INTRODUCTION

Drinkers are often unfamiliar with the disconnect between blood alcohol concentration (BAC) and perception of impairment (Harrison and Fillmore, 2005). Specifically, underestimation of actual BAC is common when BACs are in excess of 0.10% (Thombs et al., 2003). This may begin to explain why individuals feel able to drive with a BAC above the legal limit (Grant et al., 2012). Breath alcohol concentration (BrAC) estimation training is effective in increasing estimation accuracy in nonalcoholic drinkers (Huber et al., 1976; Shortt and Vogel-Sprott, 1978). Such training offers a potential means of preventing drunk driving or excessive alcohol intake.

Previous studies have not investigated personality traits that might facilitate or preclude successful acquisition of estimation training. Anxiety is one such trait that may predict high BrAC estimation accuracy. High-anxious individuals may be keenly aware of their subjective responses to stimuli (Van der Does et al., 2000) and, consequently, display accurate self-awareness of psychomotor impairment. In an earlier study by our group, high-anxious individuals were less confident in their driving ability after a simulated alcohol binge compared with their low-anxiety counterparts (Staniforth et al., 2010). These findings suggest that higher levels of trait anxiety may predict success in BrAC training due to the association between anxiety and interoception.

Sensation seeking and impulsivity may also predict estimation accuracy. Compared with infrequent sensation seekers, frequent sensation seekers engage in more high-risk behaviors while driving under the influence of alcohol (McMillen et al., 1989). These frequent sensation seekers may be less aware of the effects of alcohol, or may require higher doses to experience intoxicating effects. Similarly, drinkers with high levels of impulsive behavior have shown low levels of arousal and stimulation after consuming alcohol relative to low-impulsive drinkers (Shannon et al., 2011). Impulsive individuals may be less responsive to the biphasic effects of alcohol, and may require higher doses to differentiate these effects. Consequently, high sensation seeking and impulsivity may be negatively correlated with estimation accuracy.

The assumption that BrAC estimation training will change subsequent alcohol consumption and risky behavior has never been tested. Alcohol intervention programs for problematic drinkers can increase the ability to refuse alcohol (Sklar et al., 1997). If therapeutically effective, estimation training may increase drinking refusal self-efficacy by providing drinkers with information about the relationship between subjective intoxication and BrAC. Understanding this relationship will help drinkers appraise intoxication level accurately, which in turn may facilitate more cautious behavior after drinking. Furthermore, evaluation of potential deleterious consequences of risky behavior is a reliable predictor of both alcohol consumption (Mooney et al., 1987) and driving under the influence (Wilson and Jonah, 1985). Drinkers perceive fewer negative consequences from risky behaviors relative to their sober counterparts, leading to elevated likelihood of participation in risky activities (Fromme et al., 1997a). However, such increases in risk-taking behavior while under the influence of alcohol can be reversed when feedback is given about alcohol content (Burian et al., 2003).

In the current study, we tested the ability of binge drinkers to estimate BrAC after an intervention that incorporated estimation training. To model normative binge drinking patterns, we incorporated a simulated binge paradigm (Bernosky-Smith et al., 2011) that included four randomized doses in order to reach a BrAC of 0.08%. We hypothesized that the intervention group would improve estimation accuracy when compared with a control group who provided estimates without training. We also hypothesized that estimation accuracy would be greatest among individuals with high anxiety, low sensation seeking and low impulsivity. We predicted that estimation training, through education and increased self-awareness,
would facilitate reductions in drinking, risky simulated driving and self-reported driving under the influence at follow-up. Finally, we predicted that BrAC estimation training would increase the ability to refuse alcohol and decrease self-reported risk behavior at follow-up.

