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Confirmatory factor analysis of the Autonomy over Tobacco Scale (AUTOS) in adults

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HIGHLIGHTS

- Items tap symptoms of withdrawal, psychological dependence and cue-induced craving.
- A hierarchical structure, with 3 1st- and 1 2nd-order domains fits adolescent smokers.
- Structure was tested in 2 independent samples of adult smokers ($n = 434$ and 335).
- The AUTOS is unidimensional in adult smokers.

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ABSTRACT

Introduction: The Autonomy over Tobacco Scale (AUTOS), a 12-item self-administered questionnaire, was designed to measure autonomy in three correlated lower-order symptom domains: withdrawal, psychological dependence, and cue-induced craving. The factor structure of the AUTOS remains an open question; confirmatory analyses in adolescents supported the hierarchical structure, while exploratory analyses in adolescents and adults yield single-factor solutions. Here we seek to determine whether the hypothesized hierarchical structure is valid in adult smokers.
Methods: The AUTOS was administered to two independent convenience samples of adult current smokers: a calibration sample recruited in the US for online studies, and a confirmation sample drawn from the prospective Nicotine Dependence in Teens study in Montreal. We tested competing hierarchical and single-factor models using the robust weighted least-squares (WLSMV) estimation method.
Results: A single-factor model that allowed correlated error variances between theoretically related items fit well in the calibration sample ($n = 434$), $\chi^2_{SB}(52) = 165.71$; $\chi^2/df = 3.19$; SRMR = 0.03; CFI = 0.96; NNFI = 0.95; RMSEA = 0.07 (95% CI: 0.06, 0.08). Reliability of the single factor was high ($\omega_B = 0.92$) and construct validity was adequate. In the confirmation sample ($n = 335$), a similar model fit well:$\chi^2_{SB}(53) = 126.94$; $\chi^2/df = 2.44$; SRMR = 0.04; CFI = 0.95; NNFI = 0.93; RMSEA = 0.07 (95% CI: 0.05, 0.08). Reliability of the single factor was again high ($\omega_B = 0.92$) and construct validity was adequate.
Conclusion: The AUTOS is unidimensional in adult smokers.

1. Introduction

Smokers who have full autonomy over tobacco can decrease their consumption or stop using tobacco at any time without experiencing unpleasant symptoms or feeling that they must exert undue effort. Thus, a smoker exhibits diminished autonomy over tobacco to the extent that quitting or cutting down on the frequency of smoking or amount consumed requires mental effort (e.g., "self-control") or is accompanied by other symptoms such as craving or withdrawal (DiFranza et al., 2002). The Autonomy over Tobacco Scale (AUTOS), a 12-item self-administered questionnaire, was designed to measure autonomy in three correlated domains within which symptoms can arise: withdrawal, which is triggered by abstinence; psychological dependence (e.g., relying on tobacco to provide certain benefits like dealing with stress); and cue-induced craving, which is triggered by identifiable environmental or internal cues (DiFranza, Wellman, Ursprung, & Sabiston, 2009).

Confirmatory factor analyses of the AUTOS with two adolescent samples suggested that our hypothesized theoretical model, in which

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autonomy is a higher-order latent factor represented by the three lower-order latent symptom domains (withdrawal, psychological dependence, cue-induced craving), fit well (DiFranza et al., 2009; Wellman et al., 2012). To date, only an exploratory factor analysis has been conducted with adults; it yielded a single factor that accounted for 59% of the variance (DiFranza et al., 2009). Researchers and clinicians would benefit from knowing whether the AUTOS should be viewed as multidimensional or unidimensional in smokers at different ages. If the hierarchical structure is supported in adult smokers, researchers can be confident in using all three subscales as independent measures, as well as using the AUTOS as a single index of autonomy. However, if the hierarchical structure is not supported among adult smokers, then the AUTOS should be used only to measure overall autonomy in that subgroup.

