Environmental and Individual Predictors of Error in Field Estimates of Blood Alcohol Concentration: A Multilevel Analysis*

JOHN D. CLAPP, PH.D.,† JONG W. MIN, PH.D., AUDREY M. SHILLINGTON, PH.D., MARK B. REED, PH.D., JAMES E. LANGE, PH.D., AND MEGAN R. HOLMES, B.A.

Prevention Science Collaborative, San Diego State University, 6386 Alvarado Court, Suite 224, San Diego, California 92120

ABSTRACT. Objective: Using self-report survey data and measures of breath alcohol concentration (BrAC), this study examined the validity of an estimate of blood alcohol concentration (eBAC). Differences between eBAC and BrAC were modeled to identify sources of error related to survey-derived eBAC. Further, using hierarchical multilevel analyses, environmental event characteristics were examined as sources of eBAC error. **Method:** College students were interviewed and provided breath samples at randomly selected parties on Friday and Saturday nights. Interviews included items assessing the total number of drinks consumed, duration of drinking event, gender, and weight, which allowed for the calculation of eBAC. **Results:** Overall, eBACs were inaccurate. Total number of drinks consumed was associated with underestimates of eBAC, whereas time drinking was associated with overestimates of eBAC. Environmental variables, including party size, rowdy behavior, having food present, and observing many intoxicated partygoers, were also associated with eBAC errors. **Conclusions:** Current self-report survey methodology to calculate eBAC may be insufficient to estimate BAC with any accuracy. Environmental factors associated with the last drinking event for which BAC is being estimated should be considered when calculating eBAC. (*J. Stud. Alcohol* **67**: 620-627, 2006)

THE HIGH COST OF BIOLOGICAL MEASURES of blood alcohol concentrations (BACs) has resulted in few studies (see Lange and Voas [2001] and Thombs et al. [2003]) of college student drinking that have collected biological BAC data. Thus, most epidemiological studies (e.g., Johnston et al., 1995, 2005; Wechsler et al., 1994, 1998, 2000) and prevention trials (e.g., Clapp et al., 2003, 2005; Weitzman et al., 2004) in the college-drinking field have relied on self-report measures of alcohol consumption. Common self-report measures of alcohol consumption include heavy episodic drinking measures (Wechsler et al., 2000), frequency of drinking, drinks per occasion, and total drinks for a period (Clapp et al., 2003; Gruenewald and Nephew, 1994). Expressed as averages (e.g., mean drinks per occasion in the past month), drink counts (e.g., number of days in past month with one or more drinks), or categorical percentages (e.g., heavy vs nonheavy episodic drinker), such indicators require respondents to recall their drinking behaviors for specific periods. The capacity of respondents to accurately assess their alcohol consumption (i.e., number of standard drinks consumed over a specific time interval) is the primary concern associated with self-report measures.

Event-based drinking data, typically obtained as a count of the number of drinks consumed at a given occasion, can be used along with other survey items (i.e., gender, duration of drinking event, and weight) to estimate BACs (eBACs). Given eBAC is often the only viable alternative for researchers interested in using BAC as an outcome measure, research assessing the validity of such measures and how they are derived is important.

Survey-based estimates of BAC

In 1932, Widmark first published the formula ($A = r \times p \times C_0$) for calculating eBAC, where alcohol concentration in blood (A) equaled body weight (r) multiplied by the fraction of body mass in which alcohol would be present if the alcohol was distributed equally throughout the body's blood (p) multiplied by time (C_0). Decades later, Matthews and Miller (1979) noted Widmark's calculation of eBAC failed to take into account gender differences in the volume distribution of alcohol in the human body. Further, the Widmark eBAC calculation was limited to a relatively small number of drinks consumed over a short time (Matthews and Miller, 1979). Two years later, Watson and colleagues (1981) found the Widmark formula overestimated BAC and was particularly inaccurate for females. They reasoned that when alcohol-loading doses were considered in the Widmark formula, p was calculated in grams of alcohol per kilogram of body weight without taking into account the ratio of

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†Correspondence may be sent to John D. Clapp at the above address or via email at: jdclapp@mail.sdsu.edu.

body fat to total body mass, thereby biasing eBAC values for females, who have different ratios of body fat to total body mass compared to males. To address this concern Watson et al. (1981) presented a revised formula for calculating eBAC.