METHODS

Participants
Forty-six healthy men (n = 25) and women (n = 21) between the ages of 21 and 30 years participated in this study. The mean age (±SD) of this sample was 24 (±3) years, and participants had a mean (±SD) body mass index (BMI) of 24 (±3). Participants were recruited via television and internet networking site advertisements for a study examining the ability to estimate BrAC. A phone interview was conducted to assess drinking habits, medical history and illicit drug use. A binge was defined as four (females) or five drinks (males) consumed within a 2-h period (NIAAA, 2004). Participants who binged at least once in the past month were recruited to ensure familiarity with the administered alcohol dose. Exclusion criteria included a BMI below 18 or exceeding 30, an Axis I psychiatric disorder indicated by the modified structured clinical interview for DSM-IV disorders (SCID: First et al., 2002), an IQ below 80 on the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999), a head injury or use of psychoactive medication within the past 6 months, inability to provide a valid driver’s license, smoking >30 cigarettes per day and current habitual use of illicit drugs. A score above 15 (Bergman and Källmén, 2002) on the Alcohol Use Disorders Identification Test (AUDIT; Babor et al., 2001) resulted in exclusion from participation.

Informed consent/baseline measures
After giving informed consent, participants were administered the SCID and WASI, BMI was measured and a urine sample was collected to test for the presence of illicit drugs (Multi-drug 6 line urine screen; Innovacon, Inc., San Diego, CA) and for pregnancy in females (Quick Vue; Quidel, San Diego, CA). Participants completed self-report measures, practiced the STISIM Drive™ Driving Simulator and were scheduled to return for three alcohol administration sessions. The study protocol was approved by the Wake Forest School of Medicine Institutional Review Board.

Self-report measures
Barratt Impulsiveness Scale (BIS-11)
The BIS-11 was administered to measure trait impulsivity (Patton et al., 1995). The BIS-11 is a 30-item self-report questionnaire assessing general impulsiveness. Items can be answered with one of four responses: 1, rarely/never; 2, occasionally; 3, often; 4, almost always/always.

Cognitive Appraisal of Risky Events
The Cognitive Appraisal of Risky Events (CARE) was used to measure past frequency and outcome expectancies for participating in risky activities (Fromme et al., 1997b). Participants reported frequency of engaging in risky activities over the past 3 months (past frequency). Participants also responded to 7-point Likert scales (1, not at all likely; 7, extremely likely) to rate the likelihood of negative (expected risks) and positive (expected benefits) consequences of 30 potential risky activities (e.g. smoking marijuana, five or more drinks on one occasion, driving after drinking). CARE past frequency was assessed over the past 3 months during consent. CARE past frequency was also assessed at 1 month follow-up for participation in risk behaviors during the past month, and at 3-month follow-up for participation in risk behaviors during the past 2 months.

Drinking Refusal Self-Efficacy Questionnaire
The Drinking Refusal Self-Efficacy Questionnaire (DRSEQ) is a 3-factor, 31-item questionnaire measuring self-reported confidence in resisting drinking when exposed to specific drinking cues (Young et al., 1991). Items are answered on a 6-point scale with ‘1’ indicating ‘I am very sure I would drink’ and ‘6’ reflecting ‘I am very sure I would not drink’. Higher scores reflect stronger confidence in resisting alcohol.

Sensation Seeking Scale (SSS-V)
The SSS-V is a 40-item forced choice questionnaire measuring the personality trait of sensation seeking, which incorporates thrill and adventure seeking, experience seeking, disinhibition and boredom susceptibility (Zuckerman, 1994).

State-Trait Anxiety Inventory
The State-Trait Anxiety Inventory (STAI) trait version was designed to measure a stable propensity to experience anxiety, and tendencies to perceive stressful situations as threatening (Spielberger et al., 1970). The trait scale consists of 20 statements that require individuals to rate how they generally feel. Items can be answered with one of four responses: 1, almost never; 2, sometimes; 3, often; 4, almost always.

Timeline Followback Questionnaire
The Timeline Followback (TLFB) questionnaire consists of a calendar on which participants provide retrospective reports of daily alcohol intake (Sobell and Sobell, 1992). The TLFB questionnaire was completed during the initial screening session for number of alcohol drinks consumed daily during the past 3 months. The TLFB questionnaire was also completed at 1-month follow-up for drinks consumed daily during the past month, and at 3-month follow-up for drinks consumed daily during the past 2 months.

