A Multi-Year Field Investigation of Alcohol Consumption among University Students: Innovations in Assessing and Intervening to Reduce Alcohol-Related Harm

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Abstract

Alcohol use and abuse among college/university students continues as a major public health concern. One potential source of alcohol-related harm is the inability of students to estimate their current level of intoxication (gBAC). The current four field studies use breathalyzers to investigate student gBAC and the efficacy of a variety of BAC-feedback tools at promoting greater awareness of driving risks while under the influence of alcohol.

The research was conducted across 89 nights spanning seven academic semesters from Fall 2009 to Fall 2012. Research tables were setup between the hours of 6:00pm and 2:00am at three locations near downtown bar establishments and one on-campus location near a late-night dining facility. Unique subject codes were created to track participants across multiple nights of participation. In total, 12,432 blood alcohol concentration (BAC) readings were collected from 10,225 unique individuals.

Study 1 examined general epidemiology across all nights. The average BAC of drinking participants was .100 mL/L. Results revealed significant differences in BAC as a function of demographic and environmental factors. Additionally, it was found the average student was incorrect in estimating his or her BAC by .034 mL/L.

Studies 2 and 3 examined the accuracy of BAC-estimation tools (i.e., nomograms, sobriety tests, and phone applications) and the efficacy of these tools to increase awareness of driving-related risks. On average, both nomograms and BAC-estimation phone applications
were incorrect in estimating BAC by over .05 mL/L. Sobriety tests performed slightly better than chance at discriminating BACs of .08 mL/L.

Participants receiving BAC-feedback had increased awareness of driving risk across levels of intoxication. Nomogram and breathalyzer feedback tended to promote healthier perceptions of external risk. Sobriety testing shifted the internal perception of feeling less safe to drive. No effect was observed for BAC-estimation phone applications.

Study 4 found individuals who received breathalyzer feedback across multiple nights of the research were significantly more accurate at estimating their BAC. Specifically, individuals on the fifth night of participation were .017 mL/L more accurate at estimating their BAC as compared to the first night. Future research areas and policy implications are discussed.
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Prior to arriving at Virginia Tech as an undergraduate, I had difficulty deciding between an interest in engineering and a love for psychology. Even before starting my first day of classes, Dr. Finney, the psychology department head at the time, took hours out of his schedule to meet with me and discuss my future as a student at Virginia Tech and beyond. That act of kindness inspired me to pursue an academic career in psychology. It was Dr. Finney that started me on the path toward a Ph.D. in psychology. It was a fitting honor to have him serve on this dissertation committee. I will always be thankful for the time he took to inspire my first steps on this journey.

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A Multi-Year Field Investigation of Alcohol Consumption among University Students:

Innovations in Assessing and Intervening to Reduce Alcohol-Related Harm

Alcohol use and abuse among college and university students continues as a significant public-health concern. Despite the prevalence of alcohol-related harm, significant issues remain with both the measurement of alcohol consumption and the efficacy of interventions to reduce this harm. The following four field studies explored a framework for extending beyond traditional measures of self-reported alcohol consumption toward breath-alcohol assessment at high-risk drinking locations in a university community. The research also investigated the efficacy of blood alcohol concentration (BAC)-education interventions in a field setting.

The data collected for these studies included over 12,432 measures of BAC across seven academic semesters. The analyses of these data examined a multitude of demographic and environmental predictors of alcohol consumption to identify risk factors for at-risk drinking. After exploring these risk factors and the epidemiology of alcohol consumption among university students, the current studies examined the efficacy of BAC education to promote perceptions and behaviors related to the prevention of alcohol abuse and its negative side effects. These interventions included sobriety testing, nomograms, BAC-estimation phone applications, and breathalyzer feedback. Thus, the proposed studies not only attempted to examine the epidemiology of university-student alcohol consumption, but also to promote alcohol-related safety through BAC-education interventions in a field setting.

Overview of Alcohol-Related Harm to Youth

Across the world, alcohol use and abuse remains one of the leading causes of morbidity and mortality among youth (World Health Organization, 2009). Alcohol-related harm is also a significant problem for youth in the United States. In addition to a host of negative alcohol-
related outcomes, youth aged 18-20 have the highest prevalence of alcohol dependence of any age group (Grant et al., 2004).

The negative effects of alcohol consumption are particularly evident at our nation’s colleges and universities where college students drink significantly more than their non-college-attending peers (Merline, Jager, & Schulenberg, 2008; Stone, Becker, Huber, & Catalano, 2012; White et al., 2006). Furthermore, college students are more likely than their non-college attending peers to drive under the influence of alcohol (28.9% vs. 21.6%, respectively; Hingson, Zha, & Weitzman, 2009; Slutske, 2005; Slutske et al., 2004).

In fact, approximately 80% of college students admit to consuming alcohol, and about 40% of college students report drinking heavily (NIAAA, 2002). This translates into six percent of students being officially diagnosed as alcohol dependent; a third of students fitting the criteria for alcohol abuse under current diagnostic criteria; and 44% of students reporting at least one symptom of either alcohol abuse or dependence (Knight et al., 2002).

Several field studies have identified the exceptional risks associated with alcohol consumption in the university environments of downtown bars, private parties, and university-sanctioned fraternity parties (Fournier, Ehrhart, Glindemann, & Geller, 2004; Glindemann, Ehrhart, Drake, & Geller, 2007; Glindemann, Ehrhart, Maynard, & Geller, 2006; Glindemann & Geller, 2003; Glindemann, Geller, & Fourtney, 1991; Glindemann, Geller, & Ludwig, 1996; Glindemann, Wiegand, & Geller, 2007; Timmerman, Geller, Glindemann, & Fournier, 2003). In all of these studies, a team of trained research assistants were sent to designated indoor or outdoor environments with breathalyzers to measure participants’ blood alcohol concentration (BAC). Across all settings, average BAC was found to be above the legal limit of 0.08 mL/L.
The extent of college student use and abuse of alcohol carries significant negative consequences. It is estimated college alcohol consumption results in 1,825 student deaths each year (Hingson et al., 2009). Moreover, an estimated 600,000 injuries, 700,000 assaults, and 90,000 sexual assaults result from college drinking annually (Hingson, Heeren, Winter, & Wechsler, 2005).

Alcohol consumption among college students has become such a national health concern that Healthy People, the U.S. Department of Health and Human Services’ ten-year blueprint to monitor and improve areas of extreme health risk, continually rates reducing binge drinking to be one of its top priorities. Unfortunately, not only has this aim been unattained, but rates of college binge drinking have steadily risen. The ten-year goal of Healthy People 2010 was to reduce the percentage of college students who binge drink from 39% in 2000 to 20% by 2010. However, the percentage of binge drinkers actually increased to 44.7% during this time (Hingson et al., 2009). Subsequently, Healthy People 2020 established the ten-year goal of reducing college binge drinking to 36% by 2020. Even if this goal were met, it would only reduce binge drinking three percent below 2000 levels.

**Driving Under the Influence of Alcohol**

While a multitude of factors are associated with college alcohol-related injury and death, the most significant source of this harm is traffic safety (Hingson et al., 2009). In 2010 alone, an estimated 5,419,000 traffic crashes occurred on our nation’s roadways – resulting in 32,885 deaths and 2,239,000 injuries (NHTSA, 2012b). This translates into a fatality every 16 minutes. Alcohol was involved in 31% of these traffic fatalities (NHTSA, 2012a).

These statistics are even more troubling for U.S. youth aged 15-20, where traffic fatalities are the leading cause of death (NHTSA, 2004). While youth comprise only 10% of drivers, they
constitute 14% of all traffic crashes (NHTSA, 2012c). Approximately 30% of youth drivers killed in traffic fatalities had a positive BAC (i.e., BAC > .00), and 25% were over the legal level of impairment (i.e., BAC > .08; NHTSA, 2012c). The percentage of fatalities that are alcohol-involved rises sharply from 15% at age 15 to 40% by age 20. However, some research indicates rates of alcohol-related traffic risks take a significant upturn when college students reach the age of 21 (Beck et al., 2010).

Independently, both the age of drivers (Janke, Masten, McKenzie, Gebers, & Kelsey, 2003; Massie, Campbell, & Williams, 1995; Mayhew, Warren, Simpson, & Haas, 1981; Peck, Gebers, Voas, Romano, 2008; Romano, Peck, & Voas, 2012; Sivak et al., 2007; Stewart & Sanderson, 1984; Williams, 1985) and alcohol impairment (Blomberg, Peck, Moskowitz, Burns, & Fiorentino, 2005; Evans, 2004) are well-documented risk factors for traffic harm. However, not only do driver age and level of intoxication have independent, additive effects (Gebers, 1999; Peck, Arstein-Kerlake, & Helander, 1994), they also have a significant synergistic interaction (Peck et al., 2008). Consequently, this means young drivers operating a motor vehicle while intoxicated are at a greater risk than would be explained by the unique effects of age or intoxication alone.

Yet, alcohol-involvement is particularly high for drivers under age 35 (NHTSA, 2008). This is especially true for college students. It is estimated approximately one quarter of college students have driven under the influence of alcohol in the past 30 days (Beck et al., 2008; Clapp et al., 2005; Everett, Lowry, Cohen, & Dellinger, 1999; Hingson, Heeren, Zakocs, Kopstein, & Wechsler, 2002; Rothman, DeJong, Palfai, & Saitz, 2008). That translates into two million college students driving under the influence of alcohol each year. The uniquely detrimental impact of alcohol on young adult frontal executive functioning (a type of functioning highly
involved in driving skills) often turns these high rates of drink driving into high rates of traffic crashes and fatalities (Domingues, Mendonça, Laranjeira, & Makamura-Palacios, 2009).

In addition to drink driving, riding with an intoxicated driver is a frequent behavior among college students. In one study, 56.7% of students reported accepting a ride from an individual who had been drinking, and 34.2% of students reported accepting a ride after the driver had two or more drinks (Olivera et al., 2002). It has also been estimated 37.2% of college students rode with an intoxicated driver in the previous month (Calafat et al., 2009).

A multitude of demographic and psychological risk factors are related to higher rates of both drink driving and riding with an intoxicated driver including: being male (Beck et al., 2010; Romano, Peck, & Voas, 2012); young (Peck et al., 2008; Romano, Peck, & Voas, 2012; Subramanian, 2005; Zador, Krawchuk, & Voas, 2000); less educated (Romano, Peck, & Voas, 2012); unmarried (Romano, Peck, & Voas, 2012); unemployed (Romano et al., 2012); personality dispositions such as sensation seeking (Calafat et al., 2009); previous history of drunk driving (Portman et al., 2010); history of drugged driving (Arria, Caldeira, Vincent, Garnier-Dykstra, & O’Grady, 2011); driving ability while sober (Harrison & Fillmore, 2005); lower intentions to drive sober (Barry, Howell, & Dennis, 2011); using a private car (Calafat et al., 2009); drinking knowledge (Baum, 2000); and lower confidence in drinking below the legal limit (Barry et al., 2011).

Traffic safety has emerged as a major contributor to alcohol-related harm among college students. While many interventions target drink driving, significant development and novel solutions to this problem are warranted.

**A Novel Research Paradigm**
As noted by Ralph Hingson, “The magnitude of problems posed by excessive drinking among college students should stimulate both improved measurement of these problems and efforts to reduce them (NIAAA 2007, p. 3).” Thus, novel approaches designed to address this alcohol-related harm must not only make measurement and methodological advancements in how alcohol consumption is assessed, but also find unique ways to educate and reach the drinking population on campuses of colleges and universities. This research establishes a framework to simultaneously address both scientific domains. Through the use of breath alcohol testing in a field setting demarcated by at-risk alcohol consumption, the following series of studies connects accurate alcohol-consumption assessment with a variety of individually-based educational interventions targeting the drinker at the critical moment when s/he is making consumption and transportation decisions.

Beyond Self-Reported Drinking

The vast majority of research on alcohol consumption relies exclusively on self-reports of drinking (Clapp et al., 2009; Gruenewald & Nephew, 1994; Wechsler et al., 2002). This requires individuals to accurately recall the precise number of standard drinks consumed during a given drinking occasion or, often, across multiple occasions during a specified period of time. This time period of recall can often span as far as a month. This approach raises several practical and accuracy-related measurement questions.

Practically, the number of drinks consumed is often only a proxy for the real research question – level of intoxication. Particularly when studying extreme or binge drinking, the number of drinks consumed is often peripheral to the central question of achieved intoxication. A variety of factors impact the relationship between quantity of alcohol consumed and intoxication, including: gender, tolerance, speed of alcohol consumption, body mass index, and
As an example, imagine a study of alcohol consumption on one’s 21st birthday. Drinker A is a male who regularly consumes alcohol, often to extreme intoxication. On his 21st birthday, Drinker A consumes 21 drinks spread across ten hours of drinking. Drinker B is a female who has never consumed alcohol previously. On her 21st birthday, Drinker B consumes 21 drinks over two hours. While traditional approaches to measuring alcohol consumption would view the consumption of Drinker A and Drinker B identically, this approach misses critical and substantial differences in both level of intoxication and risk to the drinker.

Understanding the lack of information provided by self-reported number of alcoholic beverages consumed, The National Institute on Alcohol Abuse and Alcoholism (NIAAA) Advisory Council (2007) has suggested definitions of heavy drinking include reference to both BAC and time spent drinking. Kypri and colleagues (2005) have extended this logic to conclude estimated BAC (eBAC) should be used as a more precise measure of alcohol consumption. Current calculations of eBAC are derived from standard drinks consumed, duration of drinking, BMI, and gender. This calculation originally came from the Widmark formula (Widmark, 1932), but has been adjusted to better account for gender differences in metabolism (Matthews & Miller, 1979; Watson, Watson, & Batt, 1981). The construct of eBAC has been incorporated as an outcome measure in a number of studies (e.g., Alexander & Bowen, 2004; Hansson, Rundberg, Zetterlind, Johnsson, & Berglund, 2007; Perkins, DeJong, & Linkenbach, 2001; Stahlbrandt, Johnsson, & Berglund, 2007; Turner, Bauerle, & Shu, 2004).

Certainly, eBAC is a closer approximation of intoxication than reported number of standard drinks. However, eBAC is prone to a variety of errors. In fact, Clapp and colleagues
(2006) found eBAC and actual BAC to be only moderately correlated ($r = .35$). A number of factors impact the accuracy of eBAC, including the drinking environment, party size, and intoxication of partygoers (Clapp et al., 2006, 2009). For example, eBAC was underestimated at private parties and overestimated at a bar setting (Clapp et al., 2009). Discrepancy between eBAC and actual BAC has also been linked to time spent drinking, number of drinks consumed, gender, and year in school (Hustad & Carey, 2005).

Ultimately, eBAC still relies on self-reported number of drinks consumed. Unfortunately, while various techniques and methodologies can be used to enhance the accuracy of self-report (e.g., Finney, Putnam, & Boyd, 2006), self-report is known in the psychological sciences to be notoriously prone to both random and systematic errors (for a review see Schwarz 1999, 2007). For a variety of reasons, this error is particularly prevalent for self-reported alcohol consumption (Ekholm, 2004; Grant et al., 2011; Russ, Harwood, & Geller, 1986; Shillington, Clapp, Reed, & Woodruff, 2011; Waterton & Duffy, 1984; Whitford, Widner, Mellick, & Elkins, 2009). These reasons include blacking out, fatigue, social desirability (Davis, Thanke, & Vilhena, 2010), misunderstanding the definition of a “standard drink” (Kerr & Stockwell, 2011; Lemmens, 1994), ignorance of standard drink volumes (White et al., 2005; White et al., 2003), poor recall while intoxicated (Babor, Steinberg, Anton, & Del Boca, 2000; Hustad & Carey, 2005), and environmental factors that influence self-monitoring of alcohol consumption (Clapp, Min, & Shillington, 2006). Thus, even the best-fitting BAC equation produces discrepancies between eBAC and actual BAC (Carey & Hustad, 2002; Hustad & Carey, 2005).

As has been shown, self-reports of quantity and frequency of alcohol consumption, along with calculated eBAC, are markedly inaccurate in measuring an individual’s level of intoxication. However, using the methodology of Glindemann, Geller, Clarke, Chevaillier, and
Pettinger (1998), breath alcohol testers can be used to provide a highly accurate measure of BAC (Schechtman & Shinar, 2011). This BAC reading creates an accurate, standard, interpretable, and objective measure of an individual’s level of intoxication. This not only provides an accurate measure of alcohol consumption, but also a meaningful number to educate student drinkers on their level of intoxication and risk.

**Intervening in the Field**

Physiological measures of alcohol consumption enable a transition to field research at the very locations where at-risk alcohol consumption occurs. In general, field research has a variety of strengths including external validity, testing generalizability, observing the natural unfolding of behaviors, and evaluating specific populations or environments of interest (Graziano & Raulin, 2004; Kenrick, Neuberg, & Cialdini, 2010). In this context, field research with breath-alcohol-testing equipment also has the added benefit of providing the ideal means and timing to intervene on student drinking and transportation behaviors at the critical moment these behavioral decisions are made. In many ways, this is analogous to point-of-purchase advertising where advertisers target a consumer at the critical moment of product purchase.

This approach is consistent with Russ and Geller (1985) who argue more emphasis should be placed on intervention strategies that exert their impact after individuals drink, but before they operate a motor vehicle. In addition to improving measurement accuracy, breath alcohol testing can also functionally serve as a source for prevention intervention (Russ, Geller, & Leland, 1988). After all, many researchers have argued that since drinkers are often unaware of their alcohol impairment, receiving personal feedback about one’s BAC may reduce the probability of alcohol-impaired driving (Geller, Altomari, & Russ, 1984; Geller & Lehman, 1988; Geller & Russ, 1986).
Beyond BAC feedback in a field setting, BAC education is a widely used and supported component of interventions designed to prevent excessive alcohol consumption. In this regard, it is a harm-reduction approach, which has received support for its utility with alcohol use and abuse (Marlatt & Witkiewitz, 2002). More specifically, BAC education is a component of a variety of interventions including: BASICS (Dimeff, Baer, Kivlahan, & Marlatt, 1999), AlcoholEdu (Outside the Classroom, 2010), and Heads UP (LaBrie, 2010). In fact, one meta-analysis of college drinking interventions found 73% of these programs incorporated BAC education (Carey et al., 2007). A field study of bars found BAC education significantly reduced patron alcohol consumption in a 12-month, self-report follow-up (Van Beurden, Reilly, Dight, Mitchell, & Beard, 2010).

These intervention techniques rely on the premise college students are largely unaware of their level of intoxication while consuming alcohol. This conclusion is supported by the research literature. Several studies have had individuals guess their BAC (gBAC) and compare that number to their actual BAC as measured by breath alcohol testers. It should be noted gBAC which is an individual’s unaided estimation of his or her BAC differs from eBAC which is a mathematically-derived BAC estimate based on entering demographic and alcohol-consumption information (i.e., number of drinks, BMI, gender, and drinking duration) into a version of Widmark’s equation. While some of these studies of gBAC have reported individuals tend to underestimate their BAC at higher BACs and overestimate their BAC at lower BACs (Grant et al., 2011; Thombs et al., 2003), it has also been shown individuals at higher BACs tended to overestimate their BAC (Russ, Harwood, & Geller, 1986). Others have argued error in estimation goes up in general as the number of drinks and actual BAC increases (Bullers & Ennis, 2006; Kraus et al., 2005).
While the directionality of the error between gBAC and actual BAC is mixed, there is research consensus that students are inaccurate at estimating their BACs (Beirness, 1987; Bullers & Ennis, 2006; Clapp et al., 2009; Cox et al., 1995; Grant et al., 2011; Kraus et al., 2005; Lansky, Nathan, Ersner-Hershfield, & Lipscomb, 1978; Lewis, Merz, Hays, & Nicholas, 1995; Nicholson, Wang, & Mahoney, 1994; Russ, Harwood, & Geller, 1986; Thombs, Olds, & Snyder, 2003; Williams, 1991). Error in estimating one’s BAC (i.e., gBAC) has also been linked to making risky driving decisions (Beirness, 1987), suggesting BAC feedback may not only make individuals more aware of their level of intoxication, but also result in safer driving decisions. It is worth noting individuals are not only inaccurate at judging their own impairment, but also inaccurate at guessing other’s impairment (McKnight, Langston, Marques, & Tippetts, 1997).

**Support for the Field Intervention Approach**

The field intervention method described above is an individual-level intervention approach focusing on BAC education when alcohol and driving-related decisions are made. In addition to the frequency and success of similar approaches, there are a variety of reasons to be uniquely optimistic about intervening at the site of alcohol consumption. Research has consistently demonstrated the effectiveness of individual-level approaches at preventing alcohol abuse (Carey et al., 2007; DeJong & Hingson, 1998; Larimer & Cronce, 2007; Marlatt & Witkiewitz, 2002). Individual-level interventions target individuals and provide specific feedback that pertains to the drinker. A meta-analysis of 62 studies with 13,750 participants found individual, face-to-face interventions that provided personalized, normative feedback predicted the greatest reductions in alcohol-related problems (Carey et al., 2007). This is the exact approach used in the current studies.
As noted by Russ, Geller, and Leland (1988), BAC feedback effectiveness is likely dependent on the social/environmental context. While there has been support for individual-level, BAC-education interventions (DeJong & Hingson, 1998; Marlatt & Witkiewitz, 2002), research also demonstrates general educational interventions alone are ineffective, potentially because they generally occur beyond the time and place of alcohol consumption and are not personalized (Larimer & Cronce, 2007). Thus, the approach in the present studies provided personalized feedback in a non-recreational, professional, research context at the time of alcohol consumption. This provided the drinkers with an objective measure of their level of intoxication that can inform and be associated with their perceived impairment.

The following studies examined a variety of mechanisms and procedures for delivering BAC feedback. Specifically, breathalyzer feedback, sobriety testing, BAC charts (i.e., nomograms), and BAC-estimation phone applications were selected as potential feedback/educational interventions.

