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Confirmatory Factor Analysis of the Minnesota Nicotine Withdrawal Scale

Benjamin A. Toll, **Stephanie S. O'Malley**, **Sherry A. McKee**, **Peter Salovey**, and **Suchitra Krishnan-Sarin**
Benjamin A. Toll, Stephanie S. O'Malley, Sherry A. McKee, and Suchitra Krishnan-Sarin, Department of Psychiatry, School of Medicine, Yale University; Peter Salovey, Department of Psychology, Yale University

Abstract

The authors examined the factor structure of the Minnesota Nicotine Withdrawal Scale (MNWS) using confirmatory factor analysis in clinical research samples of smokers trying to quit (n = 723). Three confirmatory factor analytic models, based on previous research, were tested with each of the 3 study samples at multiple points in time. A unidimensional model including all 8 MNWS items was found to be the best explanation of the data. This model produced fair to good internal consistency estimates. Additionally, these data revealed that craving should be included in the total score of the MNWS. Factor scores derived from this single-factor, 8-item model showed that increases in withdrawal were associated with poor smoking outcome for 2 of the clinical studies. Confirmatory factor analyses of change scores showed that the MNWS symptoms cohere as a syndrome over time. Future investigators should report a total score using all of the items from the MNWS.

Keywords

tobacco; nicotine; withdrawal; craving; confirmatory factor analysis

The accurate assessment of nicotine withdrawal has received considerable attention over the past 3 decades (e.g., Hughes & Hatsukami, 1986; Patten & Martin, 1996; Shiffman & Jarvik, 1976). Although several scales have been developed for this purpose, the Minnesota Nicotine Withdrawal Scale (MNWS) is the one most frequently used (Shiffman, West, & Gilbert, 2004). This eight-item scale measures withdrawal symptoms (i.e., craving, irritability, anxiety, difficulty concentrating, restlessness, increased appetite or weight gain, depression, and insomnia) listed in the *Diagnostic and Statistical Manual of Mental Disorders* (4th ed.; *DSM–IV*; American Psychiatric Association, 1994), and these symptoms are generally scored on an ordinal scale ranging from 0 (*not present*) to 4 (*severe*; Patten & Martin, 1996). The MNWS has been validated in multiple studies (Hughes, 1992; Hughes, Gust, Skoog, Keenan, & Fenwick, 1991; Hughes & Hatsukami, 1986). In both the Hughes (1992) and Hughes et al. (1991) studies, although observer ratings of MNWS withdrawal symptoms were not highly concordant with self-ratings, both sets of ratings were sensitive to abstinence effects, showing evidence of good reliability and validity for the scale.

When considering the potential factor structure of the MNWS, the underlying theoretical construct of the withdrawal syndrome warrants consideration. As indicated in the *DSM–IV* (American Psychiatric Association, 1994), a syndrome connotes that multiple symptoms are

Correspondence concerning this article should be addressed to Benjamin A. Toll, Department of Psychiatry, Yale University School of Medicine, 1 Long Wharf Drive, Box 18, New Haven, CT 06511. E-mail: benjamin.toll@yale.edu.

present such that they can be grouped together in association with a common origin (Shiffman et al., 2004). The withdrawal syndrome is made up of a series of symptoms that occur after cessation of smoking, characterized by "irritability, anxiety, nocturnal awakening, depression, difficulty concentrating, hunger, restlessness, impatience, and a strong desire (i.e., craving) for nicotine" (Hughes, 1992, p. 689).

A recent review conceptualized the withdrawal syndrome as a temporary disruption of homeostasis leading to a difference in the internal state resulting from cessation or reduction of nicotine use (Shiffman et al., 2004). Classic psychopharmacologic theory maintains that during this disruption of homeostasis, aversive symptoms will appear in reaction to the withdrawal of chronic levels of nicotine in the system. These aversive symptoms threaten abstinence and reward smoking when drug replacement restores homeostasis (Piasecki, Jorenby, Smith, Fiore, & Baker, 2003b). Thus it follows that withdrawal is by definition a temporary syndrome in which the body is in a state of distress and trying to restore homeostasis as quickly as possible. Because of the temporary nature of this syndrome, the timing of the measurement of symptoms is important, as symptom severity may vary over time and symptoms eventually disappear. However, the time course of these symptoms appears to have greater variability than initially believed (Piasecki, Jorenby, Smith, Fiore, & Baker, 2003a, 2003b, 2003c). There is also evidence that some withdrawal symptoms (i.e., hunger, negative affect) do not dissipate even after 30 days, but it is unclear whether these are actually withdrawal symptoms or underlying psychopathology (Gilbert et al., 2002, 2004; Hughes, 1992). Nevertheless, these findings suggest that the assessment of withdrawal needs to account for the variability and time course of symptoms, and there are implications for the factor structure of the scale. For instance, it is possible that the nature of the syndrome may change over the course of the cessation attempt, in which case the factor structure of the scale may differ across time. This is also in accordance with the theoretical construct of withdrawal, which suggests that symptoms in this time-limited syndrome might wax and wane over time, with homeostasis eventually being restored. It may be the case that certain symptoms (e.g., hunger, negative affect) cluster together at later time points of assessment. In addition, given the frequency with which symptoms are grouped together and the time-limited course of symptoms after nicotine deprivation (Hughes, 1992), withdrawal should be considered a syndrome with serious clinical significance.