STISIM Drive™ Driving Simulator
A programmed driving procedure sensitive to various doses of alcohol (Bermosky-Smith et al., 2011) was used to evaluate risky driving behavior. Participants navigated a nine-mile course that alternated between suburban (speed limit 35–45) and highway driving (speed limit 55). Errors were defined as off-road accidents, collisions, pedestrians hit, speeding tickets, traffic light tickets, stop sign tickets, centerline crossings and road edge excursions. Risk behavior was quantified as mean speed, total errors committed and total time spent speeding. All participants completed the driving simulation after alcohol administration during the pretraining session and then again during the testing session.
**Study design**

Participants were semi-randomly assigned to the intervention (n = 11 females, 12 males) or control (n = 10 females, 13 males) group; assignments were occasionally adjusted to insure roughly equal proportions of sex and drinking levels (1–7, 8–13 or 14 or more self-reported weekly standard drinks) in each group. Participants completed six sessions over a 4-month period: consent, pretraining baseline, training, testing and two follow-up sessions. Participants were asked to eat before each alcohol administration session (pretraining, training and testing). At the beginning of every session, participants were tested for the presence of illicit drugs and for pregnancy in females and were excluded from the study for positive results during the screening and alcohol sessions. The mean interval between alcohol sessions was 7 days (range 1–14 days). Follow-up sessions occurred 1 and 3 months after the testing session.

**Alcohol administration sessions**

An expired-air sample was obtained to confirm a BrAC of 0.00% (INTOXILYZER 5000, CMI, Inc., Owensboro, KY). Alcohol administration simulated an alcohol binge according to the guidelines set forth by NIAAA (2004). Four doses were administered in random order over 2 h: 0.32, 0.24, 0.16 and 0.08 g/kg (0.8 g/kg total). The doses were varied in this manner to strengthen training efficacy by encouraging differentiation of each drink’s unique effects. In women, doses were reduced by 8% to equate peak BrAC across sex (Hindmarch et al., 1991). Each dose was administered in a soda vehicle totaling 237 ml. Participants were given 10 min to consume each drink, followed by a 20-min absorption period before consumption of the next drink. At the conclusion of BrAC estimates, expired-air samples were taken every 20 min until dismissal. Participants with BrAC ≤0.03% were free to leave the laboratory with a designated driver.

**Pretraining session**

Estimates were made verbally on a scale of 0 (sober) through 100 (above the legal limit to drive). Participants were informed that an estimate of 80 would equate to 0.08%, or the legal limit for driving under the influence of alcohol. Estimates were made 60, 90, 120, 150 and 180 min after administration of the first drink. Participants completed the driving simulation after providing the BrAC estimate at 120 min.

**Training session**

Participants in the intervention group underwent external and internal BrAC training. External training comprised individualized explanations of BrAC-dose relationships for body weight and sex, as well as basic information regarding alcohol metabolism. Internal training consisted of listening to a standard relaxation CD to increase interoceptive awareness. Incorporation of instruction in relaxation techniques has been included in previous studies of BrAC estimation training (Huber et al., 1976; Lipscomb and Nathan, 1980). Prior to each BrAC estimate, participants were asked to concentrate on current physical symptoms, emotions and feelings. A subjective intoxication scale was administered to the intervention group prior to each BrAC estimate to aid in awareness of internal states and their association with varying BrACs. Participants responded to

**Testing session**

This session assessed estimation accuracy in the absence of BrAC feedback. The intervention group was asked to use the training to increase BrAC estimation accuracy. Participants in the control group were asked to estimate their BrAC just as they did during the previous two sessions. All participants had the opportunity to earn a monetary bonus of $4 during the testing session for each estimate within 15% of actual BrAC (Huber et al., 1976; Lipscomb and Nathan, 1980). Following alcohol administration, participants completed the driving simulation once more. Administration of alcohol, timing of BrAC estimates and time of simulated driving were identical to the pretraining procedure.

**Follow-up sessions**

All participants returned to the laboratory 1 and 3 months post-training. They were re-administered the TLFB, CARE and DRSEQ. All participants were financially compensated upon study completion.

