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Examining Delay Discounting and Response to Incentive-Based Smoking-Cessation Treatment Among Pregnant Women

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EXAMINING DELAY DISCOUNTING AND RESPONSE TO INCENTIVE-BASED SMOKING-CESSATION TREATMENT AMONG PREGNANT WOMEN

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Abstract

Delay discounting is considered by many to be a risk factor for substance use disorders and other health-related behavior problems. While these health-related behavior problems are often treated with incentive-based interventions, little is known about whether delay discounting (DD) moderates response to that treatment approach. The present study examined how response to incentive-based smoking-cessation treatment varied as a function of baseline DD scores among pregnant women participating in randomized controlled clinical trials examining the efficacy of financial incentives. Women were assigned to a condition wherein they earned vouchers exchangeable for retail items contingent on abstinence from recent smoking or to a control condition wherein they received vouchers of comparable value but independent of smoking status. Individual differences in DD of hypothetical monetary rewards were measured at the study intake and follow-up assessments. We examined whether individual differences in baseline scores on that instrument predict antepartum and postpartum smoking status using logistic regression, and if sustaining abstinence caused changes in DD scores from intake to 24-weeks postpartum. We did not see any significant main effects of DD or interactions of DD with treatment on antepartum or postpartum smoking status. Treatment condition, baseline smoking rate (cigs/day), a history of quit attempts pre-pregnancy, and educational attainment were all associated with increased odds of abstaining from smoking at the late-pregnancy antepartum assessment, and treatment condition was the only significant predictor of abstaining from smoking at 24-weeks postpartum, three months after the treatment formally ended. We saw no discernible evidence that sustained abstinence from smoking was associated with post-treatment decreases in DD. Overall, we saw no evidence that being a steeper discounter is associated with a lack of success in quitting smoking in either treatment condition. Being assigned to the incentives condition was the only predictor of antepartum and postpartum abstinence. The observed associations of a lower baseline smoking rate, higher educational attainment, and a history of having attempted to quit smoking previously with increased odds of success in achieving antepartum smoking abstinence is consistent with results from previous reports on predictors of response to this treatment underscoring the reliability of these relationships.

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Introduction

Impulsivity is considered by many to be a risk factor for substance use disorders and an emerging predictor of treatment outcome among those attempting to discontinue substance abuse (Baker *et al.*, 2003; Bickel, Odum, & Madden, 1999; Heil *et al.*, 2006; MacKillop *et al.*, 2007; Madden, Bickel, & Jacobs, 1999; Mitchell, 1999; Vuchinich & Simpson, 1998; Washio *et al.*, 2011). The construct has been defined as "a predisposition toward rapid, unplanned reactions to internal or external stimuli [with diminished] regard to the negative consequences of these reactions to the impulsive individual or others" (Moeller, Barratt, Dougherty, Schmitz, & Swann, 2001). Rather than being a unified construct, impulsivity appears to involve multiple dimensions that vary within and between individuals (Evenden, 1999). The construct is measured in a variety of ways using diverse assessment tasks or instruments, including the delay-discounting (DD) task, which is the focus of the present study (Bickel & Marsh, 2001).

Importantly, scores on these various measures of impulsivity are associated with increased risk for cigarette smoking, other substance use disorders, as well as a wide range of other health-related behavior problems (e.g., obesity, non-adherence with medical prevention regimens; de Wit, 2008; Reimers *et al.*, 2009; Swann *et al.*, 2002; Swann *et al.*, 2004). Increasingly, such health-related behavior problems are being treated with incentive-based interventions (e.g., see Higgins, Silverman *et al.*, 2012), but relatively little is known about how type or severity of impulsivity may moderate response to that treatment approach. To begin addressing that question, I examined how individual differences in DD predicted response to treatment among pregnant smokers enrolled in randomized controlled clinical trials examining the efficacy of financial

incentives in promoting smoking cessation (Higgins, Washio, *et al.*, 2012; Higgins, Washio, Lopez, *et al.*, 2014). Women in these trials were assigned to an incentive-based smoking-cessation intervention wherein they earned vouchers exchangeable for retail items contingent on abstinence from recent smoking or to a control condition in which vouchers of comparable value were received independent of smoking status.

Background on DD

DD is a behavioral-economic task that is used to examine individual differences on what can be considered a dimension of impulsivity, namely the rate at which rewards lose value and aversive events lose salience as delay to their receipt increases (Bickel & Marsh, 2001). DD was originally characterized in laboratory animals, showing that they reliably prefer smaller- over larger-magnitude rewards when the former is more immediately available than the latter (Rachlin & Green, 1972). Moreover, the relationship between reward value and temporal delay is best described by a hyperbolic function that is well characterized by the following equation, $v = A/(1+kD)$, whereby v=discounted value of the delayed reward, A= the undiscounted value of the delayed reward, k= the measured rate of delay discounting, and D is the delay to the receipt of the reward (Mazur, 1987). Higher k values indicate greater discounting of future rewards and can be used to quantify individual differences in discounting.

