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Design and assessment of a personal breathalyzer intervention to support responsible drinking

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ABSTRACT

This study explores current drinking practices and attitudes of college students and design opportunities for encouraging safe and responsible drinking behaviors in this population. With 86 participants in total, we conducted surveys, interviews, and a two-week user study that involved the use of BACtrack Mobile Pro, an FDA-approved personal breathalyzer which can be connected to a smartphone app. For the user study, we conducted pre-study and weekly surveys, user experience evaluations, and in-depth post-study interviews with 24 college students who regularly consume alcohol. We identified and compared two groups of participants based on the Alcohol Use Disorders Identification Test (AUDIT), which is a screening test for risky drinking behaviors. We propose a new system, smartphone app user interface, and experiences based on our findings. Finally, we discuss the role and implications of future technological interventions that could lead to safe and responsible drinking behaviors among college students.

1. Introduction

Excessive drinking is prevalent among college students, and it is considered a serious public health issue. According to a survey conducted by researchers at the Center for Disease Control and Prevention, binge drinking was most prevalent among young people aged 18–34 years and occurs at a significantly higher rate compared to older age groups (Kanny et al., 2018). Young students in colleges are more likely to drink heavily than non-college students of the same-age who do not live with their parents (Bachman et al., 1984; O'malley and Johnston, 2002). Another national report shows that about 60% of college students between 18–22 years old have drunk excessively within the past month (Substance Abuse and Mental Health Services Administration, 2014). Many college students establish drinking habits right after they leave home to go to college, and they view drinking as a normal part of their daily and social lives in college. They also often consider driving under the influence (DUI) to be a normal part of the college experience (National Institute on Alcohol Abuse and Alcoholism, 2015). Although drunk driving occurs very frequently among U.S. adults, a national survey revealed that "the highest percentage of drivers with BACs of 0.08 g/dL or higher was for 21-to-24-year-old drivers (28%)" (National Highway Traffic Safety Administration, 2016). Being under the influence of excessive alcohol consumption could lead to car accidents, physical injuries, sexual assault, and long-term kidney and liver problems. Annually, about 1800 students between 18–24 years of age die from alcohol-related accidents (Substance Abuse and Mental Health Services Administration, 2014). The number of alcohol-related injuries and deaths caused by college students has risen steadily over the past three decades, significantly outpacing that of adults of other age groups (Hingson et al., 2009). Therefore, it is important for college students to build responsible drinking habits to reduce risks of future accidents and health problems.

One effective way of minimizing the negative results of college students' drinking is creating interventions for those who are at an early stage of alcohol consumption (Scott-Sheldon et al., 2014). The advance of information and communication technologies (ICTs) could provide an opportunity to apply technological interventions to reduce one's negative consequences of excessive drinking. Despite the importance of safer and healthier drinking behaviors among college students, this has been a relatively understudied area by Human-Computer Interaction (HCI) researchers. Our purpose of this study is (1) to understand current drinking practices and attitudes of college students who drink on a regular basis establishing a drink habit, (2) to explore their experiences of using the breathalyzer in their life, and (3) to improve ICT designs that could help them be aware of their drinking status, reduce risks of excessive alcohol consumption, and have a habit of responsible

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drinking.

In this paper, we begin by reviewing existing studies on interventions that are related to excessive alcohol consumption. We then describe our surveys, interviews, and a two-week user study of BACtrack Mobile Pro, an FDA-approved personal smart breathalyzer, with college students who drink alcohol regularly. We report the use and perception challenges based on analysis of device usage logs, surveys, and interviews. We suggest our design that improved the currently existing smartphone app for the breathalyzer. Finally, we discuss the role and design implications of future technological interventions to support safer and healthier drinking behaviors among college students.

2. Related work

In this section, we review definitions that are related to excessive alcohol consumption as well as strategies and technologies that have been used to help intervene and support changes to safer drinking behaviors.