**Statistical methods**

Independent samples t-tests were used to examine pre-consent group differences in age, BMI, IQ and self-report measures. Error score for BrAC estimates was calculated at each of the five time points as the absolute value of the difference between actual and estimated BrAC multiplied by 100. For example, if a participant provided a BrAC of 0.06%, and estimated BrAC as 0.04%, the error score for that estimate would be 2 (i.e. (0.06 − 0.04) × 100). Total error score was calculated as the sum of the five error scores during each session. Both pretraining and testing total error scores had skewed distributions that necessitated use of the log-transformed values in the multivariate models of these measures when used as dependent variables. When the pretraining error score was included as a baseline adjustment in the multivariate setting, the original scale was retained. Total error score was used in analyses to control for individual differences in estimation across each session.

Pearson correlations quantified relationships among IQ, STAI total, BIS-11 total, SSS-V total, CARE expected risks total, log of pretraining error score and log of testing error score (SigmaPlot; Systat Software, Inc., San Jose, CA). A 2 × 2 analysis of variance (ANOVA) with repeated time and non-repeated group factors was used to compare total error score between the intervention and control groups across the pretraining and testing sessions.

All multivariate models were examined using SAS (SAS Institute, Cary, NC) PROC GLM. Association between self-report measures (BIS-11, STAI, CARE expected risk, SSS-V) and IQ with pretraining total error score was investigated in an
analysis of covariance (ANCOVA). The difference in testing total error score between groups was tested with covariate adjustment for pretraining error score, STAI, CARE expected risk and IQ.

The effect of BrAC training on subsequent drinking level and DRSEQ was examined in a model via use of heavy drinking days, mean drinks per week and DRSEQ score as dependent measures. The effect of BrAC training on simulated driving and subsequent self-reported risk-taking were analyzed in an additional model via use of simulated mean speed, simulated time spent speeding, CARE number of times drove after drinking, CARE past frequency total, CARE expected risks total and CARE expected benefits as dependent measures. These models were tested for effect of randomization group after adjusting for baseline measure, age and IQ. Analyses controlled for differences in IQ as variations in intelligence may have contributed to differences in the ability to acquire BrAC estimation training. Additionally, analyses controlled for participant age as alcohol consumption patterns are likely to change with age (Gotham et al., 1997). Significance level was held at 0.05 for all tests.

RESULTS

Group differences

There were no group differences in measures except higher mean ± SD IQ in the intervention group (122 ± 9) compared with the control group (112 ± 12; t(44) = −3.05, P < 0.01) and lower mean ± SD BIS-11 in the intervention group (54 ± 7) compared with the control group (61 ± 10; t(44) = 2.75, P < 0.01). BIS-11 was included in a model using IQ, STAI, SSS-V and CARE expected risks as independent predictors of pretraining error score and had no significant effect on results. IQ was included as a covariate in all models and also had no significant effect on results.

Breath alcohol concentration

Mean (±SD) peak BrAC in the control group was 0.080 (±0.014) during pretraining and 0.076 (±0.016) during testing. In the intervention group, mean (±SD) peak BrAC was 0.075 (±0.017) during pretraining and 0.074 (±0.016) during testing (see Fig. 1). Across all sessions, a majority of participants (72%) achieved peak BrAC at 120 min, while the remainder of participants reached peak BrAC at 90 min (8%), 150 min (17%) or 180 min (3%).

Total error score

Mean (±SD) total error scores in the control group were 16.60 (±10.33) during pretraining and 15.61 (±12.36) during testing. Mean (±SD) total error scores in the intervention group were 14.86 (±8.36) during pretraining and 5.86 (±2.54) during testing. Post-hoc Holm–Sidak analyses of an interaction effect (F(1,44) = 7.51, P < 0.01) revealed that total error scores decreased after training in the intervention group, but not in the control group (t(44) = 4.35, P < 0.001).

