No evidence of the clinical utility of single-item breakpoint to inform on tobacco demand in persons with substance use disorders

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Conflicts of interest

None.

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Abstract

*Rationale***:** Behavioral economics has shown that single-item demand indicators are promising for capturing crucial aspects of nicotine reinforcement. It is suggested that brief breakpoint measures perform comparably to full-length demand indices in characterizing nicotine dependence; however, there have been no thorough assessments of their validity in clinical settings. *Objectives:* This study aimed to assess the validity and accuracy of a single-item breakpoint in informing on tobacco demand. *Methods***:** The sample consisted of 88 treatment-seeking smokers (% males = 70.5%) enrolled in substance use treatment. Participants provided data on smoking characteristics and completed the Fagerström Test for Nicotine Dependence, a single-item breakpoint measure, and a 14-item cigarette purchase task (CPT). Hierarchical regressions were performed to compare the predictive capability of a single-item breakpoint and full-length tobacco demand indicators in determining nicotine addiction severity. *Results***:** The single-item breakpoint was significantly correlated with all indices stemmed from the CPT and both latent factors (all r values = .250-.368). Neither the brief breakpoint nor the full-length breakpoint significantly predicted nicotine dependence. After controlling for sex and smoking variables, Factor 2 [β = .565, p <.001] and its observed variables Omax [β = .279, p = .006], 1/elasticity [β = .340, p = .001], and intensity [β = .551, p <.001], robustly predicted nicotine dependence severity. *Conclusions***:** Our findings do not support the validity of single-item breakpoint measures for characterizing nicotine dependence in substance users. In a bid to foster translational research, brief demand measures capturing Omax, intensity, and elasticity should be developed.

Keywords: behavioral economics, cigarette demand, nicotine dependence, single-item breakpoint, substance users

1. Introduction

The implementation of tobacco control policies and educational campaigns have led to significant decreases in the prevalence of smoking (Feliu et al. 2019). Unfortunately, rates are still very high among certain subpopulations, such us substance users (Agaku et al. 2019; Guydish et al. 2016; Ingram et al. 2017). The co-occurrence of substance use disorders (SUDs) and smoking is a critical health concern, as it carries increased risk of suffering from physical illnesses and premature death (Callaghan et al. 2018; Campbell et al. 2019). SUDs have also been associated with poor smoking cessation outcomes (Notley et al. 2019; Vlad et al. 2020), highlighting the necessity to better understand the nature of nicotine addiction in this population.

Reinforcer pathology (RP), a framework rooted in behavioral economics (BE), has contributed to this endeavor. Research on RP has characterized nicotine reinforcement in substance use dependents (Farris et al. 2017; Gowin et al. 2019; Kräplin et al. 2020; Peters et al. 2017) and suggested potential effective interventions and treatment targets (González-Roz et al. 2020; Mackillop et al. 2016). The central assumption of RP is that cigarette smoking depends on two synergistic processes: impulsive choice (preference for immediate rewards over delayed ones) and/or the excessive valuation of nicotine (Bickel and Athamneh 2020). Based on these tenets, a plethora of measures to assess drug-related and drug-free reinforcement have been validated for research and clinical purposes (Acuff et al. 2019).

The cigarette purchase task (CPT) is one of the assessment tools most widely adopted to date (Reed et al. 2020). A CPT assesses cigarette demand at increasing prices and represents a cost-efficient and valid method to inform on the multidimensional nature of nicotine reinforcement (the “amplitude” or volumetric demand and the difficulty in ceasing the behavior, also known as “persistence”) (Bidwell et al. 2012;

Mackillop et al. 2008). Cigarette demand correlates with markers of tobacco use (e.g., cigarettes per day, CO, nicotine dependence) (Farris et al. 2017; González-Roz et al. 2019a), and it is sensitive to cross-substance relationships with alcohol (Green et al. 2021). There is also evidence on heightened demand after laboratory-induced distress (Dahne et al. 2017) and withdrawal (Aston et al. 2021), which suggests that demand can be considered as a marker of tobacco use maintenance.

