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Effect of Smartphone Breathalyzer Feedback on Willingness to Drive in Moderately Intoxicated Individuals: A Randomized Trial

Jeffrey P. Ebert,
Perelman School of Medicine, University of Pennsylvania, Philadelphia, PA 19104

Henry R. Kranzler,
Perelman School of Medicine, University of Pennsylvania, Philadelphia, PA 19104

Ian J. Barnett,
Perelman School of Medicine, University of Pennsylvania, Philadelphia, PA 19104

Jessica E. Hemmons,

Ruiqi Yan,
Perelman School of Medicine, University of Pennsylvania, Philadelphia, PA 19104

Evan Spencer,
Perelman School of Medicine, University of Pennsylvania, Philadelphia, PA 19104

M. Kit Delgado
Perelman School of Medicine, University of Pennsylvania, Philadelphia, PA 19104

Abstract

Objective: The present study examined the impact of smartphone breathalyzer feedback on individuals' decisions to drive when they are moderately intoxicated. Although the legal driving limit for blood alcohol content (BAC) in the U.S. is <0.08%, crash risk begins to increase at moderate BACs ≥0.04%.

Methods: We conducted a laboratory-based, randomized controlled trial in 20 adult drivers aged 21–39 with a history of binge drinking. Participants were given sex- and weight-based doses of alcohol over 90 min with a target peak BAC of 0.10%. Smartphone breathalyzer measurements were taken every 15 min until the participant's BAC declined to 0.03%. Ten participants received feedback on their BAC readings, while the other 10 were blinded to BAC readings. After each

Corresponding author: Jeffrey P. Ebert, 3535 Market St, Suite 1500, Philadelphia, PA 19104, jeffrey.ebert@pennmedicine.upenn.edu.

Author contributions
Conceptualization: HRK, IJB, MKD
Formal analysis: IJB, RY
Funding acquisition: MKD
Investigation: JEH, ES
Methodology: HRK, MKD
Project administration: JEH
Supervision: MKD
Visualization: RY
Writing – original draft: JPE, MKD
Writing – review and editing: JPE, HRK, IJB, MKD

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measurement, participants were asked to rate on 10-point scales how much they were intoxicated, able to drive, and willing to drive.

Results: At BACs ≥0.04% and <0.08%, learning about BAC was associated with lower perceived intoxication (−2.0, CI: [−3.1, −0.8]), greater perceived ability to drive (2.4, CI: [1.0, 3.9]), and greater willingness to drive (3.9, CI: [2.5, 5.3]), all *p*s < .001.

Conclusions: Being aware of their BAC may make drinkers more willing to drive up to the legal BAC limit of 0.08%, despite being in a range associated with increased crash risk. We recommend that breathalyzer apps provide salient feedback about the risks of driving with a BAC in the moderately intoxicated range.

Keywords

alcohol breath test; willingness to drive; alcohol consumption; blood alcohol concentration; smartphone breathalyzer

In 2022, 13,524 people were killed in drinking and driving-related motor vehicle crashes in the United States, representing 32% of all driving-related deaths (NHTSA, 2024). This statistic likely underestimates the problem because it includes only drivers at or above the federal blood alcohol concentration (BAC) limit of 0.08%, whereas driving impairment occurs at BACs as low as 0.04% (Compton et al., 2002).

The decision to drive after drinking depends critically on subjective perceptions of intoxication and fitness to drive (Amlung et al., 2014). When asked about their decision to drive after drinking, people often report that they did not feel the effects of the alcohol or did not believe it would affect their driving (NHTSA, 1995). Laboratory studies have shown that, without training or feedback, gauging one's BAC and level of impairment is difficult (Aston & Liguori, 2013). Drinkers systematically overestimate how long it takes to become intoxicated and underestimate how long it takes to be unimpaired. Likewise, for a given BAC, drinkers report feeling more impaired as they ascend the blood alcohol curve than as they descend it. Because of this "acute tolerance" on the descending BAC limb, people incorrectly see driving as less dangerous and are more willing to drive (Amlung et al., 2014). Chronic drinkers are especially likely to underestimate their BAC, predisposing them to drinking and driving and riskier driving (Laude & Fillmore, 2016).

