An Evaluation of the Full Level of Response to Alcohol Model of Heavy Drinking and Problems in COGA Offspring*

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ABSTRACT. Objective: The low level of response (LR) to alcohol is an endophenotype related to heavier drinking and alcohol problems. Structural equation models (SEMs) indicate LR affects alcohol outcomes (ALCOUT) both directly and through mediation by drinking in peers (PEER), alcohol expectancies (EXPECT), and drinking to cope with stress (COPE), with some variation depending on the sample tested. This article presents the first full test of this LR-based model in young subjects from the Collaborative Study on the Genetics of Alcoholism (COGA). **Method:** Data were generated from 325 12- to 22-year-old (47.4% male) drinking offspring from COGA families, using the Self-Report of the Effects of Alcohol questionnaire to determine LR early in the drinking career and a validated, structured interview for demography and alcohol use/problem patterns. Standardized questionnaires were used to measure PEER, EXPECT, and COPE, with the model tested through the maximum likelihood estimation for analyses of the variance/covariance matrix using both Amos and Mplus. **Results:** The SEM yielded good fit characteristics and explained 59% of the variance, with LR relating both directly to ALCOUT and as partially mediated by PEER and COPE. Although GENDER related to both LR and ALCOUT in the model, and AGE related to ALCOUT, the SEM results were invariant across both AGE and GENDER, with generally similar invariant results regarding the presence or absence of an alcohol-use disorder diagnosis. **Conclusions:** The results support the applicability of the LR-based model of heavy drinking and alcohol problems in the COGA offspring, a group with different demography compared with the two other samples of adolescents tested to date. The modest differences observed across samples will be evaluated in future research to enhance understanding of how the model operates across socioeconomic groups. (*J. Stud. Alcohol Drugs* **70:** 436-445, 2009)

THE IDENTIFICATION OF RISK FACTORS for alcohol-use disorders can offer important clues for their early identification and prevention (Schuckit, 2002). In recent years, several genetically influenced intermediate characteristics (or phenotypes) have been evaluated using structural equation models (SEMs) and related statistical techniques to further our understanding of how such biological risk factors relate to additional life characteristics in affecting the predisposition toward heavy drinking and associated problems (Schuckit et al., 2006, 2008b). These have included the search for mechanisms through which impulsivity and behavioral disinhibition affect the development of alcohol- and drug-related disorders (Ohannessian and Hesselbrock, 2008; Sher et al., 2000; Tarter et al., 2004).

Our efforts have focused on another genetically influenced intermediate characteristic, or endophenotype: the low level of response (LR) to alcohol (Schuckit, 2002). LR can be measured by observing the intensity of reaction to alcohol at a given blood alcohol concentration (BAC), where lower alcohol-related changes indicate a lower LR (Schuckit and Smith, 2000). This characteristic has also been studied through retrospective reports of the need for more drinks for specific effects, where a higher number of drinks are equivalent to less reaction per drink, or a lower LR (Schuckit et al., 2007).

The mechanisms underlying the low LR are complex but are not likely to primarily reflect acquired tolerance (the need for more drinks to obtain the effects previously experienced with fewer drinks), because the relationship between a lower LR and current as well as future higher drinking quantities and problems is seen among those as young as age 12 and those who are very light and infrequent drinkers and remains

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robust even when earlier drinking patterns are used as covariates in the analyses (Schuckit et al., 2008b,c; Trim et al., in press).

A less intense reaction per drink is hypothesized to increase the number of drinks likely to be consumed per session because, especially when young, people often drink to achieve an effect such as intoxication, consuming as much as is needed to get the effect they want. A low LR may then operate in relationship to elements of the Social Information Processing Model (Dodge et al., 2003), where LR affects how people process the feedback they receive from the use of alcohol (i.e., the need for three or four drinks for desired effects), affecting their expectations of what alcohol is likely to do when they drink and the acceptability of heavier alcohol intake. This influences the selection of heavy-drinking friends through Peer Cluster Theories, where adolescents associate with peers with similar characteristics, with the observation of drinking among peers reinforcing the acceptability of intoxication (Brown et al., 2008; Henry et al., 2005).

In this context, in accordance with Social Learning Models, a low LR and heavier drinking peers may also contribute to the acceptability of heavier drinking and affect how alcohol is used, the probability of heavier drinking, and associated problems (Lonczak et al., 2001). Stresses associated with these problems might then be addressed by using the anxiolytic and muscle relaxant properties of acute alcohol to feel more relaxed, with the feelings of "reward" contributing to continued escalation of drinking (Bradizza et al., 1999; Zimmerman et al., 2004).

The key elements of the LR-based model of heavy drinking illustrated in Figure 1 have been tested in both adults and adolescents and in both cross-sectional SEMs as well as longitudinal latent trajectory analyses (Schuckit et al., 2005, 2008b,d; Trim et al., 2008). In all models, a low LR was associated with heavier drinking and alcohol-related problems, and although a lower LR and fewer alcohol problems were seen in girls than in boys, gender did not influence the overall performance of LR in the model. A lower LR was associated with heavier drinking in peers in very young adolescents, was significantly related to positive expectations of the effects of alcohol in both models in which it was considered, and correlated with a greater probability of using alcohol to cope with stress in the single LR-based model for adolescents in which coping mechanisms had been included.

