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Evidence for essential unidimensionality of AUDIT and measurement invariance across gender, age and education. Results from the WIRUS study

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ABSTRACT

Introduction: Globally, alcohol use is among the most important risk factors related to burden of disease, and commonly emerges among the ten most important factors. Also, alcohol use disorders are major contributors to global burden of disease. Therefore, accurate measurement of alcohol use and alcohol-related problems is important in a public health perspective. The Alcohol Use Identification Test (AUDIT) is a widely used, brief ten-item screening instrument to detect alcohol use disorder. Despite this the factor structure and comparability across different (sub)-populations has yet to be determined. Our aim was to investigate the factor structure of the AUDIT-questionnaire and the viability of specific factors, as well as assessing measurement invariance across gender, age and educational level.

Methods: We employed data (N = 4,318) from the ongoing screening study in the Norwegian national WIRUS project. We used Confirmatory Factor Analysis (CFA) to establish the factor structure of the AUDIT. Next, we investigated the viability of specific factors in a bi-factor model, and assessed measurement invariance of the preferred factor structure.

Results: Our findings indicate the AUDIT is essentially unidimensional, and that comparisons can readily be done across gender, age and educational attainment.

Conclusion: We found support for a one-factor structure of AUDIT. To the best of our knowledge, this is the first study to investigate the viability of specific factors in a bi-factor model as well as evaluating measurement invariance across gender, age and educational attainment for the AUDIT questionnaire. Therefore, further studies are needed to replicate our findings related to essential unidimensionality.

1. Introduction

Alcohol use is strongly associated with poor health and negative functional outcomes, but the association with health is also complex (Griswold et al., 2018). Globally, alcohol use is among the most important risk factors related to disease burden, and commonly emerges among the ten most important factors (Gakidou et al., 2017). Also, alcohol use disorder is a major contributor to global burden of disease, especially among men (James et al., 2018). Several studies have established robust associations between alcohol use and sociodemographic variables, such as gender, age and educational attainment (e.g. Bratberg et al., 2016; Eigenbrodt et al., 2001; Marchand et al., 2011; Schnohr et al., 2004; Thørrisen et al., 2018; Wilsnack et al., 2000; Wilsnack et al., 2009). Accurate measurement of alcohol use and identification of potential alcohol-related problems is important in a public health perspective. Moreover, it is important to validate instruments across sociodemographic variables.

The Alcohol Use Identification Test (AUDIT) was developed as a brief ten-item screening instrument to detect alcohol use disorder (Babor et al., 2001; Saunders et al., 1993). It is widely used, has been implemented in different settings and populations, and has demonstrated psychometric qualities often superior to those of other alcohol screening instruments (de Meneses-Gaya et al., 2009). Some work has been done on the factor structure and factorial invariance of the AUDIT,

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but the findings are not conclusive.

1.1. The factor structure of the AUDIT

The most common way to use AUDIT is perhaps as a one-dimensional measure and adhering to the recommended cut-offs referred to in the WHO-manual (Babor et al., 2001) as indications of different levels of alcohol-related problems. Studies specifically investigating the factor structure of AUDIT, have found support for one factor, as well as two (Drinking habits/consumption patterns (item 1-3) and Consequences (item 4-10)) and three factors (Drinking habits (item 1-3), Alcohol dependence (item 4-6) and Harmful alcohol use (item 7-10)) (Blair et al., 2017; Doyle et al., 2007; Hallinan et al., 2011; Karno et al., 2000; Moehring et al., 2018; Peng et al., 2012). At present, there seems to be more evidence supporting a two-factor structure of AUDIT. Specifically, a recent study by Moehring and colleagues (Moehring et al., 2018) concluded that two factors was preferable over a one-factor structure across six different German populations drawn from three different settings; general hospitals, general medical practices and the general population. They did, however, also note that one factor was a viable structure of AUDIT, and they did not investigate the previously suggested three-factor structure. In the same study, the authors also investigated whether the factor structure and metric were the same for men and women. They found support for a common structure and metric regardless of gender, meaning that AUDIT measures the same construct and that observed differences between men and women are trustworthy. To the best of our knowledge, this study is one of only a handful of studies specifically investigating the factor structure and metrics across different sub-populations defined by sociodemographic factors (Moehring et al., 2018; Peng et al., 2012; von der Pahlen et al., 2008). Peng and colleagues (2012) also found evidence for measurement invariance across gender. However, von der Pahlen and colleagues (2008) did find evidence for measurement non-invariance across gender and age groups (men only) in a Finnish population sample. Furthermore, previous studies have so far only investigated comparability across gender or age, or a combination of these two characteristics. Establishing a viable factor structure of AUDIT and evaluating the comparability of both structure and metrics is a fundamental requirement for the valid use of the screening instrument for both clinical and epidemiological purposes. Based on self-report data from a large cohort of Norwegian employees, the present paper aims to be a contribution in that respect.

People who are currently working may be at surprisingly high risk of binge drinking, in part due to higher levels of socializing (Seid et al., 2016) some of which is likely directly initiated by the workplace (Nordaune et al., 2017). Therefore, it is possible that the psychometric properties of scales that are designed to screen for alcohol use disorder function differently in people who are being screened as part of a workplace intervention compared to a general population setting or a help-seeking (patient) setting. At the workplace, people may be reluctant to disclose problematic drinking due to fear of repercussions. Nevertheless, screening tools such as the AUDIT is sometimes used to assess alcohol problems among people identified through their workplace, such as physicians (Sorensen et al., 2015), or mixed groups of employees (Watson et al., 2015).

The aim of the present study was to investigate the factor structure of the AUDIT questionnaire and the viability of specific factors in a sample of employees, as well as assessing measurement invariance across gender, age and educational level.

2. Material and methods

2.1. Design

This cross-sectional study is part of the ongoing screening study in the Norwegian national WIRUS project (Workplace Interventions preventing Risky Use of alcohol and Sick leave). Other results from the WIRUS project are published elsewhere (Aas et al., 2017; Nordaune et al., 2017; Thørrisen et al., 2018).

Table 1
Age and educational level and mean AUDIT-score across gender.

	Male	Female	P-Value
	n = 1457	n = 2861	
Age			< .001
	46.3 (11.6)	44.6 (11.2)	
Educational level			< .001
Primary/lower secondary	56 (3.8%)	51 (1.8%)	
Upper secondary	356 (24.4%)	661 (23.1%)	
University/college ≤4 years	474 (32.5%)	988 (34.5%)	
University/college 4+ years	571 (39.2%)	1161 (40.6%)	
Mean AUDIT-score			< .001
	4.8 (3.5)	3.6 (2.7)	

2.2. Population and sample

In the WIRUS screening study, 20 large companies (> 100 employees) in Norway were recruited. These private (n = 8) and public sector (n = 12) companies were categorized according to the European Classification of Economic Activities (Eurostat, 2008): Transportation and storage (n = 1), manufacturing (n = 4), public administration (n = 8), human health and social work activities (n = 4), accommodation and food service activities (n = 1), education (n = 1), and other service activities (n = 1).

Included companies provided email addresses for all their employees. Employees (n = 18,000) received a web-based questionnaire inviting them to participate in the survey. A total of 5,136 employees agreed to participate and responded on the questionnaire (28.5%), and n = 4,318 (84.1%) had valid information on AUDIT and constitute the final sample. Table 1 indicates the mean age, educational level and mean AUDIT-score across men and women. Among the eligible participants, 66.3% were female. The mean age for the eligible participants was 45.0 (standard deviation 11.6) years. A majority of the participants reported university/college education (74.0%). Men were somewhat older, had a higher mean AUDIT-score and were more likely to report primary education only compared to women (all $p < .001$). Additional analysis, comparing participants with valid responses on AUDIT and those without on demographic information, indicated that those without valid responses were more frequently female ($p < .001$), somewhat younger ($p = .013$) and had lower levels of educational attainment ($p < .001$) compared to those with valid responses (see supplementary Table X1)[1] .

2.3. Measurements/variables

Gender was self-reported. Information about gender was used as is for all analyses. Age was self-reported. Age was used as a continuous variable for initial analyses of demographical information. For comparison of model fit, age was used as a dichotomous variable (18-45 years and 46+ years). Self-reported educational level was recorded as a four-level variable, discriminating between primary/lower secondary, upper secondary, university/college education up to four years and university/college education for more than four years. Educational level was used as is (four levels) for initial analyses of demographical information. For comparison of model fit, education was used as dichotomous variable, grouping primary/lower secondary and upper secondary education together, and university/college education regardless of study length together.

[1] Supplementary material can be found by accessing the online version of this paper at http://dx.doi.org and by entering doi: …

The official Norwegian version of the AUDIT recommended by the Norwegian Directorate of Health was used in the present study, consisting of 10 items measuring different aspects of alcohol habits and potential negative consequences of these alcohol habits.

2.4. Ethics

The study was approved by the Regional Committees for Medical and Health Research in Norway (approval no. 2014/647). Respondents were informed about the study's aim and confidentiality, and assured that participation was voluntary (Aas et al., 2017). All participants provided written informed consent

2.5. Statistical procedure

First, the mean age, educational level and mean AUDIT-score were compared across men and women. Second, we investigated the factor structure of the AUDIT questionnaire based on previously suggested models. Using confirmatory factor analysis (CFA) we estimated the model fit of previously suggested models: the original one-factor model, a two-factor model (Drinking habits (item 1-3) and Consequences (item 4-10)), and a three-factor model (Drinking habits (item 1-3), Alcohol dependence (item 4-6) and Harmful alcohol use (item 7-10). Additionally, we aimed to test whether there was support for a bi-factor structure, allowing for one general factor and specific factors if we found support for more than one factor in the preceding factor analyses (Chen and Zhang, 2018; Reise, 2012). The number of specific factors in the bi-factor model was to be based on the best fitting model (i.e. either a two- or three-factor model). In the present study a combination of RMSEA < 0.08 and CFI > 0.90 was considered acceptable fit, while indices of < 0.05 and > 0.95, respectively, were considered good (Byrne, 2012). All CFA analyses were performed using diagonally weighted least squares (DWLS) estimators suitable for ordinally scaled responses (Forero et al., 2009). We also estimated the model-based reliability ω (Widhiarso and Ravand, 2014). For the bi-factor model we estimated the ωH and the ωS. The ωH gives an indication of the overall reliability of the general factor, while the ωS is the reliability of the specific factor beyond the general factor (Widhiarso and Ravand, 2014). The explained common variance was also estimated for the bi-factor model, as this is a frequently used indicator of level of unidimensionality (Quinn, 2014; Reise et al., 2013). Furthermore, we investigated if the preferred model was configural and scalar invariant across gender, age and education (Bowen and Masa, 2015; van de Schoot et al., 2012). There are different recommendations in relation to how to assess measurement invariance (Putnick and Bornstein, 2016; van de Schoot et al., 2015). In the present study, we assessed both configural invariance and scalar invariance (Putnick and Bornstein, 2016; van de Schoot et al., 2015), following the recommended procedure described by Svetina and colleagues (Svetina et al., 2019). Shortly, we first estimated a baseline (configural) model for each grouping variable (gender, age and education) where thresholds and loadings are estimated freely using delta parmeterization. Next, we estimated a model where the thresholds where constrained to be equal, and finally we estimated a model where both the thresholds and loadings (scalar) are constrained to be equal. A decrease in model fit was considered indicative of non-invariance if the decrease was more than .015 for RMSEA and more than -.01 for CFI collectively (Chen, 2007; Putnick and Bornstein, 2016; van de Schoot et al., 2015). To enable comparison of model fit across the different demographically defined groups, it was necessary to collapse some of the extreme responses on several items to avoid missing responses in some groups. Collapsing of responses was necessary for item 3-6 and item 8 (Moehring et al., 2018). All analyses were performed using R (R Core Team, 2013), the semTools (Jorgensen et al., 2018) and the lavaan packages (Rosseel, 2012) was used for the CFA. In additional analyses, we compared those with and without valid responses on AUDIT on demographic variables[2] .

3. Results

3.1. Confirmatory factor analyses

Initially, three different factor structures for AUDIT was investigated using confirmatory factor analysis (Table 2). The one-factor model (Model A) yielded adequate fit, as indicated by a RMSEA of 0.049 and a CFI of 0.933, and a model-based reliability ω of 0.77. Modification indices suggested that the one-factor model could be further refined if the residual variances of AUDIT items 2 and 3 were allowed to correlate, due to a high overlap between these two items. This was allowed for as they are conceptualized as part of the same factor and relate to drinking habits (Model B). This modification yielded a RMSEA of 0.038 and CFI of 0.961. The fit of the two-factor model (Model C) was somewhere in between the two one-factor models in relation to model fit as indicated by a RMSEA of 0.041 and a CFI of 0.953, and a model-based ω of 0.66 for the drinking habits factor and 0.76 for theconsequences factor. The correlation between the two factors was 0.82. When attempting to estimate a model with three factors (Model D), the model was not identified as evident by a covariance matrix of latent variables which was not positive definite. Further inspection of the covariance matrix indicated a failure to discriminate between factors 2 and 3.

3.2. Viability of specific factors

As both a one-factor and two-factor model seemed to fit the data adequately, we aimed to investigate the viability of specific factors in a bi-factor model. Three different bi-factor models were attempted; a bi-factor model with two specific factors (item 1-3; drinking habits and item 4-10; consequences), a bi-factor model with only drinking habits as specific factor, and a bi-factor model with only consequences as specific factor. The two first bi-factor models could not be identified as there was not enough residual variance after estimation of the general factor for the proposeddrinking habits factor (item 1-3). A bi-factor model (Model C) with only consequence as specific factor could be estimated and yielded acceptable fit: RMSEA of 0.046 and CFI of 0.951. In order to assess the viability of items 4-10 as a specific factor beyond the general factor, we estimated the overall model-based reliability and the explained common variance (ECV) of the general factor. The overall model-based reliability coefficient ω was 0.91, while the ωH was 0.77. The factor-specific reliability excluding the general factor was ω S 0.14. The ratio between ωH and ωS was 5.5. The ECV was 0.78. The relatively high ECV and the very low reliability of the consequences factor was taken as an indication of essential unidimensionality. The standardized factor loadings of the one-factor model and the bi-factor model is presented in Table 3. A one-factor model (Model B) was therefore retained for further analyses.

3.3. Measurement invariance

Testing for measurement invariance was done across gender, age and education for a one-factor model (Table 4). For gender, the change between the baseline model and the equal thresholds model was ΔCFI -0.002 and $\Delta RMSEA$ -0.001, with no further change of CFI. For RMSEA a further Δ of -0.003 was observed when constraining both thresholds and loadings to be equal.

For age, there was a change between the baseline model and the equal thresholds model of ΔCFI -0.003 and no change for RMSEA. Constraining both thresholds and loadings yielded a change of ΔCFI 0.003 and $\Delta RMSEA$ -0.005.

For education, no change of CFI was observed across constraints,

[2] Supplementary material can be found by accessing the online version of this paper at http://dx.doi.org and by entering doi: …

Table 2
Comparison of model fit.

Model	Chi-square	Df	RMSEA	RMSEA lower CI95%	RMSEA upper CI95%	CFI	TLI
Model A: One factor	393.202	35	0.049	0.044	0.053	0.933	0.913
Model B: One factor, correlated residual variance[a]	243.346	34	0.038	0.033	0.042	0.961	0.948
Model C: Two factor	286.132	34	0.041	0.037	0.046	0.953	0.937
Model D: Bi-factor, with specific consequence factor	287.044	28	0.046	0.042	0.051	0.951	0.922
Model E: Three-factor[b]	N/A	N/A	N/A	N/A	N/A	N/A	

[a] Allowing for AUDIT-item 2 and 3 to have correlated residual variance.
[b] Model not identified: Covariance matrix of latent variables was not positive definite, and standard errors could not be identified. Problem involving factor 2 and 3.

Table 3
Standardized factor loadings for a 1-factor model and a bi-factor model with one specific factor (item 4-10).

	One-factor structure	Bi-factor structure	
		General	Specific (consequence)
AUDIT 1	0.45	0.49	-
AUDIT 2	0.64	0.67	-
AUDIT 3	0.84	0.95	-
AUDIT 4	0.78	0.64	0.49
AUDIT 5	0.77	0.64	0.44
AUDIT 6	0.70	0.65	0.22
AUDIT 7	0.77	0.64	0.53
AUDIT 8	0.81	0.72	0.35
AUDIT 9	0.52	0.44	0.29
AUDIT 10	0.67	0.53	0.45
Mean factor loadings	0.69	0.64	0.39

Table 4
Measurement invariance testing across gender, age groups and educational attainment.