DD tasks used with humans often involve hypothetical monetary outcomes (e.g., Bickel, Odum, & Madden, 1999; Madden *et al*., 1997). Participants make a series of choices between immediately available hypothetical monetary rewards and a delayed, larger amount across different temporal delays. The value of the immediate reward is systematically adjusted until a value is identified where the participant is indifferent

between the immediately available and delayed reward. In other words, the indifference point is the monetary amount at which the immediately available and delayed options are valued equivalently. Identifying indifference points across a range of temporal delays and then fitting Mazur's hyperbolic equation described above to the data allows one to quantify the degree to which individual participants discount delayed rewards (Johnson & Bickel, 2002). Consistent with the results observed in preclinical studies, humans often prefer the smaller, more immediate over the larger, more delayed reward and the shape of the discounting function is generally well fit by Mazur's hyperbolic equation. Although a comparable titration procedure can be used to quantify discounting of delayed losses, that procedure has been investigated relatively little overall and, to our knowledge, not at all with regard to substance abuse treatment response (Odum *et al*., 2002). Thus the present study is focused on a version of DD examining sensitivity to delayed hypothetical rewards (Johnson & Bickel, 2002).

Relationship of Delay Discounting with Health-Related Behavior Problems

As noted above, there is a growing body of empirical evidence demonstrating that DD is associated with a wide-range of health-related risk behaviors (Bickel *et al*., 2007; Davis *et al.*, 2010; Epstein *et al.*, 2010; Rogers *et al*., 2010). Indeed, excessive discounting of delayed reinforcers has been proposed to be part of a trans-disease process that is common to a wide range of health-related risk behaviors (Bickel *et al.*, 2012). Consistent with that notion, a pronounced bias towards preferring immediate rewards (i.e., upper 20^{th} percentile of *k* values on a DD task) predicts a significantly lower likelihood of adherence to a wide range of preventive services/activities, including abstaining from cigarette smoking in the longitudinal U.S. Health and Retirement survey

(Bradford, 2010). Additionally, greater DD is associated with dependence on cocaine (Heil *et al.*, 2006), opioids (Madden, Bickel, & Jacobs, 1999), alcohol (MacKillop *et al.*, 2007; Vuchinich & Simpson, 1998), and nicotine (Baker *et al.*, 2003; Bickel, Odum, & Madden, 1999; Mitchell, 1999). Greater discounting is also associated with the number of cigarettes smoked per day (Ohmura, Takahashi, & Kitamura, 2005), and smoking relapse in laboratory studies (Dallery & Raiff, 2007; Mueller *et al.*, 2009) as well as outcomes in several clinical trials (MacKillop & Kahler, 2009; Sheffer *et al.*, 2012; Yoon *et al.*, 2007). There is also at least one trial that is discussed more below in which DD predicted treatment response in cocaine-dependent outpatients receiving the same incentive-based intervention that will be investigated in the present study (Washio *et al.*, 2011) and another noting that greater discounting is associated with poorer treatment outcomes for cannabis use (Stanger *et al.*, 2012). More recently, a study was conducted examining whether discounting changes with sustained smoking abstinence (Secades-Villa *et al.*, 2014). In that study, smokers and abstainers showed no differences on DD immediately post-treatment; however, abstainers were discounting significantly less compared to smokers at a 12-month follow-up, suggesting that sustained smoking abstinence is associated with reductions in DD.

Important to note is there have been exceptions to the positive associations between DD and risk for unhealthy behavioral choices outlined above. For example, Bradstreet and colleagues (Bradstreet *et al.*, 2012) reported that DD did not differentiate significantly between pregnant spontaneous quitters and continuing smokers. By contrast, what might be considered another aspect of impulsivity (e.g., social discounting) significantly differed between quitters and smokers, with quitters showing less social

discounting (i.e., selfishness) than smokers as a function of degree of separation (i.e., greater generosity). More recently, White and colleagues (White *et al.*, in press) conducted a follow-up study to Bradstreet *et al.* (2012), again examining the ability of DD to predict spontaneous quitting among pregnant smokers. Social discounting was not examined in the follow-up study as it was not assessed in the majority of participants included in this larger study. DD, educational attainment, and smoking rate (cigarettes smoked per day) were each univariate predictors of quitting. In multivariate analyses, educational attainment remained a significant predictor and there was a significant interaction of DD and smoking rate, with DD being a significant predictor at lower but not higher smoking rates. Turning to studies in the general population of smokers, at least one study revealed a gender difference with DD discriminating between male but not female smokers and non-smokers (Jones, Landes, Yi & Bickel, 2009). Lastly, DD scores at study intake assessment failed to predict treatment outcomes in a study examining an incentive-based intervention designed to reinforce exercise among college undergraduates (Pope, 2013).