2.1. Alcohol consumption-related terminologies & standards

A standard drink is defined as "any drink that contains about 0.6 fluid ounces or 14 g of "pure" alcohol". For instance, 12 fluid ounces of regular beer (about 5% alcohol), 8–9 fluid ounces of malt liquor (about 7% alcohol), 5 fluid ounces of table wine (about 12% alcohol), and 1.5 ounce shot of 80-proof distilled spirits (e.g. gin, tequila, vodka, whiskey, etc.) (about 40% alcohol) are counted as "a drink". While counting a standard drink might be unclear because of the different level of alcohol, size of a container, or a mixed drink, knowing the standard size of drink would be helpful for healthy and safe drinking (National Institute on Alcohol Abuse and Alcoholism, 2016).

Based on this standard, some terms indicate serious drinking. According to the Centers for Disease Control and Prevention, "heavy drinking" and "binge drinking" descriptors are considered excessive drinking. Heavy drinking is defined as "drinking 15 drinks or more per week for men and 8 or more for women". Binge drinking is defined as "a pattern of drinking that causes the blood alcohol concentration (BAC) level to rise over 0.08", which is the legal limit to drivers in the U.S. The result of drinking could be diverse, depending on one's characteristics, such as gender. For example, for men, binge drinking typically means consuming "five or more drinks on an occasion within about 2 h", but for women, it is consuming four or more (Centers for Disease Control and Prevention, 2018; National Institute on Alcohol Abuse and Alcoholism, 2004).

Although heavy drinking and binge drinking describe how much alcohol a person consumes based on the number of drinks consumed, there are terminologies and standards that indicate one's physical or mental status affected by alcohol use. Risky drinking is defined as behaviors that are not relevant to clinical abuse or dependence but could possibly lead to the development of serious problems. It is characterized by symptoms of heavy drinking such as frequent blacking out, lowered self-esteem (e.g., feeling a sense of guilt), or unhealthy body image (e.g., significant weight gain) (Devos-Comby and Lange, 2008). Acute alcohol intoxication means a clinically harmful health condition which is caused by one's consumption of a large amount of alcohol. Symptoms of the intoxication include impairment in some tasks that requires skill, ataxia, impaired judgment, amnesia, vomiting, coma, and even death (Vonghia et al., 2008). Alcohol Use Disorder (AUD) is a diagnostic instrument issued by the American Psychiatric Association as a part of "the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5)" in 2013 that integrates alcohol dependence and alcohol abuse into a single disorder (American Psychiatric Association, 2013). Anyone who meets any 2 of 11 symptoms (e.g., difficult to stop drinking, drinking when feeling depressed, etc.) within a 12-month period is considered to have AUD with "mild (2–3 symptoms), moderate (4–5 symptoms), and severe (more than 6 symptoms)" subclassifications. On the other hand, responsible drinking and its characteristics are not clearly defined (Barry and Goodson, 2010; Maani Hessari and Petticrew, 2018). College students consider responsible drinking as drinking in moderation, refraining from drinking and driving, monitoring and limiting drinking, knowing one's drinking limit, pacing one's alcohol consumption, preventing intoxication, or planning. Regardless of whether college students are above minimum legal drinking age or below, they have similar perspectives on responsible drinking (Barry and Goodson, 2011). In our study, we define responsible drinking as one's attitude and behavior to minimize risks of excessive alcohol consumption.

College student drinking could be considered an early-stage of developing drinking practices. Even though binge drinking is prevalent in this population, they have much potential to establish a better habit of drinking. Thus, our study focuses on college students who are at the early-stage of drinking having potential to develop both responsible drinking behavior and risky drinking behaviors.

2.2. Screening and brief intervention

Screening and brief intervention (SBI) is created to check one's drinking behavior with questions focusing on the individual's drinking patterns, risks of excessive drinking, benefits of lowering alcohol consumption, and recommendations that focus on reducing alcohol use patterns. Referral to treatment might be added if it is appropriate (Centers for Disease Control and Prevention, 2014; Community Preventive Services Task Force, 2013). Depending on the assessment score from SBI, feedback about several results of excessive drinking and recommendations of behavior change are given in order to raise individual's awareness (Community Preventive Services Task Force, 2013). A variety of validated instruments have been used with SBI, including "Alcohol Use Disorders Identification Test (AUDIT)", "Cut, Annoyed, Guilty, Eye-opener (CAGE)", "Car, Relax, Alone, Forget, Friends, Trouble (CRAFFT)", "Problem Oriented Screening Instrument for Teenagers substance use/abuse scale (POSIT)", and others (Knight et al., 2003). Various kinds of brief interventions for excessive drinking have been used based on delivery context, such as targeted population (Heather, 1995).

