

Psychometric Evaluation: Differential Person Function Analysis of the Modified Cigarette Evaluation Questionnaire Further Modified for E-vapor and Nicotine Products

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ABSTRACT

The modified Cigarette Evaluation Questionnaire (mCEQ) is a self-report questionnaire to assess the subjective effects of cigarettes. Often, participants in a single study are asked to complete different "versions" of the mCEQ, whereby the mCEQ items are modified to reference different tobacco product categories, such as e-vapor ("mCEQ-E") or nicotine products (nicotine polacrilex gum) ("mCEQ-N"), and scores from these versions are directly compared. However, this assumes that the effects of tobacco products are equally important or equivalent across product categories. In the current study, we directly explored this assumption through differential person function (DPF) analyses. Data from participants (N=345) in 5 clinical studies who completed more than one version of the mCEQ were utilized.

First, results from factor analytic and Rasch modeling approaches supported the removal of an item from the Psychological Reward scale (reduce hunger) and supported combining two scales (Satisfaction and Sensations) as a single scale ("Satisfaction/Sensation").

Second, Rasch models generally revealed similar item difficulties across mCEQ versions for the Psychological Reward and Satisfaction/Sensation scales, although the item hierarchies were not identical, supporting the need for DPF analyses.

Finally, DPF analyses indicated that 9.3% and 17.7% of persons exhibited significant DPF for the Psychological Reward and Satisfaction/Sensations scales, respectively. For example, Satisfaction/Sensation items specifying cigarettes were easier to endorse than the same items specifying e-vapor or nicotine gum, suggesting that scores on this mCEQ-C scale are not directly comparable to the mCEQ-E or mCEQ-N. Researchers should be cautious when directly comparing raw scores from the different mCEQ versions, and differential scoring generated from Rasch models for the mCEQ versions is recommended.

BACKGROUND AND OBJECTIVE

- ▶ The modified Cigarette Evaluation Questionnaire (mCEQ) is a commonly used 12-item multi-dimensional self-report instrument to assess the reinforcing effects of cigarettes (Cappelleri et al., 2007).
- ▶ The mCEQ (referred to here as the mCEQ-C) is commonly modified to reference e-vapor products ("mCEQ-E") and nicotine polacrilex gum ("mCEQ-N") in research studies (e.g., Ebbert, Croghan, North, & Schroeder, 2010; St. Helen, Havel, Dempsey, Jacob, & Benowitz, 2015).
- ▶ This instrument includes 4 scales: Smoking Satisfaction (items 1, 2, 12), Psychological Reward (items 4-8), Aversion (items 9, 10), Craving Reduction (item 11) and Enjoyment of Respiratory Tract Sensations (item 3) (Cappelleri et al., 2007).
- ▶ Despite its popularity, little is known about the psychometric properties of the mCEQ. To our knowledge, two studies have evaluated the psychometric properties of the mCEQ. The first evaluated the factor structure and reliability of the mCEQ through secondary analysis of clinical data from 3 phase II clinical trials for varenicline (Cappelleri et al., 2007). The second explored predictive validity of the mCEQ through secondary analysis of mCEQ data from a study evaluating the reinforcing effects of Spectrum research cigarettes during acute smoking abstinence (Arger et al., 2017).
- ▶ The psychometric invariance of the mCEQ-C, or the modified versions of this instrument (i.e., mCEQ-E, mCEQ-N) has not been established. Said differently, when researchers directly compare reinforcing effects of cigarettes, e-vapor, and nicotine polacrilex gum using the mCEQ-C, mCEQ-E, and mCEQ-N, they are operating under the assumption that the modified items are not functioning differently (i.e., that respondents are not interpreting the items in meaningfully different ways) when modified to reference different tobacco products. This assumption requires empirical evaluation.
- ▶ The objective of the current study was to directly explore this assumption through differential person function (DPF) analyses.