To our knowledge, the association between DD and response to incentives-based smoking cessation has not been previously reported. Yoon *et al.* (2007) reported that baseline DD predicted relapse back to smoking status at 24-weeks postpartum in a cohort of women who had quit spontaneously. The studies mentioned above (Bradstreet *et al.*, 2012; White *et al.*, in press) regarding pregnant smokers examined spontaneous quitting and not response to a formal intervention. Examining whether DD moderates response to incentive-based interventions is of particular interest as such interventions are designed to offer relatively immediate reinforcement for healthy choices and thus might be expected

to be more effective than other treatment approaches with steep discounters who may be unable to tolerate the longer delays typically involved with naturalistic rewards for quitting smoking during pregnancy (e.g., improved birth outcomes). The results from the Washio *et al*. (2011) study on response to incentive-based interventions among cocaine-dependent outpatients are consistent with that position. Washio and colleagues reported a significant association between greater DD and lower rates of abstinence in an incentive-based intervention condition with relatively low reinforcement magnitude but not in a condition with higher magnitude reinforcement. That is, when the magnitude of the incentives was low and thus less effective, DD predicted abstinence levels. However, as the magnitude of the incentive value increased and efficacy increased, then the ability of DD to predict abstinence levels decreased to non-significant levels. Considering that incentive-based interventions are increasingly being used to effectively alter the same health-related behaviors for which DD and other types of impulsivity are reported to be risk factors (Higgins, Silverman, *et al.*, 2012), knowing whether response to incentive-based interventions may vary across different levels of impulsivity severity is an important question.

Overarching Rationale for the Present Study

The primary purpose of the present study is to examine whether DD predicts response to abstinence-contingent incentives. While positing that incentive-based interventions leverage present bias (i.e., an aspect of impulsivity) to promote healthy choices may be theoretically compelling (Higgins *et al.*, 2012; Loewenstein *et al.*, 2007), we know of relatively little empirical evidence addressing how impulsivity may moderate treatment response to incentive-based treatments. Again, the Washio *et al.* (2011) study

in cocaine-dependent outpatients mentioned above showed a significant association between greater DD and lower rates of abstinence in an incentive-based intervention condition with relatively low reinforcement magnitude and less efficacy but not in a condition with higher magnitude reinforcement and greater efficacy. Those findings are consistent with what would be predicted from a present-bias account of the effectiveness of incentive-based treatments, but we know of no other evidence addressing the role of impulsivity and response to incentive-based interventions. Important to recognize is that there are alternative mechanisms through which incentive-based interventions may act to improve outcomes. For example, financial incentives function as generalized reinforcers and may simply increase abstinence levels through a reinforcement mechanism independent of individual differences in sensitivity to delay or other aspects of impulsivity. As another example, financial incentives increase activity in brain regions associated with top-down cortical functions underpinning attention, error monitoring, and other executive functions essential for successful long-term goal seeking (Aston-Jones & Cohen, 2005; Muller *et al.*, 2007) and that are often diminished among those with substance use disorders (Garavan & Hester, 2007; Lundqvist, 2005). Perhaps incentives improve treatment response in part by increasing activation of such self-regulatory processes. The purpose of the present study is to rigorously characterize the extent to which response to incentive-based smoking-cessation treatment among pregnant women varies conditional on individual differences in DD, a widely used task for assessing individual differences in impulsivity.

Methods

Participants

Participants (N = 232) were from three randomized controlled clinical trials. Two of those trials were described in separate reports (Heil *et al.*, 2008; Higgins, Washio, Lopez, *et al.*, 2014). The third trial was described as part of a review on the use of incentive-based interventions for smoking cessation among pregnant women (Higgins, Washio, *et al.*, 2012). Each of the trials were conducted in the same university-based outpatient research clinic and approved by the local institutional review board. Participants were recruited from local obstetric clinics and the Federal Special Supplemental Nutrition Program for Women, Infants and Children in the Burlington, Vermont area. To be eligible for inclusion, participants had to report currently smoking at the first prenatal care visit with biochemical verification, reside within the county in which the clinic is located with no plans to leave the area for 6 months following delivery, and speak English. Exclusion criteria included incarceration, previous participation in a trial on incentives for smoking abstinence or living with a trial participant, current opioid substitution therapy, current use of psychotropic medications other than antidepressants, being greater than 25 weeks gestation, and living in a group residence (for more details see Higgins, Washio, Lopez, *et al.*, 2014; Higgins, Washio, *et al.*, 2012).