1.1. Objective and hypotheses

Our objective in this study was to investigate which factor structure of the AUTOS best describes adult smokers. We tested two competing hypotheses:

H1. The structure of the AUTOS is hierarchical, with autonomy as a second-order latent factor represented by three first-order latent factors: withdrawal symptoms, psychological dependence, and cue-induced craving.

H2. The structure of the AUTOS is unidimensional, with autonomy as first-order latent factor represented by the 12 individual items.

2. Method

2.1. Recruitment and data collection

2.1.1. The calibration sample

The calibration sample was recruited in 2010 through electronic communications to participate in several online studies of tobacco dependence (DiFranza, Savageau, & Wellman, 2012; DiFranza et al., 2013). Links to the surveys were posted on the websites of a large health care system in Central Massachusetts and its associated medical school, and on www.Craigslist.com/Boston. In addition, a single email invitation was sent to staff and students of a state university in Central Massachusetts and to students of six universities in Mississippi that participate in a research network coordinated by the Social Science Research Center of Mississippi State University. No incentive was provided for participation.

To maximize the range of cigarette consumption of current smokers in the calibration sample, the electronic communications asked potential participants if they had smoked at least one cigarette in the preceding 3 months and if they wished to participate in "a research study about the experiences people have when they smoke." They were provided with a link that directed them to the consent page of the survey, which was hosted on a password-secured server. After reading a description of the survey, respondents attested that they were at least 18 years of age and currently smoked cigarettes, and agreed to participate. The survey contained the AUTOS, demographic questions and additional items appropriate to the particular study; it could be completed in less than 10 min. All study procedures were approved by the Institutional Review Boards of the University of Massachusetts Medical School, Fitchburg State University, and Mississippi State University.

A total of 841 individuals began to complete the questionnaire, five of whom indicated that they were less than 18 years of age and were therefore eliminated. We analyzed the data contributed by participants who completed the questionnaire in its entirety. Therefore all participants in the calibration sample had complete data on the AUTOS.

2.1.2. The confirmation sample

The confirmation sample was drawn from the Montreal-based prospective Nicotine Dependence in Teens (NDIT) cohort study. Detailed information on participant recruitment and retention, survey design and administration, and additional aspects of the NDIT study is available in O'Loughlin et al. (2014). Briefly, the NDIT study involved in-class surveys every 3 months during grades 7–11 (1999–2000 to 2004–2005) with two additional postsecondary school surveys in 2007–2008 and 2011–2012. In the 2007–2008 survey, from which data for the current study were drawn, questionnaires were mailed to participants' homes; they contained the AUTOS, demographic questions, and items assessing a wide variety of other variables. Participants provided consent, and the NDIT study was approved by the McGill University Institutional Review Board and the Ethics Research Committee of the Centre de Recherche du Centre Hospitalier de l'Université de Montréal.

Participants who indicated that they had smoked on at least 1 day during the preceding 3 months and who provided complete data on the AUTOS were included in the confirmation sample.

2.2. Participant characteristics

In the calibration sample ($n = 434$), 61.8% of participants were female, 86.9% identified as White, 0.5% as American Indian/Alaskan Native, 2.6% as Asian, 3.5% as Black, 4.2% as Hispanic, and 2.3% as mixed race; the mean age was 33.3 years (SD = 13.7, range: 18–78). Approximately one-sixth (17.4%) smoked less than monthly, 9.0% smoked at least monthly but less than weekly, 17.4% smoked 1–6 days per week, and 56.1% smoked daily; on average they smoked 8.2 ($SD = 7.8$, range: <1–50) cigarettes per smoking day. Compared to participants in the calibration sample, those who began but did not complete the survey ($n = 402$) were younger ($M_{age} = 31.1$ years, $SD = 14.1$; $t(787) = 2.22$, $p = 0.026$), smoked less frequently ($\chi^2(3) = 196.08$, $p < 0.001$) and smoked fewer cigarettes per day ($M_{cpd} = 3.5$, $SD = 6.5$, $t(555) = 8.28$, $p < 0.001$). The groups did not differ in distribution by sex or race/ethnicity.

