis and recalculates the parameters of the model (Therneau & Grambsch, 2000). The variability of each model parameter across all one-participant deletions is then the robust estimate of the variance of the parameters.)

The statistical model calculates the relative risk ratio that a participant will produce a negative urine at any given time point, given a vector of time-independent and time-dependent predictor variables that describe the participant's prior spending or saving behavior. All models control for baseline methamphetamine dependence, cumulative expenditures, and cumulative successful earning days³ to account for a participant's acquired wealth in the study at any point.

Analysis of covariates

As expected, baseline methamphetamine dependence severity, as measured by number of days of methamphetamine use in the 30 days prior to baseline, was negatively associated with response to treatment as measured by negative urine results. Each k days of additional methamphetamine use in the 30 days before baseline resulted in $0.965^{k*}[0.942, 0.989]$ times lower risk of having a negative urine sample than a participant without those k days of use at any point during treatment, $Z=2.84$, $p<0.01$. For example, compared to a participant with zero use at baseline, a participant with one day of use at baseline would be 3.5% less likely to have a negative urine result, and a person with ten days of use at baseline would be 30.0% less likely to have a negative urine result at any point during treatment.

We examine the effects of both participants' acquired wealth, as measured by cumulative successful earning days, and total expenditures on negative urine results at any given point. First, cumulative successful earning days were added to the model as a time-varying factor to account for the amount of wealth that a participant had accumulated to date. As expected, for each k additional clean tests in the previous time periods, a participant had $1.186^{k*}[1.155, 1.219]$ higher risk of a negative urine sample in the subsequent study visit, $Z=12.4$, $p<0.001$. For example, a participant with one negative urine result to date would be 1.19 times more likely to have a negative urine result in the current visit, and someone with ten negative urine results to date would be 5.51 times more likely to have a negative urine result in the current visit compared to one with zero negative urine results to date.

Second, a model including only cumulative prior expenditures as a time-varying factor accounted for the amount of wealth that a participant had spent to date. As expected, for each k additional dollar spent in the previous time periods, a participant had $1.008^{k*}[1.007, 1.009]$ higher risk of a negative urine sample in the subsequent visit, $Z=6.75$, $p<0.001$. For example, compared to a participant who had spent zero dollars to date, a participant who had spent ten dollars to date was 1.083 times more likely to have a negative urine results in the current visit, and someone who had spent one hundred dollars to date was 2.218 times more likely to have a negative urine at the current visit.

To contrast the effects of acquired wealth, as measured by cumulative successful earning days, and cumulative prior expenditures, we entered both into the model. However, cumulative prior expenditures was unrelated to risk of negative urine samples after controlling for baseline use and cumulative successful earning days $p>0.05$. Both covariates are retained for all subsequent models.

The marginal effects presented in the following models are all valuated at mean levels of covariates: baseline methamphetamine use (9.74 days), cumulative successful earning days (15.93 days), and cumulative prior expenditures (US\$134.20).

³As an alternative to using cumulative successful earning days, analyses were performed using cumulative cash balance. However, these models did not produce significantly different results.

Results

Sample demographics

This analysis included men with a mean age of 36.4 years (S.D.=7.0), with 14.6 (S.D.=2.5) years of education who earned per month on average US\$2450.09 (S.D.=US\$3250.22), and spent US\$248.35 (S.D.=388.06) on methamphetamine in the 30 days prior to baseline. In all, 59.8% of the participants were HIV positive, 76.8% identified as Caucasian, 17.1% Hispanic, 3.7% Asian/Pacific Islander, and 2.4% African-American.

Overall methamphetamine use outcomes

As reported in Shoptaw et al. (2005), participants in the CM conditions showed significant reductions in urine-verified methamphetamine use during treatment compared to a standard cognitive behavioral therapy condition. No differences were found between the two CM conditions in overall negative urine samples (CM 25.95 (S.D.=16.37), CM+CBT 32.33 (S.D.=16.38) $t(80)=-1.76$ $p>0.05$). Additionally, no differences were found in spending behaviors between participants receiving CM only or CM + CBT (Mean purchases_{CM-only} = 7.24 and Mean purchases_{CM+CBT} = 5.40, $F(1,67) = 1.17$, $p = .28$). Thus, for the purposes of examining the effects of spending and saving behavior on negative urine samples both CM groups are collapsed.