Self-report behavioral proxies for intoxication

Despite such refinements in eBAC formulas, no measure of eBAC gained universal acceptance. During the 1990s, researchers often used measures of heavy episodic drinking as a proxy for intoxication rather than calculating eBACs.

Heavy episodic drinking is most commonly defined operationally as five or more drinks during a single drinking occasion, specifically by the Centers for Disease Control and Prevention, the Substance Abuse and Mental Health Services Administration (Williams and Clark, 1998), the Monitoring the Future Survey (Johnston et al., 1995), and the Core Institute's Core Alcohol and Drug surveys (Presley et al., 1994). A series of national studies of college drinking by Wechsler and associates (beginning with Wechsler et al. [1995]), however, employed a gender-specific operational definition of heavy episodic drinking of five or more drinks for men and four or more drinks for women.

Research has shown these operational definitions of heavy episodic drinking are relatively poor proxies for intoxication. Lange and Voas (2001), for instance, investigated the extent to which these heavy episodic drinking definitions predicted BAC estimates by breath alcohol concentration (BrAC) sample levels of .08 or higher, the legal threshold for drunk driving in many states. They found both men and women had to consume one to two more drinks than the five/four standard to reach the specified BrAC level of .08. Similarly, Thombs et al. (2003) found that BrACs and the related number of drinks required to achieve them were nearly identical to those reported by Lange and Voas (2001). Further, Thombs et al. (2003) found the five-plus/four-plus heavy episodic drinking definition failed to have good specificity, had poor positive predictive value related to BrAC, and had relatively high rates of false positives.

Sources of estimate error in eBAC measures

In a recent study, Hustad and Carey (2005) examined several algorithms for calculating eBAC from self-administrated survey items, compared the accuracy of the eBACs relative to BrAC, and modeled components of the eBAC algorithms to detect which factors were associated with discrepancies in the estimates. BrAC samples were collected in public settings proximal to bars located near a university. Survey items used to construct eBACs were collected from participants via a web-based survey the following day. Hustad and Carey (2005) reported that time spent drinking, number of drinks, gender, and year in college were associated with discrepancies in the eBAC-BrAC estimates.

The Hustad and Carey (2005) study is an important contribution to the understanding of the validity of self-reported alcohol consumption and its relation to eBAC. First, the study identified that Matthews and Miller's (1979) equation yields the most accurate eBAC calculation related to BrAC. Second, as noted above, the study identified which aspects of the equation were associated with inaccuracy in eBAC. Despite collecting BrAC samples in natural settings, the authors did not examine the influence of environmental factors as they relate to discrepancies in eBAC and BrAC estimates. Such factors may impact respondent recall and, ultimately, the validity of eBACs.

The present study examines the influence of environmental factors on the accuracy of eBAC and presents analyses consistent with the recent study reported by Hustad and Carey (2005) and Carey and Hustad (2002). Furthermore, unlike the methodology used by Hustad and Carey (2005), we collected both self-report measures of drinking as well as BrAC samples during the same field interview, thereby reducing potential recall bias that might occur when asking individuals to report alcohol consumption from past drinking occasions. Finally, we augmented these data with observational data collected during the drinking events.

Method

Sample and setting

A total of 618 student surveys and corresponding BrAC samples, collected at 46 randomly selected college parties, were included in the present study. These data were collected as part of a larger, multiyear epidemiological and prevention trial conducted at San Diego State University. The overall study—including the methodology used to collect the data presented here—was approved by the San Diego State University institutional research board. Data were collected over 15 observation nights.

San Diego State University has a diverse population of 23,792 undergraduate students. The racial and ethnic breakdown of the university is as follows: 4.1% black, 12.6% Asian American/Pacific Islander, 15.7% Hispanic, and 45.9% white (the remainder is unspecified). Fifty-five percent of the student population is female. The mean age of undergraduates is 22.8 years.

Respondents to the survey did not accurately reflect the campus population: 74.5% of our sample was white and only 10.6% was Hispanic. Blacks (2.5%) and Asian American/Pacific Islanders (7.4%) were also underrepresented in our sample. The mean (SD) age of the sample (20.1 [2.1] years) was also lower than the campus mean. Given that the bulk of students living near the campus are freshman and sophomores (two thirds of the sample were freshmen or sophomores) and that older students tend to drink in bars and clubs (Clapp et al., 2006), this lower mean is not surprising.

