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Reinforcer Pathology and Response to Contingency Management for Smoking Cessation

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Background: The recognition of the interplay between cigarette demand and impulsivity as a proxy of reinforcer pathology (RP) has prompted studies that assess these 2 constructs. Scarce research has examined their interrelation within clinical contexts. This secondary analysis sought to identify different types of treatment-seeking smokers based on cigarette demand and delay discounting and examine their differential response to contingency management (CM). ***Method:*** The dataset included 305 participants (68% female) receiving either a cognitive–behavioral treatment (CBT) or CBT + CM. A cluster analysis based on the bifactorial structure of a cigarette purchase task (i.e., psychological inertia and persistence) and delay discounting (base-10 logarithmic transformation of the area under the curve) was conducted. Clusters were compared in abstinence rates at posttreatment and 6-month follow-up. ***Results:*** Two RP subgroups emerged, Cluster 1 (n = 128) and Cluster 2 (n = 177), which were interpreted as "individuals with excessive tobacco valuation" and "steep discounters," respectively. At 8 weeks, the percentage of abstinent individuals was higher in those in Cluster 2 compared to those in Cluster 1 (76.3% vs. 61%; $\chi^2 = 8.291$, $p = .004$, $\phi = .16$). The nonsignificant effect of treatment condition on cessation outcomes indicated that both clusters equally benefited from CBT or CBT + CM. ***Conclusions:*** Support was reached for the generalizability of CBT and CM irrespective of patients' RP subtype. The fact that CM did not enhance abstinence outcomes beyond those obtained with CBT alone, underscores the need to evaluate the effect of innovative treatment procedures tailored to these RP phenotypes.

Keywords: contingency management, reinforcer pathology, smoking, delay discounting, cigarette demand

Research on the etiology and treatment of nicotine dependence has recently drawn from the reinforcer pathology (RP) framework (Bickel, Jarmolowicz, Mueller, & Gatchalian, 2011; Murphy et al., 2017). RP conceptualizes nicotine dependence as an altered reward process that renders individuals to overvalue nicotine use (i.e., drug demand) and/or prefer small immediate rewards (i.e., impulsive choice; Bickel, Johnson, Koffarnus, MacKillop, & Murphy, 2014). Stemming from the field of behavioral economics, these two behaviors have been traditionally assessed through drug demand and delay discounting (DD) procedures (Koffarnus & Kaplan, 2018).

Contingency management (CM) is a behavioral intervention based on operant conditioning that uses tangible incentives (i.e., vouchers) to reinforce specific behaviors, such as submission of drug-negative biological specimen samples (Cahill, Hartmann-Boyce, & Perera, 2015; McPherson et al., 2018). CM's efficacy for smoking cessation is well established and has been proven to promote high cessation rates at both short- (Petry, Alessi, Olmstead, Rash, & Zajac, 2017) and long-term follow-up (Sayegh, Huey, Zara, & Jhaveri, 2017; Secades-Villa, López-Núñez, Weidberg, González-Roz, & Alonso-Pérez, 2019). Nevertheless, questions remain about the subgroups for which this intervention may be most effective and best targeted (Forster, Dephilippis, & Forman, 2019). Previous studies, several of them by Dr. Petry and colleagues, have demonstrated that CM is effective regardless of income level (López-Núñez, Secades-Villa, Peña-Suárez, Fernández-Artamendi, & Weidberg, 2017; Rash, Petry, & Alessi, 2018), severe mental health conditions (Japuntich et al., 2019; Petry, Alessi, & Rash, 2013; Tidey, Rohsenow, Kaplan, Swift, & Reid, 2011), and concomitant drug use (Alessi & Petry, 2014; Cooney et al., 2017; Rohsenow, Martin, Tidey, Colby, & Monti, 2017).

Incipient research has stressed that steeper DD and high cigarette demand lead to poor short-term cessation rates, which fall below 53% (Barlow, McKee, Reeves, Galea, & Stuckler, 2017;

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Harvanko, Strickland, Slone, Shelton, & Reynolds, 2019; Krishnan-Sarin et al., 2007; Secades-Villa, Pericot-Valverde, & Weidberg, 2016). Against this background, there is some preliminary evidence suggesting that high-magnitude reward CM treatments are promising for reducing cigarette use in highly impulsive individuals (Renaud & Halpern, 2010; Tomko, Bountress, & Gray, 2016). However, despite the recognition of the synergistic effects of impulsivity and cigarette demand in accounting for RP (Amlung & MacKillop, 2014), we know of no studies to date investigating how these two key interrelated behavioral repertoires affect CM response.