Overall Spending Behaviors

Participants averaged a total of 6.3 unique purchases with their earnings (S.D. = 7.1) and had earned an average of US\$557.61 by the end of the study (S.D. = US \$468.46), or 43.7% of the total possible. The distribution of number of total purchases was bimodal and supported creating two groups of purchasers. A median split divided the participants into *spenders* ($n=40$), who made an average of 10.0 purchases (S.D.=7.4), which was significantly more than the *savers* ($n=42$), who made an average of 0.9 purchases (S.D.=0.7), $t(80)=8.00$, $p<.001$. Figure 2 shows a trend over time for spenders to do better in treatment over time compared to savers. To analyze this trend, we must control for our covariates above which is accomplished using the lagged counting process version of the Cox Proportional Hazards model for recurrent event survival analysis.

Hypothesis1: Substitutability—Consistent with hypothesis1, making a purchase at any visit significantly decreased the risk of a positive urine result at the subsequent visit, even after controlling for covariates. Making a purchase in the previous time period significantly increased the likelihood of providing a negative urine result in the subsequent visit 1.011* [1.005, 1.017], $Z=3.43$, $p<0.001$. For example, a participant with baseline methamphetamine use of 9.7 days, with 15.9 cumulative clean urines, who has spent \$134.20 to date, was significantly (1.011 times) more likely to produce a negative urine sample on the next visit than if they had not made a purchase.

Hypothesis 1b: Purchase types: Hedonic vs. Utilitarian—The hedonic or utilitarian nature of the purchase made in the previous time period did have an effect on the likelihood of a negative urine test in the subsequent period. Participants who made a hedonic purchase in the previous visit were significantly more likely (0.42%) to provide a negative urine sample than those who made no purchase 1.004* [1.000,1.008], $Z = 2.06$, $p < 0.04$. Similarly, those who made a utilitarian purchase in the previous visit were significantly more likely (0.33%) to provide a negative urine sample than those who made no purchase 1.003*[1.000, 1.006], $Z = 2.19$, $p < 0.03$. There were no statistically significant differences between the hedonic or utilitarian types of goods purchased, however, on the likelihood of providing a negative urine sample $Z=0.35$, $p=0.72$.

Hypothesis 1c: Purchase types: Consumable vs. Durable—Participants who made a consumable purchase in the previous visit were significantly more likely (0.68%) to provide a negative urine sample than those who made no purchase $1.007^*[1.002, 1.011]$, $Z = 3.02$, $p = 0.003$. Similarly, those who made a durable purchase were significantly more likely (0.60%) to provide a negative urine sample than those who made no purchase $1.006^*[1.003, 1.009]$, $Z = 3.55$, $p < 0.001$. There were no statistically significant differences between the consumable or durable nature of goods purchased on the likelihood of providing a negative urine sample $Z=0.28$, $p=0.78$.

Hypothesis 2: Delay Discounting—Contrary to hypothesis 2, participants who saved their CM earnings, by choosing not to purchase on days even when money was available, were significantly more likely to have stimulant positive urine results compared to participants that did not save. The longer participants delayed purchases when they could have purchased something (with a monetary voucher balance greater than zero), the less likely they were to provide a negative urine result at their next visit $0.937^*[0.870, 1.011]$, $Z = 1.68$, $p = 0.09$. In fact, each additional day of delaying reward was associated with a 6.26% decrease in the likelihood of providing a negative urine sample at the subsequent visit.

