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Examining interrelationships between the cigarette purchase task and delay discounting Among pregnant women

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Abstract

Two common behavioral economic simulation tasks used to study cigarette smoking are the Cigarette Purchase Task, a measure of cigarette demand, and delay discounting, a measure of the subjective value of rewards as a function of delays to delivery. Few studies have evaluated whether combining these tasks enhances understanding of smoking beyond either alone. The current study represents an initial evaluation of the intersection between cigarette demand indices and delay discounting among pregnant smokers by examining associations between these measures and whether a woman makes antepartum quit attempts before entering prenatal care (a reliable predictor of eventual quitting). Participants were 159 pregnant women enrolled in a smoking-cessation trial. Low O_{max} and shallow discounting were each associated with antepartum quit attempts. Participants were next categorized into four subgroups (low O_{max} , shallow discounting; low O_{max} , steep discounting; high O_{max} , shallow discounting; high O_{max} , steep discounting) using median splits. Those with shallow discounting and low O_{max} were more likely to have made quit attempts than each of the other three subgroups. That is, steep discounting appears to undermine the association of low O_{max} and efforts to quit smoking during pregnancy while high O_{max} overshadows any protective influence associated with shallow discounting.

Keywords

behavioral economics; Cigarette Purchase Task; cigarette smoking; Delay Discounting; pregnant women; quit attempts; reinforcement pathology; translational science

Smoking during pregnancy is the leading preventable cause of poor pregnancy outcomes in the U.S. and other developed countries, and in utero tobacco smoke exposure increases risk for a wide range of adverse health outcomes (Cnattingius, 2004; Dietz et al., 2010; Higgins

& Solomon, 2016). Furthermore, cigarette smoking is a major contributor to health disparities, as it is overrepresented among socioeconomically disadvantaged women (Higgins & Chilcoat, 2009). Even when using relatively effective smoking-cessation interventions with pregnant women, only approximately 35% of women are able to quit (Higgins et al., 2012; Higgins & Solomon, 2016). Thus, examining individual differences in risk for continuing to smoke during pregnancy may inform efforts to improve interventions targeting this population.

Behavioral economics is a discipline that integrates the principles of psychology and microeconomics and has been applied to studying different types of substance abuse, including cigarette smoking (Bickel, Johnson, Koffarnus, MacKillop, & Murphy, 2014; Vuchinich & Heather, 2003). One common behavioral economic simulation model used to study cigarette smoking is the Cigarette Purchase Task (CPT), in which participants report the number of cigarettes that they would smoke across an increasing range of hypothetical monetary prices to estimate demand, or the degree to which consumption remains stable across escalating price (Jacobs & Bickel, 1999). The CPT is an efficient alternative to time- and labor-intensive laboratory drug self-administration studies (Bickel & Madden, 1999a, 1999b), and is a valid method of studying cigarette demand (Farris, Aston, Abrantes, & Zvolensky, 2017; Madden & Kalman, 2010) that produces demand curves corresponding closely to those involving actual drug consumption (Amlung, Stojek, Murphy, & MacKillop, 2012; Wilson, Franck, Koffarnus, & Bickel, 2016). Furthermore, because the CPT permits experimental examination of changes in demand without asking study participants to smoke, the task can be useful for research with especially vulnerable populations such as pregnant women or adolescents (Higgins et al., 2017). CPT demand is typically characterized by five indices: Demand Intensity (i.e., number of cigarettes participants estimated smoking per day if cigarettes were free of cost); O_{max} (i.e., peak expenditure, or the total amount of money participants would spend daily on smoking); P_{max} (i.e., the financial price associated with O_{max}); Breakpoint (BP , i.e., the price at which participants indicated they would quit smoking rather than incur the cost); and α (i.e., overall sensitivity to changes in price, which was calculated as rate of change in elasticity across the demand curve). Higgins et al. (2017) conducted an initial study validating the CPT with pregnant cigarette smokers. Overall, Hursh and Silberberg's (2008) exponential demand equation provided a good fit for both group and individual-participant cigarette demand among pregnant women, and demand varied in correspondence to two well-validated predictors of individual differences in smoking cessation in this population (i.e., cigarettes smoked per day and antepartum quit attempts). Moreover, CPT indices were more strongly associated than conventional variables with making antepartum quit attempts, a significant marker of eventually quitting smoking during pregnancy (Kurti, Davis, Skelly, Redner, & Higgins, 2016; Lopez, Skelly, White, & Higgins, 2015; White, Redner, Skelly, & Higgins, 2014).