Invariance test	Constraint	CFI	RMSEA	*ΔCFI*	*ΔRMSEA*	Verdict[a]
Gender						
	Configural: Baseline	0.960	0.061	-	-	
	Equal thresholds	0.958	0.060	−0.002	−0.001	
	Scalar: Equal thresholds and loadings	0.958	0.057	No change	−0.003	
	Additive[a]			−0.002	−0.004	Invariant
Age						
	Configural: Baseline	0.965	0.059	-	-	
	Equal thresholds	0.962	0.059	−0.003	No change	
	Scalar: Equal thresholds and loadings	0.965	0.054	0.003	−0.005	
	Additive[a]			No change	−0.005	Invariant
Education						
	Configural: Baseline	0.969	0.056	-	-	
	Equal thresholds	0.969	0.054	No change	−0.002	
	Scalar: Equal thresholds and loadings	0.969	0.050	No change	−0.004	
	Additive[a]			No change	−0.006	Invariant

A verdict of scalar non-invariance was given when *ΔCFI* > 0.01 combined with *ΔRMSEA* > 0.015 was observed.
[a] Additive change from baseline.

but for RMSEA the change was *Δ* -0.002 between the baseline and the equal thresholds model, and *Δ* -0.004 between the equal thresholds model and the model with equal thresholds and equal loadings. Overall, there was little evidence for measurement non-invariance across constraints for gender, age and education.

4. Discussion

4.1. Overall factor structure

In the present study, we found initial support for a 1-factor and a 2-factor model. A finding of support for both a 1- and 2-factor model in relation to model fit is supported by previous publications. Notably, our fit indices are similar to Moerhing and colleagues findings from 2018 (Moehring et al., 2018), and may be taken as further confirmation of the notion that AUDIT may best be modelled as a one- or two-factor structure. In contrast to previous studies, however, we also investigated the viability of specific factors in a bi-factor model. Our bi-factor model yielded little support for specific factors beyond a general factor. The 1-factor model did fit the data marginally better when allowing to a correlation between residuals of item 2 and 3, but the 1-factor model seems to preferable due to parsimony and evidence of essential unidimensionality in the bi-factor analysis. Three factors were not supported by our data, as we were not able to identify this model. Based on our findings, we therefore conclude that a one-factor structure is the most robust factor structure for AUDIT.

4.2. Measurement invariance across sociodemographic factors

In this study, we investigated measurement invariance for gender, age, and educational attainment. As the one-factor model was the preferred model, measurement invariance was tested for this model. For gender, we found support for configural and scalar measurement invariance, meaning that both the factor structure and metrics are comparable for men and women. This is in line with previous publications (Moehring et al., 2018; Peng et al., 2012), and further strengthens the evidence that AUDIT is a relevant and suitable questionnaire for men and women and that comparisons between them are meaningful. Our findings also supported the notion of configural and scalar measurement invariance across categories of age and education. The finding regarding measurement invariance is contrary to the findings reported from a Finnish population study (von der Pahlen et al., 2008), where they reported evidence of measurement non-invariance across age groups for men. Based on our findings, we therefore believe that the factor structure is comparable across age and education categories, and that comparisons between different age or educational groups can be readily relied on.

4.3. Implications

Based on our findings we suggest that using the AUDIT as a unidimensional measure is preferable over for instance a two-factor conceptualisation. This means that sum scores based on the whole scale can be used as a measure of potential alcohol-related problems. In this particular study, we did not aim to investigate AUDIT as a continuous nor as a cut-point measure for potential substantial alcohol-related problems. We acknowledge that the ability to explore for instance the convergent validity of the scale in relation to alcohol cut-point thresholds is warranted (Blair et al., 2017), especially considering our results that indicate the scale as essentially unidimensional in nature. Furthermore, we think that our study should encourage further study into the viability of the frequently used AUDIT-C (items 1-3) as an independent measure of alcohol misuse (Doyle et al., 2007), as well as other shorter versions of AUDIT (Kim et al., 2012). In relation to comparisons between different sociodemographic groups, our findings indicate that comparisons across different gender, age and educational groups are suitable. However, further studies should investigate this assertion, and try to replicate our findings in different populations and different cultures.

