Latent variable models of alcohol-related constructs

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Lennox, R. D., Zarkin, G. A., & Bray, J. W. (1996). Latent variable models of alcohol-related constructs. *Journal of Substance Abuse*, *8*(2), 241–250.

Abstract:

This study examines the improvement in validity coefficients and structural relationships derived from formally modeling latent variables of adverse alcohol-related constructs. Results of a confirmatory factor analysis of responses from 8, 755 participants in the 1988 National Household Survey of Drug Abuse support a three-factor model of alcohol abuse, dependence, and adverse consequences. A comparison of construct inter-correlations shows latent variables to be superior to measurement approaches using unweighted sums, quantity × frequency calculation, and single-item measurement.

Keywords: validity coefficients | structural relationships | latent variables | alcohol-related constructs

Article:

For nearly a century, psychologists have struggled to find methods of controlling for and/or understanding the various sources of error inherent in people's self-report of behavior, attitudes, and beliefs (Nunnally, 1978). In the early years of psychometric theory, researchers attempted to control for random variation in self-reports by correcting bivariate correlation for attenuation (Spearman, 1904), thereby reducing total variation proportionate to the estimated random measurement error. Other approaches followed that built on classical measurement theory, which posited that a given self-reported score was a function of a true score plus some random measurement error. The practice of summing redundant items that were assumed to differ only in their unique random error was seen as a method of asymptotically offsetting the random error component. The result was assumed to be a total score that was more reliable than any one item (Lennox & Dennis, 1994). These statistical issues are complicated further by conceptual disagreement about which behavior or attitudes belong to a given construct and which do not.

Measuring Alcohol-Related Constructs

Research in the field of alcoholism contains similarly variable measurement practices and beliefs. Researchers routinely rely on both single-item measures of alcohol consumption and large scales of alcohol problems. Clark and Hilton (1991) pointed out that researchers disagree on what construct a given item is attempting to measure. For example, they noted that there is substantial disagreement about whether problems resulting from alcohol consumption are to be regarded as adverse consequences of abuse or as symptoms of dependence. Muthen, Grant, and Hasin's (1993) analysis of the DSM criteria for alcohol abuse and dependence illustrates the difficulties of attempting to combine alcohol abuse and alcohol dependence into a single continuum. Grant, Harford, Hasin, Chou, and Pickering's (1992) comparison of the DSM-III-R and the DSM-IV criteria for diagnosing alcohol abuse and alcohol dependence also produced convincing evidence that the two constructs are empirically distinct subsets of problem-oriented drinking. Another level of the dimensionality problem relates to the role of heavy drinking in the alcohol abuse/alcohol dependence classification. Some researchers, for example, may regard frequent intoxication as a problem-oriented symptom of alcoholism, whereas others may consider it just an indicator of ingestion of high levels of alcohol not linked to pathology at all. These two interpretations differ in terms of whether researchers consider intoxication per se an alcohol-related problem.

Clark and Hilton (1991) suggested that the one area of agreement among most alcohol researchers is that the empirical association among alcohol constructs has been disappointingly low. Structural relationships between alcohol consumption and alcohol problems rarely account for more than 10% of the variance. Data in Clark and Hilton's analysis of the 1984 National Drinking Survey show that a number of indicators of alcohol problems share less than 10% of their variance, and other indicators are virtually uncorrelated with one another. Despite attempts to improve these disappointing results with multiple-item scales and the cross-product calculation of quantity and frequency as a measure of alcohol consumption, a substantial lack of strong convergence exists among alcohol-related constructs.

Of course, the constructs may not be correlated among themselves, and the available methods may be perfectly reliable and valid measures of their respective constructs. If so, the resulting correlations reflect the true state of affairs, and the appropriate task for the alcohol researcher is to explicate a theory that explains the empirical distinctiveness of the alcohol constructs. However, if the existing measures are excessively influenced by measurement error, the estimated correlations may be attenuated. If this is the case, the estimated correlations do not reflect the true association, and the alcohol research field must find methods of improving the measurement technology. We contend that the field has not yet exhausted all alternative methods of measuring the alcohol constructs and that the cause of the low correlation may lie in the fallibility of the measures previously used.

Three Alcohol-Related Constructs

Clark and Hilton's (1991) study of the National Drinking Surveys provides a compelling synthesis of the important components of the linkage between alcohol consumption and problem drinking. They argued that the problem-drinking dynamic consists of three categories of alcohol-

related behavior: (a) alcohol abuse--the frequent ingestion of excessive amounts of alcohol; (b) alcohol dependence--the presence of physical or behavioral manifestations of addiction to alcohol; and (c) adverse alcohol-related consequences. Importantly, all three categories can be considered behaviors, but Clark and Hilton contended that they are conceptually distinct.