The smartphone-paired alcohol breath testing device ("smartphone breathalyzer"), a recent consumer technology, promises to remove the guesswork concerning BAC. The user blows into the device, and within seconds a smartphone application provides a BAC estimate. Although many smartphone-paired breathalyzers substantially underestimate BAC, some are as accurate as police-grade breathalyzers (Delgado et al., 2021). We conducted a randomized controlled trial with people who reported a history of binge drinking to examine how receiving BAC feedback from such a device would affect their willingness to drive when moderately intoxicated. There were competing hypotheses at play. On the one hand, if individuals who drink tend to underestimate their BAC, receiving objective information about it should act as a corrective and make them less willing to drive. On the other hand, if people believe that the legal limit BAC of 0.08% is the point at which driving becomes

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dangerous or legally consequential, learning that their BAC is below this limit could have the unintended consequence of making them more willing to drive.

Materials and Methods

We recruited participants for a laboratory study of behaviors related to drinking and driving using fliers placed around a university campus and nearby hospital. Interested individuals were screened by telephone. Inclusion criteria were: being 21–39 years old; having consumed ≥4 (women) or ≥5 (men) drinks on at least one occasion in the past year (history of binge drinking) without adverse effects (to minimize risk of adverse events during procedure); having averaged <4 drinking days and <12 drinks per week in the past 2 months (unlikely to be highly alcohol dependent); and being willing to use a ride share to get home after the study visit. Individuals were excluded if they desired alcohol treatment or received it in the past 6 months, evidenced alcohol use disorder per DSM-5 criteria, did not speak English, were pregnant, or had a medical condition that limits alcohol consumption. The telephone screen included the Columbia-Suicide Severity Rating Scale, and anyone experiencing suicidal ideation or behavior was excluded from the study and provided resources that addressed their suicidality (Posner et al., 2011).

Participants gave written informed consent, having been informed that they would be asked to drink three alcoholic beverages (vodka plus juice), at a dose equivalent to 4–6 drinks over the course of 2 hours, resulting in moderate levels of intoxication and blood alcohol. Study sessions were conducted with 1–3 participants in a clinical laboratory setting and lasted 5–6 hours. To prepare for the session, participants were instructed to eat a small meal before fasting for 2 hours, and to abstain from caffeine for 8 hours and alcohol for 24 hours. Midway through the session, participants received a small meal. Breath alcohol concentration (BrAC) was used as a proxy for BAC and measured with a BACtrack Mobile Pro device (BACtrack, San Francisco, CA). Prior research validated the accuracy of this device to measure BAC within ±0.001% of a police-grade breathalyzer and estimate BAC within ±0.01% of a blood test for the range of BACs under present investigation (Delgado et al., 2021).

Upon arrival, participants' BAC was measured to confirm that it was 0.00%. A nurse trained in the protocol then administered a brief medical screening that included blood pressure and heart rate measurement, and a urine pregnancy test for female participants. Next, participants completed an intake survey that asked about basic demographic information and included the following measures: Driving History and Experience Questionnaire (Harrison & Fillmore, 2005); Drinking and Driving Questionnaire (McCarthy et al., 2012); 26 items of the Barratt Impulsiveness Scale-11 (Patton et al., 1995); the 4-item Brief Sensation Seeking Scale (Stephenson et al., 2003); and a 51-item temporal discounting task (Senecal et al., 2012).

Participants were given weight- and sex-based doses of 100-proof vodka (1.0 g per kg for men and 0.9 g per kg for women) mixed with orange juice, spaced 40 min apart (Delgado et al., 2021). These doses were intended to raise blood alcohol to the following levels: dose 1, 0.03–0.04%; dose 2, 0.07–0.08%; dose 3, 0.10% (Watson et al., 1981). Each dose

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was consumed within a standard 10-min window to minimize inter-participant variability in consumption rate. Twenty min after finishing each drink, participants were instructed to rinse with a non-alcoholic mouthwash before being administered the BACtrack Mobile Pro breathalyzer. After 3 initial readings, we continued to administer the breathalyzer every 15 min until the participant's BAC reached 0.03% or less.