**Research Plan**

The following studies tested the efficacy of field interventions to promote BAC awareness. This approach is based on the premise college students make at-risk decisions under the impairment of alcohol in part because of a lack of awareness of their level of intoxication. Certainly, this premise has received recent empirical support (e.g., Grant et al., 2011) and the general intervention method is grounded in empirical research (e.g., Carey et al., 2007). As conceptualized originally in Russ and Geller (1985), these interventions can provide individualized feedback to the drinker through “a BAC chart…, via self-testing of BAC, or through performance on behavioral measures (p. 16).”
The following four studies tested the fundamental assumption college-student drinkers are unaware of their BAC and also evaluated the efficacy of breathalyzer feedback, BAC charts, and sobriety testing at promoting safe decision-making after college students consumed alcohol. Incorporating technological advances that could not be foreseen at the time of their original article (Russ & Geller, 1985), this research also estimated the accuracy and efficacy of BAC-estimation phone applications.

**Overview of Dataset**

All data were collected by research teams in the Center for Applied Behavior Systems (CABS). The Center for Applied Behavior Systems was founded by Alumni Distinguished Professor E. Scott Geller in 1987. The Center is housed within the Virginia Tech Psychology Department. Each year, CABS supports approximately 60 undergraduate researchers, five graduate students, and two center coordinators. As a graduate student in CABS, the dissertation author directed and supervised the collection of all data for the present research.

Across 89 nights, spanning seven academic semesters and four years, researchers collected data between the hours of 6:00pm and 2:00am near downtown bars and at an on-campus, late-night dining facility of a large public university in the southeastern United States. Researchers recruited passersby at these locations and collected demographic, environmental, and psychological information from participants. All participants also created a unique, anonymous subject code so they could be tracked across repeated nights of participation. After completing this questionnaire, participants were then administered a breath alcohol test to determine their BAC. These BACs can be associated with various psychological states, environmental events, drinker perceptions, and social phenomenon.
While a common study protocol and method were followed across all nights, the survey questions and procedure varied depending on the research topic for a given night or set of nights. Several standard questions were asked across all nights. This included demographics, estimated BAC, intended BAC, and designated-driver related questions. The following studies answered various questions from this larger database. Studies 1 and 4 examined questions asked across all nights and investigated the full database. Studies 2 and 3 examined more specific research questions and only used data from the nights when specific procedures and questions were employed.

**General Method**

**Overall participants and setting.** In total, 12,432 BACs were collected from 10,225 unique individuals at research tables between the hours of 6:00pm and 2:00am. These research tables were set up near downtown bar establishments and a late-night, on-campus dining facility at a large university in the southeastern United States. Data were collected on 89 nights across seven academic semesters.

Approximately, 70% of participants were male (n = 7,046). Slightly more than 20% of participants were members of a Greek organization (n = 2,116). Seniors represented the largest percentage of participants based on class (n = 3,991; 39.3%)

**Apparatus.** Participants’ BACs were assessed using handheld Lifeloc FC-20 breath alcohol testers (Lifeloc Technologies, Inc., Wheat Ridge, CO). Lifeloc FC-20 models are accurate to ±0.005 mL/L. Each data-collection team used two breathalyzers and rotated use of these units to prevent alcohol saturation and provide adequate time for reset. To ensure optimum performance and accuracy, the breathalyzers were calibrated regularly throughout the four years of data collection.
**General procedure.** On each night of the study, three teams of researchers set up tables at multiple downtown locations near college-bar establishments and one on-campus location near a late-night dining facility. Each of these three research teams consisted of two recruiters/surveyors and one breathalyzer administrator. An undergraduate or graduate project leader was also assigned to each table to ensure a consistent protocol was followed and to aid in maintaining an effective research environment.

All research personnel completed IRB Human Subjects Training prior to collecting data. Additionally, each research assistant was required to attend a two-hour training session at the beginning of each semester. Immediately prior to each shift of data collection, research assistants attended a one-hour training session on the project.

Surveyors began by randomly recruiting passersby at each of these locations. These individuals were trained to recruit at random, irrespective of an individual’s perceived level of intoxication. Thus, completely sober people could also be recruited into the study. Once a passerby indicated interest, the surveyor handed him or her an information sheet about the project, asked if s/he was 18 years of age or older and, thus, able to provide consent. The surveyor informed the potential participant that study data are collected anonymously and confidentially, and s/he is free to withdraw from the study at any time.

The potential participant was then given the opportunity to ask any questions about the study procedure or research. Surveyors notified potential participants they could not eat, drink, smoke, or chew gum for the duration of the procedure, as it adversely impacts breathalyzer readings. If the individual agreed to participate, s/he was then administered the survey.

The surveyor read all questions aloud and recorded participant responses. This was done to ensure written responses were legible and the participant fully comprehended each question.
It was also done to make sure the questionnaire was taken seriously. The surveyor first collected demographic information, including gender, college attendance, year of study, and Greek-life status. The time and location of the survey were also recorded. The participant was then administered questions specific to the particular night of data collection.

After completing the survey, the participant was passed along to the breathalyzer administrator. At this point, the breathalyzer administrator used a permanent marker to write the Greek letter psi (ψ) on the back web of the participant’s hand. This ensured participants could only get breathalyzed once per night. Then, the participant swished approximately two ounces of water in his or her mouth to remove any residual alcohol (Chu, Wells, King, Farrar, & Drummer, 1998).

The participant’s BAC was then assessed using a handheld breath alcohol tester. A standardized sampling procedure was used to ensure the collection of alveolar (i.e., deep lung) air. Individuals blowing over .200 mL/L were asked to re-swish their mouth with water and retest to make sure the reading was not due to residual alcohol. Participants were then confidentially informed of their BAC and shown a chart explaining this reading. All participants who registered above .05 mL/L were cautioned not to drive.

**Overview of Current Studies**

Study 1 provided a general epidemiological assessment of college drinking. This study analyzed the 12,432 breath alcohol test readings from various drinking locations across 89 separate nights during seven consecutive academic semesters. The study provided valuable insight into environmental and social determinants of alcohol consumption among university students. This included calculating average BACs, as well as BAC differences as a function of specific demographic characteristics, including gender, year in school, and membership in a
Greek-life organization. The relationship between drinking intentions, estimated BAC, and BAC was also explored. Finally, BAC data from designated drivers (DDs) was examined. The sobriety of both DDs and the passengers of DDs was investigated. Gender, Greek-life membership, and factors determining the choice of a DD were explored as potential risk factors for DD intoxication.

Study 2 investigated the efficacy of a variety of individual-based field interventions to promote greater awareness of one’s level of intoxication. Nomograms, sobriety tests, and breath alcohol feedback were used to provide BAC education and awareness. The accuracy of nomograms and sobriety tests was examined in comparison to actual BAC. Individuals receiving each type of intervention were compared to a control group in order to assess if receiving different types of BAC feedback increased perceptions of driving risk at higher BACs.

Study 3 investigated the efficacy of a developing technological phenomenon — smart phone applications. A multitude of BAC-estimation phone applications are created and downloaded hundreds of thousands of times by users. Yet, the accuracy and efficacy of these phone applications to prompt safer driving choices have not been systematically compared. This study examined the accuracy of the eight most downloaded free BAC-estimation phone applications. Furthermore, it tested whether these phone applications can shift an intoxicated individual’s perceptions toward safer driving decisions as compared to receiving nomogram feedback or no feedback.

Study 4 provided a longitudinal examination of the effects of repeated BAC feedback. While the impact of breathalyzer feedback on same-night drinking and driving decisions has received limited research attention, the longitudinal effects of this feedback have not been comprehensively investigated. Across multiple years, participants received BAC feedback at
research stations set up near downtown bar establishments and on-campus near a late-night dining facility. These individuals were longitudinally tracked using a unique, anonymous subject code. This study examined the impact of this repeated BAC feedback. More, specifically, this research determined whether repeated BAC feedback reduced the discrepancy between participant-estimated and actual BAC.
Study 1: A Four-Year Field Investigation of Demographic, Environmental, and Psychological Determinants of Alcohol Consumption among University Students

Few investigations of alcohol consumption have been conducted using actual assessments of blood alcohol content (BAC) in a field setting. Yet, the more commonly implemented method of using self-reports of alcohol consumption is often plagued by inaccuracies and error. Using the field methodology of Glindemann and colleagues (1998), the current study provided a multi-year, field assessment of college drinking in downtown and on-campus settings.

The aims of the current study were to a) provide a general epidemiological assessment of at-risk college drinking; b) examine psychological, environmental, and demographic risk factors for high-risk alcohol consumption; and c) assess a variety of college-student perceptions and decisions while under the influence of alcohol. Special emphasis was placed on the relationship between drinking intentions, participant-estimated BAC, and observed BAC as assessed via professional breath alcohol testers. The use, safety, and potential side effects of designated drivers (DDs) were also evaluated.

Basic Epidemiological Assessment

A dearth of alcohol research has been conducted in field settings regarding at-risk alcohol consumption. This is particularly true for downtown bar locations and on-campus. Research conducted in a similar setting during 1992-1995 found average BACs of drinkers were .063mL/L (Glindemann et al., 1998). In early 2000, the same research team found an average BAC between .087 mL/L and .090 mL/L (Glindemann et al., 2007). Future research is needed to examine the stability of this trend.

Designated Drivers
Much research has been dedicated to protective strategies for reducing alcohol-related harm. These protective strategies have not only been shown to reduce drinking, but also alcohol-related negative consequences (Martens et al., 2004). One of the most commonly reported protective strategies among college students is the use of a DD (Delva et al., 2004; Haines et al., 2006; Martens et al., 2004; Walters, Roudsari, Vader, & Harris, 2007). In fact, one study found 75% of females and 70% of males reported using DDs frequently (Walters et al., 2007). It has also been estimated 86% of college students have used a DD at least once, albeit 94% of individuals said the DD occasionally consumed alcohol (Barr & MacKinnon, 1998). Males tend to be more likely than females to use a DD (Haines et al., 2006).

Unfortunately, riding with a drink driver is also a frequent behavior among college students. In one study, 56.7% of students reported accepting a ride from an individual after they had been drinking, and 34.2% accepted a ride after an individual had two or more drinks (Olivera et al., 2002). Also, 37.2% of college students reported riding with an intoxicated driver in the previous month (Calafat et al., 2009).

The time of the night DDs are chosen is critical to the level of alcohol impairment among DDs (Timmerman et al., 2003). A recent study among college students found choosing a DD before beginning drinking was significantly related to lower intoxication of the DD (Demody, Cheong, & Walther, 2012). Yet, only slightly more than half of college students believe a DD should be chosen before drinking begins (Glascoff, Knight, & Jenkins, 1994; Lange, Voas, & O’Rourke, 1998). Even more disconcerting is the observation DDs are often chosen as the person who is least intoxicated (DeJong & Winsten, 1999; Ditter et al., 2005; Knight, Glascoff, & Rikard, 1993; Rothe, 1996)
Aside from the sobriety of the DD, the impact of having a DD on alcohol consumption is also a concern. The current body of research is inconclusive regarding whether having a DD results in higher levels of intoxication among passengers. A plethora of self-report studies have demonstrated that having a DD is associated with higher levels of intoxication (Barr & MacKinnon, 1998; Boots & Midford, 1999; Caudill et al., 2000, 2001; DeJong & Winsten, 1999; Harding & Apsler, 1993; Harding, Caudill, & Moore, 2001; Harding, Caudill, Moore, & Frissell, 2001). Yet, other studies demonstrated no such relationship (Rothschild, Mastin, & Miller, 2006; Timmerman et al., 2003). Higher levels of alcohol consumption among drinkers with a DD could not only be dangerous for the drinker, but also for the DD who faces increased driving risk (e.g., distractions from passenger roughhousing, vomiting, or passing out) as the intoxication of passengers increases (Rothe & Carroll, 2009; Sakar, Andreas, & de Faria, 2005).

Other research evidence links misestimation of BAC, particularly underestimation, with at-risk driving decisions (Beirness, 1987). Additionally, since research consistently demonstrates physiological impairment begins at or below a BAC of .05 mL/L (e.g., Filtness, Rudin-Brown, Mulvihill, & Lenné, 2012; Friedman, Robinson, & Yelland, 2011; Greenfield, 1998; Hutt, 1997; Levinthal, 2002; Mann, 2002; Moskowitz & Burns, 1990), DD sobriety was examined at a variety of intoxication levels. Thus, the current research examined the following questions: Do college-student DDs remain sober, and does having a DD encourage higher levels of intoxication?

**Gender**

Gender differences in alcohol consumption are dynamic. Traditionally, male students have been shown to consume greater quantities of alcohol than their female counterparts (Geller, Altomari, Russ, & Harwood, 1985; Geller, Clarke, & Kalsher, 1991; Geller & Lehman, 1988;
O’Malley & Johnston, 2002; Presley, Meilman, & Lyerla, 1993; Vaisman-Tzachor & Lai, 2008; Tremblay et al., 2010). However, this phenomenon may quickly be changing on college campuses.

While gender differences in alcohol consumption remain significant in high school, these differences are markedly less in college (Clapp, Min, Shillington, Reed, & Croff, 2008; Grucza et al., 2009; Keyes, Li, & Hasin, 2011; Keyes, Martins, Blanco, & Hasin, 2010). Recent research suggests college males and females are both drinking at higher levels, but rates of drinking among females are growing faster than those among males (Grucza, Norberg, & Bierut, 2009; National Center on Addiction and Substance Abuse, 2007).

While there are a multitude of studies examining the relationship between gender and alcohol consumption (Schulte, Ramo, & Brown, 2009), there is substantially less research examining the underlying social and psychological mechanisms for changes in gender-related trends in alcohol consumption. Essentially, this area of research examines either, (a) changes in gender-related alcohol use patterns over time, or (b) the determinants of gender differences in alcohol consumption at a single time point. Rarely are these two research questions combined to examine changes in the determinants of gender differences in alcohol consumption over time. Thus, there is research gap in the examination of the underlying reasons for changing trends in alcohol consumption as a function of gender.

However, some plausible explanations have emerged from the research literature. One possible explanation for the decrease in gender differences in alcohol consumption is a merging of alcohol expectancies prior to adulthood between males and females (Chen, Grube, & Madden, 1994; Randolph, Gerend, & Miller, 2006). Particularly for underage drinkers, increased availability of alcohol across both genders may also play a role in this phenomenon (Brown et al.,
Furthermore, changes in parental monitoring, which has been demonstrated as a protective factor for females (Schinke, Fang, & Cole, 2008) may also lead to a lessening of gender differences in alcohol consumption (Barnes, Reifman, Farrell, & Dintcheff, 2000; Tildsley & Andrews, 2008; Webb, Bray, Getz, & Adams, 2002).

It is also likely a host of socialization factors (e.g., norms, peer pressure, and gender roles) could be attenuating gender differences in alcohol consumption. A variety of studies have demonstrated the strong relationship between alcohol-consumption norms and drinking behaviors (Bates & Labouvie, 1995; Graham, Marks, & Hansen, 1991; Jacobs & Johnston, 2005). This is especially true for gender-specific norms versus gender-nonspecific norms, and a change in acceptance of female drinking could thusly turn into females consuming greater quantities of alcoholic beverages in relation to males (Lewis & Neighbors, 2004). These norms regarding alcohol consumption have also been shown to translate into gender roles for alcohol consumption (Perkins, 2003; Maccoby, 1988). Indeed, changing perceptions of alcohol-specific gender roles could also result in increases in female alcohol consumption (Chomack & Collins, 1987; Landron, Bardwell, & Dean, 1988; Ricciardelli, Connor, Williams, & Young, 2001; Wilsnack & Wilsnack, 1978).

The vast majority of alcohol research on gender differences relies entirely on self-reported alcohol consumption. Yet, substantial gender differences in the processing of alcohol make the use of self-reported number of alcoholic beverages consumed highly misleading as a measure of intoxication. For example, statistically treating a male who reports consuming five alcoholic beverages as consuming a greater amount of alcohol than a female who reports consuming four alcoholic beverages would neglect the fact that the female may actually achieve a higher level of intoxication. Analyzing the number of drinks consumed versus the level of
intoxication in this example would actually produce opposite results. Thus, field research with breath alcohol testing is critical for assessing gender differences in alcohol consumption.

In addition to overall gender differences in level of intoxication, the interaction of gender and designated driving has critical application ramifications. Timmerman and colleagues (2003) found female DDs had significantly lower BACs than their male counterparts in a downtown field setting. However, this study included only 66 DDs and only 20 of these DDs were female. Furthermore, this work was conducted a decade ago. With the changing trends in gender-based differences in alcohol consumption, questions still remain. Are males still reaching significantly higher levels of intoxication than females? Do female DDs still remain more sober than their male counterparts?

**Membership in a Greek-Life Organization**

It has been consistently shown that members of Greek-life organizations consume more alcohol than non-members of Greek-life organizations (Cashin, Presley, & Meilman, 1998; Scott-Sheldon, Carey, & Carey, 2008; Wechsler, Kuh, & Davenport, 1996). This relationship also extends to heightened risk for a variety of alcohol-related negative consequences including: hangovers, driving under the influence of alcohol, and unprotected sex (Wechsler, Kuh, & Davenport, 1996). However, field research that used BAC as a dependent variable found no significant differences between the BACs of Greek-life and non-Greek-life students when consuming alcohol in the same setting (Fournier et al., 2004; Glindemann & Geller, 2003).

A field study of fraternity versus non-fraternity parties adds innovative insight into one possible reason for this discrepancy between self-report and field research regarding alcohol consumption among Greek-life students (Glindemann & Geller, 2003). Across 1,525 participants at 19 separate parties, the effect of party type (i.e., fraternity vs. non-fraternity) and
Greek-life membership were examined. Results indicated that while BACs were significantly higher at fraternity parties than non-fraternity parties, BACs were not significantly different for Greek versus non-Greek attendees at either type of party. Thus, members of a Greek-life organization may face heightened environmental risk factors which result in higher overall rates of alcohol consumption. However, this does not necessarily mean Greek-life individuals drink more than non-Greek-life individuals within a given context or environment. Certain environmental factors likely influence the amount of alcohol consumption and degree of intoxication.

Thus, in a specific downtown context, are Greek-life students reaching higher levels of intoxication than peer, non-Greek-life students?

**Drinking Night**

Research on college students has demonstrated self-reported patterns of alcohol consumption change as a function of the day of the week (Dierker et al., 2006; Hoeppner et al., 2012; Wood, Sher, & Rutledge, 2007). Out of the weekdays, Thursday is linked to the highest rates of alcohol consumption (Del Boca, Darkes, Greenbaum, & Goldman, 2004; Tremblay et al., 2010; Wood et al., 2007). Yet, field research has also demonstrated alcohol consumption among college students on Thursday night is more popular and extreme than even weekend drinking (Glinde mann, Geller, Clarke, Chevaillier, & Pettinger, 1998).

This is troubling because weekday drinking is linked to a variety of negative outcomes. In terms of academics, Thursday drinking is associated with lower interest in college schoolwork (Hoeppner et al., 2012). In terms of health and safety, it has been shown college females who drink on Thursday are significantly more likely to experience negative consequences stemming from alcohol (Ward, Cleveland, & Messman-Moore, 2013).
To date, the research in this area remains inconclusive. This leaves alcohol researchers and college administrators wondering which drinking night produces the most extreme levels of intoxication? The current multi-year field research provides insight regarding this empirical question.

**Intoxication Intentions**

The relationship between drinking intentions and actual consumption carries significant implications for alcohol-related negative consequences and intervention efforts. If college students are largely inaccurate in their estimated BACs, it seems plausible the relationship between actual intoxication and intended levels of intoxication may be similarly disparate.

An examination of the relationship between drinking intentions and alcohol intoxication was conducted by Glindemann, Geller, and Ludwig (1996). These researchers measured the intended BAC of partygoers one week prior to a fraternity party and again as they entered the party. Results showed a moderate to strong correlation between both BAC and intended intoxication one week prior to the party \((r = .54)\) and between BAC and intended intoxication when entering the party \((r = .63)\). It is noteworthy these correlations were markedly higher for males (.63 & .67, respectively) than for females (.28 & .29, respectively). However, while the correlations indicate the level of association between intentions and BAC, the researchers do not provide the average difference between intended and actual BAC. Furthermore, the study only examined 43 individuals and was conducted more than 15 years ago.

Research has demonstrated a link between expected intoxication and self-perceptions of impairment (Fillmore, Roach, & Rice, 2002; Williams, 1991). It has been found intoxicated individuals who intended to have BACs below the legal limit actually reported feeling safer to drive compared to individuals at the same BAC but who intended to have BACs over the legal
limit (Smith, Geller, & Schry, 2010). Thus, BAC intentions also have implications for alcohol-impaired driving.

**Method**

**Participants and Setting**

In total, 12,432 surveys were collected from 10,225 unique participants across 89 separate nights. Data were collected across seven academic semesters between Fall 2009 and Fall 2012. The sample was 69.5% male (n = 7,046) as compared to female (n = 3,094). Furthermore, 20.9% of participants were members of a Greek-life organization (n = 2,116) as compared to non-members of a Greek-life organization (n = 7,995). Student classification (e.g., freshman, sophomore, etc.) of the sample is provided in Figure 1. Seniors represented the largest group of participants (n = 3,991; 39.3%).

**Procedure**

The general procedure described in the overview section was used to collect survey information and administer breath alcohol tests to participants. Individuals were limited to participation once per night, but could participate across multiple nights of the study.

**Results**

All analyses only examined an individual’s first time participating in the study. Furthermore, only college students were included for these analyses. This resulted in 8,470 remaining participants for data analysis.