In the confirmation sample ($n = 335$), 57.3% of participants were female, 87.1% self-identified as White, 1.5% as Arab, 3.6% as Asian, 0.9% as Black, 2.1% as Latin American, and 4.5% as mixed or other race; the mean age was 20.5 years ($SD = 0.82$, range: 18.5–24.4). One-fifth (20%) smoked less than monthly, 25.7% smoked at least monthly but less than daily, and 54.3% smoked daily; on average they consumed 7.3 cigarettes per smoking day ($SD = 7.3$, range: 0.5–30.0).

2.3. Measures

Response options for the 12 AUTOS items (see Table 1) are *describes me not at all*, *describes me a little*, *describes me pretty well*, and *describes me very well*, scored 0–3. Among adult smokers, internal consistency was high ($\alpha = 0.93$). Concurrent validity was demonstrated by differences in AUTOS scores relative to smoking status (nondaily < daily) and the correlation of scores with cigarette consumption (DiFranza et al., 2009), longest period of abstinence, smoking because of momentary need, duration of smoking, concern about deprivation, and other variables (DiFranza, Savageau, & Wellman, 2012).

2.4. Data analysis

We conducted confirmatory factor analyses (CFA) on the asymptotic covariance matrix of both samples using the robust weighted least-squares estimation method, which is recommended for ordinal indicators with fewer than five response options (Flora & Curran, 2004). This estimation method produces a Satorra–Bentler scaled chi-square (χ^2_{SB}: Satorra & Bentler, 1994) as a measure of overall model fit.

The hierarchical model was specified by loading indicators uniquely onto each appropriate lower-order factor, fixing the first loading of each congeneric set of indicators to 1.0 for identification, and constraining the

Table 1
Item response distributions for the 12 AUTOS items in the calibration and confirmation samples.

Item	Calibration sample ($n = 434$)				Confirmation sample ($n = 335$)			
	0	1	2	3	0	1	2	3
1. When I go too long without a cigarette, I get impatient	174	121	93	46	156	105	47	27
2. When I go too long without a cigarette, I get strong urges that are hard to get rid of	174	94	97	69	196	79	41	19
3. When I go too long without a cigarette, I lose my temper more easily	215	101	70	48	187	81	41	26
4. When I go too long without a cigarette, I get nervous or anxious	203	99	76	56	196	78	42	19
5. I rely on smoking to focus my attention	264	98	47	25	275	44	14	2
6. I rely on smoking to keep from feeling bored	173	135	75	51	178	98	42	17
7. I rely on smoking to deal with stress	108	126	113	87	188	85	27	35
8. I would go crazy if I couldn't smoke	231	107	65	31	221	73	23	18
9. When I feel stressed, I want a cigarette	64	84	123	163	94	106	63	72
10. When I see other people smoking, I want a cigarette	75	137	111	111	87	134	72	42
11. When I smell cigarette smoke, I want a cigarette	172	149	74	39	173	111	36	15
12. After eating, I want a cigarette	130	68	87	140	116	56	58	105

error variances to be uncorrelated. Based on the CFA with American adolescents (DiFranza et al., 2009) we believed that the model could be improved by correlating error variances between two pairs of theoretically related items; thus, we examined modification indices and examined a modified model as necessary. The same procedure was followed in testing the single-factor model in which autonomy was the only latent variable.