After screening, but prior to the laboratory session, eligible individuals were randomly assigned to either treatment (*BAC Feedback*) or control (*No Feedback*) conditions. After each BAC reading, individuals in the treatment group were shown their BAC while those in the control group were not shown their BAC. All participants then completed the dependent measures in silence, rating their level of intoxication, ability to drive a motor vehicle, and willingness to drive in that moment on 10-point visual analog scales (Harrison et al., 2007; Harrison & Fillmore, 2005; Van Dyke & Fillmore, 2014).

Participants were compensated with a $100 debit card. To ensure they could get home without driving, we provided a private rideshare trip from the clinical laboratory to their destination and waited with them until the driver arrived. The university Institutional Review Board approved the study, which was registered on ClinicalTrials.gov (NCT05028413).

The primary outcome in the analysis was self-reported willingness to drive while moderately intoxicated ($0.04\% \leq BAC < 0.08\%$). Secondary outcomes were perceived intoxication and ability to drive. Outcome differences between treatment and control were analyzed using linear mixed effects models with a random intercept for each individual and fixed effects for BAC, treatment, and intoxication level. The treatment by intoxication level interaction was included to estimate the incremental impact of feedback on outcomes for each intoxication level. Thus, the sum of the treatment and interaction term for each intoxication level indicated its total treatment effect. For each outcome, models were fit both with and without sex, history of alcohol-impaired driving, and driving frequency to examine the sensitivity of results to confounding.

Additional linear mixed effects analyses were conducted to estimate the independent and interactive contributions of BAC limb (ascending vs. descending) and BAC feedback on self-reported outcomes while individuals were moderately intoxicated. The descending limb was defined idiosyncratically for each participant as all observations after peak measured BAC.

Data are available upon request for non-commercial research purposes.

Results

Of 25 individuals screened, 20 went on to participate (Figure S1): 13 individually, 4 as dyads, and 3 as a triad. Of these participants, 12 (60%) identified as male and 8 (40%) as female; 16 (80%) as white, 3 (15%) as Asian, and 1 (5%) as Black; none identified as being of Hispanic ethnicity (Table 1). Mean age was 27.1 (range 21–37). Mean peak BAC was 0.09% (range 0.06%–0.12%); Figure S2 shows BAC readings by group over time. Mean number of breath-testing rounds per participant, from first dose of alcohol until BAC

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declined to 0.03% or less was 12.6 (range 7–18). There were no adverse events during the study.

For a period of 105 min beginning 50 min after the final dose of alcohol, BAC Feedback participants were significantly more willing to drive than No Feedback participants (Figure S3).

At moderate levels of intoxication (0.04% ≤ BAC < 0.08%), BAC feedback was associated with less perceived intoxication (−2.0, CI: [−3.1, −0.8]), greater perceived ability to drive (2.4, CI: [1.0, 3.9]), and greater willingness to drive (3.9, CI: [2.5, 5.3]), all *p*s < .001 (Figure 1). These findings were robust to the inclusion of participant sex, alcohol-impaired driving history, and driving frequency in the models, all *p*s < .001. Tables S1–S3 provide full model statistics.

In the models that included BAC limb, treatment group, and their interaction term, BAC feedback was again associated with less perceived intoxication, $p = .012$, greater perceived ability to dive, $p = .009$, and greater willingness to drive, $p < .001$, while moderately intoxicated. Descending Limb was associated with less perceived intoxication, $p = .047$ and greater perceived ability to drive, $p = .010$, but not associated with willingness to drive, $p = .21$. The limb by treatment interaction was non-significant for perceived intoxication, $p = .76$, perceived ability to drive, $p = .97$, and willingness to drive, $p = .078$, and the results for treatment were directionally similar on both BAC limbs (Table S4, Figure S4).

At legally impaired levels (BAC ≥ 0.08%), BAC feedback did not impact perceived intoxication (−0.2, CI: [−1.6, 1.3]), $p = .83$, or ability to drive (0.0, CI: [−1.9, 1.9]), $p = 1$, but individuals who received feedback were more willing to drive (2.3, CI: [0.2, 4.3]), $p = .029$. With covariates included, there were no significant differences between treatment and control groups on any of these outcomes, all *p*s > .09.