**General Epidemiological Assessment**

Across all participants, 16.4% (n = 1,391) were completely sober (i.e., BAC = 0.00 mL/L). The average BAC of drinking participants was .0998 mL/L (SD = .047). Over 80% of drinking participants had a BAC over .05 mL/L (i.e., legal impairment). The legal limit to drive
(i.e., .08 mL/L) was exceeded by 62.9% of participants. Greater than 10% of participants were more than twice the legal limit (i.e., .160 mL/L). The maximum BAC was .267 mL/L. A histogram of BACs is provided in Figure 2, and shows a nearly perfect normal distribution of BACs.

**Demographic Differences in Alcohol Consumption**

The relationship between demographic variables and BAC was examined with a 2 Gender (Female vs. Male) X 2 Greek Status (Greek vs. Non-Greek) X 5 Class Status (Freshmen vs. Sophomores vs. Juniors vs. Seniors vs. Graduate Students) analysis of variance (ANOVA). The overall ANOVA was significant, $F(19, 6990) = 22.90, p < .01; \eta^2 = .059$. There was a significant Class by Greek-life membership interaction, $F(4, 6990) = 3.02, p = .02; \eta^2 = .002$. Significant main effects were observed for Class [$F(4, 6990) = 35.85, p < .01; \eta^2 = .02$], Gender [$F(1, 6990) = 5.18, p = .02; \eta^2 = .0007$], and Greek-life membership [$F(1, 6990) = 39.17, p < .01; \eta^2 = .006$]. Tukey’s posthoc testing showed freshmen and sophomores had lower BACs than juniors and seniors. Juniors and seniors also had significantly higher BACs than graduate students ($p$’s < .05). Males and members of Greek-life organizations had higher BACs than females and non-members of Greek-life organizations. Table 1 shows average BACs as a function of demographic group.

The significant interaction between class and Greek-life membership is depicted in Figure 3, indicating differences in Greek-life affiliation on BAC did not emerge until sophomore year. Average BACs are also depicted as a function of class and gender in Figure 4. Finally, average BACs as a function of Greek-life membership and gender are depicted in Figure 5.

**Environmental Factors and Blood Alcohol Concentration**
The day, semester, and year of participation were assessed as environmental factors potentially contributing to differential levels of intoxication. This was investigated with a 5 Day (Monday vs. Wednesday vs. Thursday vs. Friday vs. Saturday) X 2 Semester (Spring vs. Fall) X 4 Year (2009 vs. 2010 vs. 2011 vs. 2012) ANOVA. The overall model was significant, F(16, 7062) = 5.58, \( p < .01; \eta^2 = .012 \). There was a significant main effect for day, F(4, 7062) = 7.26, \( p < .01; \eta^2 = .004 \). No other main effects nor interactions reached significance (\( p \)'s > .05).

However, the interaction between semester and day approached significance, \( p = .0502 \).

Average BACs as a function of these environmental factors are provided in Table 2.

Tukey’s posthoc testing was used to examine BAC differences by day. Results indicated BACs on Monday were significantly lower than BACs on every other day except Friday. The BACs on Thursday were significantly higher than BACs on Friday. No other significant differences were observed as a function of day. Average BACs on Thursday, Friday, and Saturday are provided as a function of gender in Figure 6.

**Transportation Decisions**

Both the selected means of return transportation and time this transportation decision was made were recorded. Analyses focus on DDs and the time transportation decisions were made. Overall, 2,320 (32.5%) student participants reported making their transportation decision days in advance. Most commonly (\( n = 3,781; 52.9\% \)) students reported making their transportation decision earlier that day. Another 779 (10.9%) students made their decision after arriving downtown. Finally, 262 (3.7%) participants were still undecided about how they were getting home at the time of participation in the research.

Many of the DDs in this study (37.9%) were completely sober at the time of participation. Designated drivers who consumed alcohol also had a significantly lower BAC (.0628 mL/L) than
drinking non-DDs [0.0996 mL/L; \(t(6651) = 10.03, p < .01\)]. An ANOVA was performed to examine if DD sobriety changed as a function of when the DD was selected. Results were non-significant, \(F(3, 164) = 2.39, p = .07\). Table 3 provides DD sobriety information as a function of when the transportation decision was made.

**Demographics and DDs.** Two Chi-Square tests were performed to examine the relationship between gender, Greek-life membership, and DD sobriety. Designated drivers who consumed alcohol were classified as non-impaired (BAC < .05) or impaired (BAC ≥ .05). Gender and Greek-life membership were examined in separate, 2 X 2 Chi-Square tables.

The first Chi-Square test examined the relationship between gender and DD sobriety. Results indicated male DDs were significantly more likely to be impaired (60.2%) than female DDs (40.8%; \(\chi^2 = 5.23, p = .02\)). While a higher percentage of Greek-life DDs (66.7%) were impaired as compared to non-Greek-life DDs (51.8%), the second Chi-Square test was not statistically significant, \(\chi^2 = 1.83, p = .18\). Table 4 shows DD sobriety as a function of demographics.

**Impact of having a DD.** Overall, 42.5% of students reported having a DD. Results indicated females (49.97%) were significantly more likely than males to have a DD (39.30%), \(\chi^2 = 63.21, p < .001\). Members of a Greek-life organization (67.21%) were also significantly more likely to have a DD than non-members of a Greek-life organization (34.48%), \(\chi^2 = 525.24, p < .001\).

A 2 Have DD (Yes vs. No) X 2 Gender (Female vs. Male) X 2 Greek-life Status (Greek vs. Non-Greek) ANOVA was performed on the dependent variable of BAC to examine the impact of having a DD on alcohol consumption as a function of gender and Greek-life status. The overall ANOVA was significant, \(F(7, 6422) = 14.93, p < .01; \eta^2 = .016\). There was a
significant interaction for gender and having a DD, F(1, 6422) = 6.79, p < .01; \eta^2 = .001. The three-way interaction, Greek-life status and have DD interaction, and main effect for having a DD all failed to reach significance, p’s > .10. The interaction between gender and having a DD is depicted in Figure 7, showing males with a DD tended to have a slightly higher BAC than males without a DD, while there was no impact for females.

**Student Drinking Intentions**

A moderate correlation was observed between intended and actual BAC (r = .413, p < .01). On average, the discrepancy between BAC and intended BAC was .0435 mL/L. Students averaged a BAC of .0123 mL/L lower than their intended BAC. Indeed, 57.8% of the students had BACs lower than their intended BAC.

A 2 Gender (Female vs. Male) X 2 Greek-life Status (Greek vs. Non-Greek) ANOVA was performed on the discrepancy between intended and actual BAC. The overall model was significant, F(3, 5094) = 6.45, p < .01; \eta^2 = .004. There was a significant main effect for gender, F(1, 5094) = 15.93, p < .01; \eta^2 = .003. Results showed females had a significantly smaller discrepancy between intended and actual BAC (.0401 mL/L) than males (.0450 mL/L). Neither the interaction nor the main effect for Greek-life status was significant, p’s > .10.

**Student Estimation of Intoxication**

On average, students were incorrect in estimating their BAC by .0338 mL/L. However, the directionality of estimation error varied largely as a function of current BAC. Individuals with lower BACs tended to overestimate their level of intoxication, whereas individuals with higher BACs tended to underestimate their level of intoxication. This relationship is graphically depicted in Figure 8.
A 2 Gender (Female vs. Male) X 2 Greek-life Status (Greek vs. Non-Greek) ANOVA was performed on the discrepancy between estimated BAC and actual BAC. The overall model was significant, \( F(3, 4988) = 6.06, p < .01; \eta^2 = .004 \). There was a significant main effect for gender, \( F(1, 4988) = 7.39, p < .01; \eta^2 = .001 \). A significant main effect was also observed for Greek-life status, \( F(1, 4988) = 9.11, p < .01; \eta^2 = .002 \). The interaction term was not significant, \( p > .10 \). Results indicated males and non-Greek-life students were slightly more accurate at estimating their BAC. This is graphically depicted in Figure 9.

Discussion

General Epidemiological Assessment

The vast majority of alcohol research relies heavily on self-reports of drinking (Clapp et al., 2009; Gruenewald & Nephew, 1994; Wechsler et al., 2002). Particularly when assessing binge drinking, self-reports can create substantial inaccuracy in the measurement of alcohol consumption (NIAAA, 2007). The limited research using breath alcohol testers in a similar field setting has found BACs around .063 mL/L from 1992-1995 and .087- .090 mL/L from 2005 to 2006. The present research was conducted from 2009 to 2012 and found an average BAC of .100 mL/L. Considering these research studies were conducted on the same university campus, this could accurately represent a 10-59% increase in average BACs over the past decade in this particular university context. It is difficult to determine if a similar increase in levels of intoxication in this university setting generalizes to other colleges and universities.

In addition to a high mean BAC, a majority of drinking participants were reaching at-risk levels of intoxication. Over 80% of the alcohol-consuming participants were at a BAC over .05 mL/L and nearly 63% were over the legal limit to drive. Furthermore, it is possible the average BAC is slightly underestimated because extremely intoxicated individuals would not be
physically capable of participating in the research. Thus, the true upper-end of intoxication in this setting was not captured by the data. Regardless, the observed levels of intoxication are at truly dangerous levels, placing many students at high risk for physical and psychological harm.

**Demographic Differences in Alcohol Consumption**

There has been a host of inconsistent and conflicting literature regarding demographic differences in alcohol consumption. Some of this inconsistency emerges from how alcohol consumption is measured (i.e., eBAC, BAC, or standard drinks consumed; NIAAA; 2007). For example, in consideration of average gender differences in body mass and alcohol processing, a finding that males consume greater numbers of standard drinks than females does not necessarily reflect differences in levels of intoxication or associated risk. This was a point made by Henry Wechsler when he defined different numbers of standard drinks for each gender as qualifying as binge drinking (Wechsler, Dowdall, Davenport, & Rimm, 1995). This scholarship recognized females are at greater risk with fewer standard drinks.

Differences in drinking context can also create differential drinking outcomes as a function of drinker demographics. Greek-life drinkers reflect one notable example. While many studies have linked membership in a Greek-life organization to higher levels of alcohol consumption (e.g., Scott-Sheldon et al., 2008; Wechsler et al., 1996), it has also been shown Greek-status did not predict level of intoxication within a single setting (e.g., Fournier et al., 2004; Glindemann & Geller, 2003). Thus, the overall difference in alcohol consumption related to Greek-life is often a function of members of a Greek-life organization more often finding themselves in at-risk drinking environments (e.g., fraternity parties; Glindemann & Geller, 2003).

The current investigation is the largest field study using breath alcohol testing to examine the relationship between demographics and BAC. Several important findings emerged from this
study. Statistically, many relationships between demographic factors and BAC were observed. Indeed, Table 1 shows a variety of BAC differences which are summarized.

**Gender differences.** Significant gender differences were observed. On average, males had a BAC that was .0035 mL/L higher than the average BAC of females. This lends support to previous research that found significant gender differences in alcohol consumption (e.g., Geller et al., 1985, 1991; Vaisman-Tzachor & Lai, 2008; Tremblay et al., 2010). Yet, while this difference is statistically significant across more than 10,000 BAC readings, the difference may not have reached practical or clinical significance. To add perspective, this BAC difference is small enough that it falls below the margin of error for even the highest quality breath alcohol testers. Thus, these findings may actually be more consistent with research that shows an attenuation of gender differences in BAC (Grucza et al., 2009; Keyes et al., 2011).

**Greek-life status.** Members of a Greek-life organization were not only half as likely to be sober as compared to non-Greek-life members, but also had BACs averaging an extra .0132 mL/L. In addition to statistical significance, this BAC difference also borders on clinical significance. However, this level of BAC increase would not drastically multiply health risk.

While other field studies have not shown a significant difference in BACs based on Greek-life membership (i.e., Fournier et al., 2004; Glindemann & Geller, 2003) it is possible earlier studies did not have the power to detect a similarly small effect. Results align with a multitude of self-report studies showing significant BAC differences as a function of Greek-life membership (e.g., Cashin et al., 1999; Scott-Sheldon et al., 2008; Wechsler et al., 1996). However, the data suggest this difference is small within this specific, college-drinking context.

**Class status.** Results indicated a separation in the BACs of underclassmen and upperclassmen. Indeed, upperclassmen averaged a BAC .0197 mL/L higher than the BACs of
underclassmen. Graduate students and alumni had BACs between the class extremes. Freshman and sophomores were also significantly more likely to be completely sober.

The discussion of class status cannot be separated from considerations of the legal drinking age. While the majority of freshmen and sophomores are under 21, this is not the case for all other groups. This creates very different drinking experiences and opportunities for underclassmen versus upperclassman. Indeed, the mere fact so many underclassmen were intoxicated is noteworthy in itself.

Clearly, both freshmen and sophomores, many of whom are presumably underage, are gaining access to alcohol. However, within these field contexts, their access to alcohol and drinking opportunities are clearly different. Thus, underclassmen may be more likely to rely on pregaming before they enter a public drinking setting or sneaking limited numbers of alcoholic beverages downtown. Both of these conditions would limit the observed BACs of underclassmen. Accordingly, it is difficult to determine if these BAC differences would generalize to an environment without similar legal constraints on alcohol consumption.

**Class by Greek-life status interaction.** There was a small, but statistically significant, interaction of class and Greek-life status on mean BAC. As can be observed in Figure 3, there is a strong trend for members of a Greek-life organization to have higher BACs across all years of school with the exception of freshmen year, where there is no noticeable difference. Thus, main effects for both class and Greek-life membership should be interpreted in consideration of this significant interaction. However, with only a statistically small interaction, it would be remiss to disregard all consideration and discussion of main effects. Thus, these main effects still add insight into college alcohol consumption.
It is interesting this impact of Greek-life affiliation on BAC did not emerge until sophomore year. However, once this gap in BAC emerged, it remained present even through graduate students. This provides evidence for a cultural/social explanation for BAC differences in Greek-life status, as opposed to a more dispositional explanation. Freshmen year is when many individuals are just beginning to join and participate in Greek-life organizations. Thus, there would be minimal time for membership in this type of organization to influence alcohol consumption behaviors. Yet, the lack of a BAC difference between these individuals initially, suggests members of a Greek-life organization were not already reaching higher levels of intoxication than non-members. In other words, selectivity does not bias the differences shown later. While BACs tend to rise for both groups from freshmen through senior years, this trend is much greater for members of a Greek-life organization.

**Environmental Factors and Blood Alcohol Concentration**

Alcohol consumption differences were examined across days of the week, academic semester, and calendar year. Across all of these environmental factors, only day of the week reached significance. Results indicated Thursday not only had the highest average BAC of the weekdays, but was also higher than both Friday and Saturday nights. This is consistent with previous field research conducted by Glindemann and colleagues (1998).

While Thursdays had significantly higher average BACs than both Fridays and Saturdays, it should be noted the actual BAC differences were not large (i.e., .0075 mL/L and .0056 mL/L, respectively). However, these results are not troubling simply because Thursday nights were the most prominent drinking night. Even irrespective of other nights of the week, the high levels of intoxication on Thursday nights are alone concerning because Thursday-night
drinking is associated with a host of negative academic and health outcomes (Hoeppner et al., 2012; Ward et al., 2013).

This finding raises several sets of further research questions. One set of research questions addresses the motives for engaging in weekday versus weekend drinking. Related to these questions are potential barriers or protective factors that inhibit weekday drinking. An additional set of research questions focuses on implications for academic policy. Future research could examine the role of Friday classes in reducing Thursday-night drinking. For example, does holding fewer Friday morning classes lead to increases in Thursday-night drinking?

College students often refer to Thursday as the new Friday when it comes to alcohol consumptions. Unfortunately, this phrase is evolving into Wednesday is the new Thursday. Indeed, several colleges have drinking cultures associated with days of the week other than Thursday. Researchers and university administrators need to quickly find ways to address this growing problem. Indeed, the issue of weekday drinking has the potential to naturally get worse before it gets better.

**Transportation Decisions**

**Designated driver sobriety.** This study examined both the timing of transportation decisions and the use of designated drivers. The BACs of nearly 400 designated drivers were evaluated. A little more than one third of DDs were completely sober. Unfortunately, DDs choosing to consume alcohol often had BACs that put them at significant risk for negative driving consequences. Impairment often begins at BACs as low as .02 mL/L. More significant driving impairment is observed at .05 mL/L (Filtness, Rudin-Brown, Mulvihill, & Lenné, 2012; Friedman, Robinson, & Yelland, 2011). The per se legal limit is currently set at .08 mL/L in all
50 states. This means .08 mL/L serves only as a guideline for legal enforcement, and drivers with BACs less than .08 mL/L are still at risk for DUI.

Thus, it is troubling the average BAC of DDs who consumed alcohol was .061 mL/L. Over half of these DDs were over .05 mL/L, and nearly 30% were over the per se legal limit of .08 mL/L. This indicates DDs who choose to consume alcohol are frequently becoming moderately to significantly impaired by alcohol. This has significant implications for DDs who choose to consume alcohol and individuals deciding whether or not to ride with a drinking DD. Indeed, the findings highlight the need for caution and care if and when a DD decides to consume alcohol.

**Timing of transportation decision.** Only limited field research has been conducted on the time a student drinker’s transportation decision was made (e.g., Timmerman et al., 2003). Thus, it was surprising the vast majority of student drinkers made their transportation decision well in advance of beginning to drink in this study. Indeed, less than 15% of student drinkers made their transportation decision during their current drinking session or were still undecided at the time of participation. Over half of the students who consumed alcohol made their transportation decision earlier in the day and nearly one third made their transportation decision days in advance.

It was hypothesized the timing of transportation decisions would be particularly important for the selection of DDs. Specifically, it was predicted DDs selected after arriving downtown would achieve higher BACs than DDs selected prior to the initiation of drinking. Results were not supportive of this hypothesis. Indeed, DDs selected after arriving downtown had the lowest average BAC (.0589 mL/L). Conversely, DDs selected days in advance of drinking had the highest average BAC (.0860 mL/L). This runs counter to previous studies of
DD behavior (Demody et al., 2012; Timmerman et al., 2003). However, a higher percentage of DDs were completely sober (51.2%) when they were chosen days in advance as compared to after arriving downtown (35.5%).

It is likely an interplay of other factors impacted the relationship between DD sobriety and time the DD was chosen. For example, the ability to select a DD days in advance may suggest a pattern or ritual of downtown alcohol consumption. Thus, these individuals may tend to be heavier drinkers. This may translate into higher average BACs for DDs selected days in advance of drinking downtown. Particularly in consideration of research that suggests DDs are selected as the least intoxicated drinker (DeJong & Winsten, 1999; Ditter et al., 2005; Knight et al., 1993; Rothe, 1996), this finding should not be interpreted as suggesting it is safer to wait until drinking has begun to select a DD. Instead, the results suggest the selection and drinking behaviors of a DD are critical decisions with strong consequences regardless of time the DD was selected.

**Demographics and designated driving.** The sobriety of designated drivers was examined as a function of gender and Greek-life status. Significant differences were observed as a function of gender. Among the male DDs who consumed alcohol, 60.2% were impaired (i.e., BAC over .05 mL/L), whereas only 40.8% of the female DDs who drank were impaired. This suggests it is safer to have a female versus a male DD. However, it is still worrisome that two out of five female DDs were impaired. Thus, the results from this study showed females were safer DDs than males, but DDs of both genders were all too often achieving at-risk levels of intoxication for driving.
While DDs who were members of a Greek-life organization were more likely to be impaired in this study (66.7%) than non-Greek DDs (51.8%), this difference failed to reach statistical significance.

**Considerations for interpreting designated driver results.** It is worth noting the DDs in this study consisted of individuals who were passersby at various locations near drinking establishments. Thus, they do not reflect the full range of DDs on a given night. In particular, this excludes DDs who pick up riders without ever leaving their motor vehicle. This type of DD usage is associated with additional risks and benefits that may not generalize to the DD sample in this study. Indeed, all conclusions regarding DDs should be considered in terms of DDs who are actively participating in the drinking scene by leaving their vehicles. This is true even if they choose not to take the first sip of alcohol.

This may be particularly impactful when considering Greek-life DDs. Many fraternities and sororities have sober crews who continuously pick-up and drop-off members of their organizations all night. These individuals are held to extreme standards of sobriety and are required to be completely sober. This type of DD would not be recruited into the current study. Future research should examine the sobriety of DDs who are not drinking at the locations where they are picking up their friends.

**Impact of having a designated driver.** The impact of having a DD on sobriety was examined as a function of both gender and Greek-life membership. The belief that individuals with DDs achieve greater levels of intoxication has tempered enthusiasm and support for DD-promotion programs and DD usage. Indeed, self-report research has found a link between having a DD and increases in self-reported, single-occasion, alcohol consumption (e.g., Caudill et al., 2000, 2001; Harding et al., 2001).
Results from this study provided partial support for the claim individuals with DDs achieve higher BACs. Specifically, it was found that males with a DD were significantly more intoxicated (.1037 mL/L) than males without a DD (.0986 mL/L). No significant differences were found based on membership in a Greek-life organization.

When weighing the value of promoting DDs with these findings several factors should be considered. Primarily, while males with DDs were found to reach higher levels of intoxication, the difference in BACs was minimal (i.e., .0051 mL/L). Accordingly, even for males there is minimal additional risk for having a DD. Conversely, not using a DD carries significantly more risks. In consideration of the minimal BAC differences, results strongly promote the usage of safe, sober DDs for college students.

It should also be noted differences in having a DD available were observed across both gender and Greek-life membership. Indeed, 10% more females reported having a DD (49.97%) as compared to males (39.30%). Furthermore, members of a Greek-life organization were nearly twice as likely to report having a DD available as compared to non-members of a Greek-life organization (67.21% vs. 34.48%, respectively). This seems to contradict previous research that found males were more likely to use a DD than females (Haines et al., 2006). The results of the present study could suggest a changing trend in DD use or that females may have DDs available that they do not use.