It is important to note that the CPT is a well-accepted proxy of nicotine dependence severity that informs on the potential addictiveness of different products (e.g., e-cigarettes, nicotine reduced cigarettes) (Higgins et al. 2020a; Streck et al. 2020) across different age populations and/or comorbidities, such as adolescents (Cassidy et al. 2020), young adults (González-Roz and MacKillop, 2021), smokers with affective disorders (Secades-Villa et al. 2018), and patients in opioid-maintenance therapy (Higgins et al. 2020b). The demand indices of the CPT and its derived latent components (amplitude and persistence) are also sensitive to smoking abstinence outcomes, such as in-treatment nicotine intake decreases (Weidberg et al. 2018), negative carbon monoxide samples (Mackillop et al. 2016), and continuous smoking abstinence (González-Roz et al. 2020; Secades-Villa et al. 2016).

Recently, several studies have provided evidence on the utility of the CPT for patient profiling, in such a way that smoking cessation therapies can be specifically tailored to the patient's needs. The study by Nighbor et al. (2019) showed that pregnant women who present shallow discounting and demand (as indicated by Omax) report higher antepartum quit attempts. Similarly, the study by González-Roz et al. (2019) reported on the generalizability of contingency management across two subtypes of treatment-seeking smokers characterized by distinct levels of tobacco demand.

Currently, BE scientists are tasked with bridging the gap between laboratory and real-world scenarios. However, the use of purchase tasks in clinical contexts, such as tobacco cessation units, could be particularly challenging and arduous because of the length of CPTs (number of items generally ranges from 5-73) and the complexity of the analytic procedures (i.e., use of exponentiated equations to generate demand curves).

Two initiatives on this front are the validation of single-item state (Athamneh et al. 2019) and trait demand indicators (comprising breakpoint, intensity, and Omax) (Murphy et al. 2019). The first study showed modest significant correlations between a single-item breakpoint and nicotine dependence. Conversely, across two samples of SUD adolescents and adults, Murphy et al. (2019) provided no evidence of single-item demand associations with severity of nicotine dependence or cigarettes per day. The use of substantially different demand tasks in terms of time frames (trait versus state) and price densities (i.e., 0-64U$ vs. 0-5U$) might arguably have led to these divergent results. The use of extremely high and low numbers of prices has been shown to alter demand estimations (i.e., by producing a ceiling effect in low-price density tasks and unrealistic demand in tasks with extremely high unit prices), such that they deviate from real-world patterns of cigarette use (González-Roz et al. 2019b; Roma et al. 2016).

This study sought to inform this area of research by assessing the construct validity of a single-item breakpoint in treatment-seeking smokers in SUD treatment. Specifically, it sought to: 1) assess the relationship between a single-item breakpoint, demand measured by a 14-item CPT, and smoking variables, 2) compare the predictive capability of the single-item breakpoint and each full-length demand index on nicotine dependence severity, and 3) provide cut-offs that will maximize (in terms of sensitivity and specificity) the likelihood of correctly identifying SUD smokers with different nicotine addiction levels.

2. Method

2.1. Participants and procedure

The study sample consisted of 88 smokers in SUD treatment recruited for an ongoing randomized controlled trial (clinical gov register: *blinded*). Table 1 informs on participant characteristics. Participants were recruited through their referral therapists, flyers, and posters displayed around SUD facilities. Inclusion criteria were as follows: 1) being at least 18 years of age, 2) self-reporting ≥10 cigarettes per day, 3) undergoing SUD treatment, and 4) having availability to attend both therapy and follow-up assessments. Self-reported current severe diagnosis (active psychotic disorder and/or active suicidal ideation) precluded participants from involvement in the study.

If they met the inclusion criteria, interested candidates were given details on the study procedures and asked to sign informed consent prior to collection of baseline data. The study procedures were approved by the local ethics committee (license nº 144/16).