Overall goodness of model fit was indicated according to the following guidelines: descriptive fit ratio (χ^2_{SB}/df) < 3 (Iacobucci, 2010); standardized root mean square residual (SRMR) < 0.09; comparative fit index (CFI) ≥ 0.95; non-normed fit index (NNFI) ≥ 0.95; root mean square error of approximation (RMSEA) < 0.07 (Hu & Bentler, 1999; Iacobucci, 2010; Steiger, 2007). We compared nested models using the difference test for the scaled chi-square (Bryant & Satorra, 2012). Reliability of the latent factors was assessed by calculating McDonald's omega (ω; McDonald, 1970), two forms of which are recommended: ω_A is used when item error variances are uncorrelated, while ω_B is modified to account for covariance between items (Gignac, 2009). Construct validity of the latent factors (i.e., the degree to which the variance extracted by the factor exceeds the variance attributable to measurement error) was assessed by calculating average variance extracted (AVE — also referred to as $\rho_{vc\ (\eta)}$ — Fornell & Larcker, 1981).

Omega is analogous to Cronbach's alpha and can be interpreted in a similar fashion; thus, values of CR > 0.80 are adequate for basic research and those >0.90 are acceptable for clinical decision-making (Gignac, 2009; Nunnaly, 1978). Values of AVE >0.50 indicate adequate construct validity, since the amount of variance extracted is greater than the amount of error variance (Fornell & Larcker, 1981). In a multi-factor model, discriminative validity of the first-order latent factors (i.e., the degree to which the first-order factors measure different constructs) is indicated when the square-root of a factor's AVE is greater than the correlation between the factor and the other first-order factors in the model (Fornell & Larcker, 1981). Descriptive statistics were calculated with SPSS version 22 and the CFA was conducted with the lavaan package for the R statistical system (Rosseel, 2012).

3. Results

3.1. The hierarchical model

The hierarchical model initially produced an improper solution in the calibration sample, as indicated by (i) a negative variance for the psychological dependence latent factor and (ii) a covariance matrix that was not positive definite (Chen, Bollen, Paxton, Curran, & Kirby, 2001; Gerbing & Anderson, 1987). After fixing the variance of the psychological dependence factor to 0.005, which has been shown to produce results equivalent to the original misspecified model (Gerbing & Anderson, 1987), a proper solution was achieved.

In the calibration sample, the initial hierarchical model, with uncorrelated error variances, was not a good fit: $\chi^2_{SB}(52) = 259.15$; $\chi^2/df = 4.98$; SRMR = 0.04; CFI = 0.93; NNFI = 0.91; RMSEA = 0.10 (95% CI: 0.08, 0.11). The withdrawal factor demonstrated high reliability ($\omega_A = 0.93$) and adequate construct validity (AVE = 0.77). Reliability of the cue-induced craving factor was moderate ($\omega_A = 0.82$) and construct validity was adequate (AVE = 0.54). However, reliability and construct validity of the psychological dependence factor were below acceptable standards ($\omega_A = 0.78$, AVE = 0.48). Although modification indices suggested that model fit could be improved by allowing the error variances of two pairs of items to correlate, in light of the poor psychometrics of the psychological dependence factor we did not test a modified model.

With the confirmation sample, the model with uncorrelated error variances was a relatively good fit: $\chi^2_{SB}(51) = 126.86$; $\chi^2/df = 2.48$; SRMR = 0.04; CFI = 0.94; NNFI = 0.93; RMSEA = 0.07 (95% CI: 0.05, 0.08). The withdrawal factor again demonstrated high reliability ($\omega_A = 0.91$) and adequate construct validity (AVE = 0.72), while the cue-induced craving factor demonstrated moderate reliability ($\omega_A = 0.82$) and adequate construct validity (AVE = 0.54). Reliability and construct validity of the psychological dependence factor were again low ($\omega_A = 0.74$, AVE = 0.42).