Assessments

At the study intake assessment in each of the trials participants completed questionnaires examining socio-demographics, current smoking status/history, smoking environment and motivations, confidence and intentions to quit smoking, and provided

breath and urine specimens. They also completed the DD task. Abbreviated versions of the intake assessment were administered again at seven subsequent assessments completed antepartum (early- and late-pregnancy) and postpartum (2-, 4-, 8-, 12-, and 24-weeks). Smoking status was biochemically verified at each assessment using urine cotinine testing (cutpoint = $\leq$ 80 ng/ml; Enzyme Multiplied Immunoassay Technique, Microgenics Corporation, Fremont, CA; a Roche Cobas Mira analyzer, Dade Behring Inc., Deerfield, IL).

The DD task was completed in a quiet room with a staff member present. The DD task used a notebook computer running Microsoft Visual Basic 6.0. The DD program has been described previously (Johnson and Bickel, 2002). Briefly, participants were seated in front of the computer screen, which displayed the following message:

> Imagine that you have a choice between waiting (length of time) and then receiving $1,000 or receiving a smaller amount of money right away. Please choose between the two options.

In the instructions, the length of time given was either 1 day, 1 week, 1 month, 6 months, 1 year, 5 years, or 25 years. When participants were ready to begin the task, they clicked on the start button located on the screen, and the DD program was initiated. Participants chose between two different options, always a fixed amount ($1,000) at a fixed delay, or a smaller amount available immediately. The DD program adjusted the value of the smaller reward across trials according to an algorithm wherein different values of the smaller reward were presented until an indifference point was found, in which the value of the smaller, immediate amount was subjectively equivalent to the delayed $1,000 reward (Johnson & Bickel, 2002). Once the indifference point for a

given delay was determined, the next delay was introduced until an indifference point was established for each of the 7 delays noted above. Delays were presented in a fixed ascending or descending order for a given participant but determined randomly across participants. Prior to assessment of each new delay, participants were presented again with the instructions listed above.

Treatment Interventions

All study participants were assigned to an incentive-based smoking-cessation intervention wherein they earned vouchers exchangeable for retail items contingent on abstinence from recent smoking or to a control condition in which vouchers of comparable value were received independent of smoking status. There was a common contingent incentives intervention and control condition in each of the trials. One of the trials also included a third condition, which was a revised contingent incentives condition that was designed to increase abstinence above levels achieved with the usual incentives condition. Each of these interventions are described below. Note, however, that the outcomes achieved with the usual and revised incentive conditions did not differ and thus were combined for purposes of the present study.

Usual contingent voucher condition (CV). Vouchers redeemable for retail items were earned contingent on submitting breath CO specimens ≤ 6 ppm during the initial five days of the cessation effort. Beginning in Week 2, vouchers were delivered contingent on urine-cotinine levels ≤ 80 ng/ml, a criterion that required a longer duration of smoking abstinence than breath CO. Voucher delivery was independent of self-reported smoking status and based exclusively on meeting the biochemical-verification criterion. Vouchers began at \$6.25, and escalated by \$1.25 per consecutive negative

specimen to a maximum of $45.00, where they remained barring positive test results or missed abstinence monitoring visits. Positive test results or missed visits reset the voucher value back to the original low value, but two consecutive negative tests restored the value to the pre-reset level. The incentives intervention was in place from study initiation through 12-weeks postpartum.

Revised contingent voucher condition (RCV). The same voucher schedule as outlined above was followed in this RCV condition except that potential earnings were rescheduled, moving $300 forward as bonuses that could be earned during Weeks 1-6 by meeting a $\leq$ 4 ppm breath CO criterion during Week 1, testing cotinine negative at the first urine test on the 2nd Monday of the quit attempt, and thereafter by submitting two cotinine-negative specimens per week through Week 6. More specifically, bonuses earned by reaching a cutoff of $\leq$ 4 ppm CO during Week 1 started at $18.75 and increased by $3.75 for each successive negative sample reaching a maximum potential bonus of $33.75 for the 5th consecutive negative specimen meeting the $\leq$ 4-ppm CO cutoff during Week 1. Women in this condition earned the same incentive as in the CV condition if they met the $\leq$ 6 ppm CO but not the $\leq$ 4 ppm cutoff in Week 1. Testing cotinine-negative on the 2nd Monday resulted in an additional bonus of $87.50 above usual CV incentive earnings on that date. Five more bonuses of $15.50 each were available on Thursdays (2nd test day of each week) during Weeks 2-6 if a woman also tested negative for smoking at the earlier test conducted that same week.