2.2. Measures

All participants provided baseline data on a single in-person assessment visit that took approximately 60 minutes. A battery of questions on demographics (age, sex, monthly income level), smoking, and SUD variables were presented to each participant using electronic tablets.

SUD diagnosis was assessed according to the DSM-5 criteria using The Structured Clinical Interview for DSM-5- Clinician Version (SCID-5-CV; First et al. 2016). SUD severity was determined according to the DSM guidelines: mild (scoring 2-3), moderate (scoring 4-5), and severe (scoring ≥6). Also, participants provided a urine sample for cotinine and drug testing (cocaine, opioids, amphetamine, methamphetamine, and cannabis). Urine cotinine was assessed during the baseline visit by trained research assistants using a BS-100 chemistry analyzer (Shenzhen Mindray Bio-Medical Electronics Co. Ltd., Shenzhen, P. R. China). Breath samples were collected to assess CO and alcohol intoxication levels. The remaining substances (cocaine, opioids, cannabis, amphetamine, and methamphetamines) were assessed by drug testing panels.

Nicotine dependence was assessed using the Fagerström Test for Nicotine Dependence (FTND; Heatherton et al. 1991). Based on total scores, the FTND establishes the following levels of nicotine dependence: very low (0-2), low (3-4), medium (5), high (6-7), and extremely high (8-10).

The Beck Depression Inventory-II (Beck et al. 1996) was used to characterize the sample in terms of depressive symptoms. The BDI-II assesses the presence of depressive symptomatology during the past 14 days. The severity cut-offs are as follows: minimal (0-13), mild (14-19), moderate (20-28), and severe (29-63).

Trait cigarette demand (in a 24-h period) was assessed using a single-item breakpoint measure ("how much would you be willing to spend on a single cigarette?") and a full-length CPT containing 14 prices (González-Roz et al. 2019b) (from 0 to US $22; US $0, US $.01, US $.02, US $.05, US $.11, US $.27, US $.54, US $1, US $2, US $3, US $4, US $5, US $11, US $22). Data from the CPT allow to generate four observed indicators [intensity (overall consumption at unrestricted cost), Omax (maximum demand), Pmax (price associated to maximum demand), and breakpoint (price at which consumption ceases)] (MacKillop et al. 2008), as well as one derived indicator (elasticity, which reflects the ratio of the percentage change in quantity to the percentage change in price) (Gilroy et al. 2020). Participants completed both tasks in the order indicated. Before responding, participants were given an instructional vignette informing on the task procedure and a set of constraints: (1) nicotine use must be exclusively from this source, (2) the cigarettes are of your favorite brand, (3) the quantity of money is that which is typically available to you, (4) all requested cigarettes must be consumed in a day, (5) cigarettes are for your personal use, sharing or stockpiling them not being permitted.

2.3. Data analyses

Descriptive and frequency analyses were conducted to inform on demographics, smoking, and SUD characteristics.

The orderliness of the CPT data was examined according to recommended guidelines (Stein et al. 2015). A two-step procedure was followed: Firstly, raw data were examined individually to detect the presence of non-systematic cases, which were defined as: (1) <.025 log reductions in consumption from the first to the last price, (2) jumps of more than 10% in price increments, and (3) ≥2 reversals from zero. The implementation of the Stein et al. (2015) triple algorithm did not detect any inconsistent data. Secondly, standardized scores of raw CPT data and demand indices were computed to identify the presence of outliers using a z +/- 3.29 cut-off score, which conforms to a prior recommendation for handling outlying values (Tabachnick and Fidell, 2018) and most standard practices in the BE literature (e.g., Acker et al. 2012; Mackillop et al. 2016). All outlying values were replaced by one unit above the next highest non-outlying value, except for elasticity outliers which were replaced instead by one thousandth (e.g., .001+.017). This decision was adopted to produce minimal deviations from the original data. These analyses revealed good quality data, as evidenced by a low percentage of outlying values [*n* of cases =19/1,232 raw data points; (.015%)]. With regard to the CPT demand indices, we detected 6 outliers out of a potential 352, which represented a percentage of .017%.