The symptoms that compose the MNWS are thought to represent withdrawal adequately, as they are in concordance with laboratory studies showing that "cessation from tobacco increases aggressive responding, is labeled as anxiety-like in animal studies, impairs performance on cognitive tasks, increases energy intake, increases pleasantness of sweets, increases false starts in vigilance tasks, and increases rapid eye movement intensity" (Hughes et al., 1991, p. 52). Hughes (1992) considered a symptom to be valid if results showed significant measurable differences in the symptom during periods of abstinence as compared with periods of smoking (i.e., nicotine consumption). After establishing a baseline measurement, researchers have shown that these MNWS symptoms are valid signs of nicotine withdrawal, as they are alleviated by nicotine replacement therapy and occur with the termination of tobacco smoking (Hughes et al., 1991; Hughes, 1992).

Several detailed studies of tobacco withdrawal have used the MNWS with large samples of participants (e.g., $N = 893$) and shown that the total score of the MNWS is a reasonable unitary construct (e.g., Piasecki et al., 2003c). These studies reported that a series of correlational analyses showed positive correlation indices among all eight of the MNWS symptoms when both a single day and rates of change over time were considered. Also, the coefficient alpha for the total scale score was over .80, and no single item consistently improved alpha after deletion from the MNWS. Therefore, on the basis of theory and research, it would be expected that factor analysis of the MNWS would yield a single factor. In a study with 794 ex-smokers

who had quit 0 to 31 days before administration of the MNWS, Etter and Hughes (2006) conducted both exploratory and confirmatory factor analyses yielding a single factor structure.

However, in two other studies in which researchers examined the structure of the MNWS using exploratory factor analysis, multiple-factor solutions were reported. In a sample of 105 smokers studied 1 to 2 weeks after quitting, Hughes et al. (1991) reported a factor analysis that yielded four factors: mood (anger, anxiety, difficulty concentrating, impatience, and restlessness), somatic complaints, other symptoms (hunger and insomnia), and craving. In another study with 178 smokers who quit, Hughes (1992) conducted a factor analysis 7 days after they quit, which yielded three factors: mood (anxiety, difficulty concentrating, irritability, and restlessness), appetite (hunger and weight gain), and insomnia. In Hughes's study, the mood factor accounted for 39% of the variance, and the appetite and insomnia factors each contributed 12%, accounting for a total of 63% of the variance in his data. It should be noted that the timing of the assessment of both of these studies differed from the timing of the Etter and Hughes (2006) study, and the sample sizes were much smaller, which might account for the different factor analytic findings.

As a result of these discrepant findings regarding the factor structure of the MNWS, recommendations on how to score the instrument are unclear. Although many researchers sum the items in the MNWS to report a total symptom score (e.g., Jorenby et al., 1996; Piasecki, Fiore, & Baker, 1998), Shiffman et al. (2004) criticized this scoring procedure as being less than optimal because some factor analytic research has revealed three or four underlying factors. To minimize misinterpretation of the scale and improve comparability across studies, Hughes and Hatsukami (1998) suggested that researchers report mean scores for each of the items rather than a total score. Unfortunately, this may also be a less than optimal scoring format for the MNWS because the reliability of single items is typically inadequate (Tiffany, 1997).

To resolve these inconsistencies, further factor analytic work is needed to determine whether more reliable multiple-item factors exist or whether a single-factor structure best explains the data. The establishment of a standard format for scoring the scale should facilitate comparisons across studies so as to inform clinical practice. For example, a better understanding of the relationship of withdrawal to relapse could guide behavioral and pharmacological interventions. The pattern of changing withdrawal symptoms (e.g., late symptom elevations) has been associated with relapse in several studies (Piasecki et al., 1998, 2003b), and withdrawal severity is a predictor of abstinence (Kenford et al., 2002).

Another important issue in the use of the MNWS is whether ratings of craving should be incorporated into the scale. Craving was included as a withdrawal symptom in the original MNWS scale development study (Hughes & Hatsukami, 1986) because it was listed as a symptom in the third and revised third editions of the *Diagnostic and Statistical Manual of Mental Disorders* (American Psychiatric Association, 1980, 1987). However, craving was dropped from the fourth edition of this manual (American Psychiatric Association, 1994). Therefore, Hughes and Hatsukami (1998) suggested omitting this item when calculating a total score for the scale. Given that the scale is typically used to assess the intensity of the withdrawal syndrome rather than for making a diagnosis of nicotine withdrawal, an alternative approach is to examine the factor structure of the MNWS to determine whether to include this item.

Although craving was dropped from the *DSM–IV* (American Psychiatric Association, 1994) as a withdrawal symptom, Shiffman et al. (2004) asserted that this symptom is critical to assessment in clinical trials. Arguably, craving is a necessary target for adequate withdrawal assessment. Not only does craving promote relapse, but also it is believed to be a direct cause of distress and a deterrent to quit attempts (Shiffman, 2005; Shiffman et al., 2004). Some

researchers have argued that craving is the most predominant withdrawal symptom (Gritz, Carr, & Marcus, 1991). By establishing a reliable craving assessment as part of the MNWS, researchers may help to develop more effective smoking treatment plans.

In summary, there have been different findings regarding the factor structure of the MNWS and discrepancies relating to the scoring procedure for the scale. Additionally, recent studies have shown variability in the time course of withdrawal symptoms (e.g., Gilbert et al., 2002; Piasecki et al., 2003a). Thus, the present study was designed to (a) reconcile the conflicting findings regarding the factor structure of the scale to determine whether data from the questionnaire are more appropriately reported as a total score or as two or more factor scores, (b) assess the factor structure of the MNWS over time, and (c) determine if craving should be included in the total score or factor scores of the scale. The study design implemented in the present investigation has several advantages. We use three relatively large clinical research samples with controlled timing of MNWS assessment, and we assess the factor structure of the MNWS using confirmatory factor analysis over time. Last, because we have data on the long-term clinical outcomes of participants, we are able to compare factor scores derived from different confirmatory factor analytic models to analyze whether increases in withdrawal symptoms during an acute quit period predict smoking cessation treatment outcome.