Noncontingent voucher control condition (NCV). In this condition, vouchers were delivered independent of smoking status. Voucher values were $15.00 per visit antepartum and $20.00 per visit postpartum, values that resulted in payment amounts

comparable to average earnings in the CV condition in prior trials (Heil *et al*., 2008). All else was the same as in the CV and RCV conditions.

Other services. In addition to the interventions, described above, participants in all treatment conditions received usual care for smoking cessation provided through their obstetric clinics, which typically involves provider inquiry regarding smoking status and a discussion of the advantages of quitting during pregnancy. Study staff provided additional cessation counseling to all participants during four visits within two weeks of study entry, at the final antepartum visit, and during three postpartum study visits. For women who quit during pregnancy, brief counseling also occurred during routine smoking- status monitoring visits whenever temptations to smoke were reported. As a counseling guide, we used a printed booklet tailored for pregnant smokers (ACOG, 2001).

Analytical Plan and Statistical Methods

Participant characteristics were compared between treatment conditions using chi-square tests for categorical measures or *t* tests for continuous variables. As noted above, results from the revised and usual contingent incentives conditions were collapsed in the present study. Two measures of smoking abstinence were used in these analyses. First, we examined antepartum and postpartum point-prevalence abstinence. Smoking abstinence was defined as a biochemically-verified maternal self-report of no smoking in the 7-days prior to the assessment.

Regarding the DD task, the hyperbolic model was fitted to each subject's DD data using nonlinear regression. Goodness of fit was evaluated on the basis of model R^2s and residual plots. Each subject's derived discounting parameter (k) was used to compute

corresponding ED50 values (1/*k*) and log transformed *k* values to account for the skewed distribution of the discounting score for subsequent analyses. ED50 was used to assist with interpreting *k* values, and log *k* was used in the statistical analyses (Yoon & Higgins, 2008). ED50 values represent the estimated delay at which the immediate value of the reinforcer was discounted by 50% and provides an intuitive interpretation of the rate of discounting. For example, a *k* value of 0.001 equals and ED50 value of 1000 days, indicating that the delayed outcome lost 50% of its original value in 2.74 years.

The analytic plan was implemented in the following steps: (1) Subject characteristics were compared between the two treatment conditions. (2) Associations between intake DD log *k* values and baseline participant characteristics were conducted using Pearson's correlation coefficient. (3) Relationships between DD and smoking status (late-pregnancy point-prevalence assessment and 24-week postpartum point-prevalence assessment) were assessed using the same correlational analyses as above. (4) Relationships between baseline characteristics and smoking status were assessed using the same correlational analyses as above. (5) Logistic regression analysis was used to examine whether DD scores and treatment condition were independently associated with smoking status. Furthermore, DD and treatment condition were each entered as independent explanatory variables in additional models with and without an interaction term. Next, backward elimination logistic regressions were used to model predictors of smoking status allowing DD, treatment condition, DD x treatment interaction terms, and all baseline characteristics that were significantly correlated with impulsivity scores or smoking status to be considered for inclusion in the model. The criterion for retention in the regression models was set to alpha = 0.05. Separate regressions were conducted to

predict 7-day point prevalence abstinence at the late pregnancy and 24-week postpartum assessments. (6) The final step in the analytic plan examined whether sustained smoking abstinence was associated with reductions in DD. Women were categorized as smokers or abstainers based on their 24-week point-prevalence smoking status, and we compared changes in DD scores from intake to 24-week postpartum within each group using Mann-Whitney tests and between them at 24-weeks postpartum using Wilcoxon signed-ranks. All analyses were performed using SAS Version 9 statistical software (SAS Institute, Cary NC) and SPSS Version 20 (IBM).

Results

Subject Characteristics

On average, participants in this trial were relatively young and economically disadvantaged (Table 1), with a mean age of less than 25 years, approximately 25% had less than a high school education, less than 25% had private insurance, and less than 20% were married. There were no significant differences between the two treatment conditions on any of the baseline characteristics examined.

Baseline DD Levels and Associations with Baseline Characteristics

Shown in Table 2 are baseline DD scores. Median log *k* and ED50 values of study participants were −6.19 and 1.3 years, respectively, meaning that a delay of 1.3 years on average resulted in the value of the delayed hypothetical $1,000 being discounted by 50% or $500.

DD was significantly correlated with three baseline characteristics (Table 3): educational attainment (less than a high school education) and two smoking

characteristics, both having to do with smoking in the home (i.e., living with other smokers and allowing smoking in the home).