**Student Drinking Intentions**

Previously, only one study examined the relationship between intended BAC and actual BAC in a field setting (Glindemann et al., 1996). This prior study found a moderate correlation between BAC and intended BAC ($r$’s between .54 and .63). However, that study used a Likert response for intended BAC and could not calculate absolute BAC differences between achieved
and intended BAC. Thus, results from the current study build on the findings of Glindemann and colleagues (1996).

Results from the present study also indicated a moderate relationship between intended and actual BAC ($r = .41$). There was an average discrepancy between intentions and actual BAC of .0435 mL/L. Interestingly, the majority of students (57.8%) achieved BACs lower than they intended, with an average discrepancy of .0123 mL/L. On average, females were closer to their intended BAC than males. No significant differences were observed as a function of membership in a Greek-life organization.

While there was a moderate correlation between intended and measured BAC, there was a substantially larger discrepancy between these numbers. This may indicate students are largely inaccurate in consuming alcohol to their intended level of impairment. Thus, the disconnect between student drinking intentions and actual BAC may be larger than originally thought. This could be the result of a lack of student awareness of one’s level of intoxication or the power of environmental factors on an individual’s alcohol consumption (e.g., peer pressure, drink specials, peer levels of intoxication).

It is also interesting the majority of students presumably did not reach their intended BAC. There are a variety of possible explanations for this finding. It seems most plausible that students tend to overestimate the BAC where a certain level of physiological impairment will be felt. After all, students are usually basing their alcohol consumption intentions on a feeling of physiological impairment, rather than an actual BAC. Thus, these drinkers may feel they have reached their intended BAC at a slightly earlier level of intoxication. It is also possible student consumers of alcohol are reaching their intended BAC, but not at the moment their BAC is assessed at the research table. Students may continue to drink after participation in the research
and already consumed alcohol may continue to enter the bloodstream, thus raising BACs slightly after time of participation.

Student Estimation of Intoxication

Results supported the hypothesis that student drinkers are largely inaccurate at estimating their current level of intoxication. On average, drinkers were incorrect by .0338 mL/L at estimating their BAC. The results also showed the directionality of this error changed as a function of BAC.

The directionality of gBAC error has been previously examined across a multitude of studies (Beirness, 1987; Bullers & Ennis, 2006; Clapp et al., 2009; Cox et al., 1995; Grant et al., 2011; Kraus et al., 2005; Lansky, Nathan, Ersner-Hershfield, & Lipscomb, 1978; Lewis, Merz, Hays, & Nicholas, 1995; Nicholson, Wang, & Mahoney, 1994; Russ, Harwood, & Geller, 1986; Thombs, Olds, & Snyder, 2003; Williams, 1991). Yet, many of these studies have inconsistent and contradictory findings. Furthermore, no study to date has approximated the sample size used in this research.

Results from the present study show individuals tend to overestimate their level of intoxication at lower BACs and underestimate their level of intoxication at higher BACs. The effect is linear, with more extreme BACs demonstrating a proportionally greater discrepancy in gBAC and actual BAC. The directionality of this relationship tends to shift around .09 mL/L.

While this may have the benefit of discouraging impaired, yet under the legal limit, individuals from operating a motor vehicle, this finding also suggests that legally-intoxicated individuals have a greater tendency to believe they are under the legal limit. As BACs increase beyond the legal limit to drive and the individual tendency to underestimate one’s BAC rises concomitantly, the stage is set for devastating consequences. This dangerous discrepancy
between gBAC and actual BAC demonstrates a strong need for BAC-feedback interventions. These interventions are particularly needed, and ideally more effective, for individuals at BACs beyond the legal limit of .08 mL/L.

Differences in gBAC accuracy were observed as a function of both gender and Greek-life status. It was found both males and non-Greek-life students were significantly more accurate at estimating their BAC. However, while these differences were statistically significant, they were quite small (i.e., less than .003 mL/L). This suggests a BAC-feedback intervention could be uniformly helpful and needed regardless of gender or Greek-life affiliation.
Study 2: Evaluation of BAC-Feedback Tools at Impacting Perceptions of Driving Risk

Each year, thousands of intoxicated college students make decisions that result in significant harm, injury, and death. One potential factor in these costly decisions is the disconnect between an individual’s perceived and actual level of intoxication. In fact, there is a plethora of evidence demonstrating drinkers misperceive their level of intoxication (e.g., Clapp et al., 2009; Grant et al., 2011; Russ et al., 1986). Thus, it has been suggested receiving personalized feedback about one’s level of intoxication may reduce the probability of engaging in an at-risk activity such as alcohol-impaired driving (Geller et al., 1984; Geller & Lehman, 1988; Geller & Russ, 1986).

Assuming individuals are unaware of their level of intoxication, a variety of feedback approaches may be suited to providing information relevant to reducing the discrepancy between actual and perceived alcohol impairment. Improved accuracy in estimating one’s true level of impairment could then lead to safer attitudes, perceptions, and decisions. These feedback approaches include nomograms, sobriety testing, and breathalyzer feedback. Nomograms provide a cost-effective method of easily estimating one’s BAC. Sobriety testing allows an individual to directly experience their physiological level of impairment. Breath alcohol testing gives individuals a reliable and valid measure of their level of intoxication (i.e., BAC).

Nomogram Development and Efficacy

Calculating estimated BAC. It has been argued no computation is performed more frequently by forensic toxicologists than Widmark’s equation (Gullberg, 2007). This is the equation derived in the early 20th century by E.M.P. Widmark to estimate amount of alcohol in one’s body (Widmark, 1932). The original equation is denoted: $A = C_t pr$. 
Where \( A \) is the amount of alcohol absorbed and distributed throughout the body, \( C \) is the blood alcohol concentration at time \( t \), \( p \) is the body weight, and \( r \) is reduced body mass.

Several revisions have been made to this classic equation. Widmark’s original equation calculated BAC in units mass/mass; revised forms of the equation are often changed to calculate mass/volume to accommodate changes in how BAC is usually assessed. Additionally, there have been two major revisions to Widmark’s equation (Matthews & Miller, 1979; Watson, Watson, & Batt, 1981). These later revisions attempted to account for gender differences in the metabolism of alcohol.

The equation has a variety of uses. It is often used by law enforcement and the court system to back-calculate BACs at the time of a given incident, to calculate alcohol dosing for research lab studies, for experimental drinking labs as part of training courses for law enforcement and forensic personnel, and for the development of nomograms. Despite the importance of these applications, there is little appreciation for the uncertainty associated with this equation (Gullberg, 2007).

Indeed, a multitude of factors can influence the accuracy of this equation, including elimination rates of alcohol (Pavlic, Grubweiser, Libiseller, & Rabl, 2007; Thieden & Hunding, 1991), carbonation of drinks (Roberts & Robinson, 2007), and drink absorption from one’s gastrointestinal tract (Posey & Mozayani, 2007). A number of studies note the inaccuracy of the Widmark equation, particularly for non-average individuals (Devgun & Dunbar, 1994; Gullberg, 2007; Gullberg & Jones, 1994; Lewis, 1986). Statistical calculations and estimates comparing predicted BAC to measured BAC in a laboratory setting have demonstrated a margin of error for the Widmark equation around \( \pm 20\% \) for a BAC at 0.10\% (Gullberg, 2007; Gullberg & Jones, 1994).
Yet, these calculated BAC estimates can also be used for BAC education programs and large-scale interventions. Blood alcohol concentration education is estimated to be a component in more than seven out of ten alcohol interventions (Carey et al., 2007). While these interventions teach individuals the relationship between alcohol intake and bodily impairment, the applied significance of these programs could be enhanced if used to educate individuals while they are consuming alcoholic beverages.

**Nomogram effectiveness.** Nomograms are BAC-estimation tables based on the Widmark equation. They allow an individual to quickly estimate their BAC with the consideration of gender, weight, number of standard drinks consumed, and time spent drinking. Russ and Geller (1985) concluded these nomograms may have broad applications for education and intervention. Similarly, O’Neill, Williams, and Dubowski (1983) argue nomograms may be especially useful for drinkers making decisions about transportation. Thus, the potential beneficial impact of nomograms may be even greater in a field setting.

In a preliminary study of nomogram effectiveness, Glindemann and Geller (1994) distributed nomograms to 48 individuals in a natural drinking environment. They found the nomograms significantly overestimated BACs, causing many individuals to consider not driving. Thus, while Dubowski (1984) argues nomograms should be taken out of circulation because of their inaccuracy, Glindemann and Geller (1994) show this inaccuracy (i.e., overestimation of BAC) may actually lead intoxicated individuals to making safer decisions.

**Sobriety Testing**

The consumption of alcohol results in significant and systematic physiological impairment (for a review see Carpenter, 1962). Alcohol consumption results in performance deficits in reaction time (Jennings, Wood, & Lawrence, 1976; Linnoila, Erwin, Cleveland,
Logue, & Gentry, 1978), standing steadiness (e.g., Begbie, 1966; Modig, Fransson, Magnusson, & Patel, 2012) and verbal behavior (Nash, 1962). However, recent research has found the full effects of imbalance may only be evidenced after sustained sensory-motor challenges (Modig, Patel, Magnusson, & Fransson, 2012).

An understanding of these physiological deficits has led to the development of a multitude of sobriety tests to predict and differentiate various levels of intoxication. Considering the difficulty of not only judging one’s own level of intoxication (i.e., Grant et al., 2012; Russ et al., 1986), but also judging the intoxication of others (Langenbucher & Nathan, 1983; McKnight et al., 1997), sobriety tests provide a standard method for determining an individual’s intoxication. In this capacity, field sobriety tests may actually be a more accurate way of assessing performance deficits related to driving than actual BAC (Johnson, 1983; Russ & Geller, 1986, 1991; Valaske, 1985).

Emerging from the legal complexity of taking blood (which was necessary to determine BAC) without probable cause, sobriety tests emerged as a method for assessing intoxication by members of law enforcement. However, this created the need for a standard field method for administering a field sobriety assessment technique. Standardized field sobriety tests (SFST) were first developed by Burns and Moskowitz (1977) and later validated by Tharp, Burns, and Moskowitz (1981) to achieve this purpose.

The SFST battery includes the horizontal gaze nystagmus test, the one-leg-stand test, and the walk-and-turn test. Horizontal gaze nystagmus is involuntary eye movement as one’s eyes gaze to the side. This effect rarely occurs outside of the influence of substances of abuse. The one-leg stand test involves individuals standing on one leg (of their choice) while raising the other foot directly in front of them six inches off the ground. Arms must be kept directly at one’s
side for the duration of the test. Finally, the walk-and-turn test involves individuals walking nine steps heel-to-toe, smoothly turning around, and walking nine steps back heel-to-toe. Again, individuals are required to keep their hands at their sides.

The original validation tests of SFST were conducted to examine if the battery of tests could differentiate individuals with BACs over versus below .10% (Moskowitz, 1977; Tharp et al., 1981). While this was the legal limit for many states at the time this research was conducted, states slowly adopted .08% as the new legal standard for DWI. In fact, all states and the District of Columbia currently have the per se legal limit at .08%. Thus, more recent research has examined the ability of SFST to differentiate individuals at lower BACs.

In order to address the need to differentiate lower BACs, NHTSA sponsored research to examine the validity of SFST below 0.10% (Stuster & Burns, 1998). Results demonstrated the capability of SFST to discriminate BACs at .08% and .04%. More specifically, officers using the SFST were 91% accurate at discriminating BACs at .08% and 80% accurate at predicting if BACs were between .04% and .08%.

Despite being the primary study to support SFST, several characteristics of this study are noteworthy. Primarily, the Stuster and Burns (1998) study was conducted by assessing the accuracy of only seven police officers within a single police department. Furthermore, each of these police officers received specialized training in SFST prior to initiation of the study. Thus, results may not be generalizable across other police officers, other police departments, or to the general public.

Furthermore, while SFST have been judged effective within law enforcement (Grossman et al., 1996), police officers may be relying on clues beyond SFST. In addition to SFST, police officers examine the way a vehicle is driven and the physical appearance of drivers after being
stopped (Compton, 1985; Harris, Howlett, & Ridgeway, 1979). Police offers also have a variety of experiences with individuals under the influence of alcohol, enabling them to pull from a knowledge base beyond simple sobriety testing. Thus, the accuracy of law enforcement in making sobriety judgments with SFST may be partially due to factors other than SFST results.

While NHTSA studies indicate support for SFST, not all research supports the validity of these field sobriety tests. In fact, a variety of studies have shown SFST to be poor predictors of sobriety (Booker, 2004; Dixon, Clark, & Tiplady, 2009; McKnight et al., 2002; Stuster, 1997). Specifically, Stuster (1997) found no sobriety test clues to predict BACs below .08%, Dixon and colleagues (2009) found SFST were only 62% accurate in predicting legal intoxication, and McKnight and colleagues (2002) found only horizontal gaze nystagmus, not the one-leg-stand test or walk-and-turn test, was effective at differentiating low BACs. As noted by Dixon and colleagues (2009):

> Thus, while all tests in the [SFST] battery were effective at discriminating alcohol from placebo, combination of measures from the various tests did not give a clear demarcation between impaired and non-impaired performance, even though the composite measures included a variety of distinct elements including measures of speed and accuracy of performance, and also different types of error score, including false positives and false negatives (p. 417).

However, while horizontal gaze nystagmus is often lauded as a “silver bullet” for law enforcement (Stuter & Burns, 1998), even this technique has come under fire. In his admonition of SFST, Booker (1994) goes to the length of calling horizontal gaze nystagmus “fraudulent science.” Regarding horizontal gaze nystagmus research Booker (1994) claims “bypassing the usual scientific review process and touted through the good offices of the federal
agency responsible for traffic safety, it was rushed into use as a law enforcement procedure, and was soon adopted and protected from scientific criticism by courts throughout the United States (p. 133).”

Despite mixed evidence for SFST, field sobriety tests may be useful in a social context to determine a person’s level of alcohol impairment (Geller & Russ, 1986). Not only could field sobriety tests help bystanders more accurately judge the alcohol-related risks facing someone consuming alcohol, but it could also serve as a powerful physiological demonstration of alcohol impairment. In particular, field sobriety tests could force an individual under the influence of alcohol to directly confront the reality of his or her impairment. This could be especially useful when an impaired individual feels safe to operate a motor vehicle.

The efficacy of field sobriety tests at promoting safer decisions while under the influence of alcohol was investigated by Russ and Geller (1986). In their study, 195 college students were approached at two outdoor drinking events on a large university campus. The researchers had individuals complete three sobriety tests: a ruler-drop test (a measure of reaction time), progressive body balance test, and a verbal index of impairment (reciting the last six months of the calendar year backwards). The ruler-drop test involved a participant catching a ruler between his or her thumb and forefinger. The distance the ruler dropped before being caught represented the score.

Results indicated 33.4% of the variance in BAC could be explained by performance on these field sobriety tests. However, the effectiveness of sobriety tests at changing driving decisions was inconclusive. At moderate BACs, individual drinkers reported their performance on the sobriety test would influence their future driving decisions. However, as participants’ BAC increased, individuals were significantly less likely to be influenced beneficially by poor
sobriety-test performance. Thus, while some individuals were dissuaded from driving, the individuals most at risk were largely uninfluenced by their test performance.

While this study took an innovative approach to examining the efficacy of sobriety tests at influencing the perceptions of potential drink drivers, the current study implemented several changes to build upon this early research. Specifically, at the time of this research, SFST were not widely implemented. Thus, Russ and Geller (1986) used their own unique field sobriety tests. However, the reliability and accuracy of these tests at predicting sobriety remain undocumented.

Instead, the current research used a different variety of field sobriety tests, derived primarily from SFST. Both the one-leg-stand test and walk-and-turn test were incorporated and scored from the SFST battery. The horizontal gaze nystagmus was omitted because of its research inconsistency, difficulty in uniform administration, and a lack of adequate luminescence in the late-night field setting. A verbal test was also incorporated which asked individuals to count backwards from 37. This is a test widely used by police departments across the country. It is hypothesized the usage of more traditional and empirically-backed field sobriety tests may improve the effectiveness of these tests at deterring at-risk student behaviors.

**Breath Alcohol Testing**

Breath alcohol testing provides an accurate and quick method for providing BAC feedback without calculations, computations, and estimations (Schechtman & Shinar, 2011). Instead, breath alcohol testing relies on chemical reactions in a portable breath reader. This creates an efficient and precise means for providing BAC feedback. Thus, breath alcohol testing may guide drinkers to safer transportation decisions (Russ & Geller, 1985).
However, mixed empirical results have been found for the utility of providing breathalyzer feedback in a field setting. Several studies have shown the provision of breathalyzer feedback had no effect on transportation decisions among consumers of alcoholic beverages (Calvert-Boyanowsky & Boyanowsky, 1980; Oats, 1974). In contrast, Sobell, Vanderspek, and Saltman (1980) found individuals provided with breathalyzers for their cars reported significant decreases in drunk driving. Yet, Harwood (1984) found anecdotal evidence individuals were consuming more alcohol after receiving a lower than expected BAC reading.

One of the more comprehensive studies of BAC feedback in a drinking setting was conducted by Meier, Brigham, and Handel (1984). In this study, researchers approached 51 self-reporting drivers as they left a drinking establishment and guided them through either a nomogram or provided them with a breath alcohol test. Twenty-four participants registered over the legal limit. Research assistants then discreetly followed the intoxicated participants to see if they still elected to drive themselves home. A total of 83% of these participants were still observed driving immediately after receiving feedback they were legally impaired. This suggests breathalyzer feedback may help some individuals make safer transportation choices. However, the percentage of individuals who changed their behaviors was quite small in that study. The limited number of participants and dated nature of this study warrant further investigation of the impact of BAC feedback.

**Hypotheses**

The following hypotheses were examined:

(H1): Nomograms will be accurate to .02 mL/L in comparison to BAC.

(H3): The sobriety tests will be reliable.

(H2): Sobriety tests will be 80% accurate at differentiating drinkers above versus
below .08 mL/L.

(H4): Individuals in the BAC-feedback conditions will report greater driving risks as BAC increases compared to the control condition.

Method

Participants and Setting

Data were collected on three separate nights. In total, 309 individuals participated and consisted of 205 males and 103 females. Of these, 72 individuals were in a Greek-life organization and 234 individuals were non-Greek.

Measures

The nomograms used for the study were calculated using Widmark’s equation. Separate nomograms were used for each gender to account for average differences in body composition. The nomograms used in the study are provided in Appendix A.

For sobriety testing, several scoring sheets were used from NHTSA and the local police department where the research was conducted. Official SFST check sheets were used from Stuster and Burns (1998). Scoring for the counting backwards tests was taken from the local police department’s official sobriety test score log.

Five statements were read to participants to assess their perceptions of driving risk at their current level of intoxication. After each of the statements was read, the participant was asked to respond on a Likert scale ranging from 1 (Strongly Disagree) to 6 (Strongly Agree). These five statements are as follows:

(1) My blood alcohol level is below the legal limit to operate a motor vehicle.
(2) I am confident in my ability to operate a motor vehicle in my current state.
(3) My driving would be impaired in my current state.
(4) It would be safe for me to operate a motor vehicle in my current state.

(5) If I drove, I would be at risk for being arrested for Driving Under the Influence (DUI).

Selected Field Sobriety Tests

Three sobriety tests were used in the current investigation. Out of the SFST, the walk-and-turn test and one-leg-stand test were used. The third procedure was the counting backwards test. The ordering of tests was the walk-and-turn test, one-leg stand-test, and counting backwards test.

Field Sobriety Test Training

A team of six researchers was trained by the local police department on standardized techniques for delivering a variety of sobriety tests. This included intensive training on national SFST and a variety of related techniques used by the local police. One of the additional techniques was the counting backwards test where an individual counts down from 37 to 0. These research assistants were trained on both the delivery and scoring of these procedures.

Procedure

The procedure was identical to the data collection procedure described in the study overview with one significant change. Participants were randomly assigned to one of four conditions. When a participant gave verbal consent to participate, the data collector examined the next blank data sheet which contained a number indicating the participant’s experimental condition. Prior to data collection, the data sheets were randomly sorted to ensure an even distribution among the conditions.

The conditions varied based on the experimental intervention administered prior to completing the safety-perception questions. In Condition 1 (Control group) participants answered safety-perception questions prior to completing any intervention. In Condition 2
(Nomogram group) participants estimated their BAC with a nomogram prior to answering safety-perception questions. In Condition 3 (Sobriety Test group) individuals completed a sobriety test prior to answering the safety-perception questions. In Condition 4 (BAC group) participants were given a breath alcohol test and provided their reading prior to answering the safety-perception questions.

Research assistants administered all research questions, the nomogram, and breathalyzer test. All field sobriety tests were administered by the trained undergraduate researchers. Additional trained undergraduate researchers made observations for inter-observer reliability. While the primary sobriety test administrator provided verbal instructions and marked performance on the data sheet, the reliability data collector observed and recorded performance on a separate data sheet. These researchers rotated between tables and intermittently served as primary versus reliability observers. The primary and reliability observers did not communicate during the sobriety testing, nor did they compare data sheets.

**Results**

**Overall Drinking Epidemiology**

Out of 309 participants, 36 participants (11.7%) were completely sober at the time of participation. The average BAC of drinkers was .101 mL/L (SD = .045) with a maximum BAC of .227 mL/L. The intoxication levels of male drinkers (.105 mL/L) and female drinkers (.100 mL/L) was not statistically different, \( t(270) = .34, p = .34 \). However, members of a Greek-life organization (.112 mL/L) had significantly higher BACs than non-members of a Greek-life organization [.099 mL/L; \( t(268) = -2.07, p = .04 \)].

**Accuracy of Nomograms**
For the purposes of these analyses, non-drinkers (i.e., BAC = 0.00 mL/L) were excluded because they do not have a BAC to estimate. Across all BACs, nomograms were incorrect by an average of .056mL/L. This was calculated by taking the absolute value of the difference between nomogram-predicted BAC and actual BAC. Without taking the absolute value, nomograms were incorrect by .020 mL/L, indicating nomograms have a tendency to slightly to moderately overestimate BAC.