Method

Participants and Procedure

The MNWS was administered to participants in three separate clinical trials at multiple study time points. Analyses were conducted on participants who completed the MNWS and who (a) were smoking at baseline and (b) quit smoking at all subsequent time points, which was defined as reporting no smoking in the past week paired with a carbon monoxide reading of less than or equal to 10 parts per million (ppm) on the day of reporting (Fiore et al., 2000; SRNT Subcommittee on Biochemical Verification, 2002).

The first clinical trial, the abstinence study, was designed to assess the effects of acute abstinence from smoking. Participants (N = 115) received a contingency management intervention to quit smoking without the aid of medications (Krishnan-Sarin, 2005). The time points of MNWS analysis in this 4-week trial were baseline and Weeks 1 and 4. Relatively few abstinent participants completed the MNWS at later time points in this study (i.e., 45 or fewer participants from Weeks 2 through 4). Because of the low number of participants per item, it would be statistically inappropriate to conduct confirmatory factor analyses at these later time points (Hatcher, 1994). Therefore, we factor analyzed data from baseline and Week 1 only. The second trial, the message framing study, was an investigation of varying messages to assist participants in smoking cessation, and all participants (N = 238) in this study received 300 mg of sustained-release (SR) bupropion (Toll et al., 2006). The time points of MNWS analysis in this 6-week clinical trial were baseline and Weeks 2, 4, and 6. The third trial, the naltrexone + patch study, was a dose-ranging investigation of naltrexone for smoking cessation in which participants were randomized to receive placebo or 25, 50, or 100 mg of naltrexone. All participants (N = 370) in this study also received the 21-mg nicotine patch (O'Malley et al., 2006). The time points of MNWS analysis in this 6-week clinical trial were baseline and Weeks 1, 2, 4, and 6. All three studies were approved by the institutional review board of the Yale University School of Medicine, and the naltrexone + patch study was also approved by the institutional review boards of the University of Connecticut and the Veterans Affairs Connecticut Healthcare System. Table 1 presents demographics for the participants in the abstinence, message framing, and naltrexone + patch studies.

Materials

The MNWS (Hughes, 1992), which is adapted from the *DSM–IV* (American Psychiatric Association, 1994), assesses symptoms associated with nicotine withdrawal (i.e., craving, irritability, anxiety, difficulty concentrating, restlessness, increased appetite or weight gain, depression, and insomnia). Eight withdrawal symptoms are each rated for their severity on a scale from 0 (*not present*) to 4 (*severe*) for the past week (Patten & Martin, 1996).

Data Analysis Plan

We tested three confirmatory factor analytic models. Model 1 hypothesized a three-factor model. For this model, Factor 1 comprised irritability, anxiety, difficulty concentrating, and restlessness; Factor 2 consisted of appetite and insomnia; and Factor 3 included craving. This model is based on the factor analysis results reported by Hughes et al. (1991), but it could not be replicated exactly because the item assessing somatic complaints was removed from the questionnaire and is no longer evaluated in the current version of the MNWS (Hughes & Hatsukami, 1998). Model 2 hypothesized a three-factor model with irritability, anxiety, difficulty concentrating, and restlessness in Factor 1; appetite in Factor 2; and insomnia in Factor 3. This model was based on the factor analysis results presented by Hughes (1992). Model 3 tested a one-factor model that reflects the unitary score that can be derived for the MNWS. Thus all eight items of the scale were tested as one factor. This model was based on factor analysis results reported by Etter and Hughes (2006).

Confirmatory factor analyses were performed using SAS Version 9.1 for Windows on the samples from the abstinence, message framing, and naltrexone + patch studies. For each of the confirmatory factor analytic models, both covariance and correlation matrices were calculated using the CALIS (covariance analysis of linear structural equations) procedure, and parameters were estimated using maximum likelihood. The covariance matrix was analyzed to compute all of the fit indices except the standardized root mean square residual (SRMR), for which the correlation matrix was used.[1] The following model fit indices were considered: the chi-square statistic (Hatcher, 1994), the goodness-of-fit index (GFI; Mulaik et al., 1989), the nonnormed fit index (NNFI; Bentler & Bonett, 1980), the comparative fit index (CFI; Bentler, 1990), the SRMR (Hu & Bentler, 1999), and the root mean square error of approximation (RMSEA; Brown & Cudeck, 1993). To show a good fit for the model, the chi-square statistic should be nonsignificant (Floyd & Widaman, 1995). The GFI, NNFI, and CFI range between 0 and 1, with values closer to 1 indicating a better fit for the model. For these indices, values of .95 or higher are most desirable, and values of .90 or greater represent an acceptable fit of the model to the data (Hu & Bentler, 1999;McDonald & Ho, 2002). To demonstrate good fit, the SRMR should be less than .08 (Hu & Bentler, 1999). Regarding the RMSEA as a measure of good fit, Brown and Cudeck (1993) suggested that a reasonable value for the RMSEA is less than or equal to .08, and they posited that the RMSEA should never be greater than .10. Additionally, values obtained from the model representing the best fit were used to assess reliability.