4.4. Strengths and limitations

The present study has several strengths. First, the study size enabled not only investigation into the overall factor structure of AUDIT, but also investigation of measurement invariance across three sociodemographic factors. Second, by using a bi-factor model, we were able to determine the viability of specific factors beyond a general factor. Third, the data is recently collected and the findings is therefore temporally relevant. Several limitations should also be kept in mind when assessing the merits of the present study. First, the study is not population-based per se, as only individuals who were employed in participating companies were eligible. Further, the study is based only on Norwegian employees, and the participation rate was rather low (28.5%). Due to data protection regulations, we are not able to compare non-participants and participants directly, but comparisons between the invited sample and the participants indicate that the gender composition among the participants are comparable to the invited sample ($p = 0.172$). However, those participating were somewhat older compared to the invited sample ($p < 0.001$; 68.1% aged 40 or above among the participants versus 63.7% in the invited sample). These considerations may limit the generalizability of findings from the present study. Second, the gender distribution was not even, as almost 7 out of 10 were female. In terms of education, very few indicated low education (primary school), and we were also limited in age to working age. Also, we chose to dichotomise the information about age and education in the measurement invariance analyses. This was done since the recommendations of cut-off values we chose are based on similarly sized groups (Chen, 2007; Putnick and Bornstein, 2016; van de Schoot et al., 2015), and because we did not want to collapse unnecessary extreme responses across the AUDIT items. These sociodemographic constraints may have limited our ability to detect measurement non-invariance. On the other hand, evaluation of measurement invariance should be done across groups which are meaningful in terms of practical relevance, as very small groups or many different groups have implications for both statistical and real-life interpretation of the findings (Rutkowski and Svetina, 2014). Third, as we followed the recommendation of Svetina et al. (2019) using delta-parameterization, it was not possible to constrain residuals to be equal across groups (strict invariance). Although, scalar invariance is usually the last step in the hierarchy of measurement invariance tests (Putnick and Bornstein, 2016; Svetina et al., 2019), one can argue that comparisons of observable item or mean scores across groups are potentially biased without also establishing scalar invariance (Meredith and Teresi, 2006; Putnick and Bornstein, 2016).

Fourth, it has been suggested that a one-factor solution provides the best model fit in populations characterized by high prevalence of alcohol dependence, while a two-factor solution may be more appropriate in populations with low prevalence of alcohol dependence (Lima et al., 2005; Skipsey et al., 1997). As the population this study is based on were employed individuals only, we are not able to test our findings across populations with differing prevalence of alcohol dependence, such as clinical populations. Lastly, we did not investigate AUDIT in relation to criterion-related validity, such as alcohol-consumption measured with other methodological approaches or in relation to health outcomes.

5. Conclusions

To the best of our knowledge, this is the first study to investigate the viability of specific factors in a bi-factor model as well as evaluating measurement invariance across gender, age and educational attainment for the AUDIT questionnaire. Our findings indicate the AUDIT is essentially unidimensional, and that comparisons can readily be done across gender, age and educational attainment. However, further studies are needed to replicate our novel findings.

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The study was supported by the Norwegian Directorate of Health and the Research Council of Norway. The funding bodies had no role in the design of study nor in data collection, analysis and data interpretation.

7. Contributors

All listed authors take responsibility for the work and satisfy the requirements of authorship. All authors read and approved the final manuscript.

8. Contributors

JCS, MMT and RWA came up with the initial study concept and analysis plan. JCS, MMT, RWA, EO and MH contributed to revisions of the analysis plan and conceptual presentation of the results. JCS did the statistical analyses, while all authors contributed to the interpretation of the results. JCS wrote the initial draft of the article. JCS, MMT, RWA, EO and MH reviewed the original draft of the manuscript and subsequent revisions. All authors approved the final version of the manuscript.

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Conflict of Interest

No conflict declared.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.drugalcdep.2019.06.002.

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