Univariate Predictors of Smoking Status

Treatment condition was significantly correlated with 7-day point prevalence smoking status at the late-pregnancy and 24-week postpartum assessments (Table 4). Late-pregnancy smoking status was also significantly correlated with one socio-demographic variable (i.e., less than a high school education) and five baseline smoking characteristics (i.e., age of first cigarette, cigarettes per day pre-pregnancy, baseline cigarettes smoked per day, number of quit attempts pre-pregnancy, and number of quit attempts antepartum but prior to treatment entry). There were no other significant univariate associations between participant baseline characteristics and late-pregnancy or 24-week postpartum smoking status (Table 4).

Regression Results Predicting Late-Pregnancy Point-Prevalence Smoking Status

As described above, the regressions predicting late pregnancy smoking status were conducted in four blocks (Table 5). Treatment condition was a significant predictor while DD was not (Blocks 1 & 2, respectively). There was no significant interaction of treatment condition and DD (Block 3). The final backwards elimination logistic regression model (Block 4) included treatment condition, the # of cigarettes smoked per day at baseline, a history of quit attempts pre-pregnancy, and less than a high school education. The concordance for this model between the predicted probabilities and late-pregnancy smoking status was C =0.78, which indicates strong concordance (i.e., models are typically considered reasonable when the C-statistic is higher than 0.7 and strong when C exceeds 0.8 (Hosmer & Lemeshow, 2000; Hosmer & Lemeshow, 1989).

Predicting 24-week Postpartum Point-Prevalence Smoking Status

Treatment was a significant predictor of 24-week postpartum point-prevalence abstinence but DD was not (Block 1 & 2, respectively, Table 6). There was no significant interaction of treatment and DD (Block 3). Treatment condition was the only significant predictor retained in the final backwards elimination logistic regression model (Block 4). The concordance for the model was C = 0.63.

Changes in Impulsivity Over Time

There were no significant changes in DD scores from the intake to 24-week postpartum assessments when examining all participants independent of smoking status ($Z = 0.62$, $p = .54$). The same was true when women were examined separately based on their 24-week smoking status. Among women who were non-smokers at 24-weeks postpartum, median intake log *k* was -6.36 (ED50 = 1.6) while median 24-week postpartum log *k* was −7.18 (ED50 = 3.6; $Z = -0.97$, $p = .33$). Among those who were smokers, median intake log *k* was -6.33 (ED50 = 1.5) and median 24-weeks postpartum log *k* was −5.88 (ED50 = 1.0; $Z = .94$, $p = .35$).

Discussion

The primary purpose of the present study was to examine whether response to this incentive-based treatment for smoking cessation during pregnancy and early postpartum was moderated by individual differences in DD. There was evidence that greater DD was associated with the likelihood of living with other smokers and allowing smoking within the house in the present study. While each of those characteristics have been associated with smoking during pregnancy in prior studies (Cnattingius, 2004), there was no

evidence that DD or those characteristics predicted response to this incentive-based treatment antepartum or postpartum. There was no evidence of either a main effect of DD or an interaction with treatment condition. Said differently, there was no evidence that discounting was associated with outcomes in either the incentives or control conditions examined.

One possibility as to why we did not see any main effects or interactions with temporal discounting for delayed hypothetical monetary rewards would be that we do not have a sufficient range of discounting within this population. Therefore, there would not be enough of an opportunity to see any moderating response. That does not appear to be the case. The median baseline log *k* in the current study was -6.19 with an interquartile range of 3.23 (ED50 = 1.3). The Washio *et al.* study (2011) utilizing a cocaine-dependent sample had an overall median log *k* of -5.49 with an interquartile range of 3.58 (ED50 = 0.7), and White *et al.* study (in press) examining spontaneous quitting among pregnant smokers reported an overall median of -6.52 with an interquartile range of 3.00 (ED50 = 1.9). Those ranges comparable to the present study and were sufficient to discern significant associations between DD and changes in smoking and cocaine-use status.

Turning to what did predict abstinence from smoking in the present study, being assigned to the incentive-based intervention, smoking fewer cigarettes per day at baseline, reporting a history of prior quit attempts pre-pregnancy, and attaining a high school education or more all robustly increased the odds of abstinence at late-pregnancy, associations that are consistent with those we reported previously for this treatment approach (Higgins *et al.*, 2009). It is important to note that there is overlap among

participants included in the present and prior study, with 114 women (49% of current sample) having participated in both studies. Nevertheless, the consistency of results across studies underscores the reliability of these relationships.

We also saw in this current study that being assigned to the incentive-based treatment was a significant predictor of 24-week postpartum smoking status, which is 3 months after the incentives intervention was discontinued. That association was also observed in the Higgins *et al*. (2009) report and in a review of this treatment approach (Higgins, Washio, *et al.*, 2012), underscoring that the treatment effect is not lost once the incentives are discontinued, a common criticism of incentive-based interventions. Indeed, sustaining a treatment effect through the 24-week postpartum period suggests that the intervention may have fostered a long-term change in smoking status in a subset of the women treated.