Procedures: Measuring party environments

Identifying parties. For this study, we defined a party as five or more students gathered together where alcohol consumption was present. To locate parties, we developed a driving route (6.2 miles) that included several neighborhoods adjacent to our study campus. We developed the driving route over the course of a semester-long pilot phase. During the pilot phase, the study investigators and student research assistants drove and walked through the campus area on several weekend nights to determine student-housing areas. The final route includes streets with single-family homes (student rentals), three apartment complexes, and a fraternity row. Party surveys were conducted on Thursdays, Fridays, Saturdays, and some holiday nights.

During our pilot phase, because parties started and ended at various times over the course of the night, we made two sweeps of our driving route (9:00 PM and 11:00 PM) on survey nights. During these sweeps, a field manager and four research assistants slowly drove the route and noted the addresses of homes with parties. In cases where individual apartments within complexes could not be viewed easily from the road, research assistants conducted a walking sweep. On average, we located 10.91 (range: 3-20) parties per night.

Sampling parties. After each sweep, we assigned every party a number and randomly selected the order in which we observed the parties. During our first sweep, we surveyed up to three parties (depending on size, etc.). During our second sweep, we surveyed up to four parties. In instances where the party host refused to let the survey team enter the party (15.7%) or the party was disbanded once we arrived (31.7%), we went to the next party in the random sequence. On average, we observed 3.3 (range: 1-5) parties per night.

Gaining access to parties. Our survey team consisted of seven people: a field survey manager (i.e., lead interviewer), a field survey supervisor, a security person, an observer, and three interviewers. Once we arrived at a party, the field survey manager and one interviewer approached the party and asked to speak to the host. The manager then explained the study to the host (including informed consent). Hosts were offered a $20 gift card as an incentive for granting access to the party. To facilitate entry into the college parties, all of our interviewers were in their early 20s. To ensure that each member of the research team abstained from consuming alcohol on the night of the survey, research team members provided pre- and postsurvey BrAC samples.

Party survey process. Once access to the party was granted, our interviewers, observer, and field manager entered the party and began the survey. In small parties (under 20 people), we attempted to conduct a census of partygoers; on average, we surveyed 84.8% of partygoers at small parties (refusal rate = 2.8%). At larger parties, however, we interviewed as many partygoers as possible during a half-hour period (typically, 34.4% of partygoers were surveyed; refusal rate = 12.7%). Interviewers explained the study and provided a consent form to each participant. Partygoers were then asked to complete a brief survey with the assistance of the interviewers and to provide a BrAC sample (explained below). Partygoers received a $5 gift card as an incentive for their participation at the end of the assisted interview.

Collecting breath samples. Breath samples were collected using a handheld BrAC test unit (CMI Intoxilyzer SD-400; CMI, Inc., Owensboro, KY). These units were manufactured between 2000 and 2003 and were calibrated monthly. The units were programmed so BrAC values were not visible; however, respondents could call our research office the following day to obtain their BrAC measurement. These BrAC test units were also programmed to clear a sample prior to allowing a new sample to be collected.

The manufacturer of the units suggests that 15-20 minutes pass between a subjects' last sip of alcohol and the administration of a breath test. The recommended duration is set largely for legal evidentiary standards. Our field setting precluded this long duration in some cases. However, 84% of our sample had durations of 10 minutes or more between last drink and providing a breath sample. For analytical purposes we restricted our final sample to these individuals.

Measures

Self-reported survey items. The partygoer survey included items that assess the following: (1) demographics (gender, age, weight, etc.), (2) length of stay at the party, (3) length of drinking for the evening (time from first drink to last drink), (4) number of drinks consumed (one drink = one beer, one glass of wine, one mixed drink, or one shot of distilled spirits), (5) drinking plans for the evening, (6) places alcohol had been consumed prior to the party, (7) drinks consumed at the party, (8) how alcohol was obtained, (9) whether drinking games were played, and (10) whether any problems had occurred at the party. These items were modified from those used in previous studies (Clapp et al., 2003).