Many of the LR-based models have used data from the San Diego Prospective Study of 453 families (Schuckit and Smith, 2000; Schuckit et al., 2008d), where the original 453 probands were chosen 25 years ago from a nonclinical sample of higher educated 20-year-old men. In addition to several descriptions of the model performance in the original adult probands over the years (Schuckit and Smith, 2000, 2004), a recent study described the results in 113 offspring ages 12-24 (mean age = 19.7), 43% of whom were male (Schuckit et al., 2008d). Here, LR related to heavier drinking and alcohol problems both directly and as partially mediated by more positive expectations and the use of alcohol to cope with stress, but no mediation was observed for peers.

Another evaluation confirmed the predicted key relationships among a low LR, additional mediators, and heavier drinking in a general population sample of 688 13-year-olds from the Avon Longitudinal Study of Parents and Children (Schuckit et al., 2008b). Here, heavier peer drinking partially mediated the relationship between LR and alcohol outcomes, although that protocol did test two additional elements of the model—alcohol expectancies and coping mechanisms.

The LR model has also been evaluated in less well-educated and lower socioeconomic stratum offspring from families with high densities of alcohol-use disorders through the Collaborative Study on the Genetics of Alcoholism (COGA; Schuckit et al., 2005). Here, 238 offspring ages 13-19 years (mean age = 17) demonstrated the expected relationship between LR and alcohol-related outcomes as well as that between LR and alcohol expectancies, with the latter partially mediating the relationship among LR, heavier drinking, and alcohol-related problems. However, at that time the COGA protocol did not include measures of coping with stress or peer drinking, and therefore, the full LR-based model could not be studied.

This article presents data from the most recent epoch of the COGA protocol, where 12- to 22-year-old offspring participated in research measuring all elements of the LR-related model (Schuckit et al., 2008a). This offers the first opportunity to evaluate the full model outside of the San Diego Prospective Study and furthers our understanding of the application of the full model to less highly educated families with a greater density of alcohol-use disorders.

Method

The COGA offspring reported on here each gave informed consent (age 18 and older) or assent along with parental consent (for those ages 12-17) as participants in the COGA panel of offspring ages 12-22 that began in 2004. COGA is a six-center-based protocol that began in 1990 through the selection of men and women who were in treatment for alcohol-related problems. Probands were selected if they met criteria for dependence in the Diagnostic and Statistical Manual of Mental Disorders, Third Edition, Revised (DSM-III-R; American Psychiatric Association, 1987), as well as definite alcoholism using the Feighner criteria (Feighner et al., 1992), and had multiple relatives available for study. Comparison subjects were chosen using a range of methods across the centers, including random mailings to employees and students at a university, attendees at medical and dental clinics, and drivers' license records. All COGA subjects as well as available relatives were interviewed with age-appropriate versions of the Semi-Structured Assessment for the

Genetics of Alcoholism (SSAGA) interview, an instrument with 1-week retest reliabilities for alcohol-related problems in excess of .85 and similar kappas regarding diagnoses established in a comparison interview (Bucholz et al., 1994; Hesselbrock et al., 1999). The SSAGA is the source of the demographic characteristics and drinking histories reported here.

The current panel of 325 12- to 22-year-old offspring were interviewed by April 2008, had reported drinking at least one standard drink (10-12 g of ethanol) in their lifetime, and completed all of the instruments described here. An additional 141 offspring were eligible for the analyses but could not be included in the SEM because they had not yet completed their follow-up or their scores on one or more of the key domains were incomplete. Those excluded were similar to the 325 subjects for age (18.8 [SD = 0.19] vs 19.1 [0.11]; $t = -1.39$, $p = .17$) and gender (49.6% vs 47.4% male; $\chi^2 = 0.20$, $p = .65$), but a lower proportion of those not used here were white (59.6% vs 75.4%; $\chi^2 = 16.6$, $p = .001$).

The central measure in the model is the LR to alcohol during the approximate first five times of drinking as recorded on the Self-Rating of the Effects of Alcohol (SRE) questionnaire (Schuckit et al., 1997). This score was generated by averaging the number of drinks required across up to four alcohol effects actually experienced early in the drinking career, including the number of drinks required for a first effect to be noticed, the drinks needed for slurring of speech, the amount of alcohol required for developing a stumbling gait, and the drinks needed for an unwanted falling asleep (Schuckit et al., 1997).

The SRE has a Cronbach's α of .90 to .96 (Ray et al., 2007; Schuckit et al., 1997), and 1- and 5-year retest reliabilities of .82 and .66, respectively. The correlation of the SRE with future drinking and alcohol-related problems was .2 to .3, and the coefficients remained significant even after controlling for drinking parameters (e.g., drinking quantity and alcohol problems) at the time of initial study (Schuckit et al., 2007, 2008c). The SRE-generated LR score overlaps significantly with LR values from alcohol challenges, accounting for 60% of the ability of the alcohol challenge to predict alcohol outcomes (Schuckit et al., 2009).