3.2. The single-factor model

In the calibration sample, the single-factor model with uncorrelated error variances was not a good fit: $\chi^2_{SB}(54) = 300.79$; $\chi^2/df = 5.78$; SRMR = 0.05; CFI = 0.91; NNFI = 0.89; RMSEA = 0.10 (95% CI: 0.09, 0.11). Modification indices suggested that model fit could be improved by allowing the error variances between two pairs of items to correlate: item #7 ("I rely on smoking to deal with stress") with item # 9 ("When I feel stressed, I want a cigarette"), both of which assess the relationship between stress and smoking; and item #10 ("When I see other people smoking, I want a cigarette") with item #11 ("When I smell cigarette smoke, I want a cigarette), both of which tend to occur simultaneously. This modified model fit significantly better: $\chi^2_{SB}(52) = 165.71$; $\chi^2/df = 3.19$; SRMR = 0.03; CFI = 0.96; NNFI = 0.95; RMSEA = 0.07 (95% CI: 0.06, 0.08); χ^2 diff(2) = 203.74, $p < 0.001$). Reliability of the single factor was high ($\omega_B = 0.92$) and construct validity was adequate (AVE = 0.56).

In the confirmation sample, the single-factor model with uncorrelated error variances fit relatively well: $\chi^2_{SB}(54) = 157.68$; $\chi^2/df = 2.92$; SRMR = 0.05; CFI = 0.92; NNFI = 0.91; RMSEA = 0.08 (95% CI: 0.06, 0.09). Correlating the error variances between item #10 and item #11 significantly improved model fit: $\chi^2_{SB}(53) = 126.94$; $\chi^2/df = 2.44$; SRMR = 0.04; CFI = 0.95; NNFI = 0.93; RMSEA = 0.07 (95% CI: 0.05, 0.08; χ^2 diff(1) = 40.66, $p < 0.001$). The single factor demonstrated high reliability ($\omega_B = 0.92$) and adequate construct validity (AVE = 0.52). Table 1 presents the response distribution of the AUTOS items

and Table 2 presents the standardized factor loadings and variances of the items in the modified single-factor model.

4. Discussion

In developing the AUTOS we began with the notion that there may exist more than one type of tobacco dependence, as reflected in separate symptom domains of withdrawal, psychological dependence and cue-induced craving (DiFranza et al., 2009), each of which may have different determinants, may develop through different mechanisms, and may have different effects on smokers' ability to stop using tobacco. To test these hypotheses, an instrument was needed to distinguish among the symptom domains and potentially to identify individuals who had only withdrawal symptoms, only psychological dependence, or only cue-induced craving.

Based on our findings in this study, we must reject our hypothesis that autonomy over tobacco among adult smokers can be conceptualized as separate symptom domains. This contrasts with our findings that, among adolescent smokers, each domain exhibits high reliability, construct validity and discriminative validity (DiFranza et al., 2009; Wellman et al., 2012), and raises the question of whether smoking over a prolonged time span blurs the boundaries among the domains. Longitudinal research in which smokers are followed from early in their smoking careers until middle or late adulthood might shed light on this issue.

Why might distinctions between these domains fade with time? The NDIT study demonstrated that symptoms of physical dependence develop very early in the course of smoking (Gervais, O'Loughlin, Meshefidjain, Bancej, & Tremblay, 2006). Among adults, scores on the three AUTOS subscales increase in direct proportion to the severity of physical dependence (DiFranza, Wellman, & Savageau, 2012). Smoking cue-reactivity correlates with the strength of addiction (Engelmann et al., 2012). Just as the brain becomes more attuned to food cues under conditions of food deprivation, the brain becomes more reactive to smoking cues under conditions of nicotine deprivation (Lim et al., 2005). It makes sense then that as a smoker becomes more physically dependent he or she will respond more to smoking cues, both internal and external.

Certain symptoms of nicotine withdrawal overlap with those produced by stress (anxiety, restlessness, irritability, inability to concentrate). The symptoms of nicotine withdrawal can only be aborted by nicotine. Individuals who have experienced instant relief from nicotine withdrawal by smoking may conclude that smoking should also relieve anxiety, restlessness, and irritability caused by stress. In this way they acquire a psychological belief that they need to smoke to cope with stress. Therefore, it seems likely that both psychological dependence on tobacco and cue-induced craving will increase in proportion to the strength of physical dependence. This might explain why subscales can be distinguished when the AUTOS is used with adolescent smokers but why the domains may be so strongly correlated among adult smokers as to make it difficult to statistically isolate three subscales.