DISCUSSION

In this laboratory-based, randomized controlled trial, we examined how receiving feedback about one's BAC, up to a BAC of about 0.10%, impacted self-reported willingness to drive. When individuals were informed that their blood alcohol level was in the moderately intoxicated range (0.04% ≤ BAC < 0.08%), they reported feeling less intoxicated, better able to drive, and more willing to drive than an uninformed control group. When their BAC was at or above the legal limit (≥ 0.08%), after controlling for potential confounders, there were no differences between informed and uninformed groups on these measures. This pattern of results is consistent with the hypothesis that knowing that one's BAC is below the legal limit could lead to a greater willingness to drive despite being objectively impaired.

This unintended consequence of providing breathalyzer feedback is concerning, given that the relative risk of a crash at a "legal" BAC of 0.07% is twice that of a BAC of 0.00% (Compton et al., 2002). To mitigate this unintended consequence, we recommend that breathalyzer apps provide clear, salient feedback about potential driving impairments alongside BAC readings (Haney et al., 2024). We also urge greater scrutiny of the consumer breathalyzer market. Many publicly available devices significantly underestimate BAC—

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misinforming some users that they are not legally impaired, thereby compounding the problem of impaired drivers who feel safe to drive after a <0.08% reading (Delgado et al., 2021). We note that this problem could be addressed more systemically by adopting recommendations to lower the federal BAC limit to 0.05%, in line with most countries that set a limit (National Academies of Sciences, 2018).

The present study had limitations. The sample was small and non-representative. Self-reported willingness to drive was used as a proxy for the decision to drive. Peak BAC averaged 0.09% and maxed out at 0.12%, so we cannot draw conclusions about greater levels of intoxication. Because participants were given only their BAC reading, further research is needed to evaluate how app messaging affects willingness to drive and what messages might best inform individuals about the potential consequences of their measured BAC. To mimic a naturalistic, bar-like atmosphere, drinks were spread out over time, and individuals participating in the same session were free to chat when measurements were not being taken. Nevertheless, this was a laboratory experiment, and results may not generalize to real-world contexts.