Predictive validity refers to evidence of an association between a measure and some criterion (DeVellis, 1991). For instance, in smoking cessation research, scores on a measure would be related to treatment outcome as the criterion, as assessed by point prevalence abstinence (defined as reporting no smoking in the past week paired with a carbon monoxide reading of less than or equal to 10 ppm on the day of reporting). For these analyses, we compared abstinent and smoking participants on the basis of MNWS factor scores for each of the confirmatory

[1]One concern when computing the root mean square residual, which uses the covariance matrix, is that it is calculated using unstandardized variables. Consequently, its range is dependent on the scales of the observed variables. However, when calculating the SRMR, one uses the correlation matrix to compute a measure of the mean absolute correlation residual, which is the difference between predicted and observed correlations (Kline, 2005). Therefore, the correlation matrix was used to compute the SRMR.

factor analytic models. We examined whether MNWS scores obtained at the initial time point after quitting (i.e., Week 1 for the abstinence and naltrexone + patch studies and Week 2 for the message framing study) would differ for participants who reported successfully abstaining from smoking at the end of treatment compared with participants who were unsuccessful in maintaining smoking abstinence at the end of treatment.

To explore whether MNWS symptoms wax and wane together (i.e., cohere as a syndrome), we conducted a confirmatory factor analysis of change scores using the model that represented the best fit. For these analyses, we examined change scores from abstinent participants from the message framing study (i.e., change from baseline to Week 2, Week 2 to Week 4, and Week 4 to Week 6) and the naltrexone + patch study (i.e., change from baseline to Week 1, Week 1 to Week 2, Week 2 to Week 4, and Week 4 to Week 6).

Results

Confirmatory Factor Analysis

As presented in Table 2, the three models were tested against data from each of the clinical trials. When examining all of the fit indices over time, we found that Model 3 appeared to represent the best fit to the data. Although the chi-square was significant in virtually all of the models tested, when working with large samples and real-world data, the chi-square value is often significant even when the model provides an acceptable representation of the data (Floyd & Widaman, 1995;Hatcher, 1994). For the most part, the RMSEA was not greater than the .10 cutoff value suggested by Brown and Cudeck (1993). Almost all of the indices that should approach unity (i.e., the GFI, NNFI, and CFI) appeared adequate. In addition, the SRMR for this model indicated an overall acceptable fit.

Factor structure coefficients were also used to assess the factor structure of the MNWS. Table 3 shows the standardized factor loadings for each of the studies at the initial time point after quitting smoking and at the end of treatment for the message framing and naltrexone + patch studies. Generally, factor loadings above .30 are meaningful (Floyd & Widaman, 1995), and with only two exceptions (i.e., Items 6 and 8), all of the items, including the item assessing craving, fit this criterion at all time points. Although Item 6 was below the .30 criterion in all three studies at the initial time point and in the message framing study at Week 6, Item 8 was under this criterion for only the abstinence study data at Week 1.

To determine whether craving should be included in the total score of the MNWS, we supplemented the factor structure coefficient analysis by examining descriptive data from each withdrawal symptom across studies at the initial time point after quitting and at the end of treatment. As displayed in Table 4, except for the Week 6 data for the abstinence and message framing studies, craving had the highest mean score at each time point across all of the studies. The rating of increased appetite or weight gain was slightly higher than the rating of craving at the end of treatment for the abstinence and message framing studies.

Reliability

Internal consistency was measured to evaluate the degree of homogeneity or consistency of the items within the scale for Model 3. The coefficient alpha reliability estimate of this model of the MNWS for each of the studies at the initial time point after quitting was as follows: Abstinence study = .80, message framing study = .83, and naltrexone + patch study = .82. The reliability estimate for this model at the Week 6 time point for the message framing study was .77, and the naltrexone + patch study alpha at Week 6 was .84. Thus, the reliability estimates at each of these time points were found to range from fair to good across all of the three clinical studies (Cicchetti, 1994).

Predictive Validity

As displayed in Table 5, participants who were smoking at the end of treatment in both the abstinence and the naltrexone + patch studies had higher scores on Factor 1 in the week after quitting smoking, although this was a nonsignificant trend. Factor 3 in Model 1 showed a significant effect in the naltrexone + patch study, revealing that participants who were found to be smoking at the end of treatment reported higher scores on this factor (i.e., craving) in the week after smoking cessation. None of the other factors in Model 1 or Model 2 showed significant relationships with respect to smoking status in any of the studies. Model 3 revealed a significant difference due to smoking status at the end of treatment in the naltrexone + patch study and a nonsignificant trend in the abstinence study. In both of these studies, participants who reported smoking at the end of treatment had higher overall withdrawal scores in the week after quitting.

Confirmatory Factor Analysis of Change Scores

As presented in Table 6, MNWS change scores from the message framing and naltrexone + patch studies were tested with Model 3 at several points in time. In confirmatory factor analyses of change scores, Model 3 still appeared to represent a good fit to the data. As with the primary analysis, although the chi-square for this model was significant in most of the models tested, the chi-square value is often significant even when the model provides an acceptable representation of the data (Floyd & Widaman, 1995;Hatcher, 1994). Overall, the RMSEA was not greater than the .10 cutoff value suggested by Brown and Cudeck (1993). Almost all of the indices that should approach unity (i.e., the GFI, NNFI, & CFI) appeared adequate. In addition, the SRMR for this model indicated a generally acceptable fit.

Discussion

In the present study, we investigated the factor structure of the MNWS using data from three clinical research samples. Analyses were conducted on participants who were smoking at baseline and abstinent at multiple time points after quitting. Earlier findings from two previous studies that used exploratory factor analysis showed evidence for multiple factors (Hughes et al., 1991; Hughes, 1992). However, consistent with more recent analyses (Etter & Hughes, 2006), when confirmatory factor analyses were conducted in the present study, a one-factor model using all of the MNWS items provided the best explanation of the data. Moreover, this unitary factor model fit the data best at several points in time. Factor structure coefficients were also evaluated in this eight-item, one-factor model, and all but one of the items had a loading above .30 at multiple points in time, showing that each item is a relatively good indicator of the single factor assessed by the MNWS. Internal consistency was shown to range from fair to good for this one-factor model as well.