Party observations. While the survey was being conducted, the party observer drew a map of the physical layout of the party. He or she also completed a checklist that assessed the following: (1) the number of people at the party (a head count at small parties and a grid-density estimate at larger parties [see Swank and Clapp, 1999]), (2) whether the party had a theme (e.g., toga, etc.), (3) whether food was present, (4) whether there was rowdy behavior (pushing, throwing things, etc.), (5) whether there was loud music (hard to talk or hear conversation), (6) whether drinking games were being played (e.g., quarters, etc.), (7) whether illicit drugs such as marijuana were present, (8) the type of alcohol that was present, and 9) evidence of any party-related problems (fights, etc.). Party size was categorized into large (20 or more guests) and small (<20) parties.

eBAC. We computed eBAC from our survey data using Matthews and Miller's (1979) formula: $BAC = [(c / 2) \times (GC / w)] - (\beta_{60} \times t)$. In this formula, BAC is expressed in grams per deciliter, c is the number of standard drinks reported, GC is gender constant (9.0 for females and 7.5 for males), β_{60} is the metabolism rate of alcohol per hour (.017 g/dl), and t is the number of hours spent drinking (Matthews and Miller, 1979; the above is adapted from Hustad and Carey, 2005). Time spent drinking was computed using the time from a respondent's first drink to the time of the breath test.

We then computed a difference score (eBAC - BrAC) and categorized these scores into three categories: accurate eBACs (within ±.02) and BrAC underestimate (eBAC underestimates BrAC) and overestimate (eBAC overestimates BrAC) categories. By definition, any respondent with a BrAC of .02 or less could not be classified as "underestimate." To control for this, those respondents were eliminated from the analysis. Given that the primary intent of our analyses was to examine the direction and likelihood of inaccuracy, we did not focus our analyses on the relationship of estimation error to the BAC curve and intoxication. We see this as an important, but separate, issue. Previous studies (Hustad and Carey, 2005) have used variants of ordinary least squares multiple regression approaches to examine BrAC and eBAC differences. To date, none of these studies has adjusted for the almost universal nonagreement between BrAC and eBAC. Our categorization scheme was designed to allow for imperfect but reasonable estimates (within a drink). Descriptive statistics for the three categories of eBAC/BrAC agreement are presented in Table 1.

Data analysis procedure

Conceptually, each of the 46 parties visited constituted a cluster. Such clustering can yield dependent observations (in this case BrACs and the other measures within each party). Therefore, we initially conducted multilevel data analyses to assess intraclass correlation and to examine any between-cluster variation of the log odds of our multinomial dependent variable of interest. We computed a two-level hierarchical linear model (HLM), using HLM 6.02 (Scientific Software International, 2004). Results of the HLM analysis suggested there were no significant variations across clusters, indicating no evidence of dependence of observations at the party level. Given that intraclass correlation was not an issue, we employed a standard hierarchical logistic regression strategy.

First, we examined the bivariate relationships between estimation accuracy and several independent variables. Because our dependent variable, "estimation accuracy," has three categories, multinomial logistic regression was used for bivariate and multivariate analyses. It should be noted that our primary analysis strategy was to test the ability of the estimation models to accurately estimate BrAC; thus, the statistical estimates presented represent accuracy of "the estimation model," not estimates of individual respondents' BrACs. We computed bivariate analyses by running a series of multinomial logistic regressions on each independent variable. Second, for multivariate analyses, we used multinomial logistic regression to identify significant correlates of estimation accuracy, while controlling for other variables. Our multinomial logistic regression generated two logit models: (1) Logit 1 model for "underestimate" versus "accurate" and (2) Logit 2 model for "overestimate" versus "accurate." The "accurate" category was used as the reference in the analysis. Odds ratios and 95% confidence intervals of these logit models are presented in Table 2. Finally, we created a second model to examine whether party-related characteristics had any effects on the accuracy of estimation. Five party characteristic variables were included in this model: party size, presence of illicit drugs, rowdy behavior observed at the party, availability of food, and many intoxicated partygoers observed. This approach generated two models: The first model included one block of individual characteristics, and the second model included the same block of individual characteristics and a second block of party-related variables. Results from the two models are also presented in Table 2.

In the final hierarchical model, we also computed in a chi-square difference test to examine changes in the degrees of freedom between Model 1 and Model 2. The purpose of the chi-square difference test is to examine whether the block of party-level characteristics significantly contributes to the log odds of accuracy estimates above and beyond the contribution from the block of individual-level characteristics (Hosmer and Lemeshow, 2000).

In addition, as a model building strategy for multinomial logistic regression (Hosmer and Lemeshow, 2000), the following interaction terms were tested: Gender × Weight, Gender × Total Number of Drinks, and Gender × Total Hours Spent Drinking. These interaction terms were not significant, so they were excluded from all of the analyses presented in this article. In addition, no multicollinearity among independent variables was detected in any of the models tested. Missing data were excluded in a list-wise fashion, as the complexity of the multilevel analyses made imputation untenable. Outliers (i.e., eBAC or BrAC > .30) were removed from all analyses. We used Stata 8.0 to compute our multinomial regression models (StataCorp, 2004).