Predictors of total error score

Correlations among all predictors are presented in Table 1. CARE expected risks was negatively correlated with both IQ (r = −0.48; P < 0.001) and SSS-V (r = −0.49; P < 0.001), and positively correlated with log of testing error score (r = 0.38; P < 0.01; see Table 1). There were no significant predictors in the model of the log-transformed pretraining total error score. In the model of the log-transformed testing total error score, the intervention group displayed enhanced estimation accuracy compared with the control group (t(44) = −3.62, P < 0.001). Together, intervention group, STAI and CARE expected risks predicted log-transformed testing error score such that training, low anxiety and low expected risks were associated with increased estimation accuracy (F(5,40) = 9.89, P < 0.0001, R² = 0.55; see Table 2).

Effect of training on follow-up measures

In the multivariate models for testing the effect of BrAC estimation training on change from baseline to follow-up in drinking and DRSEQ measures, there were no significant group differences. Similarly, in the multivariate models for testing the effect of BrAC estimation training on change from baseline in simulated driving or CARE measures, there were no significant group differences. The intervention group displayed a trend (F(1,45) = 4.07, P = 0.0503) toward greater reduction in mean CARE expected benefits from baseline to 1-month follow-up compared with the control group whose mean expected benefits increased from baseline. However, this trend did not persist when measured at 3-month follow-up.

DISCUSSION

BrAC estimation training successfully increased estimation accuracy during testing in the absence of dose information and BrAC feedback. During testing, estimation accuracy in the intervention group improved from baseline at both low and high BrACs. After training, intervention group participants, but not control group participants, estimated BrAC within 0.01% of actual BrAC throughout the ascending and descending limbs of the breath alcohol curve. However, despite its
Table 1. Intercorrelations among all potential predictors of total error score

<table>
<thead>
<tr>
<th>Variables</th>
<th>STAI total</th>
<th>BIS-11 total</th>
<th>SSS-V total</th>
<th>CARE expected risks total</th>
<th>Log of pretraining error score</th>
<th>Log of testing error score</th>
</tr>
</thead>
<tbody>
<tr>
<td>IQ</td>
<td>0.12</td>
<td>-0.09</td>
<td>0.23</td>
<td>-0.48**</td>
<td>0.22</td>
<td>-0.25</td>
</tr>
<tr>
<td>STAI total</td>
<td>-</td>
<td>0.26</td>
<td>-0.08</td>
<td>-0.01</td>
<td>0.07</td>
<td>0.29</td>
</tr>
<tr>
<td>BIS-11 total</td>
<td>-</td>
<td>-</td>
<td>0.16</td>
<td>-0.17</td>
<td>-0.14</td>
<td>0.16</td>
</tr>
<tr>
<td>SSS-V total</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-0.49**</td>
<td>0.09</td>
<td>0.02</td>
</tr>
<tr>
<td>CARE expected risks total</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-0.16</td>
<td>0.38*</td>
</tr>
<tr>
<td>Log of pretraining error score</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.29</td>
</tr>
</tbody>
</table>

IQ, intelligence quotient; STAI, State-Trait Anxiety Inventory; BIS-11, Barratt Impulsiveness Scale; SSS-V, Sensation Seeking Scale; CARE, Cognitive Appraisal of Risky Events.

*P < 0.01, **P < 0.001.

Table 2. Predictors of log-transformed testing total error score

<table>
<thead>
<tr>
<th>Measure</th>
<th>β (SEM)</th>
<th>t-value</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-0.93 (1.35)</td>
<td>-0.69</td>
<td>0.49</td>
</tr>
<tr>
<td>Group (0, control; 1, intervention)</td>
<td>-0.61 (0.17)</td>
<td>-3.62</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Pretraining error score</td>
<td>0.03 (0.01)</td>
<td>3.03</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>IQ</td>
<td>0.00 (0.01)</td>
<td>0.03</td>
<td>0.98</td>
</tr>
<tr>
<td>SSS-V total</td>
<td>0.03 (0.02)</td>
<td>2.03</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Expected risks total</td>
<td>0.06 (0.02)</td>
<td>2.94</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

IQ, intelligence quotient; STAI, State-Trait Anxiety Inventory.

Educational impact, estimation training was not effective in eliciting positive behavioral changes at follow-up. Thus, the training was an effective tool within the laboratory, but had few long-term effects on drinking and behavior.