Discussion

These findings show that it is the act of voucher redemption, rather than the receipt of payment that affects subsequent methamphetamine abstinence. Further, frequent voucher redemption regardless of purchase size was related to methamphetamine abstinence. Finally, participants who delayed gratification and demonstrated streaks of saving by not redeeming even when vouchers were available had worse treatment outcomes once they finally redeemed their vouchers. As such, these methods and findings are novel and contribute new findings to existing CM research that focuses on delivery, likelihood, and magnitude of earnings.

While much work has been conducted showing the effectiveness of CM, examining the effects of altering various aspects of the rewards provided in CM (such as manipulating the magnitude of reward), very little work has focused on the role that the participants' psychological response plays in their redemption of these rewards and subsequent success in CM programs. We tested two of these psychological mechanisms that could be responsible for the success of CM vouchers (*substitutability* and *delay discounting*). Our work is novel in that it presents a set of analyses founded in behavioral economic theory that extend the findings of the randomized controlled trial by demonstrating that it is actually more important for individuals to spend their CM payments than to save them.

Our argument depends on two assumptions: (1) that for gay and bisexual men with methamphetamine dependence, entering treatment happens when the baseline experience of methamphetamine use no longer exceeds the discounted value of accumulating good health; and (2) earning vouchers during the trial accounts for the extent to which people value the voucher relative to new uses of methamphetamine. If these are true, then the degree to which one works to earn a voucher by abstaining from the drug during the trial should be completely dependent on the discounted value of the voucher and good health relative to the current value of using the drug, both of which are captured in baseline dependence and periods of abstinence over time during the trial. If the mechanism of the vouchers in eliciting abstinence in the trial is purely a reward function, the act of spending the voucher should make no difference above and beyond these two controls.

The substitutability model we propose holds that spending the voucher not only redeems the value of the voucher, but the act also temporarily competes for the subjective experience of the drug. Our statistical analyses showed that using the voucher in the previous period reduces the probability of using the drug in the next period above and beyond their acquired wealth, as measured by their cumulative successful earning days, as well as their discount rate and prior value of the drug (captured by baseline dependence and negative urines over the trial). We posit that these results indicate a reduction in the value of the drug as explained by a model of substitutability.

Participants who spent their incentive earnings were more likely to be abstinent at their next visit just a few days later compared to those who had money but did not spend their earnings, which strongly implicates the reinforcing power of the purchase. Although the relative risk ratios appear small at mean levels of the covariates, the effect becomes quickly relevant to success over the course of the treatment. Measuring a greater than 1% improvement in negative urine results is practically meaningful, given that this analysis controls for baseline use (i.e., severity of addiction), cumulative success in the task, and cumulative expenditures in the prior weeks. While the effect of each individual spending or saving event seems small, over the 16 weeks of treatment participants that demonstrated spending behavior had better treatment outcomes overall compared to those who did not spend. These findings lend support to a substitutability explanation of CM when used as a treatment for dependence and provides no support for reducing the delay discount inherent in stimulant treatment.

In these analyses, participants who saved their wealth thereby delaying their reward and demonstrating less steep levels of delay discounting, were actually less likely to have a negative urine sample after they made their greater value purchase. Further, the longer participants remained abstinent without making a purchase, the more likely they were to have a positive urine sample at any given visit. These findings suggest that reducing levels of delay discounting via monetary saving ultimately fails to compete with the acute reinforcing effect of methamphetamine and over time becomes counter-therapeutic to the goal of sustained abstinence. In addition, purchasing any type of good (hedonic, utilitarian, consumable, and durable) had a positive and significant effect on being drug abstinent at the next visit compared to those who did not purchase, providing support for the finding that the act of purchasing has an effect on treatment outcomes. However, no one category of goods was found to have significant contribution to treatment outcomes compared to other types of goods.