Scores from the single-factor model of the MNWS were the best predictors of end-of-treatment smoking outcome, showing a significant effect and a nonsignificant trend for the naltrexone + patch and abstinence studies, respectively. A significant association was not found in the message framing study, but this may have been due to the effect of the medication (i.e., bupropion SR) used in this study or the fact that the MNWS was administered 2 weeks after participants quit smoking in this study, whereas it had been given 1 week after participants quit smoking in the naltrexone + patch and abstinence studies. Indeed, no effects were found for this study using any of the factor models. It is noteworthy that craving (i.e., Factor 3 of Model 1) predicted outcome in the naltrexone + patch study. This is in accordance with the results of the recent study of Etter and Hughes (2006), who showed that craving was the only withdrawal symptom that predicted relapse after 14 days.

Thus, the results presented in this article offer compelling evidence for reporting a total score using all eight items of the MNWS, regardless of the point in time of assessment. These findings are consistent with the theoretical construct of withdrawal and classic psychopharmacological theory, which suggests that the withdrawal syndrome is typified as a cluster of transient symptoms that emerge when reducing or quitting tobacco use and cause distress (Gritz et al., 1991; Shiffman et al., 2004). Other studies have clearly shown that these MNWS symptoms are valid, and these investigations have typically revealed that the MNWS withdrawal symptoms are significantly different during abstinence and nicotine consumption (Hughes, 1992; Hughes et al., 1991). Our data intimate that the withdrawal syndrome, as represented by the total score of the MNWS, is a unitary construct, which is in accordance with other research (e.g., Etter & Hughes, 2006; Piasecki et al., 2003c). Nonetheless, it will be important for future investigators of the MNWS and other withdrawal scales to continue to examine whether this syndrome is a unitary or a multifactorial construct. In addition, it should be noted that other physiological changes can occur with the withdrawal syndrome that cannot be assessed using a questionnaire such as the MNWS. For instance, it has been well documented that electroencephalographic (EEG) changes follow the cessation of tobacco use (e.g., Gilbert et al., 2004). It would be interesting for researchers in future studies using biological measures like EEG, hormonal, and neurochemical changes to incorporate MNWS assessments into their procedures and analyses.

Theoretical considerations and previous research suggest that careful attention should be paid to whether withdrawal symptoms cohere over time. Because withdrawal is a time-limited syndrome with symptoms that wax and wane, it is conceivable that different clusters of symptoms might cohere together at different time points of assessment (Shiffman et al., 2004). Indeed, previous studies have shown that some symptoms remain even 30 days after smoking cessation (Gilbert et al., 2002, 2004; Hughes, 1992). Regarding the time course of withdrawal, results of the present study are in agreement with previous research showing that aggregate reports of withdrawal averaged across participants and plotted over time reveal a consistent pattern (Hughes, 1992; Piasecki et al., 2003a). Indeed, we conducted confirmatory factor analyses of MNWS change scores over time using data from the message framing and naltrexone + patch studies to assess whether MNWS symptoms cohere as a syndrome. These analyses revealed that the one-factor model showed a good fit to these data, suggesting that MNWS symptoms cluster together over time.

From a clinical perspective, recent research has shown that the changing pattern of withdrawal symptoms and withdrawal severity are associated with relapse (Kenford et al., 2002; Piasecki et al., 1998, 2003b). Our data suggest that the MNWS provides a brief measure of overall withdrawal severity that could be used to monitor patients during treatment and potentially guide treatment decisions. For example, in certain circumstances (e.g., late symptom elevations, severe withdrawal), clinicians could provide additional support and counseling or adjunctive pharmacotherapy on the basis of MNWS scores.

In our study, the items for the MNWS assessing appetite and insomnia had the lowest factor structure coefficient loadings. Given these findings, there are several options for future research. First, it may be appropriate to assess these constructs with other multi-item scales specifically designed to measure these domains. Second, when there is clinical or research interest in understanding individual symptoms of withdrawal, other scales, such as the Wisconsin Smoking Withdrawal Scale (WSWS), should be considered (Welsch et al., 1999). The WSWS was recently developed to assess nicotine withdrawal, and initial psychometric testing of this questionnaire revealed seven reliable withdrawal subscales, including Hunger and Sleep. Although it has been suggested that the WSWS may need further testing in a variety of contexts before it is adopted for widespread use (Shiffman et al., 2004), recent psychometric testing of this scale has shown promising results (Etter & Hughes, 2006).

The craving item of the MNWS demonstrated a meaningful loading in the one-factor, eight-item confirmatory factor analytic model presented in this study. Even though craving was dropped from the *DSM–IV* (American Psychiatric Association, 1994) withdrawal criteria, the data from the present study suggest that it is appropriate to include craving as an item in the MNWS. This item revealed scores that were consistently higher than scores on virtually all other items of the scale over time, but not markedly so. The one exception was appetite, which was higher than craving in both the abstinence and the message framing studies at the end of treatment. This is consistent with previous studies showing that hunger remains elevated even 30 days after smoking cessation (Gilbert et al., 2002; Hughes, 1992). In addition, craving was shown to predict treatment outcome in the naltrexone + patch study, providing further evidence of the utility of this item. In their review of the assessment of craving and withdrawal in clinical trials, Shiffman et al. (2004) concluded that craving should be assessed by withdrawal scales, so the data in the current study are in accordance with this recommendation.

In addition to the *DSM* (American Psychiatric Association, 1980, 1987) and factor studies, theoretical models of craving support the value of including craving within the withdrawal syndrome. For example, the incentive-sensitization model theorizes that addictive drugs change the brain so that the reward system for addiction is hypersensitive to drugs and drug-related stimuli (Robinson & Berridge, 2000). As a result, the incentive salience, or wanting process, is sensitized to respond to circumstances involved in obtaining drugs in such a way that craving becomes a conditioned response to drug-related conditioned stimuli. As an example, when a recently abstinent smoker views a pack of his or her preferred brand of cigarettes and his or her body experiences an urge to smoke, this may be an attempt to restore homeostasis to the system. Kassel and Shiffman (1992) contended that craving is analogous to hunger in that it may be biologically based, but it is also governed by many factors other than physiologic need (e.g., hunger can be triggered by cues and/or social context). Craving deserves a place in the withdrawal syndrome, as it reflects, in part, an attempt to restore homeostasis for reasons other than physiological deprivation of nicotine. For instance, many individuals smoke with specific friends, and they may be motivated to return to smoking to meet these social needs.

Tiffany's cognitive model conceptualizes craving as a nonautomatic process that is activated simultaneously with automatized drug-use behaviors (Tiffany, 1990, 1999). The nonautomatic processes may be implemented to either complete automatized drug use or prevent this automatic behavior. Tiffany's model has implications for withdrawal, as smokers who have recently quit often comment on automatic drug use acts they engage in and ultimately stop themselves from completing. For example, individuals experiencing nicotine withdrawal report that they reach for cigarettes devoid of a desire for nicotine, then prevent themselves from smoking. Finally, Baker's dual-affect theory suggests that craving is caused by the negative reinforcement involved in avoiding negative affect (Baker, Piper, McCarthy, Majeskie, & Fiore, 2004). This avoidance is believed to be motivated by the preconscious detection of negative affect cues. The onset of stressors or abstinence can lead to negative affect entering consciousness, at which point information processing becomes biased so that it promotes engagement of cyclical drug-seeking and drug-taking behavior. This theory regards craving as being at the core of the withdrawal syndrome, in that craving leads to drug use to avoid negative affect, which is one of the undisputed symptoms of withdrawal.

Data from field and laboratory studies of the craving process also suggest that craving is a necessary component of the withdrawal syndrome. Shiffman (2000) defined craving as comprising two components: (a) background craving and (b) episodic craving. Background craving is a steady state that is experienced throughout the day regardless of environmental cues. Conversely, episodic craving is triggered by stimuli related to prior drug use and results in strong bouts of pulsatile craving (Shiffman, 2000). As the MNWS asks respondents to rate

withdrawal symptoms over the past week, it seems that this scale measures background craving. Indeed, our data showed that craving remained somewhat elevated even 6 weeks after quitting, suggesting that it may represent the steady state background craving described by Shiffman (2000). Studies by Tiffany and Shiffman (e.g., Shiffman et al., 2003; Shiffman, Ferguson, & Gwaltney, 2006; Shiffman, Ferguson, Gwaltney, Balabanis, & Shadel, 2006; Tenneggi et al., 2002) suggest that nicotine replacement therapy only affects background craving. Moreover, it appears that background craving may fade over time, whereas episodic craving may persist longer and can be stimulated by a variety of cues despite sustained abstinence (Shiffman et al., 1997). Thus, although the MNWS may be very useful in the early weeks of abstinence, a craving measure might be needed at later stages in the quit process to facilitate the use of nicotine replacement therapy as a “rescue medication” for acute episodic cravings (Shiffman et al., 2003). In summary, contemporary theories and laboratory studies illustrate undeniably that craving is a prominent and necessary component of withdrawal, and our findings suggest that it is an important component of the MNWS.

It should be noted that our study has some limitations. The large majority of participants in the clinical samples investigated in this article received some form of active pharmacotherapy, which could affect the intensity, duration, or coherence of the measured symptoms. Nonetheless, the model fit indices for the participants who did not receive any medications (i.e., participants from the abstinence study) are similar to the indices found in the other two studies. Thus, the medications used in the message framing and naltrexone + patch studies might have minimized withdrawal symptoms for the participants in those studies, but the underlying factor structure of the MNWS appears to be stable across studies with varying medication conditions. Another concern is the time frame: Smokers reflected on their symptoms over the past week. It is possible that the results could differ if retrospection occurred over a different time scale (e.g., a single day) or if real time or momentary data were examined.

In sum, the confirmatory factor analysis data presented in this article provide evidence that the MNWS is represented by a single withdrawal factor and suggest the use of a total score for the scale, regardless of the time of assessment. In addition, craving should be included when calculating the score for this single factor.

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Table 1

Sample Demographics

Characteristic	Abstinence	Message framing	Naltrexone + patch
n	115	238	370
Age (years; *M* [*SD*])	39.45 (11.27)[b]	42.62 (11.48)[b]	46.04 (11.05)[b]
Sex (% men)	47.0	48.3	52.4
Ethnicity (% White)	60.0[b]	81.5[b]	90.0[b]
Cigarettes per day (*M* [*SD*])	22.16 (9.01)	22.68 (9.38)	27.43 (10.60)[a]
Number of years smoking (*M* [*SD*])	22.94 (11.49)	25.31 (11.47)	29.39 (10.78)[a]
Fagerström Test for Nicotine Dependence (*M* [*SD*])	5.89 (1.83)	5.37 (2.06)[b]	6.31 (2.00)[b]

[a] In a given row, means in this study differ significantly from the other studies at $p < .05$.

[b] In a given row, means of all studies with a b are significantly different from each other at $p < .05$.

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Table 2

Fit Indices for the Confirmatory Factor Models of the Minnesota Nicotine Withdrawal Scale at Baseline, Week 1, Week 2, Week 4, and Week 6

Model	χ^2	*df*	*p*	GFI	NNFI	CFI	SRMR	RMSEA
				Baseline				
Model 1								
AB	27.59	11	<.05	.94	.58	.78	.07	.12
MF	68.29	11	<.05	.92	.87	.93	.04	.15
NXP	63.36	11	<.05	.95	.92	.96	.04	.11
Model 2								
AB	22.30	6	<.05	.94	.40	.76	.08	.15
MF	63.78	6	<.05	.91	.82	.93	.05	.20
NXP	55.17	6	<.05	.95	.89	.96	.04	.15
Model 3								
AB	45.54	20	<.05	.92	.67	.76	.09	.10
MF	89.66	20	<.05	.91	.90	.93	.05	.12
NXP	132.90	20	<.05	.92	.90	.93	.05	.12
				Week 1				
Model 1								
AB	18.47	11	.07	.94	.93	.96	.05	.10
NXP	51.06	11	<.05	.95	.87	.93	.05	.12
Model 2								
AB	15.48	6	<.05	.94	.87	.95	.05	.15
NXP	46.80	6	<.05	.94	.79	.92	.06	.17
Model 3								
AB	27.27	20	.13	.92	.96	.97	.07	.07
NXP	71.84	20	<.05	.93	.90	.93	.06	.10
				Week 2				
Model 1								
MF	32.36	11	<.05	.93	.89	.94	.05	.13
NXP	67.95	11	<.05	.93	.81	.90	.06	.15
Model 2								
MF	22.41	6	<.05	.94	.88	.95	.05	.15
NXP	62.59	6	<.05	.92	.72	.89	.06	.20
Model 3								
MF	44.99	20	<.05	.92	.92	.94	.05	.10
NXP	73.29	20	<.05	.93	.89	.92	.05	.11
				Week 4				
Model 1								
MF	33.25	11	<.05	.93	.84	.92	.05	.13
NXP	51.39	11	<.05	.94	.84	.92	.05	.13
Model 2								
MF	29.29	6	<.05	.93	.77	.91	.06	.18
NXP	49.18	6	<.05	.93	.75	.90	.05	.18
Model 3								
MF	55.12	20	<.05	.90	.85	.89	.06	.12
NXP	70.64	20	<.05	.93	.88	.91	.05	.11
				Week 6				
Model 1								
MF	20.07	11	<.05	.94	.93	.96	.05	.09
NXP	39.37	11	<.05	.95	.90	.95	.04	.11
Model 2								

Model	χ^2	*df*	*p*	GFI	NNFI	CFI	SRMR	RMSEA
MF	15.57	6	<.05	.95	.89	.96	.05	.13
NXP	34.12	6	<.05	.95	.85	.94	.04	.15
Model 3								
MF	31.41	20	.05	.93	.94	.96	.06	.08
NXP	66.50	20	<.05	.93	.90	.93	.05	.11

Note. GFI = goodness-of-fit index; NNFI = nonnormed fit index; CFI = comparative fit index; SRMR = standardized root mean square residual; RMSEA = root mean square error of approximation; AB = abstinence study (baseline n = 115; Week 1 *n* = 72); MF = message framing study (baseline *N* = 238; Week 2 *n* = 124; Week 4 *n* = 118; Week 6 *n* = 103); NXP = naltrexone + patch study (baseline *N* = 370; Week 1 *n* = 242; Week 2 *n* = 240; Week 4 *n* = 214; Week 6 *n* = 205). For Model 1, Factor 1 = irritability, anxiety, difficulty, concentrating, and restlessness; Factor 2 = appetite and insomnia; Factor 3 = craving. For Model 2, Factor 1 = irritability, anxiety, difficulty concentrating, and restlessness; Factor 2 = appetite; Factor 3 = insomnia. For Model 3, unitary factor = craving, irritability, anxiety, difficulty concentrating, restlessness, increased appetite or weight gain, depression, and insomnia.

Table 3

Confirmatory Factor Analysis Items and Item–Factor Loadings for Each Clinical Trial (Model 3)

Item	Loading			Loading	
	AB, Week 1 (*n* = 72)	MF, Week 2 (*n* = 124)	NXP, Week 1 (*n* = 242)	MF, Week 6 (*n* = 102)	NXP, Week 6 (*n* = 204)
1. Craving for cigarettes	.58	.46	.52	.35	.54
2. Irritability, frustration, or anger	.87	.86	.82	.85	.75
3. Anxiety	.90	.84	.83	.77	.77
4. Difficulty concentrating	.60	.81	.72	.82	.82
5. Restlessness	.88	.82	.72	.74	.81
6. Increased appetite or weight gain	.11	.18	.29	.14	.45
7. Depressed or sad mood	.53	.68	.69	.67	.68
8. Insomnia or sleep problems	.25	.39	.34	.44	.36

Note. AB = abstinence study; MF = message framing study; NXP = naltrexone + patch study.