BrAC estimation training facilitated differentiation of alcohol effects below the legal limit for driving. Drivers often lack knowledge of drunk driving laws (Ferguson and Williams, 2002), and are unfamiliar with components of alcohol absorption and elimination (Moxnes and Jensen, 2009). Yet drinkers are expected to understand the unique effects of an arbitrary concentration such as 0.08% when making decisions about legal driving ability. Estimation training provides internal reference points and personal subjective cues for varying levels of intoxication, including BrACs near the legal limit. Public service announcements usually highlight potential consequences of drinking and driving, but fail to explain the process of intoxication or how much alcohol would result in BrACs near or above the legal limit for driving (NHTSA, 2012). In this regard, the majority of participants likely had little knowledge about the context of 0.08% prior to training. Estimation training facilitated both differentiation of various BrAC levels, and individualized awareness of alcohol’s subjective effects at the legal limit for driving.

Trait anxiety and risk expectancy were negatively associated with BrAC estimation accuracy during testing. While this may seem counterintuitive, most error scores were the result of overestimation. High-anxious individuals often perceive many situations as being risky or dangerous even in the absence of any indication of deleterious consequences (Baas et al., 2008). During alcohol use, anxiety and perceived risk from dangerous activities may result in increased caution, leading to decreased estimation accuracy. Results from the current study support previous data indicating that higher levels of trait anxiety are associated with cautious self-reports of perceived driving ability after alcohol (Staniforth et al., 2010). Participants with high anxiety and perception of risk likely felt that it was safer to overestimate BrAC than inaccurately underestimate BrAC. Our data are consistent with those of Thombs et al. (2003), who observed BrAC overestimation at levels below 0.07% and underestimation at levels above 0.10%. Participants in the current study provided peak breath alcohol samples in the range of 0.074–0.080%, below levels previously associated with underestimation. These data illustrate the need for administration of larger alcohol doses and quantification of the direction of estimation errors in studies of BrAC estimation.

There was a trend toward a temporary decrease in the expected benefits of risk behaviors in the intervention group. Though the effect was modest, training may have reduced the desire to engage in risk behaviors by decreasing their perceived advantages. This trend suggests the possible benefits of greater emphasis on personal, immediate and long-term consequences of alcohol use within training. Prevention programs are often more effective when the focus is concerned with reducing harm, rather than complete avoidance of potentially hazardous activities (Fromme et al., 1997b). Such an approach may extend the duration of changes in evaluation of risk consequences.

In summary, this study revealed that BrAC estimation training is effective in improving estimation accuracy in the laboratory, but does not translate into naturalistic settings. There was an absence of significant group differences at follow-up in self-reported drinking level or driving after drinking. Consequently, BrAC estimation training alone does not appear to be an effective way to elicit changes in alcohol consumption and other drinking-related behaviors, including simulated or actual driving. Larimer and Cronce (2007) reviewed a number of college drinking prevention investigations and reported that half of the reviewed interventions resulted in no significant behavioral changes. The studies that did show positive effects were usually focused on eliciting appropriate BAC levels via alterations of self-evaluations, perceived peer alcohol consumption norms and expectations about both positive and negative effects of alcohol (Larimer and Cronce, 2007). Interventions that are primarily educational or information-based are ineffective compared with those that include behavioral therapy or individualized motivational interviewing for problematic drinkers (Larimer and Cronce, 2002). In the current study, internal training facilitated identification of breath alcohol level, but was not sufficient to modify subsequent behavior. A personally relevant approach emphasizing...
the social, behavioral and legal consequences of drinking may improve the long-term applications of estimation training.

Funding — This research was supported by a grant to E.R.A. from the American Psychological Association, as well as NIH grants NIAAA P01AA017056 and NIAAA T32AA007565.

Conflict of interest statement. None declared.

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Bernosky-Smith KA, Shannon EE, Roth AJ et al. (2011) Alcohol effects on simulated driving in frequent and infrequent binge drinkers. Hum Psychopharmacol 26:216–23.