If the potential downsides of smartphone-paired breathalyzers can be minimized, they could be used in a variety of ways to reduce drinking and driving (Luczak & Ramchandani, 2019; Quanbeck et al., 2014; Tofighi et al., 2019). First, with repeated breathalyzer use, individuals may become more accurate at estimating their level of impairment. Second, integrating breathalyzers with rideshare apps could improve the accessibility of safe alternatives to driving. Third, individuals' sharing their BAC readings with others could add a measure of accountability. Fourth, integrating breathalyzers with driving monitoring apps could enable delivery of monetary and other rewards for abstaining from drinking and driving (Alessi & Petry, 2013; Ebert et al., 2025; Petry et al., 2000; Sloan et al., 2014). As interventions are built around smartphone breathalyzer technology, we must remain vigilant to potential unintended consequences.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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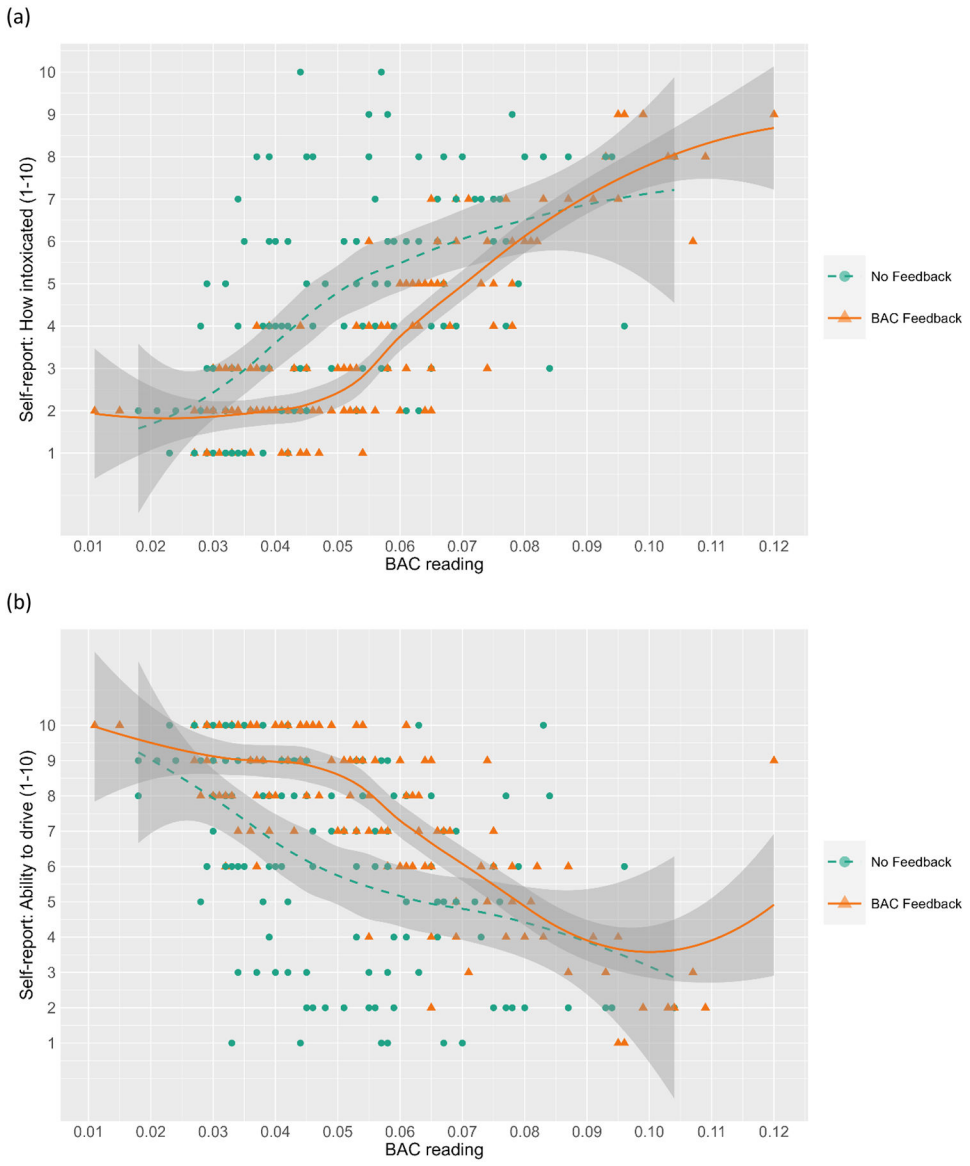
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Public Health Significance Statement

This study found that getting smartphone breathalyzer feedback that their blood alcohol level is below the legal limit can make drinkers more likely to drive impaired.

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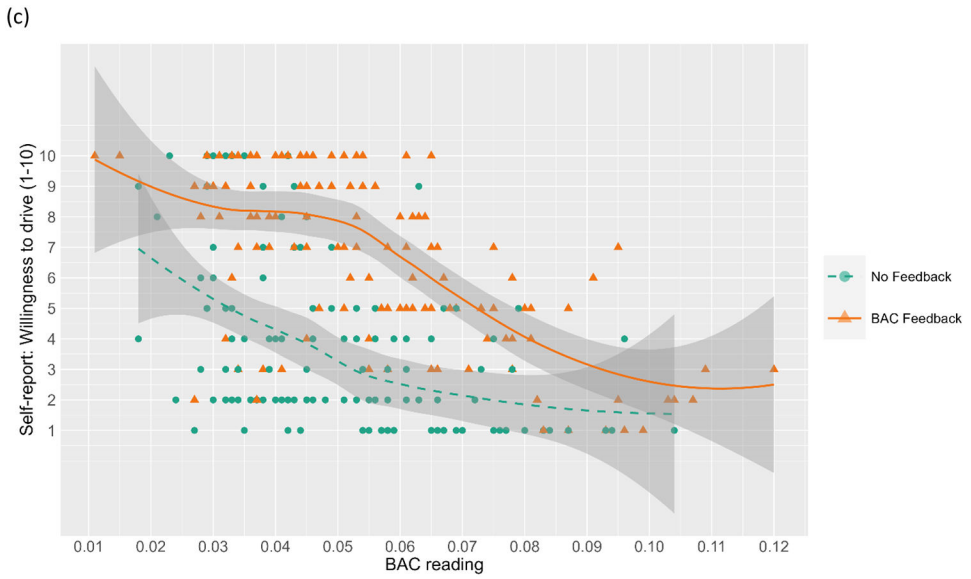


Figure 1. Self-reported a) intoxication, b) ability to drive, and c) willingness to drive as a function of BAC and treatment condition.