4.1. Limitations

Limitations of this study include use of convenience samples which may not be representative of the population of smokers. However, while the diversity in age, smoking frequency and cigarette consumption suggest that this may not be an issue, the small percentage of participants in both samples who were non-Caucasian may limit the generalizability of our findings to non-Caucasians. The online data collection technique for the calibration sample, which eliminated AUTOS data for any respondent who did not complete the questionnaire in its entirety, eliminated somewhat younger, very light smokers. As the results were very similar for the calibration and confirmation samples, selection bias does not appear to be an issue. Finally, use of self-report questionnaires is always subject to social desirability bias. In this instance, however, participants would have had no incentive to lie, as they were anonymous in the online survey and as their smoking behaviors were already known in the NDIT study.

4.2. Conclusion

With adult smokers the AUTOS can best be used to generate a single score by summing responses to all 12 items. Researchers or clinicians who wish to calculate separate subtest scores for the three symptom domains should do so with caution, recognizing that the withdrawal subscale appears to be the only one with adequate reliability and construct validity in adults. However, the AUTOS can still be used for its originally intended purpose — to track changes in individual symptoms over time after cessation — since such tracking necessitates only that the items accurately assess each symptom. With adolescent smokers, in instances where assessment of the three individual symptom domains is warranted, clinicians and researchers can feel confident that they are not violating statistical assumptions by generating both a single overall autonomy score and subscale scores for withdrawal, psychological dependence and cue-induced craving.

Table 2
Standardized coefficients for factor loadings and error variance for the 12 AUTOS items in confirmatory factor analyses.

Item	Calibration sample ($n = 434$)		Confirmation sample ($s = 355$)	
	λ	σ^2	λ	σ^2
1. When I go too long without a cigarette, I get impatient	0.88	0.22	0.84	0.30
2. When I go too long without a cigarette, I get strong urges that are hard to get rid of	0.88	0.23	0.80	0.36
3. When I go too long without a cigarette, I lose my temper more easily	0.82	0.33	0.82	0.33
4. When I go too long without a cigarette, I get nervous or anxious	0.86	0.27	0.83	0.30
5. I rely on smoking to focus my attention	0.67	0.55	0.52	0.73
6. I rely on smoking to keep from feeling bored	0.54	0.71	0.55	0.70
7. I rely on smoking to deal with stress	0.72	0.48[a]	0.75	0.44
8. I would go crazy if I couldn't smoke	0.76	0.42	0.69	0.53
9. When I feel stressed, I want a cigarette	0.76	0.43[a]	0.82	0.33
10. When I see other people smoking, I want a cigarette	0.61	0.62[b]	0.68	0.53[c]
11. When I smell cigarette smoke, I want a cigarette	0.59	0.66[b]	0.56	0.68[c]
12. After eating, I want a cigarette	0.77	0.40	0.69	0.53
	$\omega_B = 0.92$, AVE = 0.56		$\omega_B = 0.92$, AVE = 0.52	

ω_B = reliability; AVE = average variance extracted.
[a] Covariance = 0.50.
[b] Covariance = 0.37.
[c] Covariance = 0.36.

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Contributors

Drs. Wellman and DiFranza reviewed the literature, created the AUTOS, recruited the calibration sample and designed and oversaw the studies in which data were collected from its members. Dr. Wellman developed the analytic strategy and conducted the analyses, and wrote the first draft of the manuscript. Dr. DiFranza reviewed and edited drafts of the manuscript. Dr. O'Loughlin developed and oversaw all aspects of the NDIT study, reviewed the literature, and reviewed and edited drafts of the manuscript. All authors contributed to and have approved the final draft of the manuscript.

Conflict of interest

The authors declare no conflicts of interest.

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