There are several limitations to this work. Categorizing goods as hedonic or utilitarian is quite challenging, as this categorization can be extremely subjective and individual-specific (e.g., purchasing an item of clothing may be a pleasurable buying experience for one individual but a practical one for another individual). Thus, the authors acknowledge that categorization of goods as hedonic or consumable types to be a limitation to this work. In future work, it would be important to ask participants to rate the hedonic or utilitarian nature of their purchase. To truly examine how the nature of the purchase, independent from the purchaser, might affect adherence to treatment, one would ideally use a randomized controlled trial to assign participants to make a hedonic or consumable purchase of their choosing. However, the choice freedom in the study design does indicate that the goods purchased were particularly appealing to the purchaser, increasing their likelihood of serving as a substitute for methamphetamine. Moreover, it is possible that there is some agency or self-efficacy component of choice freedom in purchase selection that reinforces the effect.

A second limitation to this work was the inability to measure the participant's complete economic portfolio. It is possible that in some instances participants applied their study

earnings towards purchases that did not act as substitutes, freeing up resources from other income sources to make purchases of drug substitutes that could not be measured in this study. However, as an important first step at understanding the underlying mechanism explaining the difference between more and less successful participants in this study, further research on purchase types as experimental variables could shed more light on these questions.

Lastly, it is possible that choosing to spend a voucher captures features of the discount rate that are not captured by prior uses of the drug. However, those who have a lower discount rate should be more willing to abstain to earn the voucher but less willing to spend the voucher once it is earned, which would imply the opposite pattern of results from what we obtained. Another possibility is that earning vouchers in the trial does not fully capture the value of the voucher. Thus, participants would work more to earn vouchers and also spend them because they value them more, and as a result continue to abstain to earn more vouchers. Although possible, it seems implausible that this factor would not be captured by cumulative success in the trial. A more complex problem involves the dynamic interplay between saving vouchers and the changing value of the drug. It may be possible for participants to strategically abstain from the drug to reduce their tolerance while saving up vouchers for larger purchases, then using the drug when one has lower tolerance and compounding that reinforcement with buying large purchases. This is unlikely, however, as all of these participants met criteria for dependence, which is defined by prior failed attempts to quit or cut down drug use.

Two of the main barriers to wide-scale implementation for CM are the perceived high cost, despite studies demonstrating its cost effectiveness (Sindelar, Olmstead, & Peirce, 2007), and moral objections that public sources of funding should not pay people to behave the way they “should” already. In implementing public health policy, however, science and evidence provide solid directions for addressing public health problems, which contrasts greatly with responding to moral objections, especially when there is a lack of effective treatments. Our findings suggest that the act of voucher redemption itself is enough to drive successful CM interventions, something that has not been systematically observed previously. Bringing behavioral economic theories to join with this new examination of the data shed light on mechanisms that may be used to optimize incentive programs for drug dependence and perhaps other problem behaviors. Emphasis on purchasing behaviors during incentive-based study design and implementation could improve the precision and impact of using this method, especially when translating CM interventions into real world applications.

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Figure 1.
Participant flow diagram of RCT stages

Figure 2.
Negative urine results trends over time for “spenders” and “savers”

Appendix A

Exhaustive list of goods purchased by categorizations

	Hedonic	Utilitarian
Consumable	Application fee for buddhist pilgrimage Magazine/daily newspaper subscription (e.g., Men's Health Magazine, Body Building Magazine, Entertainment Weekly) Movie passes Movie rentals Restaurant food purchases Theater performance tickets Vacation travel (e.g. airline tickets, rental car)	Public transit tokens Fast food gift certificates Gas Groceries Pharmacy/drug store purchases Prescriptions
Durable	Art portfolio and art supplies/materials Charitable toy donation Cable television and internet service Computer purchase Fitness club membership High end bicycle supplies and accessories High end photography supplies Limousine service Music CD(s) Printer purchase	Automobile expenses (e.g., repair, tires, insurance, car payment, registration, AAA membership) Clothing College tuition Credit card payments Dry Cleaning Health Insurance Home Goods (e.g., Hold Everything, Pottery Barn) Medical services (e.g. dental visits, counseling sessions, residential treatment facility payments) Office supplies Parking violations Pool Cleaning service Public transit passes Rent/HOA payment Storage unit rental Tax preparation services Telephone services (e.g. cell phone, pager) Used television broadcast equipment Utility services (gas, water, power)