Acronyms	
mCEQ	Modified Cigarette Evaluation Questionnaire
mCEQ-C	Modified Cigarette Evaluation Questionnaire –Cigarette
mCEQ-E	Modified Cigarette Evaluation Questionnaire –E-Vapor
mCEQ-N	Modified Cigarette Evaluation Questionnaire –Nicotine gum
DPF	Differential Person Function
EFA	Exploratory Factor Analysis
CFA	Confirmatory Factor Analysis
MI	Modification Indices

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METHODS

Participants: Full Sample

- ▶ For Step 1: *Initial Psychometric Analyses*, mCEQ data came from 766 participants in 8 clinical studies. For these analyses, the first administration of the mCEQ completed by subjects in each study was utilized.
- ▶ Data were randomly split for purposes of the exploratory (n=365) and confirmatory factor analyses (n=401).

Participants: DPF Sample

- ▶ Data from participants (N=345) in 5 clinical studies who completed more than one version of the mCEQ were utilized to evaluate DPF (Steps 2 and 3).
- ▶ Specifically, 343 completed the mCEQ-C, 345 completed the mCEQ-E, and 152 completed the mCEQ-N.
- ▶ Because subjects completed a version of the mCEQ multiple times during a single study, we randomly selected one of each mCEQ version for this analysis.

Table 1. mCEQ Versions Modified to Reference Different Tobacco/Nicotine Products

	mCEQ-C	mCEQ-E	mCEQ-N
mCEQ01: Was smoking cigarettes satisfying?	Was smoking cigarettes satisfying?	Was using the test e-vapor product satisfying?	Was using nicotine gum satisfying?
mCEQ02: Did the cigarettes taste good?	Did the cigarettes taste good?	Did the test e-vapor product taste good?	Did the nicotine gum taste good?
mCEQ03: Did you enjoy the sensations in your throat and chest?	Did you enjoy the sensations in your throat and chest?	Did you enjoy the sensations in your throat and chest?	Did you enjoy the sensations in your mouth?
mCEQ04: Did smoking cigarettes calm you down?	Did smoking cigarettes calm you down?	Did using the test e-vapor product calm you down?	Did using nicotine gum calm you down?
mCEQ05: Did smoking cigarettes make you feel more awake?	Did smoking cigarettes make you feel more awake?	Did using the test e-vapor product make you feel more awake?	Did using nicotine gum make you feel more awake?
mCEQ06: Did smoking cigarettes make you feel less irritable?	Did smoking cigarettes make you feel less irritable?	Did using the test e-vapor product make you feel less irritable?	Did using nicotine gum make you feel less irritable?
mCEQ07: Did smoking cigarettes help you concentrate?	Did smoking cigarettes help you concentrate?	Did using the test e-vapor product help you concentrate?	Did using nicotine gum help you concentrate?
mCEQ08: Did smoking cigarettes reduce your hunger for food?	Did smoking cigarettes reduce your hunger for food?	Did using the test e-vapor product reduce your hunger for food?	Did using nicotine gum reduce your hunger for food?
mCEQ09: Did smoking cigarettes make you dizzy?	Did smoking cigarettes make you dizzy?	Did using the test e-vapor product make you dizzy?	Did using nicotine gum make you dizzy?
mCEQ10: Did smoking cigarettes make you nauseous?	Did smoking cigarettes make you nauseous?	Did using the test e-vapor product make you nauseous?	Did using nicotine gum make you nauseous?
mCEQ11: Did smoking cigarettes immediately relieve your craving for a cigarette?	Did smoking cigarettes immediately relieve your craving for a cigarette?	Did using the test e-vapor product immediately relieve your craving for a cigarette?	Did using nicotine gum immediately relieve your craving for a cigarette?
mCEQ12: Did you enjoy smoking cigarettes?	Did you enjoy smoking cigarettes?	Did you enjoy using the test e-vapor product?	Did you enjoy using nicotine gum?

Instructions: Please mark the number that best represents how [smoking cigarettes] using e-cigarettes/chewing gum) made you feel.
Rating scale: 1-not at all, 2-very little, 3-a little, 4-moderately, 5-a lot, 6-quite a lot, 7-extremely

mCEQ-C= modified cigarette evaluation questionnaire referencing cigarettes
mCEQ-E= modified cigarette evaluation questionnaire further modified to reference e-vapor
mCEQ-N= modified cigarette evaluation questionnaire further modified to reference nicotine gum

RESULTS

Step 1: Initial Psychometric Analyses

- EFA
- ▶ Three eigenvalues above 1.0 emerged (5.83, 1.68, and 1.17) (Kaiser, 1960).
 - ▶ Examination of factor loadings suggested a factor structure relatively consistent with previous literature (see Table 3).
 - ▶ Items 4-8 loaded most strongly onto factor 1 "Psychological Reward."
 - ▶ Although item 11 also loaded onto the first factor, due to its conceptually distinct content, this item was retained as a single-item scale, "Craving Reduction".
 - ▶ Items 1, 2, 3 and 12 (previously called "Smoking Satisfaction" [items 1, 2, 12] and "Enjoyment of Respiratory Tract Sensations" [item 3]) loaded most strongly onto factor 2. Given the empirical relationship between these items, as well as the conceptual relationship between item content, these 4 items were combined into a single scale, "Satisfaction/Sensations."
 - ▶ Finally, items 9 and 10 loaded strongly onto factor 3, "Aversion."

Table 3. mCEQ Factor Loadings

	Factor 1: Psychological Reward	Factor 2: Satisfaction/Sensations	Factor 3: Aversion
mCEQ01: Was [smoking cigarettes] satisfying?	.713	.837	
mCEQ02: Did the [cigarettes] taste good?	.468	.819	
mCEQ03: Did you enjoy the sensations in your [throat and chest/mouth]?	.518	.736	
mCEQ04: Did [smoking cigarettes] calm you down?	.853	.703	
mCEQ05: Did [smoking cigarettes] make you feel more awake?	.761	.507	
mCEQ06: Did [smoking cigarettes] make you feel less irritable?	.866	.575	
mCEQ07: Did [smoking cigarettes] help you concentrate?	.813	.514	
mCEQ08: Did [smoking cigarettes] reduce your hunger for food?	.598	.365	
mCEQ09: Did [smoking cigarettes] make you dizzy?			.772
mCEQ10: Did [smoking cigarettes] make you nauseous?			.762
mCEQ11: Did [smoking cigarettes] immediately relieve your craving for a cigarette?	.664	.564	
mCEQ12: Did you enjoy [smoking cigarettes]?	.677	.904	

CFA

- ▶ CFA models for Psychological Reward (5 items) and Satisfaction/Sensations (4 items) were created in AMOS.
- ▶ The initial Psychological Reward model yielded less than adequate fit (CFI=.964, GFI=.952, RMSEA=.145). Examination of modification indices (MI) revealed correlated errors between items 4 (calm you down) and 6 (feel less irritable) (MI=25.459). Given this finding and the conceptual overlap in the items' content, the model was subsequently adjusted to allow the errors for item 5 and 10 to be correlated. Results revealed excellent model fit (CFI=.998, GFI=.993, RMSEA=.042).
- ▶ Similarly, after allowing for correlated errors between items 2 and 3 (MI=11.873), the Satisfaction/Sensations model exhibited reasonable model fit (CFA=.999, GFI=.997, RMSEA=.059).

ITEM AND RATING SCALE FUNCTIONING

- ▶ Item 8 (reduce your hunger for food) exhibited disordered thresholds, poor fit (infit=1.57, outfit=1.66) and discrimination (.42), suggesting that this item was degrading the model. This item was removed.
- ▶ The remaining items exhibited ordered thresholds, and item fit statistics and discriminations suggested that the remaining items were productive for measurement.

Step 2: Gauge Item Difficulties and Relative Item Hierarchy Across mCEQ Versions

- ▶ Table 4 shows the item hierarchy for Psychological Reward.
- ▶ For Psychological Reward, the item difficulties and item hierarchies were relatively similar across mCEQ versions, with items 5 (more awake) and 7 (help you concentrate) being most difficult to endorse, followed by items 6 (less irritable) and 4 (calm you down).

Table 4. Item Hierarchy for Psychological Reward

mCEQ-E		mCEQ-C		mCEQ-N	
Difficulty	item#	difficulty	item#	difficulty	item#
0.58	5	0.78	7	0.69	5
0.48	7	0.51	5	0.65	7
-0.41	6	-0.48	6	-0.62	6
-0.66	4	-0.81	4	-0.72	4

Step 3: DPF Analysis

- ▶ For the Psychological Reward scale 9.3% of persons exhibited significant DPF.
- ▶ For the Satisfaction/Sensations scale 17.7% of persons exhibited significant DPF.
- ▶ Satisfaction/Sensations items specifying cigarettes were easier to endorse than the same items specifying e-vapor or nicotine gum. This finding suggests that scores on the Satisfaction/Sensations mCEQ-C scales are not directly comparable to the mCEQ-E or mCEQ-N. Additionally, Satisfaction/Sensations items specifying e-vapor were easier to endorse than the same items specifying nicotine gum. This same pattern was observed for the Psychological Reward scale, but to a lesser extent.

CONCLUSIONS

This research helps to fill the gap with respect to understanding the psychometric properties of the mCEQ. Results from the current study support the following factor structure:

Factor	Item Content
Satisfaction/ Sensations	mCEQ01: Was [smoking cigarettes] satisfying?
	mCEQ02: Did the [cigarettes] taste good?
	mCEQ03: Did you enjoy the sensations in your [throat and chest/mouth]?
Psychological Reward	mCEQ12: Did you enjoy [smoking cigarettes]?
	mCEQ04: Did [smoking cigarettes] calm you down?
	mCEQ05: Did [smoking cigarettes] make you feel more awake?
	mCEQ06: Did [smoking cigarettes] make you feel less irritable?
Aversion	mCEQ07: Did [smoking cigarettes] help you concentrate?
	mCEQ09: Did [smoking cigarettes] make you dizzy?
Craving Reduction	mCEQ10: Did [smoking cigarettes] make you nauseous?
	mCEQ11: Did [smoking cigarettes] immediately relieve your craving for a cigarette?

- ▶ Table 5 shows the item hierarchy for Satisfaction/Sensations.
- ▶ For the Satisfaction/Sensations scale, item difficulties and item hierarchies were relatively similar across mCEQ versions. Item 3 (enjoy the sensations) was the most difficult to endorse, while item 1 (satisfying) was the easiest to endorse. However, with the nicotine gum version of the mCEQ, the relative difficulty of items 12 (enjoy) and 2 (taste good) differed from the mCEQ-E and mCEQ-C.
- ▶ The differences in item difficulties and hierarchies provide support for proceeding with DPF analyses.

Table 5. Item Hierarchy for Satisfaction/Sensations

mCEQ-E		mCEQ-C		mCEQ-N	
Difficulty	item#	difficulty	item#	difficulty	item#
0.88	3	0.96	3	1.05	3
0.42	2	0.43	2	-0.08	12
-0.39	12	-0.44	12	-0.28	2
-0.91	1	-0.95	1	-0.69	1

- ▶ Researchers should be cautious when directly comparing raw composite scores from different mCEQ versions.
- ▶ Results of our analyses indicate that raw mCEQ composite scores may not offer a fair comparison across tobacco/nicotine product categories. We hypothesize that differential scoring generated from Rasch models for the mCEQ versions could enhance measurement quality over and above raw composite scores.

LIMITATIONS AND FUTURE DIRECTIONS

- ▶ Given the limitations associated with secondary analysis (e.g., limited sample sizes), additional research may be needed to replicate these findings.
- ▶ To our knowledge, qualitative research has not been conducted on the mCEQ or the modified mCEQ versions (i.e., mCEQ modified to specify tobacco product categories other than cigarettes). Qualitative research is an important strategy to establish content validity of self-report instruments; for example, cognitive interviewing could help to determine if important reinforcing aspects of e-vapor are missing from the mCEQ-E. Qualitative research may be particularly important as the mCEQ continues to be modified for new emerging categories of tobacco and nicotine-containing products.