Alcohol Abuse

The distinctiveness of alcohol dependence lies in its focus away from the simple ingestion of alcohol and toward the addictive manifestation of alcoholism. Persons scoring high on this construct do, of course, drink substantial amounts of alcohol, but they also exhibit physiological and behavioral symptoms of addiction to alcohol. Cahalan and Room (1974) argued that there are four subcategories of alcohol dependence indicators: (a) psychological dependence (drinking for escape or relief), (b) symptomatic behavior (e.g., morning shakes, sweats, blackouts), (c) loss of control (inability to control the amount of alcohol consumed), and (d) binge drinking (drinking for 24 hours or more).

Adverse Alcohol-Related Consequences

Several classes of adverse consequences of alcohol abuse are often used in the literature. They contain indicators of belligerence, spouse problems, conflicts with relatives and friends, troubles on the job, and encounters with the police. The kinds of consequences an individual manifests are in part determined by his or her personal and social environment and biological makeup.

Problem

Previous research using self-reported measures of alcohol consumption and alcohol-related consequences has routinely relied on traditional measurement approaches that assume perfect measurement or that only tacitly remove measurement error based on classical psychometric theory. Latent variable modeling, on the other hand, allows for formal specification of the measurement models that parcel out measurement error without removing them from the analysis. Latent variable models produce measurement models that allow for testable hypotheses concerning the manner in which multiple indicators of a single construct relate. We examine the improvement in the construct intercorrelations achieved by a formal specification of the measurement models rather than relying on (a) single-item indices assumed to be perfectly measured, (b) unspecified simple sums of multiple items based on tacit removal of error offset in the sum, or (c) cross-products of single indicators assumed to be perfectly measured.

METHOD

Procedures

Data from the 1991 National Household Survey on Drug Abuse (NHSDA) were used to test the factor structure of the three latent constructs. To represent the population at risk for adverse alcohol-related consequences, we included all respondents who drank alcohol in the past 30 days, were between the ages of 18 and 64, and were not enrolled in school. The sample includes individuals who are currently employed, who are not employed and are looking for work, and

who are not employed and are not looking for work. We included the latter group because they may have lost their jobs as a consequence of alcohol consumption, or their current alcohol consumption may have precluded them from finding a job. We excluded students because evidence indicates that their alcohol consumption patterns differ substantially from those of the general public. Our sample included 8,755 respondents who are active or potentially active in the labor market.

Items were extracted from the NHSDA as indicators of alcohol abuse, alcohol dependence, and adverse alcohol-related consequences. Separate items for alcohol quantity and frequency were used to assess the theoretically distinct components of alcohol abuse, with two items for each concept. The items are presented in Figure 1. The "F" prefix in the alcohol abuse item set designates frequency items, and the "Q" refers to the quantity items. The quantity and frequency items are measured as continuous variables. Dependence is indicated by a collection of physical and behavioral symptoms indicative of addiction to alcohol, which are measured as binary variables. Finally, alcohol consequences are indicated by a collection of belligerence and job-/school-related problems and are measured as binary variables.

The Latent Variable Approach

One method that has not been used to date in this literature is latent variable analysis. In this model, the covariation among multiple indicators is used as an estimate of the latent construct, with uniqueness in the individual items removed as irrelevant measurement error. Similar to the correction for attenuation described by Spearman (1904), the latent variable model formally specifies the relationship between the measured variables and the latent construct as

$$Y_i = \lambda_{i1}\eta_1 + \varepsilon_i \qquad [1]$$

where Y_1 is the ith indicator, λ_{il} is the ith indicator's loading on the latent construct, η_1 is the latent construct, and ε_i is the random measurement error separated from the latent construct.[1] The model assumes that all ε_i are uncorrelated with one another and with the latent construct. The model thus partitions the variance in the ith indicator into three components: the first common factor, random measurement error in the indicator, and error in the model. The last component represents unexplained covariation among the indicators that make up the model's goodness of fit. The main advantage of the latent variable approach is that it specifies a measurement model that is falsifiable. The assumptions regarding what portion of the variance in the indicators is reliable can be explicitly tested without relying on vague measures of internal consistency. Moreover, the structural relationships among latent variables can be tested apart from the measurement model. Thus, the attenuating effects of unreliable measurement error can be seen as part of the hypothesis tested.