In contrast to a prior report indicating that sustained abstinence reduces discounting in a general population of smokers (Secades-Villa *et al*., 2014), we saw no discernible changes in DD from intake to end of study among abstainers or smokers in the present study. Women in the present study typically entered treatment at approximately 10-weeks gestation and most who responded to the intervention would have quit smoking within the first two weeks of treatment (Higgins *et al.*, 2006) meaning that many would have been abstinent from smoking for almost 1 year at the time of the 24-week postpartum assessment. That is comparable to the period of sustained abstinence in the Secades-Villa *et al.* (2014) study. Yet this length of abstinence was not associated with a significant reduction in DD values in the present study. Important to note is that participants in the Secades-Villa *et al.* study were assessed 1-year post-

treatment compared to only 3-months post-treatment among participants in the present study. Women in the present study also experienced many unique changes associated with pregnancy and early postpartum in addition to smoking status, such as hormonal fluctuations and stress surrounding the pregnancy and postpartum period, which could have contributed to the different results observed. Further research will be necessary to more fully characterize the extent to which sustained smoking abstinence is associated with reductions in DD and individual differences in who may experience that effect.

Because the women included in the present study were all from randomized controlled trials involving common treatment conditions, we can infer a causal relationship of treatment and its effects on antepartum and postpartum smoking status. We cannot similarly infer causality between the associations of baseline smoking rate, educational attainment, and a history of quitting pre-pregnancy with smoking status in the present study, but nevertheless can use those associations to further encourage girls to remain in school at least through high school and hopefully beyond, child-bearing aged women who do smoke to at least try to quit, and for those who are unable to quit completely to reduce their smoking rates as low as possible. Those are practices that are reliably and robustly associated with an increased likelihood of succeeding in quitting should they become pregnant.

The present study has several limitations that merit mention, including the use of a relatively small sample size, a cohort selected from a small metropolitan area with an almost exclusively Caucasian population, and a sample comprised exclusively of women willing to participate in treatment-outcomes studies. How well this incentivized treatment model and results from the present study on predictors of a positive treatment

outcomes with this approach generalize to more diverse samples and other settings is largely an unanswered question although controlled trials conducted in at least one other U.S. state (Oregon) were positive (Donatelle *et al.*, 2004) and an effectiveness study in at least one other country (Scotland) resulted in positive outcomes (Radley *et al.*, 2013). Considering the broad generality that has been observed with the use of financial incentives to decrease use of other substances (Lussier *et al.*, 2006) as well as other health-related risk behaviors (Higgins, Silverman, et al., 2012) and because these incentives interventions are based on the fundamental behavioral science principle of reinforcement (Higgins *et al.*, 2004), we are optimistic that this strategy for reducing smoking and associated relationships will have generality to diverse samples and settings. One important future challenge in this research effort is getting a larger proportion of women to respond and we hope that better understanding who is and is not currently benefitting from the intervention as was done in the present study will better position us to accomplish that goal.

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Table 1. Participant characteristics

	Overall	Contingent (n = 137)	Noncontingent (n = 99)	*p*-value
Sociodemographics				
Age	24.4 ± 0.3	24.6 ± 0.5	24.1 ± 0.5	.54
% <High School Education	26.2	28.2	23.5	.42
% Caucasian	93.2	93.4	92.9	.87
Weeks Preg at Baseline	10.1 ± 0.3	9.9 ± 0.3	10.5 ± 0.4	.60
% Primagravida	56.2	56.6	55.6	.87
% Working for Pay	49.6	51.1	47.5	.58
% With Private Insurance	22.0	25.5	17.2	.13
% Married	16.5	14.6	19.2	.35
Smoking Characteristics				
Age 1st Cigarette	14.7 ± 0.2	14.9 ± 0.3	14.4 ± 0.3	.46
Cigs/day Pre-Preg	18.9 ± 0.5	18.8 ± 0.7	19.0 ± 0.8	.18
Cigs/day at Baseline	9.0 ± 0.4	8.8 ± 0.5	9.2 ± 0.5	.41
Quit Attempts During Preg	0.7 ± 0.1	0.8 ± 0.2	0.7 ± 0.2	.78
NWQ	1.6 ± 0.1	1.6 ± 0.1	1.5 ± 0.1	.54
% History of Quitting Pre-Preg	67.4	69.3	64.6	.45
% Living with Smokers	79.2	78.8	79.8	.86
% No Smoking in Home	48.7	48.2	49.5	.84
% Around None/Few Smokers	21.2	22.6	19.2	.52
Psychiatric Characteristics				
Beck Depression Inventory	10.6 ± 0.5	10.4 ± 0.6	10.8 ± 0.7	.38
% History of Depression	36.4	37.2	35.3	.77
Stress Rating	5.5 ± 0.2	5.5 ± 0.3	5.6 ± 0.3	.79

Note: Continuous variables are noted as means ± standard errors and categorical variables are noted as percentages.