SBI can be conducted in face-to-face or electronic (e-SBI) settings. Traditionally, SBI is conducted by professional health care providers in face-to-face setting, whereas e-SBI is typically conducted via virtual mediums, such as the Internet, text messages, emails, smartphone apps, and platforms of social network services (Community Preventive Services Task Force, 2013). A review of the App Store and Google Play Store identified 32 alcohol consumption monitoring apps that represent various forms of e-SBI (Milward et al., 2016). Studies have identified several advantages of intervention delivery using e-SBI. For example, young adults prefer e-SBI because they are concerned with stigmas surrounding drinking (Cunningham, 2009) and are less willing to be evaluated in person by health care professionals about their alcohol use (Kypri et al., 2003). Young adults also respond better to personalized feedback that is only made possible through e-SBI than the generic messages delivered in traditional SBI (Kypri et al., 2003). A meta-analysis of 22 studies showed that e-SBI are lower cost, more scalable and accessible, and higher impact for young students compared to mail-based and face-to-face feedback (Moreira et al., 2012). Overall, studies have found e-SBI to be more effective and preferred than traditional SBI (i.e., paper-based and face-to-face) by the young adult population.

Although e-SBI has the aforementioned advantages over the traditional delivery mechanisms, its effectiveness varies. On the positive note, studies have found that automated text messages are effective to provide drinking-related interventions to the students (Mason et al., 2014; Tahaney and Palfai, 2017). Likewise, a smartphone e-SBI app has shown to significantly reduce the number of risky drinking days of patients with alcoholism (Gustafson et al., 2014). Meta-analysis studies have found that e-SBIs effectively reduce the drinking frequency,

number of binge drinking instances per week, and alcohol-related problems among students compared to the control group (Hester et al., 2012; Khadjesari et al., 2011) Yet, other studies have demonstrated inconsistent findings. For example, studies on personalized feedback using email found that there is no significant impact on one's alcohol use behavior and patterns (Bernstein et al., 2015; Cunningham et al., 2012; Palfai et al., 2014). Another study that sent personalized messages via email to college students showed that only a small number of students (females: 8%, males: 3%) believed that they would alter their drinking habits (Bendtsen et al., 2006). The mixed findings could be explained by the duration of the studies. Meta-analysis and systematic reviews have found e-SBI to be effective at decreasing alcohol consumption in the short-term (Donoghue et al., 2014; Tansil et al., 2016), but its long-term effectiveness has yet to be confirmed (Donoghue et al., 2014; Moreira et al., 2012).

2.3. Peer-based support for alcohol recovery

Although subjects of the SBI method include people who are at high risk of risky drinking that could lead to serious problems, there are other types of support targeting people who are already suffering from alcohol dependence or substance abuse disorders including AUD and trying to recover from it. One of the types is peer-based support. One prominent organization that has been well studied is Alcoholics Anonymous (AA). AA is "an international mutual aid fellowship" for people who suffer from alcohol-related problems. It is estimated that AA consists of more than 110,000 local groups and 2 million members in 170 countries worldwide (Alcoholics Anonymous World Services Inc., 2014). AA's Twelve Step program helps recovering alcoholics increase their motivation and self-efficacy while improving their skills to cope with alcohol-related issues, and social skills. AA's main strength lies in the fact that it is easy to follow and is affordable, and it provides long-term access to recovery elements that can be self-regulated (Humphreys and Tucker, 2002; Kelly et al., 2009). Research has found that facilitating mobile communication among AA members has had a positive impact (Campbell and Kelley, 2008). On the other hand, several concerns regarding stigma and technology use in the Twelve Step program were revealed in an in-depth interview with 12 AA members. They were worried about the possibility of being discovered in public, concealing their identity, accessing resources, building consensus, achieving unity, developing autonomy, and participating in face-to-face communication (Yarosh, 2013). Similar issues were reported by research on a video-mediated online Twelve Step program through In-TheRooms.com. The online AA participants were concerned about anonymity, unity, consistency, face-to-face interaction, and immediacy (Rubya and Yarosh, 2017). Current participatory design research with female participants in recovery from substance abuse also identified concerns about privacy and safety, and the need for tracking progress and maintaining motivation (Schmitt and Yarosh, 2018). Research has also found that self-expression tools such as online blogs and forums could help people manage their drinking behaviors (Carah et al., 2017).