Nomogram effectiveness was also examined at the critical BAC ranges of .02-.14 mL/L. Results closely mirrored the findings for the full range of BACs. At this range, nomograms were incorrect by an average of .054 mL/L. Similarly, nomograms overestimated BAC by an average of .026 mL/L.

**Accuracy of Sobriety Testing**

The one-leg-stand (OLS) test was evaluated first. The reliability of this sobriety test was assessed using a Kappa statistic. Across 57 reliability observations, the Kappa statistic was .60. This indicates substantial inter-observer agreement.

Next, the ability of the OLS to discriminate BACs at .08 mL/L was examined. Only participants with BACs between .02 and .14 mL/L were used for this analysis in order to investigate OLS accuracy at the critical BAC range where the majority of sobriety decisions are made. To assess sobriety test performance, participant BAC was dichotomized into below versus above the legal limit and sobriety test performance was scored as pass versus fail. Sobriety test scoring was designed to discriminate at .08 mL/L.

A Chi-Square test demonstrated the OLS performed better than chance at differentiating between sober and legally-drunk individuals, $\chi^2 (1) = 5.36, p = .02$. If an individual was sober, the OLS predicted correctly 77.3% of the time. If an individual was legally intoxicated, the OLS
predicted they were intoxicated 38.7% of the time. Full results of OLS accuracy are provided in Table 5.

Next, the walk-and-turn test (WTT) was examined. Across 68 reliability observations the Kappa statistic for the WTT was .23, indicating only fair agreement. The correlation between primary and reliability scores was .67.

Again, only individuals with BACs ranging between .02 and .14 mL/L were included in the analysis of WTT discrimination at .08 mL/L. A Chi-Square test revealed the WTT discriminated BACs of .08 mL/L better than chance, $\chi^2 (1) = 6.99, p < .01$. The WTT was 68.0% accurate when participants were under the legal limit and 51.2% accurate when individuals were over the legal limit. Full results of WTT accuracy are provided in Table 5.

Next, the counting backwards test was examined. Individuals who incorrectly skipped or added a number were classified as failing. The Kappa-statistic (.54) demonstrated moderate agreement across 70 reliability observations.

Similar to the previous analyses, only individuals between .02 and .14 mL/L were included in this analysis, and these individuals were dichotomously classified on legality to drive according to their BAC reading and estimated legality from the sobriety test. The Chi-Square test showed the counting backwards test predicted sobriety significantly better than chance, $\chi^2 (1) = 5.51, p = .02$. This sobriety test was 67.5% accurate at predicting sobriety (i.e., BAC < .08 mL/L) and 49.2% accurate at predicting intoxication (i.e., BAC $\geq .08$). Full results of counting-backwards test accuracy are shown in Table 5.

Finally, the sobriety results of all three tests were combined. If any individual failed any of the three sobriety tests they were given an overall “fail” rating. At the critical BAC ranges of .02 and .14mL/L, this overall rating was found to significantly predict sobriety $\chi^2 (1) = 7.51, p$
This total score was 39.4% accurate at predicting sobriety and 72.0% accurate at predicting intoxication.

**Effectiveness of BAC-Feedback Interventions**

In addition to assessing the accuracy of field BAC-estimation techniques, it is also important to examine the effectiveness of these techniques at prompting shifts in perceptions of safety. Specifically, it is critical to determine if these techniques promote greater self-awareness of risks related to intoxication.

Thus, a multivariate analysis of covariance (MANCOVA) was performed with condition as the grouping variable to examine the effect of BAC feedback on the five questions related to driving-safety perceptions. Blood alcohol content was mean centered and included as a covariate, along with the interaction between BAC and condition. This centered variable was used to create the interaction term. In order to assess these relationships within critical BAC ranges where the majority of safety-related decisions are made, only participants with BACs between .03 and .16 mL/L were included in these analyses.

Using Pillai’s Trace, the MANCOVA showed a significant interaction between participant condition and BAC, $F(15, 654) = 3.09$, $p < .01$. Additionally, significant main effects were observed for both condition and BAC, $p$’s < .01. This demonstrates both experimental condition and participant BAC impacted perceptions of safety.

In order to further examine this effect, five follow-up ANOVAs were performed on each of the dependent variables. These tests were performed in a regression framework using dummy coding. The control condition was established as the reference group. A Bonferroni correction was used to control for inflated Type I error rate. An initial alpha of .10 was set. Thus, the critical alpha value for each follow-up test was .02.
1) My blood alcohol level is below the legal limit to operate a motor vehicle. The overall model for this question reached statistical significance, $F(7, 220) = 6.28, p < .01$. The dummy code for the sobriety test condition ($b = -.88, p = .01$) and interaction term between the breathalyzer condition and BAC ($b = -37.96, p < .01$) reached statistical significance. This indicates that at the mean BAC, individuals in the sobriety-test condition reported significantly less confidence their BAC was below the legal limit than individuals in the control condition. The interaction shows that the relationship between BAC and responses to this item was significantly stronger in the breathalyzer condition than in the control condition. These results are graphically depicted in Figure 10.

2) I am confident in my ability to operate a motor vehicle in my current state. The overall model failed to reach statistical significance for this question, $F(7, 220) = 2.18, p = .04$. Since the model approached significance, it is worth noting the BAC variable reached statistical significance ($b = -14.40, p = .046$). This suggests BAC may be negatively related to confidence in operating a motor vehicle. However, this cannot be supported based on the current analysis.

3) My driving would be impaired in my current state. The overall model failed to reach statistical significance, $F(7, 220) = 2.43, p = .06$. It is worth noting none of the predictors reached statistical significance, $p$’s > .10.

4) It would be safe for me to operate a motor vehicle in my current state. The overall model was statistically significant, $F(7, 220) = 2.90, p < .01$. There was a significant main effect for BAC ($b = -18.73, p < .01$) indicating individuals at higher BACs were less likely to feel safe operating a motor vehicle. There was also a significant interaction between the dummy code for the sobriety-test condition and BAC ($b = 19.97, p = .04$). This showed the relationship between BAC and item response was significantly weaker for the sobriety-test condition compared to the
control group. Regardless of BAC, individuals in the sobriety-test condition had a tendency to report consistently lower perceptions of safety. This is graphically depicted in Figure 11.

5) If I drove, I would be at risk for being arrested for Driving Under the Influence (DUI). The overall model was significant for this item, $F(7, 220) = 5.76, p < .01$. The interactions for BAC and the dummy code for the breathalyzer condition ($b = 38.12, p < .01$) and BAC and the dummy code for the nomogram condition ($b = 21.01, p = .03$) reached statistical significance. This indicates the relationship between BAC and item response was stronger for the breathalyzer and nomogram conditions as compared to the control condition. There was no significant effect for the sobriety-test condition. This is graphically depicted in Figure 12.

**Effectiveness of Feedback Techniques at Improving BAC-Estimation**

Two analyses of variance (ANOVAs) were performed to examine the efficacy of these feedback techniques at improving BAC-estimation. After receiving BAC feedback, participants reported their estimated BAC. Both the raw difference between actual BAC (i.e., breath alcohol test reading) and estimated BAC and then the absolute value of this difference were used as dependent variables in these ANOVAs. Since breath alcohol test readings were used as the measure of actual BAC, participants in the breathalyzer feedback condition were excluded from these analyses. Additionally, individuals with a 0.00 mL/L BAC were excluded from the analyses because there was no BAC to estimate. Both ANOVAs were non-significant ($p$’s > .05), indicating BAC feedback did not help individuals more accurately estimate their BAC.

**Discussion**

**Overall Levels of Intoxication**

The results highlight the at-risk levels of intoxication reached by many college students in a downtown bar setting. Indeed, the average BAC of students who consumed alcohol was
over .100 mL/L. Furthermore, nearly ten percent of drinkers were intoxicated at over twice the legal limit to drive.

The lack of significant gender differences in BAC is noteworthy. Traditionally, male students have been shown to consume greater quantities of alcohol than their female counterparts (Geller, Altomari, Russ, & Harwood, 1985; Geller, Clarke, & Kalsher, 1991; Geller & Lehman, 1988; O’Malley & Johnston, 2002; Presley, Meilman, & Lyerla, 1993; Vaisman-Tzachor & Lai, 2008; Tremblay et al., 2010). However, recent research suggests college males and females are both consuming alcohol at higher levels, but the rate of drinking among females is growing faster than the rate of drinking among males (Grucza, Norberg, & Bierut, 2009; National Center on Addiction and Substance Abuse, 2007). Results from this study suggest this parity may be realized in a downtown bar setting.

There has also been debate regarding the relationship between Greek-life membership and alcohol intoxication (Cashin, Presley, & Meilman, 1998; Fournier et al., 2004; Glindemann & Geller, 2003; Scott-Sheldon, Carey, & Carey, 2008; Wechsler, Kuh, & Davenport, 1996). Results from this study suggest Greek-life students are reaching slightly higher levels of intoxication in a downtown bar setting than non-Greek life students. However, the size of this difference (i.e., 0.010 mL/L) suggests this BAC differential may be of limited practical significance. Essentially, both Greek and non-Greek life students were, on average, drinking to excessive levels of intoxication.

**Accuracy of BAC-Feedback Techniques**

Nomograms were largely inaccurate in predicting BAC. Even at a restricted BAC range of .02 to .14 mL/L, nomograms were incorrect at predicting BAC by an average of .054 mL/L. Despite their inaccuracy, nomograms tended to overestimate BAC. Thus, they may still be
useful at deterring at-risk drinking decisions because of the inflated BAC feedback. In other words, false positives could be a good result in this situation.

Many factors may lead to the inaccuracy of nomograms in this field setting. While it may be easy to attribute this error to known inaccuracies in the Widmark equation (Devgun & Dunbar, 1994; Gullberg, 2007; Gullberg & Jones, 1994; Lewis, 1986), it may also be a result of user error. Primarily, nomogram accuracy depends on a drinker’s ability to report precisely the number of standard drinks s/he has consumed. Yet, a multitude of studies demonstrate large errors in self-reported number of drinks consumed. These reasons include misunderstanding the definition of a “standard drink” (Kerr & Stockwell, 2011; Lemmens, 1994), ignorance of standard drink volumes (White et al., 2005; White et al., 2003), poor recall while intoxicated (Babor, Steinberg, Anton, & Del Boca, 2000; Hustad & Carey, 2005), and environmental factors that influence self-monitoring of alcohol consumption (Clapp, Min, & Shillington, 2006). Thus, drinkers using nomograms may need prior education regarding standard drink definitions and techniques to aid memory recall (e.g., recording number of drinks consumed).

While sobriety-test scoring showed moderate to good reliability, sobriety-test scores only had limited utility at predicting actual sobriety. Indeed, sobriety-test scores barely predicted sobriety better than chance. In general, individual sobriety tests underestimated intoxication levels. However, combining scores across all three tests tended to overestimate level of intoxication.

Thus, this study failed to replicate research findings that supported the ability of SFST to differentiate BACs at .08 mL/L (e.g., Stuster & Burns, 1998). However, many of these studies use a police sample that allows police to make a judgment based on a variety of cues other than sobriety-test performance. For example, in addition to SFSTs, police officers examine the way a
vehicle is driven and the physical appearance of drivers after being stopped (Compton, 1985; Harris, Howlett, & Ridgeway, 1979). Thus, sobriety testing may be most accurate when paired with subjective judgments of impairment.

These findings could have significant legal ramifications, since SFST serve as the legal grounds (i.e., probable cause) for search and seizure (i.e., taking breath or blood for alcohol concentration testing). The high inter-observer reliability, paired with limited validity in the current study, raises concern for the use of SFST to estimate level of intoxication in determination of probable cause. When examining the total scores of the sobriety test battery used in the present study, these scores falsely predicted sober individuals (BACs between .02 and .08 mL/L) were intoxicated 60.6% of the time. This raises questions regarding the legality of using SFST to provide initial evidence of intoxication. Replication of these results is needed to provide legal and scientific clarification regarding the validity of SFST.

**Effectiveness of BAC-Feedback Techniques at Shifting Safety Perceptions**

Aside from the accuracy of BAC-feedback techniques is the efficacy of these techniques at shifting perceptions of personal safety. Results of the MANCOVA revealed a significant interaction between type of feedback and BAC at predicting the set of safety-perception questions. Several general trends were observed in these data.

Most notably, there was a markedly weak relationship between BAC and perceptions of safety. This is particularly evident in relation to the Control/ No Feedback condition. Thus, perceptions of safety were relatively unchanged by increasing levels of impairment. This seems to indicate individuals are not fully aware of the physiological changes that gradually increase with intoxication and are resistant to changing perceptions of safety accordingly. This observed
lack of sensitivity to the safety-related consequences of increasing levels of impairment could explain the occurrence of a host of at-risk activities people perform while intoxicated.

In general, BAC feedback tended to be more effective at shifting perceptions of safety in relation to the legal limit to operate a motor vehicle (i.e., BAC below the legal limit & risk for DUI). Conversely, this feedback tended to be less effective at shifting safety perceptions related to personal ability to drive (i.e., confidence in ability to drive, driving impairment, and safe to operate a motor vehicle). Thus, while this feedback tended to help individuals understand their legal liability, it was much less useful at helping individuals understand the physiological impairment resulting from their intoxication. In other words, BAC feedback tended to help shift external (i.e., legal), but not internal (i.e., personal) perceptions of safety.

There was also a trend for individuals in the sobriety-test group to have perception shifts that were stable across BAC. Simply put, there was often a weak interaction between actual BAC and perceptions of safety in the sobriety-test group (i.e., weaker simple slopes). Thus, while individuals in this condition may not have been as accurate at estimating their BAC and relative safety risk, these individuals typically reported safer perceptions of driving risk (i.e., reported perceiving greater risks at their current level of intoxication). For example, examination of Figure 11 demonstrates individuals in the sobriety-test condition reported feeling significantly less safe to drive across practically the entire range of BACs. Indeed, while there was no significant interaction with BAC, individuals in this condition were consistently reporting safer perceptions of driving safety.

Some of the strongest relationships between BAC and perceptions of safety were observed for the Breathalyzer and Nomogram condition. This was particularly true for questions regarding risk for DUI and BAC below the legal limit (i.e., external risk). Thus, feedback in
these conditions greatly helped individuals more accurately shift their perceptions of external risk with increasing levels of intoxication. However, while these perceptions were more closely tied to actual BAC, this feedback also made individuals at lower BACs feel less at-risk for these types of outcomes. It is possible this may produce inadvertent negative effects (e.g., drink-driving at low BACs).

Results from this study demonstrated BAC feedback can have substantial impact at shifting drinkers’ perceptions of at-risk behaviors. While individuals in the Breathalyzer and Nomogram condition were more sensitive to actual level of intoxication when estimating external risk, individuals in the sobriety condition often reported a set of safer (i.e., greater) at-risk perceptions regardless of BAC. Despite certain inaccuracies, BAC feedback may be a useful tool for reducing at-risk driving behaviors.

Unfortunately, it is impossible to determine how these shifts in perceptions directly related to same-night driving decisions. It would be valuable to know if internal versus external perceptions of safety are more or less valuable at inhibiting intoxicated driving or if driving decisions are made without regard to perceptions of safety at certain levels of intoxication. While this could not be assessed in the current study, understanding perceptions of safety provides a reasonable approximation of driving risk without the ethical and practical constraints of assessing self-reported or observed drink driving.
**Study 3: A Field Investigation of Nomogram and BAC-Estimation Phone Application**

**Accuracy and Efficacy at Promoting Driving-Risk Awareness**

Informing alcohol consumers of their level of intoxication offers a promising intervention strategy for reducing alcohol-related harm. A popular, cost-effective method for providing this information is nomograms. However, the accuracy and effectiveness of nomograms is mixed (Devgun & Dunbar, 1994; Dubowski, 1984; Glindemann & Geller, 1994; O’Neill et al., 1983; Russ & Geller, 1985).

Technological advancements have created innovative possibilities for improving the social validity of the standardized nomogram approach. Specifically, BAC-estimation smartphone applications provide a technology-based, visually-appealing, widespread, and free method of calculating one’s BAC. Yet, many questions remain regarding the accuracy and effectiveness of these applications, particularly, in relation to the classic nomogram.

**BAC-Estimation Phone Applications**

The rapid development of phone technology (hardware) and related phone applications (software) provide significant research opportunities. Phone technology has lead to several alcohol-related advancements primarily in the domains of data collection (Collins, Kashdan, & Gollnisch, 2003; Kauer, Reid, Sanci, & Patton, 2009; Patrick, Griswold, Raab, & Intille, 2008) and the delivery of health-related interventions (Franklin, Waller, Pagliari, & Greene, 2007; Patrick, Griwold, Raab, & Intille, 2008; Rodgers et al., 2005). Moreover, this technology provides potential intervention tools to prevent alcohol-impaired driving.

A multitude of phone applications have been developed for the iPhone and Android smartphone platforms. These phone applications can be downloaded directly onto a personal phone and run at the convenience of the phone user. The utility of these applications has grown with
increased smartphone saturation. In fact, it is estimated half of mobile subscribers currently use a smartphone with these app capabilities (Nielsen, 2012). Currently, smartphone users have an average of 41 phone applications downloaded on their phone, on which they spend an average of 39 minutes each day (Nielsen, 2012). The Apple app store alone reports the download of more than 46 million phone applications daily (Meeker, 2012). These numbers are growing exponentially.

Dozens of phone applications have been designed and downloaded to estimate BAC. Using at least some semblance of the Widmark equation, these phone applications allow a drinker to enter a variety of demographic and alcohol consumption variables and receive an estimate of their BAC. Millions of downloads have been reported by these phone applications, creating tremendous opportunities for beneficial prevention intervention, but also tremendous concerns.

No empirical research has yet to be published examining the accuracy or behavioral impact of these phone applications. While the drinking and transportation decisions of potentially millions of people are being shaped by these devices and their applications, the efficacy of these applications remains unknown. This is a developing and critical area for research investigation. Such was the purpose of this field study.

**Hypotheses**

The following hypotheses were examined in the current study:

(H1): Phone applications will be accurate at predicting BACs to .02 mL/L in comparison to BAC.

(H2): Individuals receiving BAC feedback will report lower perceptions of safety as BAC increases compared to the control group.
(H3): Safety perception shifts will be greater for the Phone Application condition as compared to the Nomogram condition.

Method

Participants and Setting

The sample includes 583 participants across the six nights (three consecutive Thursdays and Fridays) the study was conducted. The sample was made up of more males (n = 438) than females (n = 136). The sample was mostly non-Greek (n = 454) compared to Greek (n = 107).

Phone Application Selection

Phone applications were selected to capture the two largest platforms: the Android and Apple marketplace. The four most-downloaded, free applications were selected from each of these platforms. For the Android platform, AlcoDroid (D1), Blood Alcohol Calculator (D2), R-U-Buzzed (D3), and SoberApp (D4) were evaluated. For the Apple platform, BAC-Calculator (I1), Blood Alcohol Calculator (I2), Mr. Dui- BAC Calculator (I3), and R-U-Buzzed (I4) were evaluated.

The following information was collected for each phone application: D1 (body weight, gender, type of drink consumed), D2 (number of drinks, weight, hours spent drinking), D3 (number of drinks, weight, gender, hours spent drinking), D4 (number of drinks, weight, gender, hours spent drinking), I1 (number of drinks, weight, gender, hours spent drinking, drinking tolerance), I2 (number of drinks, weight, gender, hours spent drinking), I3 (number of drinks, weight, gender, hours spent drinking), and I4 (number of drinks, weight, gender, hours spent drinking). Screenshots of these eight phone applications are included in Appendix C.

Phone Application Administration
Six researchers were specially trained to administer each of the BAC-estimation phone applications. Each of these researchers had an electronic device capable of running either Android or Apple BAC-estimation applications. The selected platform applications were downloaded onto each device. These trained researchers filled in participant demographic and alcohol consumption information into phone applications for participants. These were the only individuals who administered BAC-estimation phone applications to participants.

**Measures**

In addition to demographic information, questions were also asked regarding estimated BAC and drinking intentions. A variety of additional questions were also asked to estimate an individual’s BAC on the phone applications and nomograms. This included questions about height, weight, number of alcoholic drinks consumed, duration of alcohol consumption, drinking tolerance, drinking history, and food intake. Individuals were also asked “How accurate do you think your predicted BAC is?” from “1” too low, to “4” accurate, to “7” too high.

Five statements were read to participants regarding driving safety perceptions. Responses to all questions were assessed with a 6-point Likert scale, from 1 (Strongly Disagree) to 6 (Strongly Agree). The questions are as follows:

1. My blood alcohol level is below the legal limit to operate a motor vehicle.
2. I am confident in my ability to operate a motor vehicle in my current state.
3. My driving would be impaired in my current state.
4. It would be safe for me to operate a motor vehicle in my current state.
5. If I drove, I would be at risk for being arrested for Driving Under the Influence (DUI).

**Procedure**
The procedures in this investigation were similar to the overall procedure. After individuals were recruited, they were randomly assigned into one of three conditions. Participants were sorted based on a number in the upper-right-hand corner of the data sheet. Data sheets were layered by condition to ensure an adequate and random sampling of each condition.

The three conditions varied according to the ordering of the study procedures. After recruitment, all individuals answered a brief series of demographic questions. At this point, procedures changed based on study condition. In Condition 1, participants were sent to the trained research assistant to enter their information into a phone application. Participants then answered the five questions regarding their safety perceptions and were administered a breath alcohol test. In Condition 2, participants used a nomogram to estimate their BAC. Participants then answered the five safety-perception questions, had their information entered into a BAC phone application, and were administered a breath alcohol test. In Condition 3, individuals answered the five safety-perception questions, were administered a breath alcohol test, and then had their information into a BAC phone application.