Table 2. Intake Delay Discounting Scores

	Overall	Contingent (n = 137)	Non-Contingent (n = 99)	*p*-value
log *k* median (IQR[a])	-6.19 (3.23)	-6.13 (3.10)	-6.30 (3.33)	.41[b]

[a] Interquartile Range
[b] p-value based on Wilcoxon rank sum test

Table 3. Bivariate Correlations Between Delay Discounting and Other Participant Characteristics

	Log k **r** ***p*-value**
Age	.07 .29
Less than HS Education	**.14** **.04**
Race	.03 .62
Gestational Age	.03 .66
Working	-.09 .15
Private Insurance	.10 .12
Married	.02 .71
Age 1st Cigarette	-.03 .63
Cigs/Day Pre-Pregnancy	-.03 .62
Cigs/Day Baseline	-.10 .12
Quits Pre-Pregnancy	-.08 .20
Quits During Pregnancy	-.09 .17
NWQ	-.02 .72
Living with Smokers	**.16** **.01**
No Smoking Home	**-.13** **.04**
Around None/Few Smokers	-.06 .36
BDI	-.01 .90
Depression History	-.01 .90
Stress	-.04 .58

Table 4. Bivariate Correlations of Treatment Condition, Participant Characteristics, and Delay Discounting with Smoking Status

	Late-Pregnancy	24-wkpp
Treatment	**.27** **<.001**	**.15** **.02**
Age	.03 .65	.03 .69
Less than HS Education	**.14** **.03**	.04 .53
Race	.08 .23	.08 .21
Gestational Age	-.09 .20	-.003 .97
Working	.10 .12	-.01 .87
Private Insurance	-.03 .66	-.02 .72
Married	-.07 .24	-.02 .77
Age 1st Cigarette	**.13** **.05**	.06 .33
Cigs/Day Pre-Pregnancy	**-.19** **<.01**	-.09 .19
Cigs/Day Baseline	**-.24** **<.001**	-.12 .08
Quits Pre-Pregnancy	**.18** **<.01**	.09 .16
Quits AP	**.20** **<.01**	.05 .48
NWQ	.01 .88	.07 .27
Living with Smokers	.01 .87	.01 .87
No Smoking in Home	.09 .16	.08 .21
None/Few Regular Smokers	-.02 .80	-.02 .79
BDI	.01	.02

	.92	.77
Depression History	.003 .97	.01 .85
Stress	.06 .35	.07 .27
Log k	.04 .55	.02 .65

Note: All bivariate correlations were conducted using Pearson's r.

Table 5. Logistic Regressions Predicting Late-Pregnancy Point-Prevalence Abstinence

Block	Chi-Square	O.R. (95% C.I.)	*p*-value
1. Treatment Alone	**16.65**	**4.45 (2.17 – 9.13)**	**<.001**
Impulsivity Alone	0.36	1.03 (0.93 – 1.15)	.55
2. Treatment Main Effect	**17.03**	**4.55 (2.21 –9.33)**	**<.001**
Impulsivity Main Effect	0.26	1.03 (0.92 – 1.15)	.61
3. Treatment	1.77		. 18
Impulsivity	0.58		.45
Interaction	0.32		.57
Log k within Contingent		1.01 (0.88 – 1.15)	
within Non-contingent		1.09 (0.88 – 1.34)	
4. Treatment	**14.82**	**4.45 (2.08 – 9.52)**	**<.001**
Cigs/day at Baseline (per 5 cigarettes)	**15.49**	**0.47 (0.33 – 0.69)**	**<.001**
Quits Pre-Pregnancy	**5.36**	**2.54 (1.15 – 5.61)**	**.02**
Education less than HS	**4.27**	**0.41 (0.17 – 0.96)**	**.04**

Table 6. Logistic Regressions Predicting 24-week Postpartum Point-Prevalence Abstinence

Block	Chi-Square	O.R. (95% C.I.)	*p*-value
1. Treatment Alone	**4.55**	**3.39 (1.05 – 10.42)**	**.03**
Impulsivity Alone	0.21	1.04 (0.88 – 1.22)	.65
2. Treatment Main Effect	**4.63**	**3.43 (1.12 –10.55)**	**.03**
Impulsivity Main Effect	0.17	1.03 (0.88 – 1.22)	.68
3. Treatment	0.06		.80
Impulsivity	2.64		.10
Interaction	2.50		.11
4. Treatment	**4.55**	**3.39 (1.05 – 10.42)**	**.03**