Results

Results on accuracy of estimation

The relationship between eBAC and BrAC is shown in Figure 1 with BAC <.02 included. Excluding BAC <.02 cases, these two measures of BAC were moderately and positively correlated ($r = .35$, $p < .01$). As shown in Table 1, the mean level of BrAC was .072 (.062), and eBAC was substantially higher, at .110 (.089). With regard to the accuracy of eBAC, approximately 24% of the sample eBACs accurately estimated BrAC (within ±.02). BrAC for more than half of the sample (52.2%) was underestimated, and 23.7% was overestimated.

Results from bivariate multinomial logistic regression

Consistent with Hustad and Carey (2005), our discrepancy categories were regressed on a series of predictive variables. Gender, participant weight, and the number of drinks reported at the event were significantly associated with the likelihood of underestimation of BrAC (not reported in either table). A higher number of drinks consumed, for instance, significantly increased the likelihood of underestimating BrAC by 54%. However, a person's higher weight was significantly associated with a decreased likelihood of underestimating BrAC. Interestingly, two of the above three variables examined—gender and weight—were not significantly related to our logit model of "overestimation versus accurate." Both the total number of hours spent drinking and the total number of drinks consumed were found to significantly increase the likelihood of overestimating BrAC by 15% and 12%, respectively.

Results from multivariate multinomial logistic regression

The first two data columns of Table 2 report odds ratios and 95% confidence intervals for two logit models: Logit 1 of Model 1 for "underestimate" versus "accurate," and Logit 2 of Model 1 for "overestimate" versus "accurate." Two