The administration of BAC-estimation phone applications was only performed by the specially trained research assistants. When a participant was at the appropriate part of the study to use the phone application, the original data collector signaled one of the phone application administrators. The phone application administrator asked the participant the necessary information to produce a BAC estimate for the given application. Participants watched as their information was entered and were then informed of their estimated BAC. Upon completion of using the phone application, the research assistant either sent the participant back to the original data collector or passed them on to the BAC administrator.
Results

Overall Drinking Epidemiology

Out of 553 participants who received a breath alcohol test, 78 (14.1%) were completely sober. Of drinking participants, the average BAC was .102 mL/L with a maximum BAC of .242 mL/L. In this sample, males (.104 mL/L) had significantly higher BACs than females (.093 mL/L; \( t(472) = -2.09, p = .04 \)). Additionally, members of a Greek-life organization (.112 mL/L) had higher BACs than individuals who were not members of a Greek-life organization (.100 mL/L; \( t(462) = -2.13, p = .03 \)).

Accuracy of Phone Applications

The average phone application was incorrect in estimating BAC by .083 mL/L (\( SD = .024 \)). Table 6 shows BAC accuracy broken down by specific phone application. This includes average BAC discrepancy and the absolute value of this discrepancy. Estimated BACs over .300 mL/L were considered “erroneous” and removed from calculations of accuracy. This was done because it is likely individuals receiving estimated BACs over this number would disregard the feedback. The percentage of erroneous BACs per phone application (ranging from 0.0% to 28.0%) is also provided in Table 6. Figure 13 shows the average discrepancy between phone-application-predicted BAC and actual BAC as a function of phone application.

The estimation of BAC near the legal limit was examined to determine if phone applications tend to over versus underestimate legal-driving status. If an individual was between the BAC range of .02 through .079, then the phone applications predicted the individual was over the legal limit 55.3% of the time. If an individual had a BAC in the range of .08 through .14, then the phone applications predicted the individual was under the legal limit 14.2% of the time.

Accuracy of Nomograms
The accuracy of nomograms was assessed by calculating the difference between actual BAC and the BAC estimated by the nomograms. On average, nomograms were inaccurate by .052 mL/L at estimating drinker BACs. Nomograms tended to overestimate BAC by an average of .020 mL/L.

Effectiveness of BAC-Feedback Interventions

In addition to understanding the accuracy of BAC feedback interventions, the efficacy of these interventions at promoting safer driving perceptions was investigated. This was examined using a multivariate analysis of covariance (MANCOVA) with the five safety-perception questions as the dependent variables. Condition, BAC, and the interaction term were examined as predictors of these dependent variables. In order to examine these relationships at the critical BAC range where many driving decisions are made only participants with BACs ranging between .030 and .160 mL/L were included in the MANCOVA.

Using Pillai’s Trace, neither condition, \(F(5, 379) = 1.43, p = .16\) nor the interaction term \(F(10, 760) = 1.53, p = .12\) were statistically significant. There was a significant effect for BAC, \(F(5, 379) = 7.30, p < .01\). Follow-up ANOVAs demonstrated BAC was a significant predictor of all five dependent variables, \(p’s < .01\).

Effectiveness of Feedback at Improving BAC-Estimation

An ANOVA was performed to examine if BAC feedback improved participant estimation of BAC. The dependent variable was the absolute difference between participant’s actual and estimated BAC. Feedback condition served as the grouping variable. The results of the ANOVA approached, but did not achieve, statistical significance, \(F(2, 469) = 2.60, p = .076\).

Discussion

Overall Levels of Intoxication
Results for overall levels of alcohol consumption were consistent with the larger dataset presented in Study 1. The average BAC of participants was well over the legal limit to drive of .08 mL/L. Additionally, a significant percentage of participants were over twice the legal limit. In this study, there were significant BAC differences as a function of both gender and Greek-life status.

**Accuracy of BAC-Feedback Techniques**

**Phone applications.** The average phone application was incorrect in estimating BAC by .083 mL/L. Even after removing erroneous BAC predictions (i.e., BACs > .300 mL/L), the majority of phone applications were inaccurate at predicting BAC by an average of .05 mL/L. Indeed, the frequency of erroneous BAC predictions is also of concern. While Study 1 showed students are poor estimators of their own level of intoxication, it is surprising phone applications were nearly twice as inaccurate as these self estimations.

The inaccuracy of these phone applications could have many troubling implications. This inaccuracy likely reduces the utility and efficacy of these phone applications at promoting safer decisions while consuming alcohol. This is largely because many individuals may not trust BAC estimations that deviate markedly from perceived levels of impairment, even though these perceptions of intoxication are inaccurate themselves.

However, if individuals do trust an inaccurate reading, there is also the potential for poor decisions to be reached. Fortunately, BAC-estimation phone applications had a strong tendency to overestimate BAC. For example, only 14.2% of individuals with BACs between .08 mL/L and .14 mL/L had an estimated BAC below the legal limit to drive. Yet, for these individuals the potential for alcohol-related harm may potentially increase. The impact of this type of incorrect phone application estimation is worthy of future research.
Despite the significant discrepancy between BAC estimations from phone applications and actual BAC in this study, this discrepancy may be even larger beyond a research context. In this study, researchers entered all information into the phone application for the participant. Researchers were specifically trained in the correct usage of each phone application and entered all information while sober. Intoxicated individuals using phone applications for the first time may have great difficulty entering information correctly. Additionally, all researchers are highly educated regarding standard drink volumes. Participants may have benefited from data collectors research knowledge while estimating drinks for the phone application. These factors make it likely phone applications would be less accurate estimators of BAC when users enter the relevant information.

Differences in quality of BAC estimations were observed across phone applications. Most notably, Sober App (D4) made erroneous predictions 28.0% of the time. There also was a tendency for the iPhone apps to outperform the Android platform apps. The most accurate phone application was Blood Alcohol Calculator (I2). However, even this application was inaccurate by an average of .044 mL/L. Thus, even the best performing phone application on the current market may be of little practical use in estimating one’s BAC.

**Nomograms.** On average, nomograms were inaccurate in predicting BAC by .052 mL/L. Thus, they performed similarly to the accuracy of phone applications. Much like phone applications, nomograms also had a tendency to overestimate BAC. Despite the general inaccuracy of nomograms, the tendency to overestimate BAC may potentially promote safer decisions.

**Effectiveness of BAC-Feedback Techniques at Shifting Safety Perceptions**
The effectiveness of BAC-feedback techniques was evaluated in terms of risk perceptions and the promotion of more accurate estimations of BAC. The MANCOVA indicated BAC-feedback techniques were not effective in shifting the safety-related perceptions of participants in this study. However, safety-related perceptions were moderately related to participant BAC.

There are many possible explanations for the lack of significant findings. Paired with study findings regarding the inaccuracy of both nomograms and BAC-estimation phone applications, it seems almost inevitable this BAC feedback would have no additive effect beyond a drinker’s own perceptions of intoxication. Indeed, this would match the reality that BAC feedback was almost twice as inaccurate as an individual’s own perception of his or her level of intoxication. Additionally, as individuals become more intoxicated, they may become less open to receiving feedback regarding physiological impairment. Ultimately, drinkers may also place a strong level of confidence in their perceptions of BAC with little room for adjustment based on BAC feedback.

The effect of BAC feedback on estimated intoxication levels was similarly non-significant. However, while these findings did not reach statistical significance, they did approach significance. Mean differences between experimental conditions on estimated BAC were practically meaningful (Phone Application = .0398 mL/L; Nomogram = .0342 mL/L; Control = .0570 mL/L). While it cannot be concluded these mean values are significantly different, it would be remiss to fully preclude the possibility of meaningful differences in a future study or with a larger n-size.

Summary

Both phone applications and nomograms were found to be largely inaccurate at estimating BACs. This is troubling because hundreds of thousands of individuals use these
feedback devices to estimate their level of intoxication. This widespread inaccuracy is a potential reason the BAC feedback in this study was ineffective at promoting safer perceptions of driving risk.

While there were substantial differences in the performance of phone applications, no phone application emerged as a standout. Indeed, there was not a single phone application that estimated better on average than individuals’ perceptions of their own intoxication. Thus, no particular phone application can be recommended for use as a result of this study. The actuality is that significant effort needs to be undertaken to examine the BAC-estimation programming of these phone applications, and new phone applications are warranted.

Nomograms were found to offer several advantages over BAC-estimation phone applications. Phone applications are not only significantly more complex to use, but also take much longer to use. The complexity of navigating the phone applications and need for dexterity make many of the existing phone applications impractical for intoxicated individuals. Another advantage to nomograms is the lack of extreme (i.e., erroneous) predictions. Indeed, the phone applications often provided profoundly unrealistic estimates of BAC. Since nomograms only calculate BACs to reasonable ranges, extreme errors are not observed or possible through the estimation tables. Even considering these advantages, the lack of nomogram accuracy makes it difficult and unreasonable to recommend their widespread usage as an effective intervention or education tool to prevent harm from excessive alcohol consumption and intoxication.
Study 4: The Longitudinal Impact of Breathalyzer Feedback on Self-Estimations of BAC

Blood alcohol concentration education is a widely used and supported technique that is incorporated into many college programs to prevent alcohol abuse. In fact, it has been estimated 73% of college alcohol intervention programs incorporate some component of BAC education (Carey et al., 2007). This includes such programs as BASICS (Dimeff et al., 1999), AlcoholEdu (Outside the Classroom, 2010), and Heads UP (LaBrie, 2010). While there has been some support for this education-based approach (Van Beurden et al., 2010), other studies have shown alcohol education approaches are ineffective when used alone (Larimer & Cronce, 2007). This may be because they are often removed from the drinking context and lack true personalization.

The most direct and accurate method of providing BAC education and feedback is at the time the individual is consuming alcoholic beverages. This allows the person to directly associate a BAC with a state of impairment. This field intervention method creates an individual, face-to-face approach which has consistently been shown to be the most efficacious alcohol intervention strategy (e.g., Carey et al., 2007). The approach is also consistent with Russ and Geller (1985) who argue more emphasis should be placed on interventions that exert their impact after an individual consumes alcohol, but before he or she makes critical decisions (e.g., operating a motor vehicle).

Yet, only a few studies have examined the impact of breathalyzer feedback as an intervention. Mixed results have been observed for these studies. Some research has indicated breathalyzer feedback has no effect on the transportation decisions of alcohol consumers (Calvert-Boyanowsky & Boyanowsky, 1980; Oats, 1974). In contrast, Sobell and colleagues (1980) found individuals provided with breathalyzers for their cars self-reported significant
decreases in drunk driving. Harwood (1984) reported anecdotal evidence individuals may actually consume more alcohol if they were disappointed by their BAC reading.

Aside from the immediate impact on transportation decisions, breath-alcohol feedback may also help individuals reduce the discrepancy between their actual and perceived BAC over multiple BAC administrations. However, only one study has examined the longitudinal relationship of BAC feedback and accuracy of estimating one’s BAC (Bullers & Ennis, 2006). That study provided individual breathalyzers to 19 participants and asked them to record a daily drinking log, including self-reported drinking behaviors, estimated BAC, and their breathalyzer reading. The researchers showed that at lower BACs, individuals became more accurate at estimating their BAC over the first four drinking occasions.

While the Bullers and Ennis (2006) study provides interesting preliminary results, the study has significant limitations. In addition to the small sample size, the study had very limited experimental control. The study relied heavily on unsupervised self-reports and drinking logs, and no information was provided on the accuracy of the breath alcohol testers. Additionally, there were some problems with the statistical analyses, including running categorical variables as continuous predictors in a regression framework.

Thus, further research is necessary to fully explore the effects of breath alcohol testing feedback over time. The current study examined this phenomenon across multiple years, with law-enforcement quality breathalyzers, and greater experimental control, albeit in a field setting. This will build on previous research while controlling for the limitations of these previous investigations.

**Hypotheses**

The following hypotheses were tested:
(H1): Female drinkers will be more accurate at estimating their BAC than male drinkers.
(H2): Greek students will be more accurate at estimating their BAC than non-Greek students.
(H3): Accuracy of BAC estimation will increase with year in school.
(H4): Repeated breathalyzer feedback will result in smaller discrepancies between gBAC and actual BAC.

Method

Participants and Setting

The full sample was used as described in the overview of dataset section. This included 12,432 times individuals participated in the study across 89 separate nights. A total of 10,225 unique individuals participated in the study. Approximately, 18% of these individuals participated in the research on at least two separate nights. The most an individual participated was on 14 separate nights. Table 7 reports the full frequency of repeat participation.

Procedure

The protocol was identical to that described in the general procedure section. As a part of the demographic information, surveyors collected participant information to create an anonymous study code. For this code, participants were asked to provide the first two letters of the city in which they were born, the first two letters of their mother’s maiden name, and the first two numbers of the month in which they were born. For example, an individual born in Richmond in April with a mother’s maiden name of Jones would have the subject code “RIJO04.” This code allowed for individuals to be tracked across nights of participation.
After providing the demographic information and study code, participants were also asked questions regarding their estimated and intended BAC. After completing the survey, individuals were administered a breath alcohol test and shown the results of this BAC assessment.

**Results**

**Accuracy of Student Perceptions of Intoxication**

Descriptive statistics were calculated for the discrepancy between BAC and both gBAC and intended BAC. This included both the raw discrepancies and the absolute values of these discrepancies. Additionally, the correlation between gBAC and BAC was calculated, along with the correlation between intended BAC and BAC. Table 7 reports these statistics for both the total sample and broken down as a function of number of times participated.

The accuracy of gBAC was further examined as a function of several demographic variables. A 2 Gender (Male vs. Female) X 2 Greek Status (Greek vs. Non-Greek) X 5 Class Status (Freshmen vs. Sophomores vs. Juniors vs. Seniors vs. Graduate Students) ANOVA was performed on the absolute value of the difference between gBAC and BAC. The overall model was significant, $F(19, 4972) = 3.89, p < .01; \eta^2 = .015$. The only significant result was a main effect for class, $F(4, 4972) = 9.03, p < .01$. Tukey’s posthoc tests revealed freshmen and sophomores were less accurate at estimating their BACs than juniors and seniors. Additionally, juniors and seniors were better at estimating their BAC than graduate students ($p$’s < .01).

A similar analysis was performed to examine potential demographic differences in the relationship between intended and actual BAC. A 2 Gender (Male vs. Female) X 2 Greek Status (Greek vs. Non-Greek) X 5 Class Status (Freshmen vs. Sophomores vs. Juniors vs. Seniors vs. Graduate Students) ANOVA was performed on the absolute value of the difference between
intended BAC and actual BAC. The overall model was significant, $F(19, 5078) = 2.43, p < .01; \eta^2 = .009$.

There was a significant main effect for gender, $F(1, 5078) = 12.68, p < .01$, showing males were significantly further from their intended BAC (.0450 mL/L) than females (.0401 mL/L). Both the main effect for class and the three-way interaction approached statistical significance ($p’s < .10$).

**Effect of Breath-Alcohol Feedback Over Time**

A mixed-effects model was used to evaluate the effect of repeated breathalyzer feedback on BAC-estimation accuracy via longitudinal participation in the study. This approach was chosen because it is robust in handling missing data (Baayen, Davidson, & Bates, 2008; Pinheiro & Bates, 2000). Additionally, this approach allowed for an examination of individual change across repeated breathalyzer administrations. Individuals who participated in the study at least five times were used to maximize exposure to repeated breathalyzer feedback while maintaining a sufficient sample size. Estimation accuracy was examined for individual time points with BACs between .001 mL/L and .200 mL/L.

The first mixed-effects model examined the effect of repeated study participation on the dependent variable of the absolute value of the difference between gBAC and BAC. The fixed effect for number of times participated reached significance, $F(4, 162) = 2.67, p = .03$. An examination of the specific parameters found a difference between BAC-estimation accuracy at Time 1 versus Time 5 ($b = .0171, SE = .0058; t(162) = 2.93, p < .01$). Thus, participants at Participation Time 1 were estimated to be .0171 mL/L less accurate at estimating their BAC as compared to their accuracy at Participation Time 5. Figures 14 and 15 show participant gBAC
discrepancies as a function of number of times participated in the study. Additionally, Figure 16 shows the mean gBAC discrepancy as a function of number of participation times.

A second mixed-effects model was run to examine the effect of repeated study participation on the dependent variable of the absolute value of the difference between intended BAC and actual BAC. This model failed to reach significance, $F(4, 171) = .43$, $p = .78$. This indicates repeated breathalyzer feedback was not effective at reducing the discrepancy between intended and achieved BAC.

**Longitudinal Consistency of BAC**

In addition to investigating the discrepancy between perceptions of intoxication and drinking intentions over time, this study also allowed for the examination of trends in level of intoxication over time. Table 8 shows the correlation between BACs at different times of participation. All correlations with an n-size over ten were statistically significant with correlations ranging between .374 and .853. Figure 17 shows individual BACs over five times of participation. This shows the consistency of participant BAC over repeated times of participation. Only individuals who participated at least five times were included in the graph.

**Discussion**

To the knowledge of the author, this is the first study to track individual drinking over time using breath alcohol testing in a field setting. The use of subject codes was an effective mechanism for providing anonymous subject tracking over time. Accordingly, the results provide unique insight into drinking patterns over time and the effects of repeated breath alcohol test feedback. Additionally, the large amount of data provided a unique opportunity to explore the relationship between estimated BAC, intended BAC, and actual BAC.
Results supported the initial hypothesis that students were inaccurate at estimating their level of intoxication. Indeed, the average drinker was incorrect in estimating their BAC by .034 mL/L. This difference varied significantly by class with upperclassman achieving higher levels of accuracy than underclassman.

There are several potential explanations for the effect of class on BAC-estimation accuracy. One possible explanation is a link between drinking experience and BAC-estimation accuracy. However, it seems unlikely experience alone would improve estimation accuracy without BAC education or feedback. Class differences could also occur because the drinking experience is likely very different for underclassmen (many of whom are underage) and upperclassman (who are typically 21 or older). While upperclassman are potentially buying traditional (i.e., standard) drinks, underclassman downtown may rely largely on pregaming (i.e., frontloading) and getting random drinks from overage friends. This may make it more challenging to estimate level of intoxication.

The study also found a large discrepancy between intended BAC and actual BAC (.0429 mL/L). In many ways this discrepancy is actually beneficial because students reached a BAC that was, on average, .0118 mL/L lower than their intended BAC. Indeed, while many students are already reaching dangerously high levels of intoxication, the average intended BAC of students was even greater still. This effect was slightly smaller for females who had a significantly smaller discrepancy between intended BAC and actual BAC as compared to males. However, it remains possible participants reached higher BACs after participating in the research.

Several interesting results emerged from the repeated tracking of participants throughout the four years of the study. The consistency of drinkers in this setting was noteworthy. This
occurred in terms of repeat participation, but also similar patterns of intoxication across this repeated participation. Approximately, 18% of participants completed the study at least two times. The BACs of these participants across multiple nights were strikingly similar. In fact, correlations between BACs across multiple nights averaged over .500 mL/L. While several self-report and diary studies (e.g., Kuntsche & Cooper, 2010) have shown similar levels of intoxication consistency (i.e., drinking habits) this is the first study to the author’s knowledge to examine these patterns using breath alcohol testing in a field setting. The study results provide strong support for the habitual nature of college alcohol consumption.

A mixed-effects model demonstrated BAC feedback may have a beneficial impact by reducing the discrepancy between gBAC and actual BAC. Thus, results supported the general conclusion of Bullers and Ennis (2006), but within a controlled field setting. However, unlike Bullers and Ennis, a significant reduction in gBAC error was not observed until the fifth assessment of BAC.

These findings may indicate learning to estimate one’s level of intoxication is a longer process than receiving a one-time BAC reading. In fact, it may take up to four or more sessions of feedback on separate drinking occasions to have noticeable accuracy gains in estimating intoxication. Many reasons for this delayed learning are possible. Most likely it takes several breathalyzer feedback sessions to “calibrate” an individual’s internal perceptions of impairment with a physiological measure of BAC. While results of this study showed students tend to have similar BACs across multiple nights of drinking, there is clearly significant room for individual-night variation in intoxication levels. Thus, drinkers may need to have several BAC readings taken at these differing levels of impairment to begin to achieve accuracy at guessing one’s level of intoxication within a given BAC range.
It is also worth noting that repeated breathalyzer feedback was useful in decreasing the discrepancy between estimated BAC and actual BAC, but not the discrepancy between intended BAC and actual BAC. Indeed, even at the fifth time of participation where participants were significantly more accurate at estimating their BAC, they were not significantly more accurate in reaching their intended BAC. Thus, there seems to be a disconnect between drinking intentions and behaviors that is independent from misperceptions of intoxication. While many theories (e.g., the theory of planned behavior; Ajzen, 1988, 1991; Ajzen & Fishbein, 1973, 1980) and interventions focus on drinker intentions, results indicate focusing entirely on the intention to behavior relationship may only provide limited benefits to reducing high-risk alcohol consumption. After all, the average drinker actually consumed less than their intentions.

There is a definite need for further research in this domain and continued tracking of participant BACs in the field. Unfortunately, with limited numbers of individuals participating in the study more than five separate times, it was impossible to fully investigate the full extent of repeated breathalyzer feedback. Future investigations and further population of the database should examine if improvements in BAC estimation continue, level off, or deteriorate beyond five breathalyzer feedback sessions.
General Discussion

This multi-year research project was designed to explore a field research methodology via breath alcohol testing while examining potential prevention intervention strategies in this setting. Thus, the aim was to intervene on at-risk alcohol consumption among university students at the critical moment of drinking while also attempting to achieve accuracy gains in the measurement of alcohol consumption through breath alcohol testing.