2.4. Self-reflection and mobile technology to support healthy drinking

People have limited capability to constantly observe their behaviors and its patterns. Current advances in technologies have improved personal informatics systems that help people gather personal data to support one's self-reflection and self-knowledge on their behavior (Li et al., 2010; 2011). According to Li et al. (2011), there are two phases of reflection. In the discovery phase, a person tries to understand their goals and look for significant factors that could influence their behavior. In the maintenance phase, a person already knows their own goals and important factors that impact on their behavior, and collects data to maintain their awareness on their status and behavior. Two phases are not always exclusive to each other, but people can overlap in both phases and transit between those phases (Li et al., 2011). This kind of personal self-reflection has an impact upon one's behavior change such as stopping addictive behaviors, initiating health-protective behaviors, or reducing aggressive behaviors (DiClemente et al., 2001; Li et al., 2011; Taylor and Chermack, 1993). In this sense, technologies for self-monitoring and management could be leveraged to reduce one's amount of alcohol consumption to refrain from getting intoxicated with a high BAC level, and to assist in one's recovery from alcohol dependence.

Although research has focused on investigating the effectiveness of e-SBI in various delivery mechanisms, little research has utilized current smart and wearable technologies such as electronic breathalyzers to influence drinking behaviors among college students. Bae et al. (2017, 2018) have developed a machine learning-based model by utilizing smartphone-based sensors that could automatically detect and monitor drinking episodes. This technology could be used to provide appropriate interventions to people who have risky drinking behaviors "in the moment" (Bae et al., 2018; 2017). In one randomized clinical trial study with patients with alcoholism, a breathalyzer was utilized to monitor the level of breath alcohol concentration (BrAC) (Alessi and Petry, 2013). Participants were prompted at randomized intervals to submit dated time-stamped BrAC videos, and they were rewarded with cash incentives if the tests were alcohol-negative as a part of the contingency management treatment. The study mainly focused on the contingency management treatment and its effectiveness, having one control group with the breathalyzer monitoring only and another treatment group with the breathalyzer plus the contingency management. Another clinical study that experimented with a phone-based diary program with alcohol-dependent patients revealed that self-journaling with the help of a breathalyzer helped the patients monitor and manage their alcohol consumption (You et al., 2015). The total amount of drinking and the number of days of heavy drinking declined after the intervention. Those studies on patients with alcoholism has revealed the positive effect of self-monitoring and technology. Similarly, research on another health issue, such as weight management, has been also shown that self-monitoring has the potential to facilitate one's behavior changes (Shih et al., 2015; Wang et al., 2015). In this sense, monitoring one's alcohol consumption using a breathalyzer could have a potential to influence one's responsible drinking behavior. However, the effects of self-monitoring with a current technology on college students' responsible drinking behaviors has not yet been clearly revealed. One study estimated blood alcohol concentration (BAC) levels based on participants' AUDIT scores, a survey screening tool developed by the World Health Organization (WHO) to assess the frequency of risky drinking. The study found that revealing BAC levels using a smartphone app to the participants, who are university students, actually increased their drinking frequency and BAC levels, and this was especially for male participants because they regarded BAC levels as a competitive game (Gajecki et al., 2014).

In our study, we focus on college students who are developing their drinking habits, not students who already have an alcohol dependence issue and need to recover from it. Since college students have different contexts and perceptions compared to alcohol-dependent patients, it is crucial to understand them and how appropriate technologies can be designed to encourage their healthy drinking behaviors.