All drinkers also completed the questionnaires required to generate scores relevant to the key domains in the LR-based model in Figure 1. The perceived level of drinking in peers (PEER) was measured through the Important People and Activities scale, which asks the participant to name up to 12 peers important in their lives and report their perceived drinking status as well as drinking quantities and frequencies (Longabaugh et al., 1993). The Important People and Activities scale has a retest reliability of .80 to .95 and correlates as highly as .8 with other relevant measures of peer drinking. PEER was a latent variable using the three indicators of the

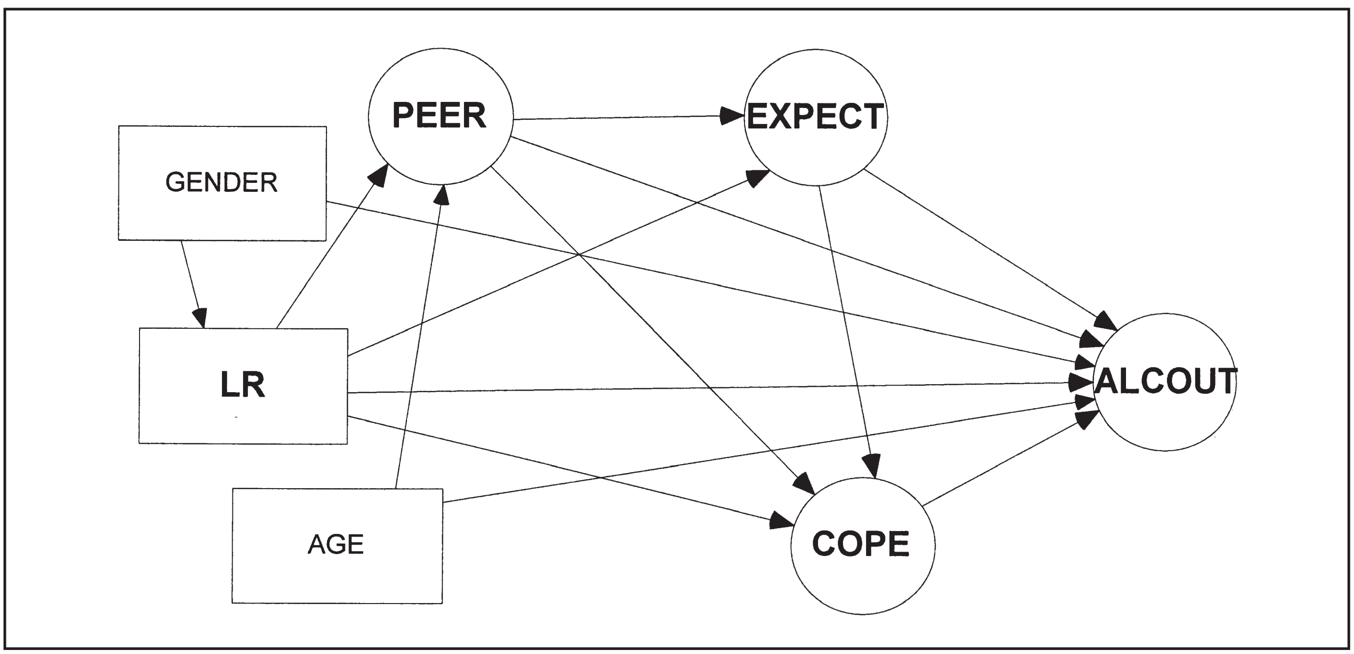

FIGURE 1. The hypothesized level of response (LR)-based model with a low LR to alcohol hypothesized to relate directly to alcohol-related outcomes (ALCOUT) as well as through heavier drinking in peers (PEER), higher positive expectancies of the effect of alcohol (EXPECT), and learning to use alcohol to cope with stress (COPE). The relationships of PEER and EXPECT to ALCOUT are also hypothesized to be at least partially mediated by COPE. GENDER is hypothesized to be related to both LR and ALCOUT. AGE is hypothesized to be related to PEER and ALCOUT.

peer drinking status (from abstainer to heavier drinker on a five-point scale), peer drinking frequency, and peer maximum drinking.

Expectations of the effects of alcohol (EXPECT) was a measure of the subjects' beliefs regarding the manner in which alcohol is likely to affect them (Agarwal et al., 2007; Kuntsche et al., 2007). This was evaluated through the adolescent and adult (age ≥18) versions of the Alcohol Expectancy Questionnaire (AEQ-A), with Cronbach's α's of >.7 to .9, a 2-month retest reliability of .7, and a good level of crossover with additional similar questionnaires (Brown et al., 1987; Kline, 1996). EXPECT was used as a latent variable of three indicators that included the global positive expectancies, social behavior, and relaxation scores determined as z scores within adolescents through age 17 and within adults age 18 or older in order to combine the two types of age-based measures.

The use of alcohol to cope with stress (COPE) was evaluated with the Drinking to Cope scale, consisting of six questions relating to the manner in which alcohol is used at times of stress. This measure has a Cronbach's α of .85 and good external validity when compared with additional scales (Beseler et al., 2008; Cooper et al., 1988). COPE was a latent variable of three indicators created by placing the six drinking-to-cope items into three parcels.