This enabled progress beyond self-report investigations of alcohol consumption, providing for a more accurate examination of demographic and environmental risk factors for high-risk alcohol consumption. An additional aim of the research was to investigate psychological mechanisms for at-risk drinking behaviors. Both BAC-estimation error and intended intoxication levels were targeted as sources of at-risk behavior and poor decision making because of the observed gap between estimated, intended, and actual BAC.

The field research also evaluated BAC-feedback interventions as a technique for influencing perceptions of driving safety among drinking participants. Toward this end, nomograms, sobriety tests, BAC-estimation phone applications, and breath alcohol tests were used to heighten intoxication awareness and, ultimately, facilitate safer driving decisions.

Beyond Self-Reported Alcohol Consumption

Across the globe and on our nation’s college and university campuses, alcohol consumption is the cause of substantial psychological and physical harm (Hingson et al., 2009; World Health Organization, 2009). Despite the significant financial costs and numbers of young lives lost, the vast majority of alcohol research relies exclusively on self-reports of alcohol consumption (Clapp et al., 2009; Wechsler et al., 2002). Yet, these self-report measures are
notoriously inaccurate (Grant et al., 2012; Russ et al., 1986; Shillington, et al., 2011; Whitford et al., 2009).

The present research extended beyond existing self-report studies of alcohol consumption. Furthermore, it aimed to build upon existing field breathalyzer research (e.g., Grant et al., 2012; Glindemann et al., 1998) by creating a multi-year dataset of thousands of student drinkers. To the author’s knowledge this is the most extensive field dataset of university-student BACs.

**Overall levels of student intoxication.** One of the most revealing findings across all studies was the extreme average BAC among university students. The mean BAC of drinking participants was .100 mL/L. Over 60% of participants were over the legal limit to drive. Furthermore, multiple participants had BACs over .250 mL/L. Astoundingly, these averages only included individuals who were sober enough to successfully complete the survey and breathalyzer process. Thus, this average BAC is likely an underestimate of student intoxication.

These results are cause for significant concern. After all, this study found the average university-student drinker is consuming alcohol at binge-drinking levels. Additionally, this magnitude of alcohol consumption is indicative of a binge-drinking culture. Based on the current research findings, there is a clear need for harm-reduction interventions on a university campus, particularly those targeting transportation decisions.

**Demographic differences in intoxication.** Demographics related to alcohol consumption have been widely investigated, but contradictory findings have resulted. A possible source of such contradiction is the method of assessing alcohol consumption (i.e., through self-reported number of drinks consumed or eBAC). This research provides some clarity to this
research domain by studying these demographic differences through a physiological measure of alcohol intoxication among a large sample of university students.

Within this particular drinking context, several demographic differences were observed. Most notably, males, members of a Greek-life organization, and upperclassmen reached higher BACs than comparable other groups. A significant interaction between Greek-life membership and class status indicated members of a Greek-life organization consistently had higher BACs from sophomore year to graduate school, but this difference was not observed for freshmen. This suggests the culture of Greek-life organizations could promote alcohol consumption and intoxication.

Given the large sample size of this study, it is not surprising many of these demographic differences reached statistical significance. However, results must be examined for both statistical and practical significance. In this regard, it is useful to examine the actual differences in BACs across particular demographic groups. These group differences in BAC ranged from small to moderate. All demographic group differences were less than .02 mL/L, and the difference between genders was .0035 mL/L. Particularly for gender differences, the small BAC differential between males and females is noteworthy in itself. This would seem to support previous research showing an attenuation of gender differences in alcohol consumption among university/college students (Grucza et al., 2009; Keyes et al., 2011).

At the individual level, these BAC differences likely have limited impact on risk and aversive outcomes for different demographic groups. However, at a broader level, even this small to moderate difference in mean intoxication could have substantial effects and consequences across hundreds of thousands of college-student drinkers. Thus, even slight
demographic differences in levels of intoxication should be taken seriously at a school and societal level.

The small effect sizes observed may also play a role in the often contradictory past research of demographic differences in alcohol consumption. Many studies of these differences would simply lack the sample size or measurement precision to find statistically significant demographic differences in alcohol consumption. Thus, this research adds insight into the nature of these demographic differences through a large sample size and precision in assessing alcohol consumption.

**Alcohol consumption by day of the week.** The day of the week was significantly related to mean BACs. Results indicated the highest levels of intoxication were observed on Thursday nights, followed by Saturday nights. This may be surprising to many readers; however, the findings are consistent with previous field investigations at this university (i.e., Glindemann et al., 1998). It is risky to generalize these findings to other colleges and universities, albeit, research from other college/university campuses has demonstrated similar results (e.g., Tremblay et al., 2010; Wood et al., 2007).

The high prevalence and magnitude of alcohol consumption on Thursday night is troubling given weekday alcohol consumption is associated with unique and serious negative consequences (Hoeppner et al., 2012; Ward et al., 2013). Thus, future research should examine the motives for Thursday night drinking and the relationship between academic class scheduling and weekday drinking. Results from these investigations could inform academic policy at colleges/universities and, perhaps, the implementation of contingencies to reduce this problem (e.g., scheduling more classes on Friday mornings).
**Designated drivers.** Very limited field research has been conducted on designated drivers. The current research extended the prior field research of Timmerman and colleagues (2003) by studying a substantially larger sample over a four-year period. The results added insight into DD behaviors among university students in a setting where decisions about driving are made.

**Overall levels of DD intoxication.** Perhaps the most startling finding is the overall level of intoxication among DDs. Indeed, over half of the DDs who consumed alcohol were over .05 mL/L, and almost one third were over .08 mL/L. It is worrisome so many self-reporting DDs reached levels of intoxication that put themselves and others at heightened risk on community roadways.

**Demographic differences in DD sobriety.** Both the percentage of impaired DDs (i.e., BACs ≥ .05 mL/L) and the mean BAC of DDs were compared across gender and Greek-life membership. Large DD-sobriety differences were observed as a function of gender. Specifically, 8% more of the female DDs were completely sober as compared to male DDs. Among the DDs who consumed alcohol, 60.2% of male DDs were impaired, whereas 40.8% of female DDs were impaired. Furthermore, the average drinker BAC of male DDs was .067 mL/L, compared to .054 mL/L for females. While this suggests females tend to make safer DDs than males, it does not suggest female DDs are safe. Indeed, it is troubling the average female DD who consumed alcohol was impaired.

No significant differences in DD sobriety were observed as a function of Greek-life membership. This is likely a result of the small number of Greek-life DDs participating in the study. Many Greek organizations have sober crews or sober individuals selected as DDs on a given night. These DDs are required to remain completely sober and spend much of the night
shuttling members of their Greek organization. Thus, these individuals would be unlikely to enter this study as a pedestrian.

**Timing of transportation decisions.** Based on the limited prior research regarding timing of transportation decisions in a drinking setting (i.e., Timmerman et al., 2003), it was surprising the vast majority of students made their transportation decisions well in advance of initiating their alcohol consumption. Indeed, less than 15% of participants had not already made their transportation decision by the time they began consuming alcohol. Nearly one third had made their transportation plans days in advance. This has significant implications for the timing and the nature of interventions to reduce the intoxication of DDs.

Previous self-report research has indicated the earlier DDs are chosen, the more likely they will remain sober (Demody et al., 2012; Timmerman et al., 2003). However, this was not entirely supported by the current research. Half of those DDs chosen days in advance were completely sober as compared to only 35% of the DDs chosen after arriving downtown. Yet, among the DDs consuming alcohol, those chosen to be a DD days in advance had the highest average BAC (.086 mL/L) as compared to DDs selected after arriving downtown (average BAC = .059 mL/L).

These findings suggest selecting the least intoxicated individual after a group begins consuming alcohol is a harm-reduction strategy. An individual selected as the DD days in advance is committed to serving as the DD regardless of his or her sobriety or the sobriety of the others in the drinking group. This could stifle a re-evaluation of DD sobriety or a change in DD if the original DD consumes too much alcohol. This suggests selecting a DD days in advance without a zero-drinking agreement, may be more dangerous than selecting a DD at the time of alcohol consumption according to the lowest perceived level of intoxication.
Regardless of demographics and the time of DD selection, those DDs who consumed alcohol were frequently reaching at-risk levels of intoxication for operating a motor vehicle. Results suggest a harm-reduction approach to DD sobriety (i.e., encouraging DDs to consume fewer drinkers) may potentially cause more harm than good. Indeed, these results suggest a greater need to promote complete sobriety among DDs.

**Having a DD.** Resistance to promoting DD programs is often based on fear individuals with a DD will consume larger quantities of alcohol than those without a DD. While the present research found males with a DD reached slightly higher levels of intoxication (.005 mL/L), the risk caused by this slight increase in BAC is minimal compared to the risk of not having a DD. Results from this research strongly support the use of a sober DD.

Significant differences in reported DD availability were observed for gender and Greek-life membership. While 10% more females had a DD as compared to males, members of a Greek-life organization were nearly twice as likely to have a DD as compared to non-Greek-life members. This seems to contradict previous research that found males were more likely to use a DD than females (Haines et al., 2006). The results of the present study could suggest a changing trend in DD use or that females may be less likely to use the DDs they have available.

**Identification and Assessment of Student Alcohol Consumption Risk Factors**

Paramount to the creation of successful interventions is the identification of risk factors for alcohol misuse. A critical risk factor is a lack of self-awareness regarding current levels of alcohol intoxication. In fact, BAC education is a widely used intervention designed to heighten this awareness (Carey et al., 2007; Van Beurden et al., 2010). Furthermore, a number of studies have documented the significant gap between drinker-estimated levels of intoxication and actual
BAC (e.g., Grant et al., 2011; Russ et al., 1986; Thombs et al., 2003). Yet, the magnitude and even the direction of this estimation error are still highly debated.

As the largest investigation of gBAC, the current research added insight into this relationship and explored the potential for gBAC to be a determinant of safe versus at-risk, alcohol-related decisions. Indeed, it was found consumers of alcohol were incorrect in estimating their BAC by an average of .034 mL/L. This is a significant discrepancy that would likely create errors in judgment and taking alcohol-impaired risks (e.g., operating a motor vehicle).

Interestingly, results from the present research found the direction and magnitude of gBAC discrepancy varied substantially as a function of one’s current level of intoxication. As demonstrated in Figure 8, individuals at lower BACs (i.e., less than .08 mL/L) tended to overestimate their BAC, whereas individuals at higher BACs (i.e., greater than .08 mL/L) tended to underestimate their BAC. Most troubling was the observation that the average magnitude of BAC underestimation grew steadily as BAC levels increased.

Thus, participants were not only inaccurate at estimating their BAC, but the individuals most at risk for impaired driving showed a strong tendency to underestimate their BAC. This presents a clear and substantial risk for individuals who perceive they are safe to drive while they are, in fact, over the legal limit. It appears evident lack of intoxication awareness is strongly present among university students, and this error in estimation could produce serious health and safety consequences. Interventions designed to reduce this error appear to have significant potential for reducing alcohol-related harm in this population.

**Blood Alcohol Concentration Feedback Interventions**
After identifying the magnitude of error associated with BAC estimation, several interventions were implemented to promote awareness of the risk associated with one’s inaccuracy at estimating BAC. The interventions studied are practical and widely used. Indeed, hundreds of thousands of individuals use these BAC-feedback methods to estimate levels of intoxication for personal, recreational, and legal applications. Thus, the efficacy of these interventions carries significant implications for individual and societal alcohol-related safety. Sobriety tests, nomograms, BAC-estimation phone applications, and breath alcohol testing were all investigated in the current research.

**Accuracy of BAC-feedback interventions.** The validity of current BAC-feedback techniques is critical to understanding the ability of these interventions to promote safer perceptions of alcohol-related risk. Research on traditional, older techniques (i.e., sobriety testing and nomograms) has often demonstrated mixed results for the accuracy of these techniques at predicting BAC. For the newer technique of BAC-feedback phone applications, no previous systematic, empirical study had been conducted to examine the accuracy of this estimation method. Thus, an assessment of BAC-feedback accuracy was a critical component of the present research.

**Accuracy of sobriety tests.** The accuracy of three sobriety tests (the walk-and-turn test, one-leg-stand test, and counting-backwards test) was examined. Scoring for SFSTs followed NHTSA guidelines, and scoring reliability was assessed. While sobriety-test scores were highly reliable across multiple observers, these tests only performed slightly above chance at differentiating BACs at .08 mL/L. This is counter to much of the official literature on sobriety-test accuracy (i.e., Stuster & Burns, 1998).
All three of the sobriety tests had a strong tendency to overestimate sobriety. That is, these tests individually tended to estimate an individual was less than .08 mL/L when this was not the case. However, if the scores of all tests were examined collectively, the total score highly overestimated intoxication. More specifically, when individuals had a BAC less than .08 mL/L, they were estimated to be over the legal limit 59.7% of the time.

This could have substantial legal consequences if these results generalize to law-enforcement situations. Indeed, this seems quite plausible considering the high reliability of sobriety-test scoring in the current study. These sobriety tests are being used to demonstrate probable cause for further blood or breath testing of alcohol intoxication. Yet, taken as a whole in this study, the results of these tests falsely labeled non-legally-impaired drinkers as over the legal limit to drive more than half of the time.

**Accuracy of nomograms.** Nomograms were investigated across both Study 1 and Study 2, with similar accuracy results. In both studies, nomograms were inaccurate by slightly more than .05 mL/L as compared to actual BAC. Consistent with previous research findings (i.e., Glindemann & Geller, 1994) there was a tendency of nomograms to overestimate BAC. In the current studies, estimated BAC averaged .02 mL/L higher than actual BAC.

**Accuracy of BAC-estimation phone applications.** The phone applications selected for this research were the four most popular, free BAC-estimation phone applications on each the Android and Apple marketplace. Yet, all of these phone applications performed poorly in comparison to actual BAC. Indeed, the average error of BAC estimation was .083 mL/L. Even when ignoring erroneous BAC estimations (i.e., estimated BACs > .300 mL/L), the average application was still inaccurate by an average of .05 mL/L. Fortunately, phone applications had a tendency to overestimate BAC. Thus, while these applications were largely inaccurate, there
was a tendency for the applications to err on the side of caution. No single phone application emerged as particularly worthy of special consideration, implying a need to develop more accurate phone applications for BAC estimation.

**Overall accuracy conclusions.** The accuracy of these widely-used BAC-feedback techniques was disappointing. Indeed, these techniques were less accurate than individuals’ estimations of their own intoxication — completely counter to the intended purpose of these techniques. This inaccuracy could have emerged in this type of field setting for a variety of reasons. However, the common poor performance of nomograms and BAC-estimation phone applications may support research regarding inaccuracies in the underlying Widmark equation (Devgun & Dunbar, 1994; Gullberg, 2007; Gullberg & Jones, 1994; Lewis, 1986).

Another plausible source of error comes from the user’s awareness/knowledge of alcohol consumed. Research has demonstrated most consumers of alcohol misunderstand the definition of a standard drink (Kerr & Stockwell, 2011; Lemmens, 1994), are unaware of standard drink volumes (White et al., 2005; White et al., 2003), and have poor recall of number of drinks consumed (Babor et al., 2000; Hustad & Carey, 2005). Thus, traditional studies of the Widmark equation where alcohol consumptions is carefully controlled and dosed in a lab setting may inadequately reflect application of the equation where number of drinks consumed is retroactively estimated and recalled in a natural drinking environment.

It should be noted, error due to the above reasons would be greatly minimized in this controlled research context. Our research assistants were trained on standard drink volumes, and they entered all information into the nomograms and BAC-estimation phone applications. This would reduce error due to user ignorance or unfamiliarity with the nomogram or phone
application. Thus, the performance of these BAC-feedback techniques may be even worse in other settings.

**Effectiveness of BAC-feedback interventions at shifting safety perceptions.** Aside from the effectiveness of various BAC-feedback techniques at shifting safety perceptions, several broad results emerged. In general, there was a surprisingly weak relationship between current level of intoxication and perceptions of driving safety. Specifically, perceptions of increased risk and lower safety did not strongly emerge with increased intoxication. This seems to indicate individuals are not fully aware of their own changing levels of impairment and corresponding increases in risk.

Furthermore, it seemed BAC-feedback was most likely to shift safety perceptions in relation to risk for DUI, or having a BAC below the legal limit, as opposed to internal perceptions of impairment, confidence, and safety in relation to operating a motor vehicle. Thus, the shifts in perception were other-directed (i.e., external) rather than self-directed (i.e., internal). This is defining external risk as one’s perception of getting caught or becoming legally at risk, whereas internal risk perceptions relate to one’s ability or confidence in safely engaging in a behavior.

The external (i.e., other-directed) shifts were particularly pronounced for the breathalyzer condition. Under this condition, it appears participants believed their BAC reading and, perhaps, re-evaluated what this number could mean for their likelihood of facing legal risk. However, even this type of feedback did not seem to impact individuals’ internal perceptions of safety. Specifically, even in the breathalyzer condition, as BAC increased, participants did not appear to interpret this feedback as information requiring them to re-evaluate their safety, confidence, or ability to drive. A similar effect was also observed for nomograms in Study 2.
Sobriety-test results were notably different from nomograms and breath-alcohol testing. In the sobriety-feedback condition, there was often a much smaller interaction between participant BAC and risk perceptions. Thus, while individuals in this condition were not more sensitive to shifting risks with increasing BACs, there was a more universal awareness of risk. This is particularly true for perceptions of safety to drive. Indeed, individuals across virtually all BACs in the sobriety-test condition, on average, reported feeling less safe driving at their current level of intoxication. Indeed, this was the only condition to influence an internal perception of safety versus the control group.

These results provide several advantages to sobriety testing as a feedback mechanism. While individuals in the nomogram and breathalyzer condition were more sensitive to their particular level of intoxication, this may encourage risk-taking at lower BACs. For example, an individual who receives feedback from a breathalyzer that their BAC is .070 mL/L, will likely feel much more confident they are not at risk for a DUI as compared to an individual who does not have BAC feedback. This could actually place them at greater risk for following through with at-risk decisions (e.g., operating a motor vehicle). Thus, at low BACs, sobriety testing may provide a more useful demonstration of physiological impairment that would also discourage impaired (albeit, not legally intoxicated) driving.

Receiving BAC feedback from a phone application had no statistically significant effect on perceptions of risk. This is likely the result of broad inaccuracies in BAC estimation across all phone applications tested. Thus, this type of feedback not only gave a poor estimation of intoxication, it also had no beneficial effect on shifting perceptions of driving risk.

**Effectiveness of BAC-feedback interventions at increasing gBAC accuracy.** Across Study 2 and 3, none of the BAC-feedback conditions appeared to help individuals estimate their
current level of intoxication. This makes sense considering the observed inaccuracy of these feedback techniques. Indeed, while individuals are .034 mL/L incorrect in estimating their BAC without feedback, many of the feedback techniques were even less accurate.

Study 4 took this research question a step further by examining the one feedback mechanism that is accurate (i.e., breath alcohol testers) across multiple trials. This provided participants with a reasonable and accurate assessment of their BAC and allowed for learning over time. Results from this study showed repeated breathalyzer feedback did help participants estimate their BAC more accurately. This accuracy improvement was not immediate, requiring five trials to see a statistically significant improvement in accuracy at estimating BAC. While these results demonstrate the potential learning benefits of breathalyzer feedback, it is unclear if this accuracy translated into more safe versus at-risk decisions.

**Overall Conclusions**

This research sought to improve upon the traditional measurements of alcohol consumption and impairment and investigate practical interventions for reducing alcohol-related harm. With over 12,000 recorded BACs, this is the largest field investigation conducted to date of alcohol consumption among university students. Results showed extreme levels of intoxication in this university setting. High levels of intoxication were reached across nights of the week and demographic groups.

Several popular BAC-feedback techniques were evaluated for accuracy and efficacy at improving drinkers’ perceptions of risk. These feedback techniques (i.e., sobriety tests, nomograms, and BAC-estimation phone applications) were widely inaccurate at estimating BAC. Thus, they had limited ability to improve an individual’s accuracy at estimating his or her BAC or risk-related perceptions. However, these feedback techniques were effective at shifting
some types of risk perceptions, particularly those related to external risk (i.e., risk for a DUI or being over the legal limit to drive).

It should be considered this research was conducted in one particular setting at one university. Results may not generalize to other geographic areas, school types, or student bodies. Yet, the results do provide a glimpse of the current college-drinking culture.

The present research should encourage future investigators to conduct research using breath alcohol testing in a field setting. The present field studies and others have demonstrated the error associated with self-reported and estimated BAC. Furthermore, this research should spawn additional BAC-feedback intervention techniques and applications. Each year over one thousand college and university students are killed as a result of excessive alcohol consumption. Innovative measurement and intervention strategies are imperative to reduce the widespread harm resulting from the misuse and abuse of alcohol.

**Future Directions**

The current studies were designed to explore the magnitude of alcohol consumption among university students and the efficacy of BAC-feedback interventions to promote healthier driving perceptions while intoxicated. The results of these four field studies over four years and 12,432 BAC assessments confirmed the premise that university students reach extreme levels of intoxication and are largely unaware of their BAC. Unfortunately, the effectiveness of current BAC-feedback mechanisms was limited in this setting. This creates several future directions for this line of research.

First, the accuracy of BAC-estimation techniques needs further investigation. Overall, the performance of nomograms, phone applications, and sobriety tests was remarkably poor. Indeed, these tools were incorrect by an average of more than .05 mL/L. The development of
more accurate estimation techniques requires focused attempts to identify the sources of estimation error. It is unclear if estimation inaccuracy was due to flaws in the Widmark equation or the accuracy of information used for these computations.