To our knowledge, no prior research has focused on designing for effective self-monitoring mechanisms using personal breathalyzers to manage alcohol consumption. We had previously conducted a pilot study that interviewed college students regarding their perception and use of smart breathalyzers (Min et al., 2018). In this research, we built on our prior work and conducted additional surveys, interviews, and a two-week user study that analyzed participants' device usage data. We then examined how they incorporated using the smart breathalyzer when they drank, and whether using the breathalyzer influenced their perception and behaviors of alcohol consumption. We proposed the improved design of the breathalyzer app. We then discussed design implications for future technologies that lead to safer drinking

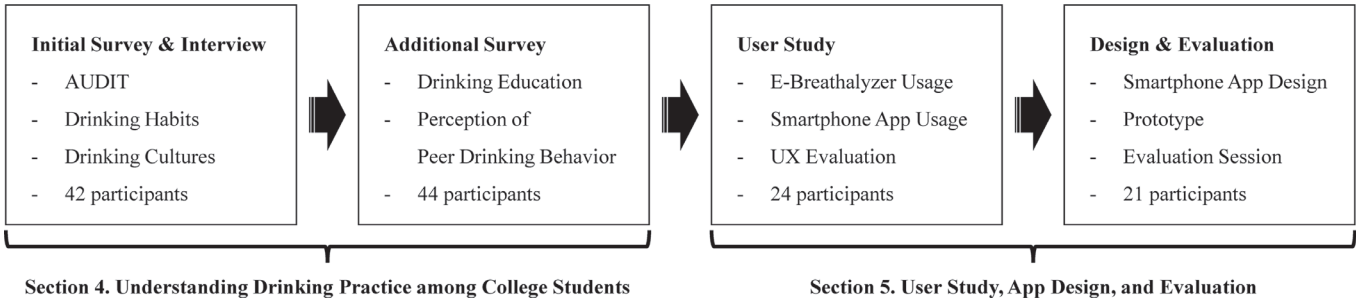

Fig. 1. 4 Stages of Study.

environments and habits among college students.

3. Method

The goals of this research are (1) to understand current college students' attitudes and behavior toward alcohol consumption, (2) to explore how they perceive and use a personal breathalyzer, and (3) to improve the current design of technologies to encourage college students to engage in responsible drinking behavior. Our research consists of four stages (See Fig. 1). First of all, we conducted an initial survey and interviews with 42 students to understand their drinking habits, practices, and environments. Second, we additionally surveyed 44 participants to figure out how they have learned about alcohol consumption and how they perceive their peers' drinking behaviors. Third, we conducted a user study on a personal breathalyzer with 24 participants among the participants of the initial survey. Finally, we iteratively designed and suggested a new system and user interfaces that could improve the smartphone app for personal breathalyzer while receiving feedback.

3.1. Initial survey and interview

To understand drinking practices of university students, we conducted an initial survey. The survey asked questions about participants' general drinking habits, behaviors, and contexts including unsafe practices. We recruited 42 students including 27 undergraduate and 15 graduate students with an average age of 23.5 years.

3.1.1. Alcohol use disorders identification test (AUDIT)

To identify whether a participant's drinking habits were risky or not, we applied AUDIT, which is a screening test tool developed by WHO. It includes 10 four-point items about frequencies of risky drinking, with maximum of 40 points. An AUDIT score of 0–7 indicates reasonable drinking behavior; 8–15 requires simple advice to reduce hazardous drinking; 16–19 indicates that the participant should monitor his/her drinking behavior and enroll in brief counseling; and a score of 20 or more indicates that the participant requires further diagnostic evaluation from medical professionals to figure out her/his alcohol dependence (Babor et al., 2001).

3.1.2. Initial interview

While conducting the initial survey, we also conducted open-ended interviews with four college students to understand their drinking habits and culture among students in more detail. Also, we asked them how well they understood the function of the breathalyzer and whether they were aware of their limits or how much they could control their drinking.

3.2. Additional survey

We also conducted an additional online survey to gather detailed information and understand college students' alcohol education and their perception of peer drinking behavior. We recruited undergraduate students only; the initial survey included graduate students. Participants reported whether they had any alcohol education before and how it emphasized specific topics with 4-point Likert scale questionnaires. Also, they were asked about their alcohol consumption practices and behaviors with AUDIT questionnaires and whether they or their friends have experienced risky behaviors due to alcohol consumption. Since this additional survey had a question pertaining to illegal behavior (e.g. illegal substance use), the survey was anonymously conducted.

We collected 58 responses from the additional online survey to contextualize the college drinking experience further. We excluded 14 participants from our data analysis due to their age, status in the school (e.g. graduated), or incomplete input. In the end, we analyzed data from 44 college students with an average age of 21 years. Even though five participants (11%) had never consumed alcohol, we included these participants in our analysis to see their perception of alcohol consumption.

3.3. Smart breathalyzer user study

To understand how college students perceive and use smart breathalyzers, we conducted a user study with smart breathalyzers. This user study consisted of a demographics questionnaire, weekly surveys, a user experience evaluation, and in-depth post-study interviews.

This user study was conducted with 24 college students (15 females and 9 males) with an average age of 21.8 years. The target population of our research included college students who consume alcohol at least once a week. These participants included three freshmen (12.5%), three sophomores (12.5%), eight juniors (33.3%), and 10 seniors (41.7%). Save for one participant who has a cellphone that includes a breathalyzer function, all participants had not possessed any personal breathalyzer before.

3.3.1. BACtrack Mobile Pro

BACtrack Mobile Pro is a personal breathalyzer that is approved by the US Food and Drug Administration (FDA). It can be paired with a smartphone or a smart wearable watch using Bluetooth. Fig. 2 shows the breathalyzer and the detachable mouthpieces. Each participant was provided with a breathalyzer with three mouthpieces for two weeks. The user breathes through an attached mouthpiece to check his BAC level. After the device calculates the user's BAC level, the BACtrack app shows the user's BAC level with recommendations for safe drinking. BACtrack can provide additional information such as the estimated time when the user's BAC level would return to 0. The app allows users to store BAC levels with an option to save the data anonymously. The user can record location information and add personal memos for each BAC level and compare data over time. BACtrack also contains a simple social feature such as sharing BAC levels via text message manually. BACtrack also features a digital button that opens Uber to provide immediate access to the ride-sharing app (BACtrack.com, 2018). Fig. 3 shows a screenshot of the BACtrack app.

Fig. 2. BACtrack Mobile Pro.

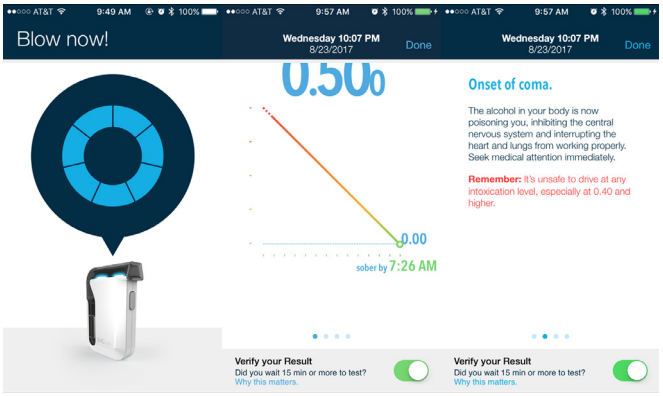

Fig. 3. BACtrack smartphone app.

We chose BACtrack Mobile Pro for our study because it is the only FDA-approved smart breathalyzer for consumer use; other FDA-approved smart breathalyzers are primarily for medical use. Smartphone integration also makes it suitable for the college student population. The cost ($129.99 USD) is relatively more affordable than other medical-grade smart breathalyzers. We have also analyzed Amazon product reviews and found BACtrack Mobile Pro to be favorable among the consumers compared to other competing products (Amazon.com Inc, 2018; BACtrack.com, 2018).

3.3.2. User experience questionnaire (UEQ)

To identify design challenges and opportunities of smart breathalyzers, we applied a User Experience Questionnaire (UEQ), a validated user experience instrument (Laugwitz et al., 2008). The UEQ consists of 26 items that assess three pragmatic (attractiveness, perspicuity, and efficiency) and three hedonic (dependability, stimulation, and novelty) factors. Attractiveness measures the user's overall impression of the product; perspicuity measures how easy it is for the user to get used to the product; efficiency measures whether the user could accomplish the tasks with needless effort; dependability measures whether the user feels that they can control the product; stimulation measures how much the user is excited and motivated to use the product; novelty measures how much the user feels the product is innovative and creative (Schrepp et al., 2014). The user grades each item using a 7-point scale that ranges between −3 (extremely bad) and +3 (extremely good). Average values over 0.8 are positive, between −0.8 and 0.8 are neutral, and under 0.8 are negative (Hinderks, 2016).