The number of lifetime alcohol problems was determined using SSAGA questions about the 11 DSM-IV (American Psychiatric Association, 1994) abuse/dependence criteria and the 7 nondiagnostic items that included binging (2 or more days without sobering up), alcohol-related fights, role interference, injury, psychological problems, and seeking help or treatment. To be consistent with our emphasis on latent variables and to obtain a broad measure of alcohol outcomes, ALCOUT was a latent variable determined through three indicators of the lifetime number of these 18 alcohol problems, the maximum lifetime number of drinks, and the maximum drinks in the prior 6 months. This panel of outcome items has been used by our group for all prior analyses of adolescents and was maintained here for consistency (Schuckit et al., 2005, 2008b,d).

In these analyses, data transformations were carried out based on the topography of the data, including square-root transformations for right-skewed distributions (e.g., in social behavior and relaxation expectancy subscales and for peer maximum drinks), logarithm transformations for displaced central tendencies (e.g., in two of the drinking-to-cope parcels and the two drinking-quantity variables), and inverse transformations for exponential forms of data (e.g., for one of the drinking-to-cope parcels and the number of alcohol problems). All analyses were run both with and without data transformations to be certain that the alteration of the data did not distort the results.

The SEM was run using the maximum likelihood estimation for analysis of the variance/covariance matrix of Amos (Arbuckle, 2003), with results confirmed using Mplus (Muthén and Muthén, 2006). The measurement model was first evaluated using a confirmatory factor analysis allowing for correlations among the latent variables and subsequently incorporated into the SEM itself. In addition, the relationships between all domains in the model were established using Pearson product-moment correlations. The final model presented here involved a respecification of the hypothesized model using modification indices.

The goodness of fit was determined through the chi-square to degrees of freedom ratio (good fit = 2:1 to 3:1), with smaller ratios indicating a better fit (Wheaton et al., 1977); the comparative fit index (CFI), where good fit was indicated by scores of >.90 (Bentler, 1990; Hu and Bentler, 1998); the nonnormal fit index (NNFI), with good fit indicated by values approaching 1.0; and the root mean square error of approximation (RMSEA), where values of <.05 indicate good fit (Hu and Bentler, 1998); along with the root mean squared residual (SRMR), with good fit indicated by scores of <.08 (Hu and Bentler, 1998). The testing of the model required that all indices were within these good fit guidelines. The criteria for model modification were a modification index of 4, along with the requirement that such modification made theoretical sense.

Regarding covariates, the only variables and factors included in the final model are those represented in Figure 3. In this model, mediation was evaluated using the cross-product approach computed by the INDIRECT command in Mplus (MacKinnon et al., 2002). The invariance procedures used here (e.g., across gender) have been described by Hoyle and Smith (1994), by Spillane et al. (2004), and in our prior publications (e.g., Schuckit et al., 2005). These include first running the full model with no invariance constraints, then requiring that equality constraints for factor loadings be the same, followed by requiring that variances be the same across groups, and then adding equality constraints requiring that the structural paths be the same for both groups and testing whether each additional set of equality constraints across the two groups reduced the model fit to the data with a chi-square test.

Results

The 325 subjects reported on here (47.4% male) had a mean age of 19.1 (2.02) years, and the racial background included 75.4% white, 11.7% black, and 12.3% white Hispanic, along with 0.6% falling into a range of other categories. By the time of interview, the maximum drinks ever consumed in 24 hours was 12.7 (5.69), the average drinks per occasion in the prior 6 months was 3.7 (4.07), and the average frequency of alcohol use was 1.3 (1.42) days per week. One or more alcohol problems had been reported by 68.3%, with an average of 2.7 (3.36) per person. In this group from COGA families, 12.0% had ever met criteria for DSM-IV alcohol dependence and 28.9% met criteria for alcohol abuse; 12.3% had conduct disorder; and 11.7% had ever experienced a major depressive episode.

These subjects came from 227 families, 207 (91.2%) of which had only one or two offspring. The small average cluster size in this sample (1.43 children/family) resulted in small design effects (a measure of interdependence) for the outcome indicators that ranged from 1.04 (maximum drinks) to 1.10 (problems). Because this suggests that clustering did not pose a problem for a single-level analysis (a design effect of ≥2.0 is considered a meaningful threshold; Muthén and Satorra, 1995), the use of multilevel modeling was not warranted.

Table 1 presents the product-moment correlations among manifest and latent variables used in the SEM. Briefly, the manifest variable of LR correlated in the predicted direction with all other variables including gender (lower LR scores in females). The correlation between LR and EXPECT ($r = .10$, $p = .09$) came close to significance, but LR was unrelated to AGE. All characteristics were related in the predicted manner to ALCOUT, EXPECT was significantly related to COPE and PEER (but not to AGE and GENDER), and PEER was significantly related to COPE.

Figure 2 presents the results of the measurement model for the SEM. The fit indices for this were good ($\chi^2 = 107.35$, 48 df, $p = .001$; χ^2/df = 2.24; CFI = .96; NNFI = .95; RMSEA = .062 [90% confidence range: .046-.077]; SRMR = .046). For EXPECT, the three indicators are the AEQ global positive, social behavior, and relaxation scores with factor loadings of .81 to .93. Regarding PEER, the factor loadings were .55 to .61 across indicators of the peer's drinking status, frequency, and maximum intake. Similar data are offered regarding COPE and ALCOUT in Figure 2.