More broadly, research on tobacco demand and DD has acknowledged several methodological problems that arise when it comes to assessing their relationship. Such problems pertain to multicollinearity and Type I error (Mackillop et al., 2016). The use of either specific cigarette purchase task (CPT) indices (e.g., O_{max}, intensity) or the area under the tobacco demand curve are two contemporary approaches that mitigate the above-mentioned problems (Amlung, Yurasek, McCarty, MacKillop, & Murphy, 2015; Nighbor et al., 2019; Weidberg, Secades-Villa, García-Pérez, González-Roz, & Fernández-Hermida, 2019). However, these approaches deprioritize one index in favor of another, imply a loss of information and substantially deviate from the multidimensional nature of the relative reinforcing efficacy construct (Bickel, Marsch, & Carroll, 2000). Using the principal components of CPT is a good compromise between the two latter approaches. This approach consists of reducing the five indices (i.e., breakpoint, O_{max}, P_{max}, elastic-
AQ: 2 ity, and elasticity) to fewer demand indicators. Although indices' loadings and nomenclatures seem to differ depending on sample characteristics, research consistently evinces a bifactorial structure of CPT (Bidwell, MacKillop, Murphy, Tidey, & Colby, 2012; O'Connor et al., 2016), which reflects volumetric (i.e., maximum response rate of tobacco use) and persistence (i.e., resistance to cease the behavior) factors in consumption dimensions. In a previous study (see González-Roz, Secades-Villa, Weidberg, García-Pérez, & Reed, 2018), support for a specific CPT structure among depressed smokers emerged: psychological inertia (conceptualized as resistance to cease using tobacco even when effective treatments are delivered) and persistence (reflecting both individuals' maximum response rate and insensitivity to increases in costs). Importantly, these components performed better over individual demand indices in terms of accurately characterizing the reinforcing efficacy of nicotine. Due to the scarcity of research conducted on the latent structure of CPT and its value for predicting cessation outcomes, its use within clinical research represents a timely and pressing need.

Inspired by Petry's work in the field of behavioral economics, this study sought to extend evidence on CM by examining for the first time (a) whether different typologies of smokers exist based on DD and cigarette demand latent factors and (b) whether the identified subgroups of smokers respond equally to a cognitive–
AQ: 3 behavioral treatment (CBT) and CBT + CM for smoking abstinence. As identifying subgroups of patients with different RP levels offers the opportunity to precisely tailor tobacco cessation interventions to patients' characteristics, it is expected that this study will provide insight into effective procedures for enhancing abstinence rates.

Method

Participants and Procedure

This secondary analysis comprised 305 treatment-seeking smokers recruited from two smoking cessation trials that examined the effect of 6- and 8-week CBT and CBT + CM programs for reinforcing abstinence (González-Roz et al., 2018; Secades-Villa, García-Rodríguez, López-Núñez, Alonso-Pérez, & Fernández-Hermida, 2014). CM conditions incorporated an escalating magnitude of reinforcement and participants could potentially earn US$307 or US$342 depending on the study assignment. No significant differences emerged in smoking status based on CM intensity at either short- (p = .25) or long-term follow-up (p = .63). To be eligible, participants in the two trials were required to meet the same inclusion criteria: (a) to be aged 18 or over, (b) to self-report smoking at least 10 cigarettes per day at the time of the intake assessment, and (c) to meet a diagnosis of nicotine dependence as per the *Diagnostic and Statistical Manual of Mental Disorders* (4th ed., text rev.) criteria (American Psychiatric Association, 2000). Individuals reporting mental health disorders and/or abuse of a substance other than nicotine were excluded from the studies and referred to other community cessation support resources. Study protocols were approved by the ethics review board of the community (Number 124/15). Table 1 displays the sociode- T1
mographic, psychological, and smoking-related characteristics of the study sample. AQ: 4

Assessment

During a single 60-min assessment session, which occurred 1 week before treatment onset, participants filled out a battery of questions to gather data on both demographics (e.g., sex, age, monthly income, employment status) and smoking behavior (e.g., cigarettes smoked per day and years of regular smoking). The Fagerström test for Nicotine Dependence (Heatherton, Kozlowski, Frecker, & Fagerström, 1991) was used as a measure of nicotine dependence severity.

A DD task and a 19 item CPT adapted from MacKillop et al. (2008) were used as measures of RP. The 19-item CPT contains 19 prices from US$0 (i.e., free) to US$1,136 (i.e., €1,000) and asks participants to inform on the number of cigarettes they would smoke per day at each of the given prices. Raw data from this task yields four observed cigarette demand indicators (breakpoint, O_{max}, P_{max}, and intensity), and one which needs to be derived (i.e., elasticity). O_{max}, P_{max} and breakpoint essentially capture the economic aspects of demand, which pertain to maximum consumption, its associated price and the exact price that causes individuals to cease the behavior. Intensity represents the overall consumption level when no cost (i.e., neither financial nor personal effort) exists, and elasticity informs on participants' demand sensitivity to increases in costs.

DD was assessed using a laptop and was presented as a choice of money that ranged between US$11.47 and US$1,136 (i.e., between €10 and €1,000) after a fixed delay, versus various amounts of money available immediately at six delays: 1 day, 1 week, 1 month, 6 months, 5 years, and 25 years. A titration procedure which has previously been used in the DD literature was adopted (Holt, Green, & Myerson, 2012). This method takes the

Table 1
Participants' Baseline Characteristics (N = 305)

Characteristic	*M* (*SD*)	*Mdn* (interquartile range)	%
Sex (% female)			68
Age, years	48.69 (11.81)		
Employment status (% employed)			61
Monthly income			
≤$692			27.5
$693–$1,383			29.5
$1,384–$2,305			34.6
≥$2,306			8.5
Cigarettes per day	21.40 (8.43)		
Years of regular smoking	29.36 (11.70)		
Previous 24-hr quit attempts	2.17 (2.75)		
FTND	6.00 (1.85)		
CO (ppm)	20.76 (13.34)		
Cotinine (ng/mL)	2,294 (1,962)		
BDI-II	20.33 (12.85)		
AUClogd	.38 (.27)		
Psychological inertia		−.06 (1.19)	
Persistence		.02 (1.14)	

Note. FTND = Fagerström Test for Nicotine Dependence; CO (ppm) = carbon monoxide in parts per million; BDI-II = second version of the Beck Depression Inventory; AUClogd = base-10 logarithmic transformation of the area under the curve.

lower and upper limit of possible values and divides this total range by 2, 3, or 4 to obtain an interval value. The value of the immediate option was one interval value above or below the upper and lower limits.

Treatment Response Outcomes

Treatment response was defined as being abstinent at both posttreatment and 6-month follow-up visits. Two measures of abstinence are provided: 7-day point-prevalence (i.e., being abstinent for at least 7 days prior to the assessment) and continuous abstinence (i.e., the mean number of days of complete abstinence since the quit day). Readings of carbon monoxide (CO) ≤4 ppm and cotinine samples ≤80 ng/mL confirmed self-reported smoking abstinence.

Statistical Analysis

Descriptive statistical analyses were conducted to analyze participants' baseline characteristics. A thorough preliminary analysis was conducted at first to identify the presence of nonsystematic CPT (see Stein, Koffarnus, Snider, Quisenberry, & Bickel, 2015) and DD data (see Johnson & Bickel, 2008). As a result, none of the participants were excluded due to nonsystematic CPT data but nine were due to nonsystematic discounting ($N_{nonmonotonicity} = 3$; $N_{nondiscounting} = 6$), thus leaving 305 for inclusion in the purported analyses. Five CPT demand indices (i.e., breakpoint, O_{max}, P_{max}, intensity, and elasticity) were computed. All were observed except elasticity, which was derived using the Koffarnus, Franck, Stein, and Bickel (2015) demand equation using a constant *k* value equal to 3.82 that resulted from subtracting mean consumption at the lowest price ($\log_{10}$ transformed) from mean consumption at the highest price ($\log_{10}$ transformed): $Q = Q_0 \times 10^{k(e^{-aQ_0C}-1)}$. Both raw CPT data and individual demand indices (i.e., breakpoint, O_{max}, P_{max}, elasticity, and intensity) were examined for the presence of outliers. Fourteen outliers (4.59%; 14/305) were identified and thus replaced by their highest nonoutlier value plus 1 unit. Afterward, CPT variables were log-transformed so as to improve the marked skewness and kurtosis (after log-transformation, skewness ranged between −0.568 and 0.778; kurtosis ranged between −0.341 and 1.451).

Given preliminary evidence supporting a bifactorial latent structure of CPT (i.e., persistence and amplitude) in cigarette smokers (Bidwell et al., 2012; O'Connor et al., 2016), a principal component analysis (PCA) with oblique rotation (oblimin) was performed to examine whether or not these latent components of CPT held for the study sample. CPT variables (breakpoint, O_{max}, P_{max}, elasticity, and intensity) were standardized and entered into the PCA. Barlett's sphericity and Kaiser–Meyer–Olkin indices were used as proxies of data adequacy for PCA. Indices' loadings across CPT factors were set at a cut-off of ≥.32 (see Tabachnick & Fidell, 2000). The regression method was implemented in the PCA to calculate factor scores ($M = 1$; $SD = 2$).

The DD rates were measured by the base-10 logarithmic transformation of the area under the curve (AUClogd). This index is a newly proposed indicator of discounting that overcomes the unbalanced contribution of each point of indifference in the Myerson, Green, and Warusawitharana (2001) procedure (see Borges, Kuang, Milhorn, & Yi, 2016). It was calculated by dividing each logged delay by the longest delay (25 years). Values range between 0 and 1, with lower values indicating greater discounting.

The HPCLUS procedure in SAS software for k-means clustering and least squares estimation to compute the cluster centroids was used to identify clusters of smokers on the basis of the following variables: psychological inertia, persistence, and the AUClogd index. This method identifies clusters of individuals based on distances that are computed from quantitative variables (SAS Institute Inc., 2016). One of the advantages of using the HPCLUS procedure is that it performs well with relatively small sample sizes and provides a single indicator for estimating the adequate number of clusters: the aligned box criterion.

Clusters were externally validated through comparisons of sociodemographic factors (i.e., sex, age, employment status and monthly income), smoking-related features (i.e., cigarettes per day, nicotine dependence, years of regular smoking, number of prior 24-hr quit attempts, CO, and cotinine), and depressive symptoms, using a set of chi-square and *t* tests analyses. Differences across groups in the percentage of abstinent patients and days of continuous abstinence were also assessed at both posttreatment and 6-month follow-up. Cohen's *D*, Cramer's *V*, and phi values were used as measures of effect size for *t* tests and chi-square analyses, as appropriate.

Lastly, separate binary regression analyses were performed for assessing the clusters' treatment response (i.e., abstinent vs. smoker) at the posttreatment and 6-month follow-up by treatment condition, controlling for variables that significantly differed between clusters at a $p < .05$ level. All analyses were carried out using the SPSS Version 25, SAS Version 9.4, and GraphPad Prism Version 7.03.

Results

Preliminary Analysis: Test of the Latent Structure of CPT

Summary statistics and factor loadings for the PCA analysis are
T2 presented in Table 2. Sample adequacy for PCA analysis was evinced by a .74 Kaiser–Meyer–Olkin index and the significance
AQ: 5 of the Bartlett's sphericity test, $\chi^2 = (866.22, 10)$, $p < .001$. The PCA solution replicated the data matrices previously reported in the literature, which indicated the existence of a bifactorial latent structure of the CPT. The two factors obtained were used in subsequent analyses and interpreted as in a prior validation study (for further details, see González-Roz et al., 2018): Factor 1 "Persistence" and Factor 2 "Psychological inertia."

Clusters of Smokers Based on Reinforcer Pathology Indicators

A two-cluster solution was identified as the best fit by the aligned box criterion. Cluster 1 (C1) comprised 42% of the sample (128/305) and Cluster 2 (C2) included 58% (177/305). In comparison with smokers in C1, those grouped in C2 showed significantly higher DD rates ($M_{AUClogd} = .32$, $SD = .25$, vs. $M_{AUClogd} = .45$, $SD = .27$), but lower psychological inertia ($M = -.46$, $SD = .87$, vs. $M = .64$, $SD = .79$), and persistence scores ($M = -.53$, $SD = .67$, vs. $M = .74$, $SD = .90$).