All ratings were made on 10-point visual analog scales. Because ability to drive was rated on a 1=Extremely able to 10=Not at all able scale, to aid interpretability ratings were reverse scored with higher values indicating greater perceived ability. Shaded regions show 95% confidence bands with loess smoother.

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Table 1. Sample characteristics.

The No Feedback (control) and BAC Feedback (treatment) groups differed only on number of drives after drinking in past year, $p = .041$, all other ps > .073. Adjusting for number of comparisons rendered all group differences non-significant, ps = 1.

	Overall	No Feedback	BAC Feedback
N	20	10	10
Peak BAC, median [IQR]	0.0900 [0.0665, 0.100]	0.0835 [0.0640, 0.0938]	0.0960 [0.0833, 0.106]
Age, median [IQR]	27.0 [23.8, 29.3]	25.0 [23.0, 26.8]	27.5 [27.0, 29.8]
Male, n (%)	12 (60.0)	7 (70.0)	5 (50.0)
Hispanic, n (%)	0 (0)	0 (0)	0 (0)
Race, n (%)			
White	16 (80.0)	7 (70.0)	9 (90.0)
Asian	3 (15.0)	3 (30.0)	0 (0)
Black	1 (5.0)	0 (0)	1 (10.0)
Length of licensure, n (%)			
1–2 years	1 (5.0)	0 (0)	1 (10.0)
5 or more years	19 (95.0)	10 (100)	9 (90.0)
Days driving per week, n (%)			
0	1 (5.0)	1 (10.0)	0 (0)
1–2	4 (20.0)	3 (30.0)	1 (10.0)
3–4	7 (35.0)	3 (30.0)	4 (40.0)
5–6	5 (25.0)	2 (20.0)	3 (30.0)
7	3 (15.0)	1 (10.0)	2 (20.0)
Miles driven per week, n (%)			
Less than 50	9 (45.0)	5 (50.0)	4 (40.0)
51–100	6 (30.0)	2 (20.0)	4 (40.0)
101–150	1 (5.0)	0 (0)	1 (10.0)
151–200	2 (10.0)	2 (20.0)	0 (0)
More than 300	2 (10.0)	1 (10.0)	1 (10.0)
Had license revoked, n (%)	0 (0)	0 (0)	0 (0)
DUIs in past year, n (%)			
0	20 (100)	10 (100)	10 (100)
Tickets in past year, n (%)			
0	19 (95.0)	10 (100)	9 (90.0)
1	1 (5.0)	0 (0)	1 (10.0)
Crashes in past year, n (%)			
0	18 (90.0)	10 (100)	8 (80.0)
1	2 (10.0)	0 (0)	2 (20.0)
Near crashes in past year, n (%)			
0	18 (90.0)	10 (100)	8 (80.0)