The SEM itself is presented in Figure 3, which demonstrates good fit characteristics ($\chi^2 = 171.64$, 83 df, $p = .001$; χ^2/df = 2.07; CFI = .95; NNFI = .94; RMSEA = .057 [.045-.070]; SRMR = .051). The model explained 59% of the variance (the R^2), with LR relating to ALCOUT both directly and as partially mediated through PEER and COPE. The level of drinking in PEER and the COPE values were also directly related to ALCOUT, with the link between EXPECT and ALCOUT mediated through the COPE domain. In this model, GENDER as a covariate had a significant contribution to ALCOUT (reflecting the lower LR scores in females), as did AGE (older offspring had higher ALCOUT values). Formal testing of mediation yielded significant mediation effects for LR to PEER to COPE (b [SE] = 0.026 [0.006], $z = 2.61$, $p < .02$), LR to PEER to COPE to ALCOUT ($b = 0.029$ [0.013], $z = 2.31$, $p < .03$), PEER to EXPECT to COPE ($b = 0.069$ [0.021], $z = 3.27$, $p = .001$), PEER to EXPECT to COPE to ALCOUT ($b = 0.78$ [0.025], $z = 3.09$, $p < .01$), and EXPECT to COPE to ALCOUT ($b = 0.126$ [0.025], $z = 5.06$, $p < .001$). Finally regarding Figure 3, to evaluate the impact of having used z scores across adult and adolescent expectancy measures, the model was repeated using raw EXPECT scores for all subjects, after converting the adult five-level scale to the adolescent 0/1 scale by splitting adult scores into groups below and above a score of 3. The result was a model with the same percentage of the variance explained (59%), similar path coefficients, and similar fit indices to Figure 3. Therefore, the use of z scores did not adversely affect model testing.

Besides testing for the direct effects of GENDER and AGE within the model, the potential effects of these variables were also evaluated via invariance procedures. This approach evaluates if relationships among variables in the model remain the same (i.e., are invariant) across subgroups. Invariance testing for GENDER yielded similar models for males and females with no significant chi-square for any step difference (factor loadings: $\chi^2 = 7.23$, 8 df, $p = .52$; variances: $\chi^2 = 1.81$, 2 df, $p = .41$; and path values: $\chi^2 = 5.95$, 9 df, $p = .75$). Model fit indices varied only slightly across invariance levels (χ^2/df from 1.60 to 1.65; CFI = .95 for all levels; NNFI from .93 to .94; RMSEA from .041 [.031-.051] to .045 [.034-.055]; and SRMR from .065 to .073). Although path values did show invariance across GENDER, for males the paths LR to PEER ($\beta = .14$, $p = .14$) and AGE to ALCOUT ($\beta = .12$, $p = .081$) were not significant. For AGE invariance testing, the sample was split between age 18 or younger versus age 19 or older, a cut-point chosen to reflect the likelihood of still living in the childhood home and to an approximate median split in this sample. AGE invariance testing yielded similar models for younger and older subjects, with no significant chi-square for any step difference (factor loadings: $\chi^2 = 7.69$, 8 df, $p = .47$; variances: $\chi^2 = 0.00$, 1 df, $p = 1.00$; and path values: $\chi^2 = 6.13$, 9 df, $p = .73$). Again, model fit indices varied only slightly across invariance levels (χ^2/df from 1.66 to 1.77; CFI = .94 for all levels; NNFI from .93 to .94; RMSEA from .045 [.035-.055] to .049 [.039-.059]; and SRMR from .066 to .069). Although

Table 1. Collaborative Study on the Genetics of Alcoholism offspring Pearson product-moment correlations among manifest and latent variables used in the structural equation models (SEMs) ($N = 325$)

	LR	ALCOUT	EXPECT	COPE	PEER	AGE
ALCOUT	.45‡					
EXPECT	.10	.30‡				
COPE	.13*	.57‡	.62‡			
PEER	.19*	.57‡	.27‡	.40‡		
AGE	.03	.15*	-.04	.03	.04	
GENDER	-.27‡	-.27*	-.05	-.01	-.01	.03

Notes: LR (level of response) is the manifest variable of the level of response using the Self-Rating of the Effects of Alcohol, where a higher score represents a lower LR reflecting more drinks required for an effect; ALCOUT represents the alcohol-related outcomes as the latent variable in the SEM; EXPECT is the alcohol expectancies latent variable; COPE represents the latent variable from the Drinking to Cope scale; the PEER score is a latent variable generated from the peer drinking scores; whereas AGE and GENDER are manifest variables as determined from the interviews.
*$p < .05$; ‡$p < .001$.