All demand indicators (breakpoint, Omax, Pmax, elasticity, and intensity) were observed, except elasticity which was derived via the exponentiated version of the Hursh and Silberberg (2008) formula to accommodate for zero demand (see Koffarnus et al. 2015: $Q = Q0 \times 10^{k}(^{e - \text{-} \alpha \, Q0C-1})$. A k value of 2.28 (i.e., obtained by subtracting mean $\log_{10}$ consumption at the lowest price from mean $\log_{10}$ consumption at the highest price) was fixed. To correct for skewness and kurtosis, all demand indicators were log-transformed as this correction significantly reduced skewness and kurtosis (skewness ranged from -.611, -.273; kurtosis ranged from -.648-.060). For completeness and ease of interpretation, both log-transformed and back-transformed statistics were provided.

The latent CPT components were extracted using principal component analysis with oblimin rotation. Of note is that all the CPT observed variables were entered in this analysis. To enhance comparability with prior research (Bidwell et al. 2012; O'Connor et al. 2016), we used the inverse of elasticity (i.e., 1/α), such that larger values reflected greater reinforcement value. The Kaiser-Meyer-Olkin (KMO) index and Bartlett's sphericity test were provided to inform on the adequacy of the data for the analysis. A KMO of at least .60 and a statistically significant Bartlett test (OECD, 2008) were used as indicators of the sampling adequacy for the PCA. The eigenvalue-one criterion was used to indicate the number of latent components of the CPT. The factor loadings cut-off was .40, in accordance with prior BE literature and available psychometric guidelines (Howard 2016). The regression method was used to calculate factor scores (M = 0; SD = 1).

A set of Pearson correlations were performed to examine the associations among the single-item breakpoint, demand indices from the 14-item CPT, the latent components of the CPT, and smoking-related variables (cigarettes per day, past 24-hour quit attempts, nicotine dependence, CO, and cotinine).

Lastly, a set of eight hierarchical linear regressions were conducted to compare the predictive capability of a single-item breakpoint and demand indices derived from the full-length CPT (breakpoint, Omax, Pmax, 1/α, intensity, and both of the latent components of the CPT) in determining nicotine dependence as measured by the FTND. Given the relevance of elucidating whether CPT demand better characterizes nicotine dependence severity in comparison with other smoking-related variables, several covariates were entered in the regression models as follows: first block (sex); second block (daily nicotine consumption in milligrams, CO, and cotinine). The number of cigarettes per day was not entered, on the basis that this measure is included in the FTND and to avoid for multicollinearity.

Finally, untransformed demand indices that were significantly related to nicotine dependence at a statistical level were entered in a receiver operating curve analysis (ROC) to identify the optimal cut-off that would maximize (in terms of sensitivity and specificity) the likelihood of correctly identifying SUD smokers with mild/moderate vs. high nicotine dependence based on FTND total scores. The Youden Index procedure (Perkins and Schisterman 2005) [(Y): Y = sensitivity + specificity -1] was used to identify optimal cut-offs. Youden's index values range between 0 and 1, where 1 indicates optimal criterion value.

Analyses were carried out using GraphPad Prism (version 7.0, GraphPad Software, La Jolla, CA) and SPSS 24 (IBM®).

3. Results

3.1. Estimation of the CPT latent structure

The PCA (KMO= .64, $\chi^2_{(365.07, 10)}$ =, p <.001) revealed two latent components, collectively accounting for 88.20% of the variance. Table 2 shows factor scores for each specific latent variable. F1 comprised breakpoint, Omax, Pmax, and elasticity, whereas F2 included Omax, elasticity, and intensity.

3.2. Relationships among the single-item breakpoint, full-length CPT, and smoking variables

The correlations among demand indices of the 14-item CPT, the single-item breakpoint, and smoking-related variables are in Table 3. The single-item breakpoint was positively associated with all the demand indices (breakpoint, Omax, Pmax, and intensity, and elasticity). With respect to the latent components of the CPT, F1 and F2 were each positively related to the single-item breakpoint.

With regard to the smoking variables, Factor 2, and its observed variables (except for the Omax-CO relationship), showed the strongest relationships with cigarettes per day ($|r$'s$|$ values ranged from .415-.799), CO ($|r$'s$|$ values ranged from .230-.476), cotinine ($|r$'s$|$ values ranged from .279-.448), and nicotine dependence ($|r$'s$|$ values ranged from .379-.644). The single-item breakpoint was associated only with the cigarettes per day variable ($|r$'s$|$ = .280).

Hierarchical regressions with each full-length demand index and the single-item breakpoint as predictors of nicotine dependence are shown in Table 4. Results revealed that Factor 2 [R^2 = .414; $F(5, 82) = 13.282$, $p < .001$] and its observed variables, Omax [R^2 = .242; $F(5, 82) = 6.562$, $p < .001$], elasticity [R^2 = .275; $F(5, 82) = 7.616$, $p < .001$], and intensity [R^2 = .399; $F(5, 82) = 12.559$, $p < .001$], predicted nicotine dependence severity, even when controlling for daily nicotine intake and biochemical measures of tobacco use.

3.3. Demand cut-offs for nicotine dependence

The ROC analyses indicated that a cut-off of 6 for Omax [AUC: .70 (95% CI: .585, .811); sensitivity: 75.9%, specificity: 52.9%], 18 for intensity [AUC: .81 (95% CI:

.718, .899); sensitivity: 85.2% specificity: 41.2%], and 107 for elasticity (1/α) [AUC: .74: (95% CI: .637, .847); sensitivity: 61.1%; specificity: 20.6%] maximized the proportion of patients correctly classified as highly dependent on nicotine.

4. Discussion

The overarching goal of this study was to assess the construct validity of a single-item breakpoint in smokers with comorbid SUDs, and more specifically to clarify which demand index better characterizes nicotine dependence in SUD smokers. The single-item breakpoint measure did not correlate with nicotine dependence severity, suggesting that it does not perform well in characterizing tobacco demand in SUD smokers. An examination of the aspects of demand with which the FTND correlated best, indicated that F2 and the variables that comprise it (Omax, intensity, and elasticity) outperformed the remaining full-length demand indices.

The lack of meaningful relationships between the single-item breakpoint and smoking variables has been reported previously (Athamneh et al. 2019; Murphy et al. 2019). Collectively, there exist at least two rationales that make this index less reliable for characterizing cigarette demand. Firstly, unlike in samples with low tobacco exposure, SUD smokers may have over- or underestimated the price at which they would cease smoking, especially in the event of a scarcity scenario, like the one where the single item breakpoint was assessed (i.e., 'imagine you can only have access to one single cigarette to be smoked in a day'). The 'scarcity' phenomenon has been extensively described in the fields of economics and social psychology (Worchel 1992) and suggests that a heuristic related to increases in the value and perceived quality of a commodity emerges when restrictions arise (in terms of both quantity of the commodity and time to access it). The contrary may have also occurred, that is, a cost-benefit analysis for some patients could have resulted in low expenditure on a cigarette, even when they show high FTND scores, simply because they perceive a lower benefit (i.e., immediate but transient distress relief) from having a single cigarette than the cost associated with obtaining it (i.e., impaired health).

A composite measure of intensity, Omax, and elasticity predicted nicotine dependence severity better than its single constituents. This finding maps on well with recent evidence on the latent structure of the CPT, suggesting that combinations of demand indices better characterize the nicotine reinforcement (Bidwell et al. 2012; Cassidy et al. 2020; González-Roz et al. 2020; O'Connor et al. 2006). Of note is that we found a slightly different latent structure than previous reports. There are at least two rationales for this discrepancy that relate to statistical and theoretical aspects. On the one hand, it is argued that using log or square-root transformations produces different demand estimates (Martínez-Loredo et al. 2020). Using one or another mathematical transformation is expected to affect the PCA solution through different factor loadings. Also, the sensitivity of CPT indices may vary according to specific sample characteristics. For example, in non-comorbid smokers, intensity and elasticity more accurately inform on nicotine dependence whereas in those with comorbid mental health disorders, Omax, intensity, and elasticity show the highest magnitude associations with nicotine dependence levels (Dahne et al. 2017; MacKillop and Tidey 2011; Mackillop et al. 2016; Secades-Villa et al. 2018).

The fact that we found Omax, elasticity, and intensity to be significant predictors of nicotine dependence suggests that further developments of brief tobacco demand measures should rely on items that capture these aspects of demand. Of note is that we have provided several cut-offs for identifying SUD smokers with high levels of nicotine dependence. Though not tested herein, they are expected to encourage the use of CPTs in clinical practice. If one of the CPT demand indicators were used, health professionals would be 61-85% confident in identifying those with higher nicotine dependence levels (and, arguably, more difficulty in quitting). However, in view of the difficulty that calculating elasticity entails, the latter would be better used for research purposes (i.e., task policy or decision making on treatment parameters). This indicator is methodologically difficult to obtain, which might discourage health professionals from using it. Conversely, intensity and Omax are easily obtained as they can be calculated directly through single item questions.

The study findings should be interpreted in the context of several limitations. Firstly, the accuracy of demand in predicting nicotine dependence severity was tested at a cross-sectional level and its causal role remains to be examined. Secondly, the use of a particular sample (i.e., SUD treatment-seeking smokers) and a specific CPT containing 14 items limits the generalizability of the study findings. Demand indicators are sensitive to both the number and range of prices used, and further studies should rely on validated CPTs or instead provide solid support of their evidence based on particular samples. Lastly, this study comprises males (70.5%). Although sex effects were controlled for, different cut-offs might have been obtained if a larger sample of females had been included.

In sum, even with the above limitations, this study sheds light on an active debate in the BE literature as well as the number and relevance of demand indicators for characterizing the reinforcement efficacy of nicotine in specific populations. These findings provide strong evidence of the superiority of Omax, intensity, and elasticity for characterizing nicotine dependence in SUD populations. Given that a composite measure of these three indices characterizes nicotine dependence better than any single demand indicator does, it is advocated that both health professionals and scientists conducting clinical research rely on such a composite measure when providing evidence on the predictive validity of these indices on abstinence outcomes.

Table 1. Demographics, psychological, and substance use characteristics

	N = 88
Demographics	
Male sex (%, n)	70.5 (62)
Age[a]	43.52 (10.35)
Education level (%, n)	
<High School	47.70 (42)
High School	43.20 (38)
≥University	9.10 (8)
Psychological variables	
BDI-II[a]	14.75 (11.42)
Smoking variables	
Cigarettes per day[a]	19.74 (9.51)
Years of regular smoking[a]	25.93 (11.16)
24-h previous quit attempts[a]	1.61 (1.96)
FTND[a]	5.80 (2.20)
CO (ppm)[a]	22.43 (17.04)
Cotinine (ng/ml)[a]	2,108,25 (1,515,34)
SUD variables	
Primary substance used (%, n)	
Alcohol	28.4 (25)
Cocaine/stimulants	42.0 (37)
Heroin/opioids	13.6 (12)
Other†	15.9 (14)
Tobacco use disorder (%, n)	90.9 (80)
Mild	18.7 (15)
Moderate	33.8 (27)
Severe	47.5 (38)
Other SUD diagnosis (%, n)	59.3 (48)
Mild	6.3 (3)
Moderate	6.3 (3)
Severe	87.5 (42)
Days at SUD treatment [a]	369.23 (695.54)

Note. BDI-II = Beck Depression Inventory, II edition; FTND = Fagerström Test for Nicotine Dependence; CO (ppm) = carbon monoxide in parts per million; ng/ml = nanograms/milliliter; SUD = Substance Use Disorder.
[a]Mean(*SD*); † Other substances used included benzodiazepines (n=2), cannabis (n=10), GHB (n=1) , ketamine (n=1).

Table 2. Cigarette demand

	M±*SD*	(Factor 1: breakpoint, Omax, Pmax, elasticity) 63.32% of variance	(Factor 2: Omax, elasticity and intensity) 24.88% of variance
14-item full-length CPT†			
1. Breakpoint	6.69±6.79	**.950**	-.117
2. Omax	13.19±11.90	**.722**	**.486**
3. Pmax	2.77±3.11	**.981**	-.186
4. Elasticity (1/α)	.0174±.0201	**.633**	**.558**
5. Intensity	21.63±10.97	-.141	**.947**
Single-item breakpoint	2.59±4.80	-	**-**

Note. Given that the inverse of elasticity was entered in the principal component analysis, larger values reflect greater reinforcement value.
†Log-transformed data were entered in the principal component analysis but were back-transformed into raw data for ease of interpretation. Factor loadings (i.e., ≥.40) are highlighted in bold.

Table 3. Bivariate correlations between the single-item breakpoint, full-length CPT indices, and smoking-related variables

	1	2	3	4	5	6	7	8	9	10	11	12	13
Variables													
1. Cigarettes per day	-	-	-	-	-	-	-	-	-	-	-	-	-
2. Prior 24-h quit attempts													
3. CO (ppm)	.410**	.065	-	-	-	-	-	-	-	-	-	-	-
4. Cotinine (ng/ml)	.474**	.019	.491**	-	-	-	-	-	-	-	-	-	-
5. FTND	.709**	-.058	.407**	.387**	-	-	-	-	-	-	-	-	-
6. Single-item breakpoint[a]	.280**	-.081	.055	.098	.194	-	-	-	-	-	-	-	-
7. Breakpoint[a]	.121	-.057	.056	.076	.122	.367**	-	-	-	-	-	-	-
8. O_{max}[a]	.415**	.019	.201	.294**	.379**	.368**	.624**	-	-	-	-	-	-
9. P_{max}[a]	.008	-.031	.008	.055	.055	.318**	.886**	.662**	-	-	-	-	-
10. Elasticity (1/α)[a]	.471**	-.029	.230*	.279**	.432**	.321**	.561**	.900**	.539**	-	-	-	-
11. Intensity[a]	.799**	-.164	.476**	.444**	.638**	.250*	.038	.400**	-.054	.424**	-	-	-
12. Factor 1	.140	-.014	.059	.117	.160	.364**	.926**	.821**	.943**	.747**	.052	-	-
13. Factor 2	.782**	-.098	.437**	.448**	.644**	.262*	.076	.633**	.013	.686**	.918**	.204	-

Note. [a]indicates log-transformed indices were used. CO = carbon monoxide; ppm = parts per million; ng/ml = nanograms/milliliter; FTND = Fagerström Test for Nicotine Dependence.

**p* = <.05; ***p* = <.01.

Table 4. Predictive value of single-item demand vs. full-length demand indices over nicotine dependence severity

	ΔR^2	*F change* (df =1,82)	*β*	*p*	95% CI
M_1: Single-item breakpoint[a]	.024	2.628	.157	.109	-.131, 1.282
14-item CPT demand					
M_2: Breakpoint[a]	.007	.744	.084	.391	-.463, 1.173
M_3:O_{max}[a]	.069	7.870	.279	.006	.447, 2.626
M_4:P_{max}[a]	.001	.148	.038	.702	-.649, .959
M_5:Intensity[a]	.216	31.341	.551	<.001	3.116, 6.550
M_6: Elasticity (1/α)	.100	11.994	.340	.001	.819, 3.029
M_7:Factor 1	.013	1.351	.114	.249	-.179, .683
M_8:Factor 2	.230	34.171	.565	<.001	.821, 1.668

Note. CPT= cigarette purchase task. [a]indicates log-transformed indices were used. Models 1-8 were controlled for sex and smoking-related variables [block 1: sex; block 2: carbon monoxide, cotinine, and daily intake of nicotine (in milligrams)].

Disclosure of interest

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Conflicts of interest

None.

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