[1] The latent variable approach does assume a linear relationship. Although the issue of nonlinearity is interesting, it is beyond the scope of this article.

Figure 1. National Household Survey on Drug Abuse Items

Alcohol Abuse
(Quantity and Frequency)

F11. On about how many different days have you had one or more drinks during the past 30 days?
Q12. About how many drinks did you usually have in a day on the days that you drank during the past 30 days?
F13. On about how many days did you have five or more drinks on the same occasion during the past 30 days?
Q14. What is the most you had to drink on any one day during the past 30 days?

Alcohol Dependence

D6. I stayed drunk for more than one day at a time.
D7. I have awakened unable to remember some of the things I had done while drinking the day before.
D8. I had a quick drink or so when no one was looking.
D9. I often took a drink the first thing when I got up in the morning.
D10. My hands shook a lot after drinking the day before.

Adverse Alcohol-Related Consequences

C1. I felt aggressive or cross while drinking.
C2. I got into a heated argument while drinking
C3. I stayed away from work or school because of a hangover.
C4. I was high or a little drunk when on the job or at school.
C5. I lost a job, or nearly lost one, because of drinking.

Statistical Analysis

In the latent variable model, the three sets of items are thought to represent distinct patterns relative to each of the three constructs. Specifically, the latent variable model examines the common factor of the item sets as representing the relevant systematic variance, with the uniqueness of the items as random measurement error or specific variance, and the residual covariation among the item subsets representing systematic but irrelevant variation. In the alcohol abuse item construct, the latent variable focuses on variation attributable to participants who frequently drink large amounts of alcohol, or alternatively drink small amounts infrequently. Drinking patterns that suggest occasional drinking of large amounts of alcohol or frequent drinking of small amounts are parceled out as indicating normal consumption and not alcohol abuse. This definition tests the latent variable and allows it to be falsified. The other two constructs are defined in the same way. The responses to the 14 items were subjected to a maximum likelihood confirmatory factor analysis (CFA) with the hypothesized structure indicating three separate but correlated factors.

RESULTS

Confirmatory Factor Analysis

Figure 2 presents the theoretical structure of the three latent factors along with their factor loadings and their factor intercorrelations. Results of the CFA showed that this model produces a good fit to the covariance matrix (Bentler-Bonnet fit index = 0.87). Although the chi-square tests also showed a significant difference between the observed and model covariance matrices, the sample size of 8,755 made the test overly sensitive to small departures. The average standardized residual covariance was only .04, indicating that there was very little covariance left to be

modeled beyond the three-factor model. The residual covariance matrix also showed little evidence of cross-factor loadings, but an examination of the correlation among errors showed that the two frequency items had correlated errors.

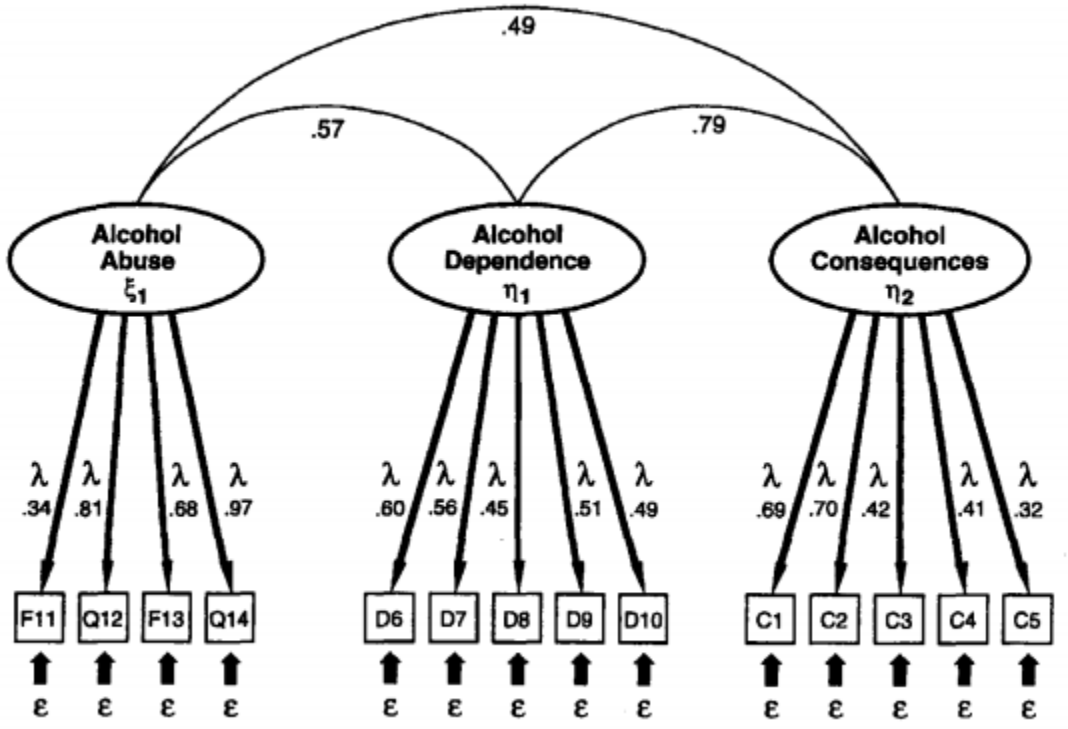

Figure 2. Confirmatory Factor Analysis

Reexamination of the items in the NHSDA suggested that the correlated errors result from a skip pattern common to both items. Freeing the restriction of uncorrelated error for these two items, however, improves the model only slightly. For the sake of parsimony, we retained the restriction of uncorrelated errors in this analysis. A two-factor model that combined abuse and dependence into a single factor also was estimated and was found to be statistically inferior to the three-factor model, χ^2diff (2) = 4,019, $p < .001$. All factor loadings are significanfly different from zero, and all but two loadings are greater than .40. The results indicate that item Q14 "What is the most you had to drink on any one day in the last 30 days?" is a nearly perfect indicator of alcohol abuse and is defined by the common factor of alcohol abuse. As shown in Figure 2, the intercorrelation among the latent variables is substantial, with alcohol dependence accounting for 62% (.792) of the variance in adverse alcohol-related consequences. The other two correlations are also substantial, indicative of their importance as elements of the abuse-consequences relationship.

Comparison of Measurement Approaches

Table 1 presents a comparison of the intercorrelations of the constructs as operationalized by four common scoring methods. The first row presents the average zero-order correlation among item sets. This analysis shows the likely results of selecting a single indicator for each of the constructs. The second row presents a single measure that is calculated by multiplying the

number of drinks one normally consumes by the number of days one drinks, resulting in an estimate of total amount consumed. The third row shows the unweighted sum of the items used in the scales. The fourth row presents the latent factor intercorrelations. Comparing the four rows demonstrates that small intercorrelations can be expected from using single items to measure each construct. Although significant, the averages are relatively small. Moreover, the distribution around these averages shows that the correlations range from .01 to .34. Researchers using single items can therefore expect to find correlations between .01 and .34; the probability of finding a significant relationship depends on which single indicator is selected to operationalize each construct.

Table 1. Correlations of Abuse, Dependence, and Problems Across Four Scoring Methods

	Between-Construct Correlations[a]		
Scoring Method	**Abuse × Depend**	**Abuse × Cons**	**Depend × Cons**
Average Zero-Order Correlations	.23	.17	.23
Quantity × Frequency	.36[b]	.28[c]	NA[d]
Unweighted Sums	.46	.39	.57
Latent Factors	.57	.49	.79

[a]Abuse = alcohol abuse; Depend = alcohol dependence, Cons = alcohol consequences.
[b]Quantity × frequency measure of alcohol abuse correlated with unweighted sum for alcohol dependence.
[c]Quantity × frequency measure for alcohol abuse correlated with unweighted sum for alcohol consequences.
[d]Quantity × frequency method is not used in measuring either of these constructs.

Using the quantity × frequency computation to measure alcohol abuse improves the correlations somewhat for the two correlations in which that variable appears. The quantity × frequency approach does not greatly attenuate the correlation, but again it assumes perfect measurement. The simple unweighted sum attenuates the correlation even less. Although it tacitly models out random error (the sums of the uncorrelated error are expected to asymptotically cancel one another out based on classical psychometric theory), it does not formally model the relationship among the indicators or allow for a formal test of the measurement model.

The latent variable models produce the highest correlation among all four approaches. The comparison between the unweighted sums and the latent variable approach shows a difference of as much as 22 correlation points.

Discussion

Despite the commonsense presumption that drinking causes adverse alcohol-related consequences, previous research has failed to uncover substantial evidence of a link between the simple intake of alcohol and its adverse consequences, independent of the likely collinearity with alcohol dependence. The inclusion of alcohol consumption levels and patterns as part of routine alcohol dependence diagnostic criteria established by DSM-IV makes it nearly impossible to distinguish between the adverse effects of heavy drinking and those resulting from the actual dependence or addiction to alcohol.

However, the lack of evidence linking alcohol consumption to alcohol-related consequences does not necessarily imply that they are unrelated. The difficulty of obtaining valid and reliable measures of alcohol consumption alone may be enough to cause a failure to detect the evidence when it is actually present (Type II error). It is also possible that, although they are comparatively valid and reliable, the measures are not sensitive enough to detect subtle nuances of the drinking dynamic.

This article has attempted to improve the sensitivity of alcohol measures by formally specifying a latent measurement model that removes random or unique variance in individual indicators and uses the overlap among multiple indicators of the same construct as an estimate of "true" score on the construct.

The results indicate that using latent variable measures of alcohol-related constructs has demonstrable advantages over traditional methods, particularly when the alternative is relying on single items as proxy measures of the latent constructs. The advantages of the latent variable approach over simple sums of multiple items are less compelling but still worth considering. Finally, the peculiar method of multiplying alcohol quantity × frequency to compute a total of alcohol ingested over a given period does not provide the measurement sensitivity promised by its seemingly precise metric (ounces of ethanol). Intercorrelations of the quantity × frequency measures with the other alcohol-related measures are unimpressive.

The implications of this research go beyond demonstrating the advantages of latent variable analysis to demonstrate the hazards of not modeling measurement error in estimating the actual degree of association among alcohol-related constructs. In a sense, this research suggests an upper bound to the population-based association among these constructs. Researchers should be allowed to gauge the sensitivity of their measurement approach relative to the highest degree of association previously found in the literature.

Underestimating the covariation among alcohol abuse, alcohol dependence, and adverse alcohol-related consequences has compelling health policy implications for assessing the importance of prevention and treatment interventions. For example, supporting a prevention strategy aimed at reducing alcohol consumption is difficult when the association between consumption and alcohol-related consequences is in the area of .20, as found in the singie-indicator results.

On the other hand, the value of interventions that focus on treating drinkers who are at high risk of becoming alcohol dependent is easier to defend when one considers the .79 correlation between dependence and consequences, as estimated by the latent variable model. These results reflect favorably on interventions aimed at detecting the precursors to alcohol dependence. Population-based screening devices could be an important tool for identifying people at risk of becoming alcohol dependent and who are prime candidates for prospective interventions. Careful application of this kind of approach may be particularly valuable in employee assistance programs (EAPs), where intervening to avert the progression of simple alcohol abuse to alcohol dependence has important implications for avoiding the reduced productivity and increased health care use (Holder, Lennox, & Blose, 1999) associated with advanced stages of alcohol dependence.

Latent variable analysis also has implications for intervention-based effectiveness studies. The kind of random error most often associated with single-item indicators often inflates the standard error of sample statistics resulting in the lack of sensitivity to reject the null hypothesis and thus Type II errors. This type of problem is particularly hazardous in health services research, where the aim is to gauge the size of the effect in the operational environment rather than simply to demonstrate a nonzero change in clinical status, as in simple efficacy studies. In cost-effectiveness studies, where the aim is not only to gauge the actual magnitude of the effect of the treatment but also to assess the marginal cost of treatment, the attenuating effects of measurement error have similar effects on estimates of the cost effectiveness of treatment.

Alcohol health services research should take seriously the threat of random and systematic measurement error on estimates of effectiveness in both prevention and treatment-effectiveness studies. The convincing evidence of effectiveness that will be required of the new health care reform era cannot be produced without modeling and accounting for the various sources of slippage in measures used to assess effectiveness.

These results draw exclusively on self-reported alcohol abuse, dependence, and consequences. The validity of the self-reports is threatened by respondents' unwillingness to report negative behavior and to some degree their inability to accurately recall behaviors (i.e., quantity and frequency).[2] The lack of substantial residual covariances between use and problems suggests that the there is little effort to deflate actual drinking levels, or that the deflation occurs in both the abuse and consequence measures. Although the low prevalence rates of some of the consequences are offset somewhat by the large sample sizes in the NHSDA, there is good reason to expect that the skewness of the consequences attenuates the coefficients. Finally, these latent variable models, and in fact most statistical procedures, assume local independence among observations. There is a strong possibility that long epidemiologic studies like the NHSDA produce correlated errors that violate these assumptions. Virtually nothing is known about the level of autocorrelation produced by aggregating the scales and items into large instruments.

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[2] Self-reported measures of drug abuse and related behavior are routinely criticized for their prima fade threats to validity. It is generally felt that drug abusers cannot be depended upon to reliably report their level of use. Despite this commonsense argument, some data suggest that they are not as error.prone as suspected (Turner, Lessler, & Gfi'oerer, 1992).

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