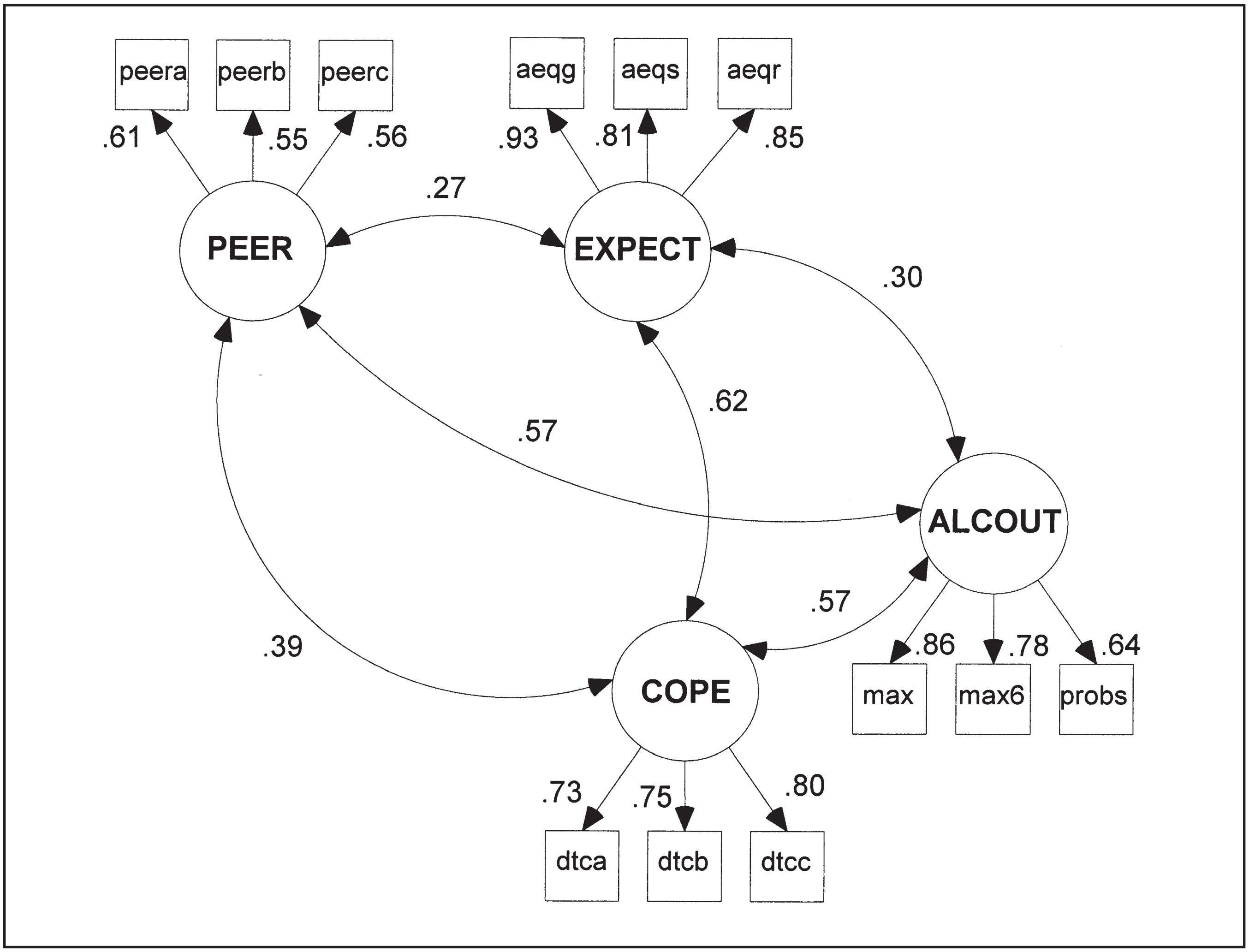

FIGURE 2. The measurement model for the 325 offspring. ALCOUT has three indicators of the offspring's maximum drinks in their lives (max), maximum drinks in the prior 6 months (max6), and number of the 18 potential problems ever experienced (probs). PEER was created through use as indicators of the three Important People and Activities scores of alcohol-use pattern (peera), their frequency (peerb), and their maximum drinks (peerc). EXPECT consists of three Alcohol Expectancy Questionnaire (AEQ) scores as indicators: the global positive score (aeqg), the social behavior score (aeqs), and the relaxation score (aeqr). The COPE domain was created by placing the six Drinking to Cope (DTC) items into three parcels of two items each.

path values demonstrated invariance across the two AGE groups, perhaps reflecting the loss of statistical power, for the younger subjects the following paths were not significant: GENDER to ALCOUT ($\beta = .11$, $p = .16$), LR to PEER ($\beta = .20$, $p = .07$), and PEER to EXPECT ($\beta = .14$, $p = .21$).

Invariance testing was also run comparing the 192 subjects with DSM-IV diagnoses of alcohol abuse or dependence with the 133 subjects without either diagnosis. This analysis yielded similar models, with no significant chi-square for step difference for variances ($\chi^2 = 0.02$, 1 df, $p = .96$) and path values ($\chi^2 = 11.81$, 9 df, $p = .23$), but there was a significant chi-square for factor loadings ($\chi^2 = 24.16$, 8 df, $p < .003$). This effect for factor loadings was reflected in model fit indices varying across invariance levels (χ^2/df from 2.38 to 14.36; CFI from .98 to .92; NNFI from .85 to .94; RMSEA from .065 [.003-.120] to .102 [.064-.143]; and SRMR from .027 to .091). Not surprisingly, given the two groups being compared, the factor loading differences were the result of the measurement for the ALCOUT latent variable, with the number of maximum lifetime drinks being more heavily loaded for those with no diagnosis.