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	Overall	No Feedback	BAC Feedback
1	2 (10.0)	0 (0)	2 (20.0)
Vehicle type, n (%)			
Automatic	18 (90.0)	8 (80.0)	10 (100)
Manual	2 (10.0)	2 (20.0)	0 (0)
Driving environment, n (%)			
Rural	1 (5.0)	1 (10.0)	0 (0)
Urban	10 (50.0)	5 (50.0)	5 (50.0)
Suburban	9 (45.0)	4 (40.0)	5 (50.0)
Drink frequency, n (%)			
Monthly or less	1 (5.0)	1 (10.0)	0 (0)
2–4 times a month	12 (60.0)	5 (50.0)	7 (70.0)
2–3 times a week	7 (35.0)	4 (40.0)	3 (30.0)
Drinks per week, n (%)			
1 or 2	6 (30.0)	4 (40.0)	2 (20.0)
3 or 4	8 (40.0)	4 (40.0)	4 (40.0)
5 or 6	5 (25.0)	2 (20.0)	3 (30.0)
7 to 9	1 (5.0)	0 (0)	1 (10.0)
Drinks per occasion, n (%)			
1 or 2	9 (45.0)	5 (50.0)	4 (40.0)
3 or 4	9 (45.0)	5 (50.0)	4 (40.0)
5 or 6	1 (5.0)	0 (0)	1 (10.0)
7 to 9	1 (5.0)	0 (0)	1 (10.0)
Hours drinking per occasion, n (%)			
1 or 2	5 (25.0)	3 (30.0)	2 (20.0)
3 or 4	15 (75.0)	7 (70.0)	8 (80.0)
Frequency binge drinking, n (%)			
Never	2 (10.0)	0 (0)	2 (20.0)
Less than monthly	9 (45.0)	7 (70.0)	2 (20.0)
Monthly	7 (35.0)	3 (30.0)	4 (40.0)
Weekly	2 (10.0)	0 (0)	2 (20.0)
Drives after drinking in past year, n (%)			
0	10 (50.0)	7 (70.0)	3 (30.0)
1	2 (10.0)	2 (20.0)	0 (0)
2	4 (20.0)	0 (0)	4 (40.0)
>3	4 (20.0)	1 (10.0)	3 (30.0)
Rides with driver who drank in past year, n (%)			
0	11 (55.0)	6 (60.0)	5 (50.0)
1	2 (10.0)	2 (20.0)	0 (0)
2	4 (20.0)	1 (10.0)	3 (30.0)

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	Overall	No Feedback	BAC Feedback
>3	3 (15.0)	1 (10.0)	2 (20.0)
Drives after drinking "too much" in past year, n (%)			
0	19 (95.0)	10 (100)	9 (90.0)
2	1 (5.0)	0 (0)	1 (10.0)
Rides with driver who drank "too much" in past year, n (%)			
0	17 (85.0)	9 (90.0)	8 (80.0)
1	3 (15.0)	1 (10.0)	2 (20.0)
Drives after ≥3 drinks in 2 hours in past year, n (%)			
0	18 (90.0)	9 (90.0)	9 (90.0)
1	2 (10.0)	1 (10.0)	1 (10.0)
Danger of driving after 1 drink, n (%)			
Very dangerous	1 (5.0)	1 (10.0)	0 (0)
Dangerous	2 (10.0)	2 (20.0)	0 (0)
Slightly dangerous	9 (45.0)	5 (50.0)	4 (40.0)
Not dangerous	6 (30.0)	2 (20.0)	4 (40.0)
Not at all dangerous	2 (10.0)	0 (0)	2 (20.0)
Danger of driving after 3 drinks, n (%)			
Very dangerous	7 (35.0)	6 (60.0)	1 (10.0)
Dangerous	8 (40.0)	3 (30.0)	5 (50.0)
Slightly dangerous	5 (25.0)	1 (10.0)	4 (40.0)
Danger of driving after 5 drinks, n (%)			
Very dangerous	17 (85.0)	10 (100)	7 (70.0)
Dangerous	3 (15.0)	0 (0)	3 (30.0)
Barratt Impulsiveness Scale-11, median [IQR] *	3.12 [2.85, 3.33]	3.12 [3.00, 3.42]	3.10 [2.77, 3.22]
Missing	1 (5.0%)	1 (10.0%)	0 (0%)
Brief Sensation-Seeking Scale-4, median [IQR]	3.25 [2.75, 3.75]	3.25 [3.00, 3.50]	3.50 [2.56, 4.13]
Missing	1 (5.0%)	1 (10.0%)	0 (0%)
Discount rate, median [IQR] †	0.00267 [0.00145, 0.00466]	0.00325 [0.00183, 0.00550]	0.00202 [0.00134, 0.00398]

*Because only 26 of the scale's 30 items were administered, it was scored by taking the mean of a participant's item ratings, after coding all items such that higher ratings indicated greater impulsiveness. Multiplying these values by 30 would allow for comparison to other samples for which summed scores were reported.

†Discount rates represent participants' k values in the exponential function $U = Ae^{-kD}$, where U is present utility, A is dollar amount, and D is delay in number of days. For example, the present utility of $50 in 30 days would be $46.15 for the median participant.