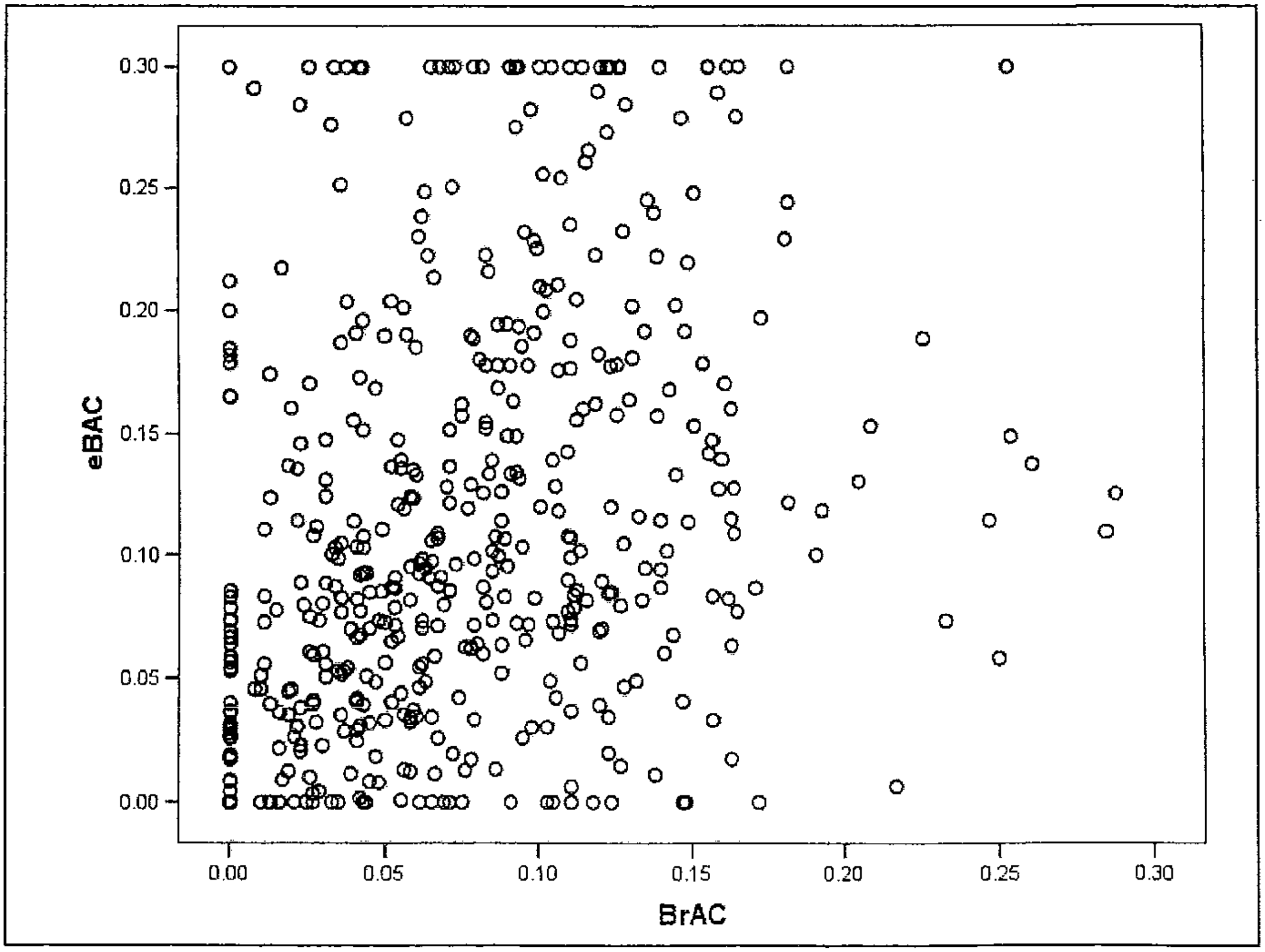

FIGURE 1. Scatter plot of estimate of blood alcohol concentration (eBAC) and breath alcohol concentration (BrAC)

TABLE 1. Characteristics of the study sample

Characteristics	Mean (SD) or % (N = 618)	Min.	Max.
Gender			
Female	36.5%	–	–
Male	63.5%	–	–
Weight, in pounds	162.8 (41.4)	96	350
Total no. of drinks (n = 551)	6.6 (5.5)	0	30
Time spent drinking, in hours	2.8 (2.1)	0	15
BrAC	.072 (.062)	.000	.300
eBAC (n = 534)	.110 (.089)	.000	.300
eBAC categories (n = 502)			
Underestimate	52.2%	–	–
Accurate	24.1%	–	–
Overestimate	23.7%	–	–
Mean difference (eBAC - BrAC)			
Underestimate	-.098 (.065)	–	–
Accurate	-.0007 (.01)	–	–
Overestimate	.07 (.088)	–	–
Time duration from last drink to breach BAC measurement (n = 456)			
0-10 minutes	16.0%	–	–
11-20 minutes	16.4%	–	–
≥21	67.5%	–	–
Percentage of abstainers, mean %	18.1 (8.8)	8.3	38.6

Notes: Min. = minimum; max. = maximum; BrAC = breath alcohol concentration; eBAC = estimated blood alcohol concentration.

variables significantly decreased the likelihood of underestimating BrAC: a person's weight (4%) and the total number of hours the respondent reported spending drinking (38%). Total number of drinks also increased the odds of underestimating BrAC relative to the accurate referent.

Logit 2 of Model 1 estimated the odds of overestimating BrAC relative to the accurate estimation of BrAC. In this model the total number of drinks respondents reported consuming decreased the likelihood of overestimating BrAC by 21%; however, the total number of hours the respondent reported drinking was significantly associated with the increased likelihood of overestimating BrAC. Weight and gender were not significant factors for the Logit 2 of Model 1.

Results from hierarchical multinomial logistic regression

Table 2 also presents results from our hierarchical multinomial logistic regression. The results presented in the third and fourth data columns (Model 2) are based on the addition of party characteristics to Model 1. In Model 2, results for individual characteristics are very similar to those from Model 1 in terms of the magnitude and direction of the odd ratios. However, four party-related variables also were significant to the log odds of estimate accuracy. In the Logit 1 of Model 2, two variables were significantly less likely to underestimate BrAC: rowdy behavior observed and food available, by 72% and 95%, respectively. In Logit 2 of Model 2, which estimated the odds of overestimating BrAC relative to accurate estimation of BrAC while modeling for both individual and party characteristics, a large party size increased the likelihood of overestimating BrAC by a factor of 3, whereas many intoxicated persons observed was significantly associated with decreased odds of overestimating BrAC by 88%. Last, the results from the chi-square difference test presented in Table 2 showed that the addition of party-related characteristics in Model 2 significantly increased the contribution to the log odds of the

TABLE 2. Hierarchical multinomial logistic regression on accurate estimate: Odds ratio (ORs) and 95% confidence intervals (CIs)