Finally, although for reasons explained earlier, LR is not hypothesized to overlap significantly with acquired tolerance, these data offered an opportunity to further explore that question. For these subjects, the correlation of LR to a self-report of having experienced tolerance to alcohol was .11 ($p = .06$), LR related to ALCOUT (recalculated after excluding tolerance) at $r = .45$ ($p < .001$), and tolerance related to the

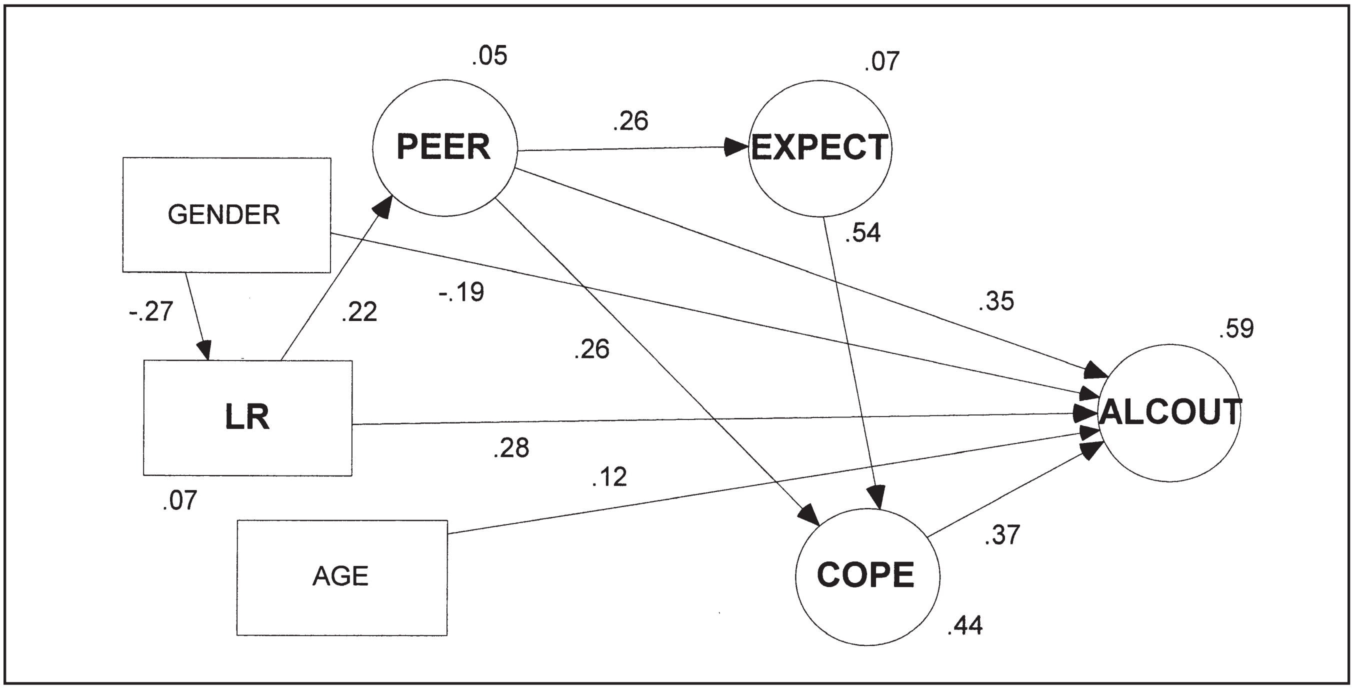

FIGURE 3. The structural equation model for the 325 drinking offspring using the measurement model indicators from Figure 2 and the abbreviations presented in Table 1. Here, only significant paths ($p < .05$) are presented, beta weights are offered for each path, and the final R^2 is noted above ALCOUT.

modified definition of outcome at $r = .43$ ($p < .001$). Using tolerance as a covariate, the correlation of LR to ALCOUT did not change much ($r = .42$, $p < .001$), and partialing for LR did not affect the correlation of tolerance to ALCOUT ($r = .43$, $p < .001$). These results support the conclusion that LR and tolerance are independent predictors.

Discussion

The current analyses report the results of the only known attempt to evaluate the entire LR-based model of heavy drinking and alcohol problems in a large population of adolescents outside of the original San Diego Prospective Study. Such evaluations can help establish the generalizability of the model evaluated at a time relatively close to the onset of drinking and when alcohol problems and heavy consumption are likely to begin (Brown et al., 2008; Faden and Fay, 2004). Comparisons of the performance of the model across populations could also offer potential clues regarding how key elements of the model might differ across subgroups of adolescents. The most salient current results offer insights regarding how LR relates to alcohol outcomes both directly and through partial mediators. In this relatively young population, PEER and COPE partially mediated the impact of LR on outcomes, potentially offering clues to environmental components that might be addressed in prevention efforts looking to diminish the link between LR and heavier drinking or alcohol problems.