Table 4

Descriptives for Minnesota Nicotine Withdrawal Scale Items for Each Study

Item	AB, Week 1 (*n* = 72)		MF, Week 2 (*n* = 124)		NXP, Week 1 (*n* = 242)		AB, Week 4 (*n* = 31)		MF, Week 6 (*n* = 102)		NXP, Week 6 (*n* = 204)	
	M	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***
1. Craving for cigarettes	1.15	1.10	1.84	1.25	2.05	1.02	0.81	1.08	0.94	0.91	0.93	0.90
2. Irritability, frustration, or anger	0.71	1.00	1.25	1.23	1.21	1.08	0.48	1.03	0.68	0.90	0.64	0.81
3. Anxiety	0.57	0.92	1.12	1.19	0.96	1.06	0.42	0.81	0.51	0.78	0.54	0.78
4. Difficulty concentrating	0.40	0.88	0.77	1.05	0.70	0.99	0.42	0.89	0.35	0.56	0.30	0.67
5. Restlessness	0.46	0.93	1.20	1.21	1.07	1.06	0.39	0.84	0.48	0.70	0.47	0.77
6. Increased appetite or weight gain	0.75	1.00	1.15	1.24	0.93	1.05	0.90	1.25	1.20	1.13	0.89	1.05
7. Depressed or sad mood	0.28	0.70	0.54	0.86	0.51	0.88	0.32	0.83	0.34	0.78	0.26	0.59
8. Insomnia or sleep problems	0.44	1.01	1.30	1.41	1.25	1.31	0.29	0.78	0.71	1.04	0.53	0.88

Note. AB = abstinence study; MF = message framing study; NXP = naltrexone + patch study.

Table 5

Minnesota Nicotine Withdrawal Scale Scores and t Values for Factor Scores for Each Clinical Trial

Study, model, and factor	*t*	*df*	Smoking *n*	Smoking *M*	Smoking *SD*	Abstinent *n*	Abstinent *M*	Abstinent *SD*	*p*
Abstinence study									
Model 1									
Factor 1	−1.73	83	54	2.56	3.33	31	1.32	2.84	.087
Factor 2	−0.56	83	54	1.26	1.49	31	1.06	1.63	.578
Factor 3	−1.06	83	54	1.20	1.19	31	0.94	1.00	.292
Model 2									
Factor 1	−1.73	83	54	2.56	3.33	31	1.32	2.84	.087
Factor 2	−0.83	83	54	0.80	1.07	31	0.61	0.80	.410
Factor 3	−0.05	83	54	0.45	1.06	31	0.46	1.00	.961
Model 3	−1.69	83	54	5.37	4.80	31	3.52	5.00	.095
Message framing study									
Model 1									
Factor 1	0.24	202	101	4.32	4.23	103	4.46	4.10	.811
Factor 2	0.68	200	100	2.29	2.04	102	2.49	2.14	.497
Factor 3	−1.33	202	102	2.15	1.21	102	1.92	1.22	.185
Model 2									
Factor 1	0.24	202	101	4.32	4.23	103	4.46	4.10	.811
Factor 2	0.04	202	101	1.12	1.18	103	1.13	1.23	.965
Factor 3	0.96	201	101	1.18	1.42	102	1.37	1.45	.336
Model 3	0.36	197	98	9.24	6.86	101	9.58	6.40	.719
Naltrexone + patch study									
Model 1									
Factor 1	−1.90	349	149	4.61	3.57	202	3.89	3.45	.058
Factor 2	−1.27	353	153	2.36	1.90	202	2.11	1.73	.204
Factor 3	−3.94	353	151	2.46	0.97	204	2.03	1.04	.000
Model 2									
Factor 1	−1.90	349	149	4.61	3.57	202	3.89	3.45	.058
Factor 2	−1.23	354	153	1.07	1.20	203	0.92	1.02	.220
Factor 3	−0.62	355	153	1.29	1.36	204	1.21	1.30	.535
Model 3	−2.44	343	146	9.99	5.81	199	8.48	5.59	.015

Note. Model 1: Factor 1 = irritability, anxiety, difficulty concentrating, and restlessness; Factor 2 = appetite and insomnia; Factor 3 = craving. Model 2: Factor 1 = irritability, anxiety, difficulty concentrating, and restlessness; Factor 2 = appetite; Factor 3 = insomnia. Model 3: Unitary Factor = craving, irritability, anxiety, difficulty concentrating, restlessness, increased appetite/weight gain, depression, and insomnia.

Table 6

Fit Indices for Confirmatory Factor Analysis of Model 3 Using Minnesota Nicotine Withdrawal Scale Change Scores

Data	χ^2	*df*	*p*	GFI	NNFI	CFI	SRMR	RMSEA
Baseline to Week 2								
MF	30.16	20	.07	.95	.97	.98	.04	.07
Baseline to Week 1								
NXP	53.78	20	<.05	.95	.92	.94	.05	.09
Week 1 to Week 2								
NXP	48.57	20	<.05	.95	.88	.91	.06	.09
Week 2 to Week 4								
MF	41.89	20	<.05	.91	.82	.87	.07	.10
NXP	50.46	20	<.05	.94	.85	.89	.06	.09
Week 4 to Week 6								
MF	38.97	20	<.05	.91	.81	.87	.07	.10
NXP	50.61	20	<.05	.94	.83	.88	.07	.09

Note. GFI = goodness-of-fit index; NNFI = nonnormed fit index; CFI = comparative fit index; SRMR = standardized root mean square residual; RMSEA = root mean square error of approximation; MF = message framing study (baseline to Week 2 n = 120; Week 2 to Week 4 n = 102; Week 4 to Week 6 n = 95); NXP = naltrexone + patch study (baseline to Week 1 n = 220; Week 1 to Week 2 n = 197; Week 2 to Week 4 n = 185; Week 4 to Week 6 n = 178). Model 3, unitary factor = craving, irritability, anxiety, difficulty concentrating, restlessness, increased appetite or weight gain, depression, and insomnia.