Another behavioral economics measure that is associated with risk for cigarette smoking and other substance use disorders is delay discounting (DD), a behavioral simulation procedure for examining reductions in the subjective value of monetary or other rewards as a function of increasing temporal delays to their delivery (Bickel, Odum, & Madden, 1999; MacKillop et al., 2011; Yi, Mitchell, & Bickel, 2010). The DD task presents participants with choices between smaller, immediate rewards and larger, delayed rewards (e.g., "would you prefer

\$31 today or \$85 in 7 days?") and has been useful in identifying individual differences in risk for cigarette smoking among various vulnerable populations (Chivers, Hand, Priest, & Higgins, 2016; MacKillop & Tidey, 2011; MacKillop et al., 2016), including pregnant women (Bradstreet et al., 2012; White et al., 2014; Yoon et al., 2007). White et al. (2014) examined whether DD differentiated women who quit smoking immediately upon learning of pregnancy (i.e., spontaneous quitters) versus women who were still smoking at their first prenatal care appointment. DD interacted significantly with smoking rate in predicting quitting among lighter but not heavier smokers. Thus, evidence suggests that DD can predict individual differences in smoking cessation among pregnant women, although these effects appear to depend on other factors governing smoking rate or smoking demand.

The interrelationship between demand and discounting has been hypothesized to underpin vulnerability to addiction and what has come to be referred to as reinforcer pathology (Bickel, Johnson, Koffarnus, & MacKillop, 2014; Jarmolowicz, Reed, DiGennaro Reed, & Bickel, 2016). In that model of risk, individuals with substance use disorders are thought to exhibit high valuation of their preferred substance in combination with a strong preference towards receiving rewards sooner rather than later. However, few studies have empirically evaluated whether combining demand and DD may enhance our understanding of individual differences in substance use beyond observations with either alone. To date, the available empirical findings are equivocal at this early stage of investigation. Although both demand and DD are related to dependence severity (Aston, Metrik, Amlung, Kahler, & MacKillop, 2016; MacKillop et al., 2010; MacKillop & Tidey, 2011; Strickland et al., 2017), several researchers have reported weak or no relationship between demand, DD, and their primary outcomes (Amlung et al., 2013; Aston et al., 2016; Teeters and Murphy, 2015). Although smoking cessation outcomes and associated markers have been predicted using the CPT (e.g., Higgins et al., 2017; MacKillop et al., 2016; Secades-Villa, Pericot-Valverde, & Weidberg, 2016) and DD (Sheffer et al., 2012; Stanger et al., 2012), we know of no studies examining their combined utility in predicting smoking cessation or associated markers, particularly in pregnant women. Given the findings of Higgins et al. (2017) that CPT indices are associated with individual differences in the likelihood of making antepartum quit attempts, a significant marker of achieving late-pregnancy abstinence, as well as the conditional relationship between DD and smoking rate in predicting spontaneous quitting identified by White et al. (2014), exploring the interrelationship between demand and DD appears to be a logical next step in efforts to better understand factors underpinning individual differences in efforts to quit smoking among pregnant women. The current study represents an initial evaluation of the interrelationship between demand and delay discounting among pregnant smokers by examining associations between these behavioral economic measures and the likelihood that a woman made attempts to quit smoking prior to entering prenatal care.

Methods

Participants

Study participants were 159 women who were biochemically confirmed to be smoking upon entering prenatal care and enrolled in an ongoing randomized controlled clinical trial on

smoking cessation; 95 of these women were included in the prior report on CPT and smoking cessation during pregnancy (Higgins et al., 2017). Trial inclusion criteria were reported previously (Higgins et al., 2017). Briefly, inclusion criteria included (a) currently pregnant and enrolled in prenatal care, (b) self-reported smoking in the past week that was biochemically verified, (b) plans to remain in the geographical area for 3 months postpartum, and (c) English-speaking. Exclusion criteria were (a) current incarceration, (b) living with another trial participant, (c) current enrollment in opioid substitution therapy, (d) current use of psychomotor stimulant or antipsychotic medications, (e) > 25 weeks gestation, and (f) living in a group home. Participants were recruited from local obstetrical clinics and the Federal Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) office located in the Burlington, Vermont area. They averaged 26 years of age, had < 12 years education, were generally unmarried, without private health insurance, and reported smoking an average of 9.60 ± 6.3 cigarettes per day at study entry and 18.2 ± 9.2 cigarettes per day before learning of the current pregnancy (Table 1). The University of Vermont Institutional Review Board approved all study procedures and all participants provided written informed consent.

Assessments

All participants completed questionnaires examining socio-demographics, smoking history, smoking environment and motivations, and intentions to quit smoking, including quit attempts that occurred during the current pregnancy but prior to entering the trial (i.e., antepartum quit attempts). Antepartum quit attempts were coded dichotomously as women with and without at least one quit attempt. Participants also completed the CPT and DD assessment (described below). Although abbreviated versions of the intake assessment were administered again at several subsequent assessments, the present study is focused exclusively on information collected at the intake assessment.

Cigarette Purchase Task

The CPT assesses the number of cigarettes that participants would smoke across an increasing range of hypothetical monetary prices. The version of CPT used in the current study was adapted from MacKillop et al. (2008). Participants were provided with the following oral instructions about how to complete the task: “Think about how you are feeling right now. The following questions ask how many cigarettes you would smoke if they cost various amounts of money. Assume that: (1) The available cigarettes are your usual brand. (2) You have the same income/savings that you have now and no access to any cigarettes or nicotine products other than those offered at these prices. (3) You would smoke the cigarettes that you request within 24 hours. You cannot save or stockpile cigarettes for a later date. (4) You can smoke without any restrictions and without factoring in what might occur in the next 24 hours related to your participation in the study.” The task included 19 prices/cigarette: \$0.00 (free), \$0.02, \$0.05, \$0.10, \$0.20, \$0.30, \$0.40, \$0.50, \$0.60, \$0.70, \$0.80, \$0.90, \$1.00, \$2.00, \$3.00, \$4.00, \$5.00, \$10.00, and \$20.00, with associated prices per pack presented to the right of the individual cigarette prices. Prices were presented in ascending order. Participants completed a computerized version of CPT on a desktop computer when completed in the clinic or an identical paper-and-pencil version of the task when the assessment was completed at the participant’s home.

Delay Discounting Task

DD was assessed using the Monetary Choice Questionnaire (MCQ-27; Kirby, Petry, & Bickel, 1999). The MCQ-27 includes a fixed set of 27 items, with immediate rewards ranging from \$11-\$78 and delayed rewards ranging from \$25-\$85 with a delay of 7–186 days. As with the CPT, participants completed a computerized version of the MCQ-27 on a desktop computer when completed in the clinic or an identical paper-and-pencil version of the task when the assessment was completed at the participant's home.

Data Analysis Methods

The CPT data from all 159 CPT participants first underwent visual inspection for outliers. Three outliers were identified with demand intensity (Q_0) level of consumption (Q) at no price [free; \$0.00] who estimated smoking 100, 120, and 2000 cigarettes in a 24-hr period; subsequent outlier analyses using Grubbs' procedure in GraphPad Prism® version 7.0a for Mac (Graphpad Software, La Jolla California, USA, www.graphpad.com) with alpha set to .05 confirmed these outliers. The associated data from these two individuals were excluded from all subsequent analyses. We examined degree of systematic responding for all remaining 156 CPT datasets using the procedure described by Stein, Koffarnus, Snider, Quisenberry, and Bickel (2015) with the following detection limits for trend (Q), bounce (B), and reversals from zero, respectively: 0.025, 0.10, and 0. Data for three participants did not pass the detection limit for trend (i.e., no elasticity in demand) and three other participants did not pass the detection limit for bounce (i.e., consumption at a price exceeded 25% of initial consumption at zero price); therefore, we excluded data for those six participants from all subsequent analyses. Finally, six participants were excluded due to at least one missing item from the MCQ-27, leaving 144 out of 159 participants for inclusion in the present study.

Responses to the CPT were used to generate individual consumption and expenditure curves for each participant. For the systematic data sets, empirical metrics included Demand Intensity or Empirical- Q_0 (i.e., cigarettes purchased at zero price); O_{max} (i.e., maximum expenditure, calculated by multiplying each Q by its associated cost [C] and identifying the largest expenditure value as O_{max}); P_{max} (i.e., the price associated with O_{max}); Breakpoint (BP) (i.e., the last price with any level of demand, analogous to Roma, Hursh, and Hudja's (2016) BP_I metric that circumvents inference of BP in datasets featuring > 0 consumption at highest CPT price); α (i.e., overall sensitivity to changes in price, which was calculated as rate of change in elasticity across the demand curve, derived using least-squares nonlinear regression in GraphPad Prism® version 7.0a for Mac (Graphpad Software, La Jolla California, USA, www.graphpad.com), via the Hursh and Silberberg (2008) exponential demand equation which states:

$$\log Q = \log Q_0 + k \cdot \left(e^{-\alpha(Q_0 \cdot C)} - 1 \right)$$

where k is the range of consumption in log units (a shared $k = 2.10$ was used for all 144 participants). We derived individual α values using a freely available GraphPad Prism®

template provided by the Institutes for Behavior Resources (<http://www.ibrinc.org/index.php?id=181>).

Regarding DD analyses, responses to the MCQ-27 were first analyzed using the method described by Kirby et al. (1999). Participants' hyperbolic discounting parameter (k value) was determined, using the spreadsheet developed by Kaplan et al. (2016). Values of overall k are estimated by taking the geometric midpoint between the discounting rates associated with each item and examining the participant's pattern of responses across trials to determine which k value is most consistent with the response pattern. Overall k on the MCQ-27 ranges from 0.00016 to 0.25, with higher values indicating a greater preference for smaller, immediate over larger, delayed rewards.

Median splits were used to separate individual CPT demand indices and discounting into high and low categories (or steep and shallow, respectively, for discounting). Four-level variables were created by combining each CPT index with discounting (e.g., low O_{max} , shallow discounting; low O_{max} , steep discounting; high O_{max} , shallow discounting; high O_{max} , steep discounting) to evaluate the intersection of CPT and DD. Conventional predictors (baseline socio-demographic and smoking characteristics) were examined using t -tests for continuous variables and chi-square tests for categorical variables. The dependent variable, antepartum quit attempts, was defined as none versus one or more antepartum quit attempts.

Spearman rank correlation coefficients were used to examine associations between the individual CPT demand indices and discounting as continuous measures. Individual demand indices and discounting were analyzed as dichotomous variables or as the four-level variables in all other analyses. Associations between CPT demand indices and discounting with antepartum quit attempts were examined using 2×2 contingency tables with chi-square tests and corresponding odds ratios. CPT indices that were significantly associated with antepartum quit attempts were then included in a backward elimination logistic regression procedure to determine their independent effects on antepartum quit attempts. The ability to predict antepartum quit attempts with the intersection of demand indices that were independently associated with quit attempts as determined by the backward elimination logistic regression and discounting (four-level variables) was assessed using logistic regression models. Lastly, the four-level variables and conventional predictors were included in a final backward logistic regression procedure. All analyses were conducted using SAS 9.4 (SAS Institute, Cary, NC) and GraphPad Prism® 7.0a (Graphpad Software, La Jolla, CA). Statistical significance was defined as $p < .05$ (2-tailed).

Results

Demand and Discounting Correlations

Table 2 reports the correlations between the five CPT demand indices and between those indices and discounting. Each of the CPT indices was significantly associated with one or more other CPT indices, but none was significantly correlated with discounting (i.e., overall k).

Predicting Antepartum Quit Attempts with CPT Demand

Two of the CPT demand indices were significantly associated with antepartum quit attempts (Fig. 1). Those exhibiting low Demand Intensity were 2.28 times more likely (95% CI = 1.10–4.72) to make antepartum quit attempts than women with high Demand Intensity ($\chi^2(1) = 5.08, p = .02$). Similarly, those with low O_{max} were 3.53 times more likely (95% CI = 1.63–7.65) to make antepartum quit attempts than women with high O_{max} ($\chi^2(1) = 10.82, p = .001$). Two other CPT indices (P_{max} and BP) approached but did not reach a significant association with antepartum quit attempts (P_{max} ($\chi^2(1) = 3.52, p = .06$); BP ($\chi^2(1) = 3.41, p = .06$) while α clearly was not associated with quit attempts (α ($\chi^2(1) = .06, p = .80$).

We then conducted a backward logistic regression predicting antepartum quit attempts using Demand Intensity and O_{max} as potential predictors. Only O_{max} was significantly associated with antepartum quit attempts at $p < .05$ in that model.

Predicting Antepartum Quit Attempts with Delay Discounting

Turning to associations between discounting and quit attempts, women exhibiting shallow discounting were 3.08 times more likely (95% CI = 1.46–6.52) to have made antepartum quit attempts than those who exhibited steep discounting ($\chi^2(1) = 9.03, p = .003$; Fig. 1).

Predicting Antepartum Quit Attempts with Conventional Predictors

Regarding associations between conventional predictors in Table 1 and quit attempts, women who were lighter smokers (<10 cigarettes per day) at intake were 3.98 times (95% CI = 1.78–8.83) more likely to have made antepartum quit attempts than those who were heavier smokers (≥ 10 cigarettes per day; $\chi^2(1) = 12.10, p < .001$). Additionally, those women who made at least one prepregnancy quit attempt were 4.39 times (95% CI = 1.59–12.13) more likely to have made antepartum quit attempts than those who did not ($\chi^2(1) = 9.12, p < .003$). No other conventional predictors significantly predicted quit attempts.

Predicting Antepartum Quit Attempts with the Intersection of CPT O_{max} , Delay Discounting, and Conventional Predictors

We next performed logistic regression modeling independent associations between the intersection of O_{max} and discounting as a four-level variable and antepartum quit attempts. Combined O_{max} and overall k was significantly associated with quit attempts (Wald $\chi^2(3) = 21.26, p < .001$), with women exhibiting low O_{max} and shallow discounting being 5.46 times more likely (95% CI = 1.94–15.41) than those with low O_{max} and steep discounting, 7.06 times more likely (95% CI = 2.25–22.15) than those with high O_{max} and shallow discounting, and 6.93 times more likely (95% CI = 2.50–19.27) than those with high O_{max} and steep discounting to have made antepartum quit attempts. None of the other combinations of O_{max} and discounting differed significantly from each other.

Finally, the backward logistic regression model was rerun including the four-level variables as well as the significant conventional predictors. O_{max} by DD group (Wald $\chi^2(3) = 15.25, p = .002$), having made quit attempts prepregnancy (Wald $\chi^2(1) = 7.77, p = .005$), and cigarettes per day (Wald $\chi^2(1) = 4.84, p = .03$) were each independently associated with having made antepartum quit attempts. Women exhibiting low O_{max} and shallow

discounting were 6.33 times (95% CI = 2.09–19.15) more likely than those with low O_{max} and steep discounting, 5.82 times (95% CI = 1.70–19.90) more likely than those with high O_{max} and shallow discounting, and 4.55 times (95% CI = 1.50–13.80) more likely than those with high O_{max} and steep discounting to have made antepartum quit attempts. None of the other combinations of O_{max} and discounting differed significantly from each other. Women who made at least one prepregnancy quit attempt were 4.96 times (95% CI = 1.61–15.30) more likely to have made antepartum quit attempts than those who did not. Lastly, lighter smokers (< 10 cigarettes per day) at intake were 2.77 times (95% CI = 1.12–6.85) more likely to have made antepartum quit attempts than those who were heavier smokers (≥ 10 cigarettes per day).

Discussion

The current results indicate that demand and discounting are associated with individual differences in attempts to quit smoking during pregnancy, consistent with previous studies (Higgins et al., 2017; White et al., 2014), and represent the first evaluation to our knowledge of the interrelationship between CPT and DD among pregnant smokers. The current results on CPT and DD as separate predictors of antepartum quit attempts systematically replicate the findings of Higgins et al. (2017) that O_{max} is associated with antepartum quit attempts, and extend those findings by documenting a role for DD in that relationship. The combination of O_{max} and DD provided a finer-grained parsing of individual differences in making antepartum quit attempts than either predictor alone by demonstrating that the subgroup of women who exhibited relatively low O_{max} and shallow DD was significantly more likely to make quit attempts than any of the other three subgroups. Put differently, these results demonstrate that the presence of steep DD obviates any positive gain associated with relatively low O_{max} in terms of making attempts to quit smoking during pregnancy. The odds of making a quit attempt among women with relatively high O_{max} is relatively low independent of whether it is accompanied by shallow and steep discounting, indicating that it overshadows any influence of discounting. Importantly, the final model demonstrates that the O_{max} and discounting four-level variable is a significant predictor of antepartum quit attempts independent of the influence of the conventional predictors of number of cigarettes smoked per day at the study intake assessment and prepregnancy quit attempts. These results are consistent with those reported by White et al. (2014) who investigated predictors of quitting smoking prior to entering prenatal care among women who were current smokers upon learning they were pregnant (i.e., referred to as ‘spontaneous quitters’ in the smoking and pregnancy literature). White et al. reported a significant interaction between the number of cigarettes smoked per day prepregnancy and DD wherein the odds of spontaneous quitting decreased as DD increased among lighter (< 10 cigarettes per day) but not heavier (≥ 10 cigarettes per day) smokers. The present results extend the White et al. observation to the use of the CPT index O_{max} rather than cigarettes per day and to predicting efforts to quit among the larger and more clinically challenging subset of pregnant women who are still smoking upon entering prenatal care. Lastly, the current results on the conventional predictors lend further support for the well-established predictive utility of cigarettes per day and prepregnancy quit attempts as independent predictors of antepartum quit attempts (Higgins et al., 2017; Kurti et al., 2016; Lopez et al., 2015; White et al., 2014).

Most germane to the purpose of the present study, these results provide support for hypotheses about interrelationships between demand and DD underpinning addiction (Bickel et al., 2014; Jarmolowicz et al., 2016) and extend the existing literature (e.g., Aston et al., 2016; Dennhardt, Yurasek, & Murphy, 2015; MacKillop et al., 2010; MacKillop & Tidey, 2011; Strickland et al., 2017) by demonstrating that the protective effects afforded by relatively low O_{max} appear to be undermined by steep discounting, or where any protective effects of shallow DD appear to be undermined by high O_{max} . The current results also add to the accumulating evidence of O_{max} as a significant predictor of quitting smoking (Higgins et al., 2017; MacKillop et al., 2016), although others have found significant associations between Demand Intensity (MacKillop et al., 2016; Murphy et al., 2017), Elasticity (MacKillop et al., 2016; Secades-Villa et al., 2016), and Breakpoint (Higgins et al., 2017; Murphy et al., 2017) and quitting. Thus, future research is needed to further clarify the relationship of the individual CPT indices to quitting smoking.

Of importance, the current results highlight the utility of low-risk simulation models such as CPT and DD in identifying individual differences in quitting smoking among pregnant women. The strong influence of factors governing cigarette consumption, as in previous studies (Higgins et al., 2017; White et al., 2014), underscores the importance of continuing to focus on proximal factors (e.g., demand for smoking) in tobacco-control efforts among pregnant women and women of reproductive age. Furthermore, the current results highlight that even those with lower demand may have difficulty quitting smoking during pregnancy, and that discounting may be a contributor to those difficulties. The identification of these particularly at-risk individuals may prove to be useful in informing interventions, such as the use of financial incentives for smoking cessation among pregnant women (Higgins & Solomon, 2016). For example, such individuals may require greater financial incentives to achieve abstinence and may be especially sensitive to the immediacy of rewards. Additionally, the current results raise a number of potentially important implications for tobacco regulatory science and tobacco control efforts. The most direct implication for regulatory science is the evidence supporting the validity and practical utility of using simulation tasks to experimentally investigate cigarette smoking, and perhaps the use of other tobacco and nicotine delivery products among pregnant women, without having to administer the product to participants to investigate processes that may be related to cigarette smoking. The current study indicates that smokers with high O_{max} should be of particular focus for research examining response to interventions and policy change (see also Hursh & Roma, 2013; Bickel et al., 2017).

Several limitations to the current investigation merit mention. First, the study sample was a convenience sample selected from an ongoing clinical trial with an almost exclusively Caucasian population rather than a nationally representative sample and thus, results may not generalize to pregnant smokers with other sociodemographic or smoking characteristics. Second, results were based on self-reported demand and discounting, which may vary from actual consumption, although hypothetical demand and discounting have been found to correspond closely to those involving actual outcomes (Amlung et al., 2012; Bickel, Pitcock, Yi, & Angtuaco, 2009; Johnson & Bickel, 2002; Madden, Begotka, Raiff, & Kastern, 2003; Madden et al., 2004; Wilson et al., 2016). Finally, whether relationships between CPT and DD and antepartum quit attempts will extend to actual late pregnancy smoking cessation

remains unclear, although studies are already underway to address that question. These limitations notwithstanding, the present study represents an important initial step in demonstrating the interrelationship between CPT demand and DD and their combined impact on the likelihood of making antepartum quit attempts among pregnant women. Furthermore, these results highlight the need for future investigation into the cross-section of behavioral economic simulation tasks to identify effective interventions and regulatory policies for vulnerable populations of substance users.

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Antepartum Quit Attempt (% of Pregnant Women)

Fig. 1. Percentages of women who reported at least one antepartum quit attempt during the current pregnancy across different risk-factor groupings.

Fig. 2. Percentages of women who made at least one antepartum quit attempt during the current pregnancy across each of the four risk groupings representing the intersection of O_{max} and discounting.

Table 1

Participant characteristics

Demographics:	
Age (years)	25.9 ± 5.2
Education	
% < 12 years	27
% 12 years	52
% > 12 years	21
% Caucasian	91
% Married	18
% Private Insurance	28
% Employed outside of the home	53
Pregnancy:	
% 1 st Pregnancy	46
Weeks Pregnant at Intake	11.5 ± 4.1
Smoking Characteristics:	
Cigs/day prepregnancy	18.2 ± 9.2
Cigs/day at intake	9.6 ± 6.3
Age started smoking (years)	15.3 ± 2.9
% Living with other smoker(s)	77
% With no smoking allowed in home	69
% With none or few friends/family who smoke	24
% Attempted to quit prepregnancy	72
% Attempted to quit during pregnancy	31
Number of quit attempts during pregnancy	0.7 ± 1.9
Nicotine withdrawal questionnaire total score	1.5 ± 0.8
Attitude Item:	
% Endorsing that smoking will generally harm baby	83

Note: Tabled values represent means and standard deviations, or percents.

Table 2Correlations between delay discounting (overall k) and individual indices of cigarette demand

	k	Q_0	O_{max}	P_{max}	BP	α
k	—					
Q_0	.038	—				
O_{max}	.040	.490 [*]	—			
P_{max}	.122	-.126	.460 [*]	—		
BP	.063	.011	.523 [*]	.766 [*]	—	
α	-.059	-.158	-.585 [*]	-.393 [*]	-.238 [*]	—

Note: All coefficients refer to Spearman correlations.^{*} Indicates a significant correlation ($p < .05$).