	Model 1		Model 2	
Characteristics	Logit 1 (underestimate vs accurate) OR (95% CI)	Logit 2 (overestimate vs accurate) OR (95% CI)	Logit 1 (underestimate vs accurate) OR (95% CI)	Logit 2 (overestimate vs accurate) OR (95% CI)
Individual characteristics				
Gender, 1 = female	1.66 (0.60-4.60)	1.88 (0.78-4.50)	1.47 (0.51-4.23)	1.87 (0.75-4.67)
Weight, in pounds	0.96‡ (0.94-0.98)	1.01 (0.99-1.02)	0.96‡ (0.94-0.98)	1.01 (0.99-1.02)
Total no. of drinks	2.01‡ (1.66-2.43)	0.79† (0.67-0.93)	2.33‡ (1.85-2.94)	0.80* (0.67-0.95)
Total hours spent drinking	0.62‡ (0.48-0.81)	1.40† (1.12-1.74)	0.54† (0.40-0.73)	1.36† (1.11-1.75)
Party characteristics				
Party size, 1 = large			0.60 (0.24-1.51)	3.01* (1.23-7.34)
Presence of illicit drug			0.55 (0.16-1.97)	0.57 (0.18-1.84)
Rowdy behavior observed			0.28* (0.09-0.89)	0.44 (0.16-1.22)
Food available			0.05* (0.00-0.60)	3.16 (0.59-16.9)
Many intoxicated persons observed			0.17 (0.03-1.05)	0.12* (0.02-0.69)
N	354		354	
Log likelihood	-235.63		-218.85	
LR chi-square	245.09‡, 8 df		278.67‡, 18 df	
Changes in chi-square	χ^2 = 33.58, 10 df, p < .001			

Notes: A response of "accurate" was used as a reference category. LR = likelihood ratio.
*p < .05; †p < .01; ‡p < .001.

accuracy estimation as indicated by the significant difference in chi-square statistics from Model 1 to Model 2 (278.67 [18] - 245.09 [8] = 33.58 [10], $p < .001$).

Discussion

This study examined individual and environmental levels of error in eBAC values computed from survey items using the formula derived by Matthews and Miller (1979). The study contributes to our understanding of the issue of eBAC accuracy by examining environmental variables. Although similar to other studies (i.e., Hustad and Carey, 2005) our methodology is unique in several ways. First, our respondent self-report data were collected in a natural drinking setting. Second, we augmented self-report data with observational data, which allowed us to use multilevel, multivariate analyses to examine the relative effects at both the respondent and party level.

Despite these strengths, our data are limited because we only examined one type of natural drinking setting—parties. Different environmental variables might be salient in bars or night clubs. Our data are also only generalizable to one campus neighborhood. Future studies are needed in other campus communities across the nation to validate our findings.

Similar to previous studies (e.g., Carey and Hustad, 2002; Hustad and Carey, 2005), we found that variables included in the eBAC calculation formula were associated with estimate inaccuracy, and these inaccuracies varied in both directions. Future research is needed to examine how the variables that comprise these formulas (i.e., time spent drinking, etc.) could be altered or weighted to yield more accurate in vivo BAC estimates. Further, it would be useful to examine how eBACs relate to the BAC curve. Specifically, a study that examined how eBACs differentially predict higher and lower BrAC, and the relative importance of estimate errors would be an important step in correcting eBAC formulas.

Our study is the first to examine environmental predictors of eBAC inaccuracy. Given that the survey items that generated eBAC values are based, in part, on event-specific drink counts and drinking durations, the examination of event influences is important. Our findings are both intuitive and surprising. For instance, the finding that larger parties are associated with overestimation makes sense. In large settings, it is reasonable to speculate that respondents may monitor their alcohol consumption with less care. Our finding concerning rowdy behavior could be similarly explained. Additionally, our finding that having food present at an event was protective of underestimation of BrAC is also intuitive because food slows down the metabolism of alcohol. In an earlier study, we have also shown that food at an event is protective of heavy drinking (Clapp and Shillington, 2001). These findings illustrate the difference between field conditions and the pharmacokinetic laboratory studies in which the eBAC formulas were established and where the consumption of food was controlled. More research is needed to understand better the mechanisms underlying how the environment influences self-monitoring and the recall of alcohol consumption information.