Differences in sociodemographic, depression, and smoking-related variables emerged across groups. Relative to individuals in C1, those in C2 showed higher depression severity ($p = .01$), but a lower number of cigarettes smoked per day ($p < .001$), nicotine dependence severity ($p < .001$), and cotinine levels ($p = .001$; see Table 3). T3

Table 2
Summary Statistics for the Cigarette Purchase Task Indices and Their Associated Latent Factor Loadings

		Principal components	
Index[c]	*M* (*SD*)	Factor 1[a] (Persistence)	Factor 2[b] (Psychological Inertia)
1. Breakpoint	.84 (.58)	**.95**	−.06
2. O_{max}	1.01 (.45)	**.85**	.18
3. P_{max}	.36 (.61)	**.97**	−.19
4. Elasticity	−2.75 (.62)	**−.49**	**−.37**
5. Intensity	1.31 (.18)	−.04	**.95**

Note. Factor loadings (i.e., ≥.32) are highlighted in bold.
[a] Variance explained = 59.48%. [b] Variance explained = 19.61%. [c] Back transformed to log10.

Relationship Between Cluster Membership and Abstinence Status by Treatment Condition

Abstinence rates by cluster membership, treatment condition and follow-up assessment are displayed in Figure 1. At the end- F1 of-treatment, smokers falling into C2 showed significantly higher cessation rates (76.3% vs. 61%; $\chi^2 = 8.291$, $p = .004$, $\phi = .16$) and higher continuous abstinence ($M = 15.66$, $SD = 11.28$; $M = 10.68$, $SD = 9.50$), $t(290) = -4.113$, $p = <.001$, Cohen's $d = 0.48$, compared to those in C1. At 6-month follow-up, differences dissipated and equal cessation rates were found across clusters in terms of either point prevalence abstinence (C1 = 31.3% vs. C2 = 39.5%; $\chi^2 = 2.218$, $p = .14$, $\phi = .08$) or days of continuous abstinence ($M_{C1} = 53.41$, $SD = 86.05$ vs. $M_{C2} = 69.86$, $SD = 92.71$), $t(282) = -1.58$, $p = .12$, Cohen's $d = -0.18$.

Table 4 shows results of the regression analyses examining the T4 association between treatment condition and abstinence status for each of the identified clusters. For those in C1, nicotine dependence severity significantly predicted posttreatment abstinence, $\chi^2(5) = 13.18$, $p = .02$, $R^2 = .14$, whereas cotinine and nicotine dependence severity were related to 6-month abstinence, $\chi^2(5) = 13.72$, $p = .02$, $R^2 = .16$. For C2, neither the treatment condition nor the remaining variables tested predicted posttreatment abstinence status. At 6 months, nicotine dependence severity was the sole significant variable predicting abstinence, $\chi^2(5) = 17.26$, $p = .004$, $R^2 = .13$.

Discussion

The main purposes of the present study were to identify clusters of treatment-seeking smokers based on the RP framework and to determine whether these patients responded differently to CBT and CBT + CM treatment. Two results are highlighted: (a) two clusters were identified based on cigarette demand and DD, C1 (characterized by excessive tobacco valuation) and C2 (characterized by steep discounting), and (b) CBT and CBT + CM promoted similar short- and long-term cessation rates regardless of cluster membership.

Cluster comparisons of RP indicators revealed that participants in C1 showed higher levels of demand as measured by the latent components of the CPT (i.e., psychological inertia and persistence), whereas those in C2 were mainly characterized by higher DD rates. Based on the overall patterns of the assessed RP facets, C1 was interpreted as "individuals with excessive tobacco valuation" and C2 as "steep discounters."

The fact that higher smoking-related variables were found in the cluster with higher persistence and psychological inertia (i.e., C1)

Table 3
Cluster Differences in Sociodemographic and Smoking-Related Variables

Characteristic	Cluster 1 (n = 128) *M* (*SD*)	Cluster 1 %	Cluster 2 (n = 177) *M* (*SD*)	Cluster 2 %	*p*	Effect size
Sex (% female)		65.6		68.9	.54	−.035
Age, years	48.06 (11.25)		49.15 (12.21)		.43	−.26
Employment status (% employed)		62.5		59.9	.64	−.03
Monthly income (%)					.21	.12
≤$692		23.4		29.8		
$693–$1,383		29.8		32.2		
$1,384–$2,305		32.3		30.4		
≥$2,306		14.5		7.6		
Cigarettes per day	24.69 (9.35)		19.02 (6.79)		<.001	.69
Years of regular smoking	29.30 (11.82)		29.41 (11.64)		.934	−.01
Previous 24-hr quit attempts	1.83 (2.05)		2.40 (3.14)		.08	−.22
BDI-II	17.92 (12.25)		22.08 (13.02)		.01	−.33
FTND	6.60 (1.68)		5.56 (1.85)		<.001	.58
CO (ppm)	20.63 (11.64)		20.85 (14.48)		.88	−.01
Cotinine (ng/mL)	2,742 (1,921)		1,983 (1,935)		.001	.39

Note. BDI-II = second version of the Beck Depression Inventory; FTND = Fagerström Test for Nicotine Dependence; CO (ppm) = carbon monoxide in parts per million.

might suggest the greater relevance of demand over discounting when accounting for levels of consumption. This hypothesis has been recently tested by Acuff, Soltis, Dennhardt, Berlin, and Murphy (2018) in an empirical examination of the RP model in heavy drinkers. Greater levels of alcohol demand were directly related to higher alcohol consumption and related problems, whereas DD was uncorrelated with alcohol consumption.

Of note is that those with greater DD rates presented higher Beck Depression Inventory scores, which is consistent with evidence showing that negative mood relates to reduced salience of valued future goals in favor of immediate and less valued ones (Bickel et al., 2019; Szuhany, MacKenzie, & Otto, 2018). Individuals with depression typically engage in low activity levels and perceive low reinforcement levels from their natural environment (Audrain-McGovern, Rodríguez, Rodgers, & Cuevas, 2011), which gives them a propensity to prefer smaller, immediate reinforcers (i.e., staying in bed, using cigarettes) over larger delayed ones (i.e., engaging in substance-free alternative behaviors).

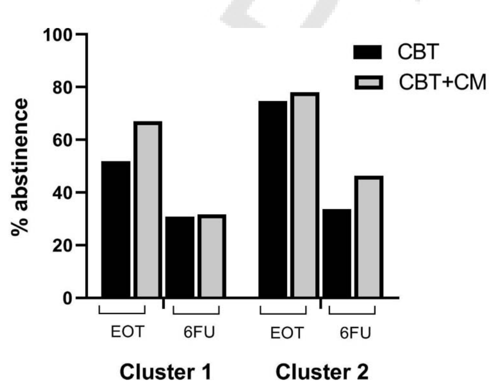

Figure 1. Point-prevalence abstinence rates at the end-of-treatment (EOT) and 6-month follow-up (6FU) by cluster membership and treatment condition. CBT = cognitive–behavioral treatment; CBT+CM = cognitive–behavioral treatment plus contingency management.

CBT and CBT + CM promoted similar cessation rates both at short-term and at long-term follow-up, regardless of cluster membership. These rates fall around the upper limit recorded in previous studies (Dallery, Raiff, & Grabinski, 2013; Krishnan-Sarin et al., 2007). The remarkably high cessation rates might have occurred as a result of delivering treatment in a more intensive fashion than preceding studies (i.e., a higher number of sessions, and twice-weekly biochemical measures of smoking, with stronger monitoring effects) and the inclusion of an impulsivity-targeted component in the CBT protocol, such as problem solving. The lack of statistically significant differences between CBT and CBT + CM may be surprising given the strong evidence in support of their efficacy for the treatment of smoking (Cahill et al., 2015; Sigmon

Table 4
Treatment Condition as a Predictor of Smoking Status at Each Timeframe Assessment by Cluster Membership