Investigations of the sources of estimation error require more rigorous experimental testing in a controlled environment. This could involve either bar labs or dosing studies where the intake of alcohol is carefully measured and time is precisely tracked. While the Widmark equation only accounts for amount of alcohol consumed, time spent drinking, and body mass, a multitude of additional factors have been linked to BAC. The impact of factors omitted from the Widmark equation should be thoroughly examined to determine if these factors could account for the lack of BAC-estimation accuracy. If BAC-estimation techniques are more accurate within these controlled settings, a consumer of alcohol’s memory and knowledge deficits would emerge as a significant portion of estimation error. This type of investigation could direct efforts toward a more complete Widmark equation or toward the development of education and memory-retrieval efforts to help alcohol consumers better input drinking information into BAC-feedback tools.

In addition to developing more accurate BAC-estimation tools, innovative strategies are needed to more profoundly increase alcohol consumer’s awareness of risk from intoxication based on BAC feedback. The results of this research demonstrated it was easier to shift an individual’s perception of external versus internal risk. Specifically, BAC feedback that produced a numerical estimate of BAC (i.e., nomograms and breath alcohol testing) often made individuals feel more at risk for a DUI or more likely to be over the legal limit to drive. However, it was less likely to shift an individual’s internal feelings regarding their ability or
safety to drive at their current level of intoxication. Sobriety testing, on the other hand, did seem to facilitate slight shifts in internal perceptions of driving safety.

Indeed, BAC-feedback techniques that shift both internal and external perceptions are necessary to maximize the effectiveness of this feedback. In many ways, this dichotomy of risk processing is related to cognitive versus emotional empathy. These are the two types of empathy related to inferring a mental state (i.e., cognitive empathy) versus having true empathic concern (i.e., emotional empathy; Davis, 1980; Davis, Hull, Young, & Warren, 1987; Dziobek, Rogers, Fleck, Bahnemann, Heekeren, Wolf, & Convit, 2008). These two empathy pathways have even been related to different biological/neural pathways (Nummenmaa, Hirvonen, Parkkola, & Hietanen, 2008; Rankin, Kramer, & Miller, 2005; Shamay-Tsoory, Aharon-Peretz, & Perry, 2009). Similarly, individuals may understand the cognitive (i.e., external) risk of driving at a certain level of alcohol intoxication, but not process the emotional or personal (i.e., internal) risk.

Thus, BAC-feedback methods need to incorporate varying components to engage both types of risk processing. For example, future research should incorporate both numerical BAC-estimation methods (e.g., nomograms and breath alcohol testing) and physiological impairment indicators (e.g., sobriety performance tests). Results from the current investigation indicate these sobriety performance tests should be expanded beyond traditional standardized field sobriety tests (SFST).

There are many possibilities for creating new sobriety performance tests and novel methods should be fully explored. One possible addition is the ruler-drop test. This involves dropping a ruler between one’s index finger and thumb. The score for the test is represented by the distance the ruler drops before being caught between the two fingers. Also, advancements in eye-tracking technology offer significant opportunities for sobriety testing. Horizontal gaze
nystagmus and eye-tracking latency could both be explored as potential indicators of impairment.

The current investigation revealed a critical need for empirically-driven prevention intervention efforts. These results also showed BAC-education could be an effective target area for intervention. However, future research needs to examine the accuracy of existing BAC-feedback tools and develop more efficacious methods for delivering this feedback to consumers of alcohol.

**Recommendations for Virginia Tech Policy**

The results of the current investigation build on 20 years of field research targeting university-student alcohol consumption in Blacksburg. Over these decades the average levels of intoxication have steadily risen, accentuating the need for widespread university and student-led action. Given the magnitude of alcohol intoxication, the solution to this problem may require nothing less than a total culture shift on the Virginia Tech campus. This is undoubtedly the case on many other college/university campuses throughout the U.S. and beyond. The following research-driven recommendations represent areas of potential improvement in this particular university setting.

**Mandatory First Year Experience (FYE) Course**

For several years, Virginia Tech has considered the implementation of a standardized first year experience (FYE) course for freshmen and transfer students. This course could educate students on a variety of topics related to education, health, and wellness. Specifically, this course could be used to teach students about standard drink volumes, BAC-estimation, and at-risk behaviors while intoxicated. Topics on sexual assault and victimization should be included,
as well as the need to take personal responsibility for intervening on behalf of the health, safety, and well-being of others.

Currently, all entering students are required to take a brief, online alcohol class called Alcohol-Wise. Many students report not taking this course seriously. Furthermore, the online administration of this course does not allow for student dialogue around issues of alcohol misuse and abuse. A FYE class could provide a unique and beneficial medium for alcohol-related education and discussion with peers and allow for the sharing of motivational emotions. At a minimum, providing students with the educational tools to protect themselves and others in particularly high-risk drinking environments could provide substantial benefit. Social skills training regarding how to intervene on behalf of the welfare of others in specific situations could be included and would be invaluable.

**Learning Living Communities**

Learning living communities provide another opportunity to reduce alcohol misuse and abuse by facilitating strong peer relationships and a sense of community. Historically, Virginia Tech has supported several of these communities around the broad themes of academic major, enhanced-learning, and themed housing. The recent implementation of residential colleges offers incremental potential for creating healthy and positive social networks for students. Thus, with residential colleges students may not feel the need to build a social network through alcohol consumption and venues conducive to at-risk drinking.

Residential colleges could be particularly useful if they are implemented university wide alongside a comprehensive FYE course as detailed above. This would create a solid network of peers who are continually engaged in healthy dialogue through a guided course experience. The
additional of an in-house faculty advisor would also add significant benefit within the residential college philosophy.

**Late Night Programming**

In recent years, Virginia Tech has made some gains in sponsoring late night social programming. However, significant room for improvement remains. The absence of university-sponsored late night activities often leaves a void that alcohol consumption is left to fill. These activities could include late-night pancake dinners, coffee houses, alcohol-free dances, video game tournaments, and sports tournaments.

**Extended Facility Hours**

Unlike the vast majority of students, most university buildings shut down well before midnight. Indeed, until recently, even the university library also closed early in the night. The lack of open academic and recreational facilities past midnight pushes students into places that remain open. This often includes bar establishments and parties.

While there are non-negligible financial costs associated with the staffing and utilities of university buildings, extending the hours of operation would provide students with healthier alternatives to late-night alcohol consumption. In particular, McComas Hall could provide a high-impact facility for extended hours of operation. This facility includes several basketball courts, treadmills, weight room, spin room, and indoor track. Incentives could be provided to encourage late night attendance including tournaments, prize raffles, free sports drinks, and free weight training. Not only could this discourage individuals from consuming alcohol, but it could also promote a set of healthy alternative activities.

Squires serves as another prime example of a facility to keep open well into the night. This would allow students the opportunity to engage in recreational activities such bowling, ping
pong, and pool. It would also provide an ideal facility for late night movies and meeting locations.

**Course Scheduling and Attendance Policies**

The results from the present research indicated alcohol consumption on Thursday night surpassed drinking across all other nights. This may be a result of many students navigating their course schedules to avoid early and/or Friday classes. Furthermore, a lack of mandatory attendance policies enables students to feel comfortable skipping classes in favor of late-night alcohol consumption. In the latter example, students are not only facing risks related to alcohol consumption, but also placing their academic performance at risk.

Creative academic scheduling and policies could create environmental deterrents to heavy weeknight alcohol consumption. In many ways, universities need to reclaim Fridays. This includes course scheduling and attendance. Instructors, particularly those teaching on Friday, should consider creative techniques for increasing course attendance. As an example, many instructors have incorporated electronic clickers into their instruction. During the course of a lecture, students interact via a personal clicker by answering questions or selecting a topic for further clarification. These “clicker points” can be incorporated into student grades, thus promoting attendance.

**Resource Allocation from Student Budget Board**

At Virginia Tech, the student budget board is charged with distributing thousands of dollars spawning from student activity fees. While events where alcohol is served are not eligible for budget-board funding, a creative incentive system could be created to reward events designed to reduce alcohol consumption among students. For example, a certain amount of funding could be set aside to specifically fund late-night programming by student organizations.
This would be even more effective if it were reserved for Thursday, Friday, or Saturday late-night programming. Additionally, this type of programming could receive special consideration for funding during the general allotment phase.

In coordination with the university-led initiatives detailed above, this process would encourage students and student organizations to also work towards creating healthy alternatives during traditional alcohol consumption times. Indeed, a combined effort is necessary to provide sufficient non-drinking alternatives to engage significant portions of the student body. Creating incentives to facilitate the development of creative, exciting, and well-attended late night events could play a significant role in reducing at-risk alcohol consumption.

**General Recommendation Strategy**

The strategies detailed above serve as several examples for cultivating a comprehensive culture change on Virginia Tech’s campus. These efforts must incorporate university administration, faculty, and students. While financial considerations could serve as a barrier to the initiation of many of these programs, the cost of not acting must also be considered. Nearly 2,000 student deaths occur each year as a result of alcohol consumption, and the impact of such harm has not escaped Virginia Tech’s student body.

Since the 1980’s the Center for Applied Behavior Systems has studied alcohol consumption on Virginia Tech’s campus. The current investigations represent the most recent and comprehensive snapshot of student alcohol consumption. The results provide clear evidence of the need to develop and implement significant ameliorative measures and the risk of not acting. Hopefully, the present field studies will encourage major university stakeholders to come together and initiate a culture shift away from binge drinking and towards student health and wellness.
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Table 1

Average BACs as a Function of Demographic Group (2009-2012)

<table>
<thead>
<tr>
<th>Group</th>
<th>Sample Size</th>
<th>Percent Sober</th>
<th>Mean BAC (SD)</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>LL</td>
<td>UL</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>3,094</td>
<td>19.7%</td>
<td>.0965 (.0475)</td>
<td>.0945 .0985</td>
</tr>
<tr>
<td>Male</td>
<td>7,046</td>
<td>15.0%</td>
<td>.1000 (.0475)</td>
<td>.0987 .1013</td>
</tr>
<tr>
<td>Greek Status</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Greek</td>
<td>2,116</td>
<td>8.5%</td>
<td>.1090 (.0477)</td>
<td>.1067 .1112</td>
</tr>
<tr>
<td>Non-Greek</td>
<td>7,995</td>
<td>18.7%</td>
<td>.0958 (.0470)</td>
<td>.0945 .0970</td>
</tr>
<tr>
<td>Class Status</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Student</td>
<td>934</td>
<td>8.5%</td>
<td>.0949 (.0492)</td>
<td>.0916 .0983</td>
</tr>
<tr>
<td>Freshman_a</td>
<td>1,908</td>
<td>36.4%</td>
<td>.0816 (.0398)</td>
<td>.0793 .0838</td>
</tr>
<tr>
<td>Sophomore_a</td>
<td>697</td>
<td>40.9%</td>
<td>.0884 (.0454)</td>
<td>.0840 .0929</td>
</tr>
<tr>
<td>Junior_b</td>
<td>1,363</td>
<td>15.7%</td>
<td>.1034 (.0488)</td>
<td>.1005 .1062</td>
</tr>
<tr>
<td>Senior_b</td>
<td>3,991</td>
<td>3.8%</td>
<td>.1060 (.0480)</td>
<td>.1045 .1076</td>
</tr>
<tr>
<td>Grad Student_a</td>
<td>683</td>
<td>10.5%</td>
<td>.0879 (.0452)</td>
<td>.0842 .0915</td>
</tr>
<tr>
<td>Alumni</td>
<td>580</td>
<td>5.3%</td>
<td>.0974 (.0464)</td>
<td>.0935 .1013</td>
</tr>
<tr>
<td>Total</td>
<td>10,225</td>
<td>16.4%</td>
<td>.0998 (.0470)</td>
<td>.0988 .1008</td>
</tr>
</tbody>
</table>

*Note. Variables in the Group column that share subscripts do not differ significantly.*
### Table 2

**Average BACs as a Function of Environmental Factors (2009-2012)**

<table>
<thead>
<tr>
<th>Group</th>
<th>Sample Size</th>
<th>Percent Sober&lt;sup&gt;a,*&lt;/sup&gt;</th>
<th>Mean BAC (SD)*</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Day</strong></td>
<td></td>
<td></td>
<td></td>
<td>LL</td>
</tr>
<tr>
<td>Thursday&lt;sub&gt;b&lt;/sub&gt;</td>
<td>4,072</td>
<td>5.4%</td>
<td>.1063 (.0478)</td>
<td>.1048</td>
</tr>
<tr>
<td>Friday&lt;sub&gt;c&lt;/sub&gt;</td>
<td>4,747</td>
<td>6.4%</td>
<td>.0988 (.0467)</td>
<td>.0974</td>
</tr>
<tr>
<td>Saturday&lt;sub&gt;b&lt;/sub&gt;</td>
<td>1,099</td>
<td>6.4%</td>
<td>.1007 (.0528)</td>
<td>.0975</td>
</tr>
<tr>
<td><strong>Semester</strong></td>
<td></td>
<td></td>
<td></td>
<td>LL</td>
</tr>
<tr>
<td>Fall&lt;sub&gt;d&lt;/sub&gt;</td>
<td>6,605</td>
<td>6.4%</td>
<td>.1028 (.0476)</td>
<td>.1016</td>
</tr>
<tr>
<td>Spring&lt;sub&gt;d&lt;/sub&gt;</td>
<td>3,620</td>
<td>7.1%</td>
<td>.1000 (.0489)</td>
<td>.0984</td>
</tr>
<tr>
<td><strong>Year</strong></td>
<td></td>
<td></td>
<td></td>
<td>LL</td>
</tr>
<tr>
<td>2009&lt;sub&gt;e&lt;/sub&gt;</td>
<td>1,348</td>
<td>6.5%</td>
<td>.1032 (.0484)</td>
<td>.1005</td>
</tr>
<tr>
<td>2010&lt;sub&gt;e&lt;/sub&gt;</td>
<td>2,606</td>
<td>4.2%</td>
<td>.1019 (.0473)</td>
<td>.1000</td>
</tr>
<tr>
<td>2011&lt;sub&gt;e&lt;/sub&gt;</td>
<td>2,994</td>
<td>7.5%</td>
<td>.1008 (.0470)</td>
<td>.0991</td>
</tr>
<tr>
<td>2012&lt;sub&gt;e&lt;/sub&gt;</td>
<td>3,277</td>
<td>7.6%</td>
<td>.1021 (.0496)</td>
<td>.1003</td>
</tr>
</tbody>
</table>

*Note.* Variables in the Group column that share subscripts do not differ significantly.

<sup>a</sup>BAC = 0.00 mL/L

<sup>*</sup>Analyses only include university students
Table 3

Designated Driver (DD) Sobriety as a Function of when Transportation Decision was Made

<table>
<thead>
<tr>
<th>Transportation Decision</th>
<th>Sample Size</th>
<th>Percent Sober</th>
<th>% &gt; .05</th>
<th>% &gt; .08</th>
<th>Mean BAC</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Days in advance</td>
<td>43</td>
<td>51.2%</td>
<td>71.4%</td>
<td>47.6%</td>
<td>.0860</td>
<td>.0575</td>
</tr>
<tr>
<td>Earlier Today</td>
<td>196</td>
<td>39.3%</td>
<td>51.3%</td>
<td>24.1%</td>
<td>.0590</td>
<td>.0423</td>
</tr>
<tr>
<td>After arriving downtown</td>
<td>31</td>
<td>35.5%</td>
<td>45.0%</td>
<td>40.0%</td>
<td>.0589</td>
<td>.0380</td>
</tr>
<tr>
<td>Currently undecided</td>
<td>12</td>
<td>33.3%</td>
<td>75.0%</td>
<td>37.5%</td>
<td>.0684</td>
<td>.0272</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>372</strong></td>
<td><strong>37.9%</strong></td>
<td><strong>52.8%</strong></td>
<td><strong>29.0%</strong></td>
<td><strong>.0613</strong></td>
<td><strong>.0413</strong></td>
</tr>
</tbody>
</table>
Table 4

*Designated Driver (DD) Sobriety as a Function of Demographics*

<table>
<thead>
<tr>
<th>Group</th>
<th>Sample Size</th>
<th>Percent Sober&lt;sup&gt;a&lt;/sup&gt;</th>
<th>% &gt; .05</th>
<th>% &gt; .08</th>
<th>Mean BAC</th>
<th>Std. Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gender</strong>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>90</td>
<td>45.6%</td>
<td>41.8%</td>
<td>18.4%</td>
<td>.0538</td>
<td>.0433</td>
</tr>
<tr>
<td>Male</td>
<td>188</td>
<td>37.2%</td>
<td>60.2%</td>
<td>36.5%</td>
<td>.0669</td>
<td>.0440</td>
</tr>
<tr>
<td><strong>Greek Status</strong>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Greek</td>
<td>50</td>
<td>38.4%</td>
<td>66.7%</td>
<td>45.8%</td>
<td>.0787</td>
<td>.0512</td>
</tr>
<tr>
<td>Non-Greek</td>
<td>229</td>
<td>52.0%</td>
<td>51.8%</td>
<td>27.7%</td>
<td>.0602</td>
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<sup>a</sup> BAC = 0.00 mL/L

* Analyses only include university students
Table 5

*Sobriety Test Accuracy as a Function of Test-Estimated and Actual BAC*

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<th>Sobriety Test</th>
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<th>Pass Test</th>
<th>Fail Test</th>
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<td>164</td>
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Table 6

*Estimation Accuracy of Individual Phone Applications*

| Phone Application | PhoneApp-Actual BAC | |Phone App-Actual BAC| |Percent Erroneous BACS |
|---|---|---|---|---|
| **Android** | | | | |
| (D1) Alco-Droid | .051 | .078 | 14.6% |
| (D2) Blood Alcohol Calculator | .019 | .050 | 0.0% |
| (D3) R-U- Buzzed | .025 | .048 | 2.8% |
| (D4) Sober App | .037 | .060 | 28.0% |
| **iPhone** | | | | |
| (I1) BAC-Calculator | -.007 | .050 | 3.1% |
| (I2) Blood Alcohol Calculator | .009 | .044 | 0.0% |
| (I3) Mr. DUI | .010 | .059 | 0.0% |
| (I4) R-U-Buzzed | .022 | .048 | 5.3% |
Table 7

Blood Alcohol Concentration Estimation and Intentions as a Function of Participation Trials

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<th>lgBAC-BAC</th>
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<th>Intended BAC - BAC</th>
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Note. Formulas with BAC only include non-sober (i.e., BAC > 0.00 mL/L) participants.
Table 8

*Correlation Between BACs across Participation Trials with Sample Size*

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*Note.** *p < .01  *p < .05*
Figure 1. Number of participants per class status.
Figure 2. Histogram showing frequency of observed BAC levels.
Figure 3. Mean BAC as a function of class status and Greek-life membership.
Figure 4. Mean BAC as a function of class status and gender.
Figure 5. Mean BAC as function of Greek-life membership and gender.
Figure 6. Mean BAC as a function of drinking night and gender.
Figure 7. Mean BAC as a function of having a DD and gender.
Figure 8. Mean error in gBAC as a function of current level of intoxication.
Figure 9. Mean error in gBAC as a function of gender and Greek-life membership.
Figure 10. Reported belief one’s BAC is below the legal limit to drive as a function of level of intoxication by feedback condition.
Figure 11. Reported belief one is currently safe to drive as a function of level of intoxication by feedback condition.
Figure 12. Reported belief one is currently at-risk for a DUI as a function of level of intoxication by feedback condition.
Figure 13. Absolute error in BAC estimation as a function of phone application.
Figure 14. Inaccuracy in BAC estimation across five consecutive BAC-assessment trials for individuals who participated in the study on at least five occasions.
Figure 15. Participant error in BAC estimation across five consecutive assessment trials for individuals who participated in the study on at least five occasions.
Figure 16. Mean error in BAC estimation across five consecutive assessment trials for individuals who participated in the study on at least five occasions.
Figure 17. Participant BAC across five consecutive assessment trials for individuals who participated on at least five occasions.
## Appendix A: Nomograms

### Females

**Approximate Blood Alcohol Percentage**

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**Effect on Person**

- **Only Safe Driving Limit**
- **Impairment Begins**
- **Driving Skills Significantly Affected**
- **Legally Intoxicated.**
- **Criminal Penalties in All States.**

### Males

**Approximate Blood Alcohol Percentage**

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Appendix B: Sobriety Test Scoring Sheet

2. **One Leg Stand Test**
   - **Clues**
     - Sways while balancing
     - Uses arms for balance
     - Hops to maintain balance
     - Puts foot down
     - Cannot perform test (4 clues -- maximum)
   - **Total One Leg Stand Clues**
     - 2 or more \( \geq 0.08 \)

3. **Walk and Turn Test**
   - **Clues**
     - Loses balance while listening to instructions
     - Starts before instructions are finished
     - Stops while walking
     - Does not touch heel to toe
     - Steps off the line
     - Raises arms for balance
     - Incorrect number of steps
     - Trouble with turn (explain)
     - Cannot perform the test (8 clues -- maximum)
   - **Total Walk and Turn Clues**
     - 2 or more \( \geq 0.08 \)

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**Counting Test:**
(\( \times \)-out skipped or jumbled numbers)

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Completed as instructed
Appendix C: BAC-Estimation Phone Applications

(D1) AlcoDroid:

(D2) Blood Alcohol Calculator:
(D3) R-U-Buzzed:

(D4) Sober App:
(II): BAC-Calculator:

This application is for entertainment purposes only.

This application cannot and should not be used to determine suitability or ability to operate a motor vehicle before, during or after drinking alcohol.

The determination of BAC (Blood Alcohol Content) on this app is based upon the information provided by the user and is calculated using the Widmark Formula.

Blood alcohol content is a result of weight, gender and number of drinks over a period of time in addition to factors such as metabolic rate, food intake, physical activity, Blood Volume etc.

![BAC Calculator Interface]

Weight: Body weight in lbs
Drinks: Total Drinks
Hours*: Total Hours since first drink

Calculate Approximate BAC

Your Approximate Blood Alcohol Contents is:

0.02%  
Dexterity Test

Enter New Calculation
(I3) Mr. DUI:

(I4) R-U-Buzzed: