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Confirmatory factor analyses and reliability of the modified cigarette evaluation questionnaire

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Abstract

We examined the validity and reliability of the modified Cigarette Evaluation Questionnaire (mCEQ) that assesses the degree to which subjects experience the reinforcing effects of smoking. Data came from three phase II clinical trials ($n=626$, $n=627$, $n=312$) on varenicline for smoking cessation. Comparative fit indexes and non-normed fit indexes from a confirmatory factor analysis exceeded 0.90. Cronbach's alpha for internal consistency reliability exceeded 0.70 for the Smoking Satisfaction domain and the Psychological Reward domain but was less than 0.70 for the Aversion domain; test–retest reliability generally exceeded 0.70 on the three multi-item domains and two single items. The validity and, in general, the reliability of the postulated multidimensional framework of the mCEQ are confirmed and supported by the analyses of three independent studies, with multi-item domains on Smoking Satisfaction (satisfying, taste good, enjoy smoking), Psychological Reward (calm down, more awake, less irritable, help concentrate, reduce hunger), and Aversion (dizziness, nauseous), as well as the single-item assessment on Enjoyment of Respiratory Tract Sensations and on Craving Reduction.
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Keywords: Modified Cigarette Evaluation Questionnaire; mCEQ; Smoking; Varenicline; Reinforcing effects

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1. Introduction

Reviews of tobacco dependence, and of cigarette smoking in particular, have stressed nicotine's role in perpetuating smoking and relapsing after a quit attempt. The emphasis on nicotine, as opposed to other constituents of tobacco, is supported by a strong body of evidence that the reinforcing effects of nicotine play a significant role in an individual's desire to smoke (Benowitz, 1999; Brauer et al., 2001; USDHHS, 1988).

These immediately reinforcing effects cover aspects such as smoking satisfaction, psychological reward, and enjoyment of respiratory tract sensations, among others, and may outweigh the expected but temporally distant adverse health consequences of smoking. It is anticipated that diminishing the reinforcing effects of smoking might increase the likelihood of a successful smoking cessation attempt and decrease the chance of relapse to smoking (Brauer et al., 2001; Rose, Behm, & Westman, 1998; Rose et al., 1994; Westman, Levin, & Rose, 1992). Consequently, a valid and reliable assessment of reinforcing effects is needed to understand their role in tobacco dependence.

A self-administered questionnaire assessing the reinforcing effects of smoking has been developed previously and applied in clinical studies to evaluate pharmacological treatments that may decrease these effects (Brauer et al., 2001; Rose et al., 1994; Rose et al., 1998; Westman et al., 1992). This instrument, the Cigarette Evaluation Questionnaire (CEQ), contains 11 items covering both the reinforcing and the aversive effects of smoking. Exploratory factor analyses demonstrated that this instrument has three multi-item domains and two single items (Westman et al., 1992).

What has been lacking is a thorough psychometric evaluation of the CEQ — an evaluation that would help to reassure smoking researchers of the value and merit of assessing reinforcing effects of smoking with this instrument. A positive psychometric evaluation would support the results and conclusions of the CEQ in previous studies, including (but not limited to) the facilitation of smoking cessation through reduced psychological relief with nicotine patch over placebo patch (Westman et al., 1992), reduced smoking satisfaction with nicotine patch–mecamylamine treatment over either drug alone (Rose et al., 1998), and reduced smoking satisfaction with de-nicotinized cigarettes over nicotinized cigarettes (Brauer et al., 2001). Conversely, such conclusions would be weakened by a negative psychometric evaluation of this instrument.

Evidence for the validity and reliability of the CEQ also has implications for future studies whose objective would be to explain the mechanism of action of pharmacological interventions or to evaluate the extent to which reinforcing effects can help distinguish among interventions. A successful validation of the CEQ would warrant its use to test the hypothesis that the hedonic or reinforcing value derived from an initial lapse would predict progression to a relapse for different treatments and, if that were true, whether this explained or mediated the effect of treatment on progression to relapse. These hypotheses are central to the enhanced understanding of a treatment with regards to how initial smoking lapses represent an important junction between smoking cessation and relapse (Shiffman, Ferguson, & Gwaltney, 2006).

The present study, then, attempts to directly address the gaps in the literature on the validation of the CEQ. More specifically, the purpose of the present study was to conduct a psychometric evaluation of a modified version of the questionnaire containing one additional item. Using a large clinical sample, the current study was designed to achieve two aims: (1) augment the limited research on the psychometric attributes of the CEQ and (2) provide evidence for the psychometric properties of the CEQ using an addition item.

2. Methods

2.1. Modified Cigarette Evaluation Questionnaire (mCEQ)

The modified version of the Cigarette Evaluation Questionnaire (mCEQ) has one extra item (Item 12 on enjoying smoking) in addition to the 11 original items (Rose et al., 1998; Westman et al., 1992). These items are rated on a seven-point scale ranging from 1 (not at all) to 7 (extremely), as shown in Table 1.

Based largely on the original factor and cluster analysis of the CEQ (Westman et al., 1992), we postulated and sought to confirm three multi-item domains (subscales) and two single items (Table 1): Smoking Satisfaction with three items (Items 1, 2, and 12); Psychological Reward with five items (Items 4 through 8); Aversion with two items (Items 9 and 10); Enjoyment of Respiratory Tract Sensations (Item 3); and Craving Reduction (Item 11). In the confirmatory factor analysis that ensued, Item 12 on enjoying smoking was added and pre-specified as belonging to the domain Smoking Satisfaction. Scores for each subscale were calculated as the average of its individual item responses. Higher scores indicated greater intensity of each smoking effect with, for example, greater satisfaction or psychological reward after smoking. There was no reverse scoring (Fig. 1).

2.2. Patients and studies

Data on the mCEQ came from three phase II clinical trials of varenicline for smoking cessation in samples of smokers who intended to quit smoking. The mCEQ was to be completed by all subjects at baseline and thereafter only by those who had smoked at any time post-baseline since they last completed the questionnaire, typically in the week prior to the assessment. Study 1 ($n=626$) was a multi-center, randomized, double-blind, parallel-group, placebo- and active-controlled study with a 7-week treatment phase. Subjects were randomized to one of three varenicline dose regimens (0.3 mg QD, 1.0 mg QD, or

Table 1
Modified Cigarette Evaluation Questionnaire (mCEQ)*

If you have smoked since you last completed this questionnaire, please mark the number that best represents how smoking made you feel (1—not at all, 2—very little, 3—a little, 4—moderately, 5—a lot, 6—quite a lot, 7—extremely).	
1.	Was smoking satisfying?
2.	Did cigarettes taste good?
3.	Did you enjoy the sensations in your throat and chest?
4.	Did smoking calm you down?
5.	Did smoking make you feel more awake?
6.	Did smoking make you feel less irritable?
7.	Did smoking help you concentrate?
8.	Did smoking reduce your hunger for food?
9.	Did smoking make you dizzy?
10.	Did smoking make you nauseous?
11.	Did smoking immediately relieve your craving for a cigarette?
12.	Did you enjoy smoking?

* Items 1, 2, and 12 were presumed or taken to measure "Smoking Satisfaction"; Items 4 through 8 were taken to measure "Psychological Reward"; Items 9 and 10 were taken to measure "Aversion"; Item 3 was taken to measure "Enjoyment of Respiratory Tract Sensations"; and Item 11 was taken to measure "Craving Reduction".

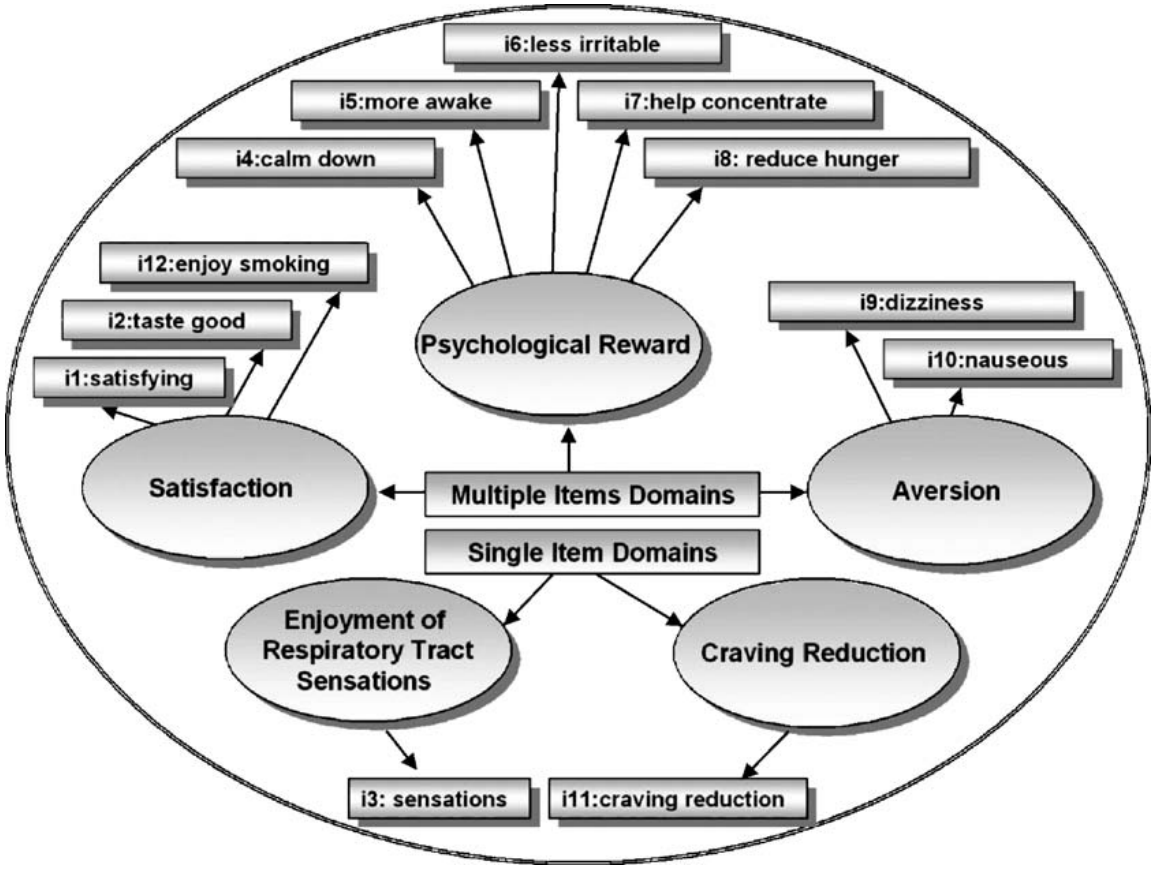


Fig. 1. Multidimensional framework of the Modified Cigarette Evaluation Questionnaire.

1.0 mg BID); to the active control, Zyban® (sustained-release bupropion, 150 mg BID; GlaxoSmithKline, Research Triangle Park, NC); or to placebo. The planned sample size was 125 subjects per treatment group.

Studies 2 ($n=627$) and 3 ($n=312$) were 12-week, multi-center, randomized, double-blind, placebo-controlled studies. Subjects in Study 2 were randomized to placebo or to one of four varenicline dose regimens (0.5 mg BID non-titrated; 0.5 mg BID titrated; 1.0 mg BID non-titrated; and 1.0 mg BID titrated), with a planned sample size of 125 subjects per treatment group. Subjects in Study 3 were randomized to a flexible-dosing regimen of varenicline (0.5 mg QD to 1.0 mg BID) or to matching placebo, with a planned sample size of 150 subjects per treatment group.

In Study 1, the baseline or initial survey of subjects (Week 0, pre-quit) was eight days before the target quit date (Week 1 + 1 day). In Studies 2 and 3, the baseline or initial survey of subjects (Week 0, pre-quit) was 7 days before the target quit date (Week 1).

Inclusion criteria for subjects in the three studies were 1) smoking an average of at least 10 cigarettes per day during the past year, 2) outpatients and assessed in a clinic setting, 3) in good health, 4) aged between 18 and 65 years, and 5) measured with a body mass index (weight in kilograms / [height in meters]^2) no less than 15 and no greater than 38. The Institutional Review Board and independent ethics committee at each center approved the protocol, and written informed consent

was obtained from all subjects. Exclusion criteria for the three studies were 1) need for treatment of depression currently or history of such treatment within the past 12 months, 2) past or present history of psychiatric disorder, 3) history of clinically significant cardiovascular disease or abnormal electrocardiogram, and 4) history of drug (except nicotine) or alcohol abuse or dependence within the past 12 months.

Among the measures collected was the Fagerström test (Heatherton, Kozlowski, Frecker, & Fagerström, 1991), a six-item measure of nicotine dependence, that was administered at screening in all three studies. Its total score can range from 0 to 10, with higher scores indicating greater nicotine dependence.

2.3. Confirmatory factor analyses

A confirmatory factor analysis was conducted on the baseline data of each study, when all subjects were still smoking. We assessed the fit of the hypothesized factor structure based on previous analyses of the CEQ. Specifically, we hypothesized that the mCEQ consists of three multi-item domains: Smoking Satisfaction with three items (Items 1, 2, and 12: satisfying, taste good, enjoy smoking), Psychological Reward with five items (Items 4 through 8: calm down, more awake, less irritable, help concentrate, reduce hunger), and Aversion with two items (Items 9 and 10: dizziness, nauseous). Each of these three latent constructs was allowed to co-vary (correlate) with the other two latent constructs.

Using the baseline data to confirm and evaluate the postulated factors, we assessed the fit of the hypothesized factor structure using the following key indices of fit: Goodness of Fit Index (GFI), Comparative Fit Index (CFI), Normed Fit Index (NFI), Non-Normed Fit Index (NNFI), and Root–Mean–Square Error of Approximation (RMSEA). For the first four of these common indices, values above 0.90 were taken to indicate an acceptable fit (Hatcher, 1994). For the RMSEA, values below 0.10 were considered desirable (Steiger, 1999) and 90% confidence intervals were obtained. A model chi-square statistic, with the null hypothesis of perfect model fit, was also obtained. In addition, tests of statistical significance were appraised for the unstandardized factor loadings and the magnitude of the standardized factor loadings (Hatcher, 1994).

2.4. Reliability analyses

For each of the three studies, we assessed internal consistency and test–retest reliability. Internal consistency, which requires at least two items per domain, was assessed on a multi-item domain at baseline using Cronbach's alpha (measuring the extent to which items on the same domain correlated with one another) and corrected item-to-total correlations (measuring the extent to which an item correlated with the total score on its domain after removing that item's score from the domain total). Using Pearson correlation coefficients, we assessed the test–retest reliability on all five domains of the mCEQ within the first week (before the target quit date) with daily diaries, beginning on Day 1 (the first post-treatment day) and ending on Day 6. Both partial correlation coefficients (which accounted or controlled for treatment group) and simple correlation coefficients were obtained.

All analyses throughout this paper were based on available subjects and performed in SAS (Hatcher, 1994; SAS, 1999).

3. Results

3.1. Patient characteristics

87% (Study 1), 81% (Study 2), and 91% (Study 3) of subjects were white. In all three studies, the mean age was 42 years (range: 18–65 years), and more than half of the subjects had made at least three prior attempts to quit smoking. The studies represented a population of smokers who on average had smoked about 20 cigarettes per day for an average of approximately 25 years. Mean (SD) of total scores at screening on the Fagerström Test for Nicotine Dependence were 5.52 (2.09) in Study 1, 5.48 (2.13) in Study 2, and 5.42 (2.15) in Study 3. All correlations between the five mCEQ subscales at baseline and the six individual items on the Fagerström test, as well as its total score, at screening were below 0.20.

For each of the five hypothesized subscales on the mCEQ, the baseline distribution of the mean score per item across individuals was similar among studies (Table 2). In general, at baseline, smoking was perceived to provide moderate levels of "Smoking Satisfaction" and "Psychological Reward," little "Enjoyment of Sensations in Throat and Chest," substantial "Craving Reduction," and very little "Aversion."

3.2. Confirmatory factor analyses

Confirmatory factor analysis at baseline involved pre-specification of three multi-item domains [Smoking Satisfaction (Items 1, 2, 12), Psychological Reward (Items 4–8), and Aversion (Items 9–10)] and their correlations. Despite a model chi-square statistic rejecting the null hypothesis of perfect fit ($p<0.0001$), values of the GFI, CFI, NFI, and NNFI each exceeded 0.90 in the three studies (Table 3). For example, values of CFI and NNFI were respectively 0.95 and 0.93 in Study 1 and Study 2, and 0.94 and 0.92 in Study 3. Values of the RMSEA were consistently less than 0.10, with 0.07 in two studies and 0.08 in one study (Table 3).

Table 2
Mean score (SE) per item on five domains of the mCEQ at baseline in three studies

Domain*	Study 1	Study 2	Study 3
Smoking satisfaction	4.31 (0.05)	4.33 (0.05)	4.41 (0.07)
	$n=625$	$n=626$	$n=312$
Psychological reward	3.59 (0.05)	3.60 (0.05)	3.51 (0.07)
	$n=625$	$n=626$	$n=312$
Enjoyment of respiratory tract sensations	2.67 (0.06)	2.80 (0.06)	2.84 (0.09)
	$n=619$	$n=621$	$n=310$
Craving reduction	5.05 (0.06)	5.04 (0.06)	5.19 (0.08)
	$n=624$	$n=625$	$n=312$
Aversion	1.42 (0.03)	1.40 (0.03)	1.34 (0.04)
	$n=625$	$n=626$	$n=312$

* Smoking Satisfaction = average of mCEQ questions #1 (Was smoking satisfying?), #2 (Did cigarettes taste good?), and # 12 (Did you enjoy smoking?); Psychological Reward = average of mCEQ questions #4 (Does smoking calm you down?), #5 (Did smoking make you feel more awake?, #6 (Did smoking make you feel less irritable?), #7 (Did smoking help you concentrate?), and #8 (Did smoking reduce your hunger for food); Enjoyment of Respiratory Tract Sensation = mCEQ question #3 (Did you enjoy the sensations in your throat and chest?); Craving Reduction = mCEQ question #11 (Did smoking immediately relieve your craving for a cigarette?); and Aversion = average of mCEQ questions #9 (Did smoking make you dizzy?) and #10 (Did smoking make you nauseous?).

Table 3
Goodness-of-fit indexes from the confirmatory factor model of the mCEQ at baseline in studies 1, 2, and 3

Index	Study 1	Study 2	Study 3
	(n=617)	(n=618)	(n=309)
Goodness-of-fit index	0.96	0.95	0.94
Comparative fit index	0.95	0.95	0.94
Non-normed fit index	0.93	0.93	0.92
Normed fit index	0.94	0.94	0.91
Root–mean–square error of approximation (90% confidence interval)	0.07 (0.06, 0.09)	0.07 (0.06, 0.09)	0.08 (0.06, 0.10)
Chi-square statistic (degrees of freedom)	139.85 (32)	140.53 (32)	98.70 (32)

In addition, all non-standardized factor loadings (or, equivalently, non-standardized path coefficients) from a latent factor to an observed item were highly statistically significant (all $t>3.73$; $p<0.001$). Their t statistics ranged from 15.67 to 23.23 for the Smoking Satisfaction factor linked to its three items, 10.39 to 25.37 for the Psychological Reward factor linked to its five items, and 3.74 to 6.35 for the Aversion factor linked to its two items. The corresponding standardized factor loadings ranged from 0.40 to 0.99 (Table 4); therefore, all loadings were tangible and at least moderate in magnitude.

Estimated correlations between the Smoking Satisfaction (latent) factor scores and the Psychological Reward factor scores from the measurement model were positive, moderate, stable, and statistically significant ($p<0.0001$; $r=0.60$, 0.58, and 0.58 in Studies 1, 2, and 3, respectively). Correlations between the Smoking Satisfaction factor scores and Aversion factor scores were negative, small, stable, and statistically significant ($p\leq 0.01$; $r=-0.17$, -0.17, -0.20). Correlations between the Psychological Reward factor scores and the Aversion factor scores were zero or close to zero and not statistically significant ($p>0.05$; $r=0.11$, 0.01, 0.00).

3.3. Reliability

For the Smoking Satisfaction domain, the test–retest reliabilities on the daily assessments across five consecutive pairs of daily measurements (Days 1 and 2, 2 and 3, 3 and 4, 4 and 5, 5 and 6) were similar in

Table 4
Standardized path coefficients from confirmatory factor analyses of the mCEQ at baseline in studies 1, 2, and 3

Study	Coefficients of smoking satisfaction domain on its three items			Coefficients of psychological reward domain on its five items					Coefficients of aversion domain on its two items	
	Satisfying	Good taste	Enjoy smoking	Calm down	More awake	Less irritable	Help concentrate	Reduce hunger	Dizziness	Nauseous
Study 1 (n=617)	0.83	0.75	0.78	0.77	0.67	0.86	0.71	0.56	0.56	0.66
Study 2 (n=618)	0.82	0.80	0.82	0.71	0.74	0.80	0.73	0.52	0.40	0.99
Study 3 (n=309)	0.80	0.82	0.80	0.72	0.68	0.78	0.73	0.58	0.51	0.85

Table 5
Reliability statistics on the mCEQ at baseline in studies 1, 2, and 3

Reliability estimates in each study	Domains on the mCEQ				
	Smoking satisfaction	Psychological reward	Enjoyment of respiratory tract sensations	Craving reduction	Aversion
Study 1					
Mean day-to-day reliability* (median $n=534$)	0.86	0.84	0.80	0.71	0.72
Cronbach's alpha (median $n=624$)	0.82	0.84	n.a.**	n.a.	0.50
Range for corrected item-to-total correlations (median $n=624$)	8.68–0.70	0.53–0.76	n.a.	n.a.	0.37
Study 2					
Mean day-to-day reliability* (median $n=516$)	0.88	0.88	0.86	0.74	0.80
Cronbach's alpha (median $n=625$)	0.85	0.82	n.a.	n.a.	0.55
Range for corrected item-to-total correlations (median $n=625$)	0.73–0.73	0.48–0.71	n.a.	n.a.	0.41
Study 3					
Mean day-to-day reliability* (median $n=259$)	0.90	0.90	0.85	0.80	0.67
Cronbach's alpha (median $n=311$)	0.84	0.83	n.a.	n.a.	0.56
Range for corrected item-to-total correlations (median $n=625$)	0.70–0.74	0.55–0.69	n.a.	n.a.	0.44

* Mean (simple) Pearson correlation coefficient of five consecutive pairs of scores after baseline from Day 1 through Day 6 (Days 1 and 2; 2 and 3; 3 and 4; 4 and 5; and 5 and 6). Median Pearson correlation coefficients were very similar to mean Pearson correlations.
** n.a.=not applicable.

the three studies (mean r across studies=0.88) (Table 5). Values of Cronbach's alpha on the Smoking Satisfaction domain were consistent in the three studies and exceeded 0.80, with a mean value of 0.84 across studies. Corresponding corrected item-to-total correlations were consistently moderate, ranging from 0.68 to 0.74 across studies.

Reliability estimates on the Psychological Reward domain reflected that of the Smoking Satisfaction domain. Test–retest reliabilities on the daily assessments of the Psychological Reward domain were similar across the three studies (mean $r=0.87$) (Table 5). Values of Cronbach's alpha on the Psychological Reward domain were consistent in the three studies and exceeded 0.80, with a mean value of 0.83. Moreover, corrected item-to-total correlations in the three studies were consistently moderate, ranging from 0.48 to 0.76.

In assessing the test–retest association between Days 1 and 6, we found that the simple Pearson correlation coefficients were virtually identical to the partial Pearson correlation coefficients, so only the simple correlations coefficients were reported here. The test–retest reliabilities on the single-item domains Enjoyment of Respiratory Tract Sensations (mean $r=0.84$) and Craving Reduction (mean $r=0.75$) exceeded 0.70 and, within each domain, results were comparable across the studies (Table 5). For the Aversion domain, test–retest reliabilities on the daily assessments were also comparable (mean $r=0.73$) (Table 5). Values of Cronbach's alpha on the Aversion domain were consistent in the three studies and below 0.60, with a mean value of 0.54 across the studies. In addition, corrected item-to-total correlations tended to be moderate, ranging from 0.37 to 0.44.

3.4. Correlations between domains

Estimated correlations between multi-item factor scores from the latent measurement model generally conformed to their corresponding correlations based on observed scores (Table 6). Pearson correlations between domain scores on the mCEQ at baseline were similar in the three studies (Table 6). In general, scores on the Smoking Satisfaction domain were moderately and positively associated with scores on the Psychological Reward domain (mean r and median r across studies = 0.48) and the Enjoyment of Respiratory Tract Sensations domain (mean r = median r = 0.51). Scores on the Smoking Satisfaction domain had a positive, modest correlation with scores on the Craving Reduction domain (mean r = 0.33, median r = 0.35). Scores on the Psychological Reward domain had a positive, modest correlation with scores on the Enjoyment of Respiratory Tract Sensations domain (mean r = 0.35, median r = 0.33) and Craving Reduction domain (mean r = 0.31, median r = 0.33). Scores on the Enjoyment of Respiratory Tract Sensations domain had a small positive correlation with scores on the Craving Reduction domain (mean r = median r = 0.17). Scores on the Aversion domain bore a small negative, statistically significant correlation with scores on the Smoking Satisfaction domain (mean r = −0.11, median r = −0.10); scores on Aversion were not consistently and tangibly related to the scores on any of the remaining domains.

Table 6
Correlations among domain scores of the mCEQ at baseline in three studies

	Domains on the mCEQ					
mCEQ Domain	Study	Smoking satisfaction	Psychological reward	Enjoyment of respiratory tract sensations	Craving reduction	Aversion
Smoking satisfaction	1	1	0.48	0.47	0.29	−0.10 (p=0.01)*
	2	1	0.48	0.56	0.35	−0.09 (p=0.03)
	3	1	0.47	0.51	0.35	−0.13 (p=0.02)
Psychological reward	1		1	0.32	0.26	0.10 (p=0.01)
	2		1	0.41	0.33	0.04 (p=0.27)
	3		1	0.33	0.34	0.01 (p=0.82)
Enjoyment of respiratory tract sensations	1			1	0.16	−0.05 (p=0.18)
	2			1	0.19	−0.06 (p=0.12)
	3			1	0.17 (p=0.002)	−0.16 (p=0.01)
Craving reduction	1				1	−0.08 (p=0.06)
	2				1	−0.05 (p=0.18)
	3				1	−0.13 (p=0.02)
Aversion	1					1
	2					1
	3					1

Sample sizes ranged from 618 to 625 in Study 1, from 620 to 626 in Study 2, and from 310 to 312 in Study 3. For each study, the estimated correlation between scores on a pair of domains is found in each cell of the table. For example, for Study 1, the estimated correlation between scores on Smoking Satisfaction and Psychological Reward was 0.48, the estimated correlation between Smoking Satisfaction and Enjoyment of Respiratory Tract Sensation was 0.47, and so forth.

* All p values <0.0001 except where noted.

4. Discussion

Evidence is strong that the reinforcing effects of nicotine perpetuate continued smoking behavior. In measuring this reinforcement, we believe it essential to first establish the validity and reliability of the selected instrument in order to better understand the effect of smoking cessation therapies on reducing these experiences (Benowitz, 1999; USDHHS, 1988). In this paper, we have advanced the psychometric properties of the mCEQ using confirmatory factor analysis and reliability analyses in three independent trials of smokers wanting to quit.

The set of confirmatory factor analyses in the three studies at baseline in the current paper supports the postulated measurement model in which a particular set of items is specified in advance to belong to a specific multi-item domain or construct. Five key indices conveyed a good or acceptable fit to the postulated model. Hence, results support the hypothesis that the collective set of three observed items on satisfaction, good taste, and enjoying smoking accurately measure the construct Smoking Satisfaction; the collective set of five observed items on calming, feeling awake, reducing irritability, helping concentration, and reducing hunger accurately measure the construct Psychological Reward; and the collective set of two items on dizziness and nauseous accurately measure Aversion.

The model chi-square statistic, though, suggested rejecting the null hypothesis of perfect fit ($p<.0001$); however, this hypothesis is likely to be implausible because it's unrealistic to expect a model to have perfect population fit. Moreover, the chi-square statistic is known to increase its sensitivity and get larger (and hence be more probable to reject the null hypothesis) with larger correlations and larger sample sizes, even for a very good fitting model where the differences between observed and predicted covariances are slight (Kline, 2005).

In addition to indicating the validity of good model fit, the data endorse the reliability of the Smoking Satisfaction and Psychological Reward subscales. Although the Aversion subscale has acceptable levels of test–retest reliability, its reliability on internal consistency is less than desired. Perhaps this is because internal consistency increases with the number of items, and this subscale consists of only two items. The single-item subscales on Enjoyment of Respiratory Tract Sensations and on Craving Reduction produce adequate levels of test–retest reliability. One plausible explanation for the low correlations (below 0.20) between the mCEQ at baseline and Fagerström Test for Nicotine Dependence at screening is that they were measured at different times, which could be a week or more apart.

In supplemental analyses (whose results are not reported because they were similar to those reported) we also evaluated the robustness of the results when the most salient effects were expected and measured, namely, immediately following the quit date and around the beginning-to-middle period of treatment — that is, at Weeks 1 and 4 in Study 1 and at Weeks 2 and 4 in Studies 2 and 3. At these times, a set of confirmatory factor analyses provided similar fit indices and path coefficients to the results reported at baseline, providing robustness to the factor structure. Additional support for a multi-factor structure was provided by a lack of acceptable fit of a single-factor solution at baseline and at post-treatment (all CFI and NNFI were less than 0.90 and in fact less than 0.80). Furthermore, fit statistics and path coefficients from a confirmatory factor analysis using path analysis with three latent variables (the three multi-item factors) and two observed variables (the two single-item indicators) were similar to those reported in the paper.

Values of Cronbach's alpha at post-treatment (Weeks 1 and 4 in Study 1, Weeks 2 and 4 in Studies 2 and 3) generally resembled those at baseline, providing reassurance on internal consistency

reliability. A notable exception, though, was the Aversion domain for which relatively low mean Cronbach's alpha of 0.54 across the studies at baseline contrasted with larger values ranging from 0.70 to 0.80 at post-treatment. Inter-domain correlations were comparable across the measurement times, including the low correlation of the Aversion domain with the other domains remaining post-treatment, providing confidence about the associations observed between domains at baseline.

The strengths of our evaluation on the mCEQ include three large samples, a priori hypotheses that were tested with confirmatory factor analysis, and insights into the reliability of the questionnaire. The current work, though, can be enhanced by future studies in which test–retest reliability on scores is assessed in a stable group of smokers before treatment intervention. The generalizability of the psychometric results in this investigation is limited to the population that gave rise to the sample, that is, at least moderately dependent smokers (at least 10 cigarettes per day) enrolled as specified in a medication treatment trial. A natural next step is to provide further evidence on the measurement properties of the mCEQ in subsequent trials on medication treatment. Although beyond the scope of the current paper, sensitivity to treatment differences on the multidimensional framework of the mCEQ will be devoted to future research.

5. Conclusions

In summary, the validity of the postulated multidimensional framework of the mCEQ is confirmed by the current analysis. In addition, with the exception of the internal consistency of the Aversion domain, the reliability of the instrument is supported by the data. This investigation provides an enriched understanding of the psychometric merits of specific sensory indicators on the reinforcing effects of smoking, such as smoking satisfaction and psychological reward, as measured by the questionnaire. Self-administered and brief, the questionnaire is suitable for use in clinical and research settings.

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