The results confirm the findings from all three prior SEM evaluations of adolescents indicating a direct relationship between a lower LR to alcohol and heavier drinking or alcohol-related problems (Schuckit et al., 2005, 2008b,d). The results are also consistent with the prior evaluation of 688 13-year-olds in demonstrating that a low LR related to heavier peer drinking (Schuckit et al., 2008b), although an evaluation of 113 12- to 24-year-old offspring from the San Diego Prospective Study did not support this conclusion (Schuckit et al., 2008d). In the latter article, the zero-order correlation between LR and peer drinking was .08 ($p = .42$), and it is not clear whether the lack of significance in the SEM reflected the relatively older age of the population, low statistical power, or the difference between the COGA and San Diego Prospective Study populations in the educational levels and incomes of the families (Schuckit et al., 2002). The evaluations of these potential explanations are important, because the differences may indicate that heavier peer drinking is more likely to function as a mediator between LR and alcohol outcomes in only some subgroups of subjects, and additional studies are needed.

Two of the three prior SEM analyses had included alcohol expectancies in the SEM, and both reported that LR was related to EXPECT on both zero-order levels and within the model (Schuckit et al., 2005, 2008d). In the current analyses with relatively young subjects, the Pearson product-moment correlation between LR and expectancies was .10 ($p = .09$), and as a consequence, no direct link was observed between these domains in the SEM. Thus, the current analyses represent an exception to the prior findings regarding the importance of expectancy within the LR model, perhaps reflecting age differences or the lower education and higher level of associated impulsivity and drug-related issues in the COGA population (Schuckit et al., 2002). Further analyses will need to determine whether expectancy is less likely to operate as a mediator of the relationship between LR and alcohol outcomes in such families.

The use of alcohol to cope with stress, although important in the adult model (Schuckit et al., 2004), had been tested only in one prior analysis of adolescents (Schuckit et al., 2008d). Similar to the current findings, in the 113 offspring from the San Diego Prospective Study, COPE, in conjunction with EXPECT, functioned as a partial mediator of the relationship between LR and alcohol outcomes. COPE also mediated the impact of expectancy on ALCOUT in both models and mediated the impact of peer drinking on outcome in the current analysis. Thus, COPE has an important indirect mediational role in both higher socioeconomic status offspring as well as in the COGA protocol.

Age did not relate to LR in any of the four adolescent SEMs tested to date, including the current evaluation (Schuckit et al., 2005, 2008b,d). This was true despite a relatively wide age range in all analyses except for the Avon Longitudinal Study of Parents and Children–based protocol, which focused only on 13-year-olds (Schuckit et al., 2008b). Therefore, although age was related to alcohol outcomes on at least a zero-order level in all four analyses, this variable did not play a key role in affecting how LR influences alcohol outcomes during adolescence. The age invariance testing reported here supports similar models for older and younger subjects, with similar directions of the relationships among domains and for path coefficients across the age groups, although older subjects were more likely to demonstrate statistical significance to the paths compared with younger individuals.

The finding in three of the four analyses, including the current results, that LR significantly related to gender (the exception being the very young subjects from the Avon Longitudinal Study of Parents and Children sample [Schuckit et al., 2008b]) suggests that gender might play a key role in the manner in which the LR-based model operates. This may reflect the facts that females weigh less, have less body water, and metabolize alcohol a bit slower than males and, thus, have a higher BAC per drink consumed (Eng et al., 2005). In all models, gender also related to alcohol outcomes either directly or via mediation by PEER. The relatively consistent relationship among gender, LR, and outcomes indicates the importance of considering this variable in these SEMs regarding the impact of gender on elements within the model. However, in general, the models appear to have operated similarly for males and females with no significant chi-square values for any step difference in the invariance procedures. In the current results the relationships between a low LR and heavier drinking peers and between age and alcohol-related outcomes appeared to be more robust for females.

In summary, the current evaluations are consistent with prior SEMs carried out in adolescent LR-based models in supporting a direct relationship between LR and alcohol outcomes as well as mediating roles for PEER, EXPECT, and COPE, with some potentially interesting differences in potential mediational roles across samples. Neither age nor gender had a major impact on the performance of the LR-based model, although for gender, several of the relationships may have been more prominent in females than in males. These results are similar regarding age and gender to prior invariance testing (Schuckit et al., 2005, 2008b,d).

The analyses presented here are also similar in many ways to the test of the full model in more than 300 middle-age probands from the San Diego Prospective Study (Schuckit et al., 2004). Consistent with the current report, the evaluation in adults also demonstrated a significant direct path between a low LR and heavier drinking/alcohol problems, along with a mediational role for COPE operating between LR and alcohol outcomes. However, the performances of both peer drinking and alcohol expectancies were less robust in the older population.

It is important to recognize the liabilities as well as the assets of the current protocol. The offspring came from families densely affected by alcohol-use disorders and represent a group with lower levels of education and income (Schuckit et al., 2002). The key variable here, LR, was determined by a retrospective, self-report measure that, although overlapping significantly with alcohol-challenge LR results (Schuckit et al., 2009), has not been as widely tested. The SEM represents only cross-sectional analyses, and thus, the prognostic implication of the model in adolescents has not yet been established. Also, further studies will be required to help establish which of the potential explanations of differences in model testing across populations are most salient. Finally, the model tests only a limited number of variables, and additional important questions (e.g., whether the number, quality, and context of alcohol experiences might affect LR, EXPECT, or other domains) were not evaluated.

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