Cluster	Posttreatment (8-week treatment), *OR* [95% CI]	6-Month follow-up, *OR* [95% CI]
Cluster 1		
Cigarettes per day	1.02 [.98, 1.08]	1.01 [.96, 1.07]
Cotinine (ng/mL)	1.00 [1.00, 1.00]	1.00 [.99, 1.00]*
BDI-II	.99 [.96, 1.03]	1.00 [.97, 1.04]
FTND	.64 [.47, .88]*	.71 [.51, .97]*
Treatment condition[a]	1.19 [.51, 2.78]	.52 [.20, 1.30]
Cluster 2		
Cigarettes per day	1.02 [.96, 1.08]	.96 [.90, 1.02]
Cotinine (ng/ml)	1.00 [1.00, 1.00]	1.00 [1.00, 1.00]
BDI-II	.99 [.97, 1.03]	1.01 [.98, 1.04]
FTND	.85 [.67, 1.07]	.78 [.63, .95]*
Treatment condition[a]	1.20 [.57, 2.54]	1.65 [.84, 3.24]

Note. *OR* = odd ratio; CI = confidence interval; BDI-II = second version of the Beck Depression Inventory; FTND = Fagerström Test for Nicotine Dependence.
[a] Cognitive–behavioral treatment was entered as the reference category.
* $p < .05$.

& Patrick, 2012). A few factors may explain this result. First, treatment effects for CM tend to be less or null when compared to other active treatments, such as standard care (Cooney et al., 2017; Kirby, Marlowe, Festinger, Lamb, & Platt, 1998). In our study, we added a CBT condition, which has proven to be an effective treatment for smoking cessation for individuals with high impulsivity (Morean et al., 2015). Second, the reinforcer magnitude used in this study (up to US$342) may have been too low to produce a rewarding effect in the participants. There exist several studies showing that low-magnitude CM (US$207.50 to US$362.50) is effective in enhancing cessation rates (Dunn et al., 2010; Packer, Howell, McPherson, & Roll, 2012). However, not all evidence supports it to facilitate substance use in difficult-to-treat populations (Dallery, Silverman, Chutuape, Bigelow, & Stitzer, 2001; Romanowich & Lamb, 2010; Silverman, Chutuape, Bigelow, & Stitzer, 1999). Sound evidence of the necessity to increase the value of incentives has recently been shown by Harvanko et al. (2019). In this study, impulsive smokers in a high-magnitude CM condition (US$773) showed enhanced CO reductions relative to those in a noncontingent control arm. Given that smokers with high DD struggle to initiate smoking abstinence (Krishnan-Sarin et al., 2007; Worley et al., 2018) and adhere to CM schedules (Harvanko et al., 2019), increasing the magnitude of incentives would have arguably led to superior CM effects (Dallery & Raiff, 2012).

Despite these promising results, it should be noted that less than 40% of the participants in each cluster remained abstinent at 6 months. Also, the fact that we found nicotine dependence as a significant predictor of cessation outcomes suggests the need to further investigate innovative procedures such as episodic thinking (Chiou & Wu, 2017; Stein et al., 2016; Stein, Tegge, Turner, & Bickel, 2018) or shaping cessation reinforcement (Lamb, Kirby, Morral, Galbicka, & Iguchi, 2010; Secades-Villa et al., 2019) to engender continuous abstinence. Nonetheless, this is preliminary evidence and more research needs to be done to investigate whether these interventions do lead to enhanced cessation rates in patients with RP.

The study findings need to be appraised in the context of several limitations. First, given the secondary nature of the study, it is not possible to elucidate whether CBT or CM accounted for the reported effects, so further adequate designs are needed to clarify this issue. Second, despite the relatively high sample size used, it could be that increasing the number of participants and their heterogeneity in RP indicators (e.g., more participants with shallow DD and high demand) might have led to a different number of clusters. Finally, this study relied on a 6-month follow-up; using a longer timeframe assessment could yield more definite results.

Despite the above limitations, this is novel clinical evidence that supports the existence of different subtypes of treatment-seeking smokers based on the interrelationship between cigarette demand and DD. These findings add to the limited data on the effectiveness of CM for smoking cessation across individuals with different clinical characteristics and suggest effects may persist beyond the period in which reinforcement is applied. Results also support the generalizability of CBT and CM strategies irrespective of patients' RP subtype. In the interest of allocating CM resources in a more efficient manner, offering CBT as a first-line treatment followed by CM for nontreatment responders would be expected to improve treatment targeting and customization, a pressing need in clinical contexts (Forster et al., 2019). Alternatively, novel treatment procedures tailored to cigarette demand and their combination with CM could be provided to enhance and extend the effects of CM.

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