Our findings have important implications for the interpretation of self-report measures of alcohol consumption. First, because there is a movement toward eBAC-based definitions of heavy episodic drinking in alcohol-related research (National Institute on Alcohol Abuse and Alcoholism, 2004), it seems imperative to develop practical methods of assessing the BACs of individuals who drink. However, the results of this study, as well as those described by Hustad and Carey (2005), highlight the imprecision of our current methods used to calculate eBAC. Our findings and those of Hustad and Carey (2005) demonstrate that physiological factors critical to the calculation of eBAC introduce estimate discrepancies. Although the introduction of these discrepancies is disconcerting, it may be plausible that eventually physiologically based estimation errors may be handled through formula refinement. More troubling are the environmental sources of errors that we have identified in this study. The fact that environmental factors such as party size and the presence of (heavily) intoxicated others predict eBAC - BrAC discrepancies casts a level of uncertainty concerning respondent recall and reporting accuracy with respect to the variables critical for BAC estimation. Because previous research has demonstrated that environmental variables such as party size are predictive of self-reported consumption (e.g., Clapp et al., 2003), we are left to question our ability to accurately create an eBAC as well as our understanding of the relationship between environmental factors and alcohol consumption.

It is also important to note from these results that <25% of BAC estimates were within ±.02 of the breath-assessed BAC. Most of the discrepancies were underestimates. The large discrepancy between the mean eBAC and mean BrAC in this sample is substantial enough to question the utility of using self-report measures in light of the systematic nature of these biases.

The basis of epidemiological, etiological, and intervention evaluation studies in the area of college student drinking, with very few exceptions (i.e., Thombs et al., 2003), is self-report data. In addition, self-report data are used heavily in interventions such as norms social marketing and normative feedback. The extent that the validity of self-report data may be jeopardized by the types of settings in which college students drink should be a major concern to both researchers and alcohol prevention professionals.

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that larger groups predicted heavier drinking. Hennessy and Saltz (1993), however, found that time spent in a bar, a variable included in our models, mediated this relationship. Future research might examine social group characteristics such as leadership, shared motivations, and competition. Further, it would be useful to measure how bar environments might influence group processes by introducing new members and/or subtracting original members (i.e., group cohesion).

4.3. Individual level

When examining our individual-level findings in the final hierarchical models, being male, planning to continue to drink after leaving the bar, and time spent in the bar all contributed to BrAC change. Similarly, intentions to get drunk predicted a greater degree of BrAC change. These findings are consistent with past studies (Clapp et al., 2003; Cox and Klinger, 1988; Hennessy and Saltz, 1993) and illustrate the importance of further examining person-level characteristics in future ecological studies. One area that was fairly limited in the present study was our measure of motivations. Future studies would benefit from standard general measure of drinking motivations (The Copper Scale for instance) and the inclusion of exploratory event specific motivations.

Interventions aimed at shifting such motivations (individual level) might include increasing the perception of risk for problems (i.e., DUI) using media campaigns (Clapp et al., 2005) or employing brief interventions in the field (Lange et al., 2006). Such interventions, coupled with environmental manipulations like those described above, might mitigate such intentions. Again, developmental and evaluative research in this area is needed.

4.4. Strengths and limitations

This study examined the relationship between environmental characteristics of bars and estimates of blood alcohol concentrations. The study is unique in that it employed both observational measures of the bar, patron interviews, and collected breath samples. Such designs have ecological validity, in that they likely reflect the "real world" better than laboratory or retrospective survey based research. The design of the present study, however, has some limitations which illustrate the challenges associated with such research. First, pre-bar drinking environments were measured using self-reports; however, having a BrAC measure upon entrance mitigates problems with self-reports of alcohol use. Another limitation is that we were unable to capture multiple pre-bar drinking environments across one evening or establish a detailed sequence of drinking behavior in multiple environments. Studies that use time and location sampling might help address this issue. We encountered the same limitations with intentions to drink after leaving the bar. Additionally, we were unable to track respondents to determine whether the drinking episode was linked to any subsequent alcohol-related problems (e.g., DUI, illness, regretted sex, etc.). Ecological momentary assessment studies might yield such information.

In sum, among bar patrons, drinking behavior within a nighttime single episode appears to occur in multiple contexts with numerous risk and protective factors. The complexity of such episodes and the environments in which they occur represent person and environment interactions that might be amenable to prevention efforts. As such, this study was a preliminary effort to better understand the nature of alcohol intoxication in dynamic settings.

Conflict of Interest

There are no conflicts of interest to report.

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