3.3.3. User study process

This research has gone through the full Institutional Review Board (IRB) approval process at our university, and we have obtained the Certificates of Confidentiality (CoC) from the National Institute on Alcohol Abuse and Alcoholism (NIAAA) - NIH. The CoC grants the research team the legal authority to refuse to provide the names or other identifications of the research subjects. This is important because many of our study participants are under the legal U.S. drinking age.

A researcher met with each participant individually and in-person. The participants were informed about the study process and confirmed that fact on an informed consent form. The researcher then conducted a pre-study interview asking them to reflect and share their experiences on drinking. Following the interview, the researcher offered a short tutorial on how to pair the BACtrack Mobile Pro breathalyzer with their smartphones and how to use the BACtrack app. The participants were asked to use the device during/after each time they consumed alcohol for a period of two weeks. At the end of each week, a short survey was sent out to query the participants' experiences of using the device during the previous week. We also analyzed the app usage data including where, when, and how often they used the breathalyzers. At the end of the second week, the researcher met with each participant to collect the device. The participants were asked to complete a post-study survey questionnaire that consists of questions that assessed their perception of the breathalyzer, their use of the breathalyzer, and the UEQ. Finally, an in-depth post-study interview was conducted to explore how they used the device, whether their perception and behaviors of alcohol consumption were influenced by using the device, and what they thought were beneficial and challenging for sustained usage. Each participant was paid $20 for participating in the study. Pre- and post-study interviews were recorded and transcribed for later analysis.

3.4. Smartphone app design, evaluation, and prototype development

We brainstormed design ideas on how to improve the existing smartphone application for BACtrack. With our design ideas for the app, we conducted design evaluation sessions with 21 students. We showed our storyboards with scenarios with main concepts to them and received their feedback. Based on their feedback, we improved our design ideas, incorporate them into the existing app designs, and developed a prototype.

3.5. Data analysis

We compiled basic summary statistics of the participants of each study. Since people have different drinking behaviors, we categorized the participants into two groups to compare differences: Safe (AUDIT score under 8), and Risky (AUDIT score above 8). Based on this category, we performed Chi-square tests and *t*-tests to compare their drinking practices as well as the breathalyzer usage and UEQ scores among heavy versus safe drinkers. We also analyzed the device usage time and frequency, but we did not analyze the BAC levels. Due to the fact that some of the participants were younger than the legal drinking age, we removed any recordings of the BAC levels from our dataset in the interest of protecting participants' privacy. For the qualitative data, we applied open coding to identify common themes among the participants and refined the emerged themes in an iterative process (Corbin and Strauss, 2014).

4. Understanding drinking practice among college students

In this section, we report our findings from initial and additional surveys and interviews. We analyze the participants' alcohol consumption behaviors, awareness, and practices as well as their perceptions on peers' drinking behaviors.

4.1. Initial survey and interview

4.1.1. Drinking contexts: With friends, and outside

From the initial survey, 42 responses were collected, and the participants consisted of 26 females, 15 males, and one person who did not disclose gender. The result shows that the participants usually have consumed alcohol at restaurants or bars (N = 40, 95.2%) with their friends (N = 42, 100%).

We classified our participants by two criteria and we conducted a Chi-square test to compare the two groups. First, we classified them into undergraduate and graduate students as the initial survey included graduate students. We found that undergraduate students are less likely to drink at home ($\chi^2(1) = 9.8$, $P < 0.01$) and alone ($\chi^2(1) = 14.1$, $P < 0.001$) significantly compared to graduate students. It indicates that undergraduate students may enjoy drinking with their friends at restaurants or bars.

4.1.2. A lack of awareness of alcohol limit

The initial interview revealed that the participants do not have enough awareness about their alcohol limits, which could cause unsafe decisions after drinking. One of the participants mentioned that she did not know that the 0.08 BAC limit for driving a car only applied to people over the legal drinking age and it is zero-tolerance for underage drinkers. Overall, there is a lack of knowledge among college students on the legal amount of alcohol they can consume before they cannot drive.

4.1.3. More help for risky drinkers

Based on AUDIT scores, we categorized them into two groups: Safe (AUDIT score under 8; 20 participants), and Risky (AUDIT score above 8; 22 participants). The safe group usually drinks at home significantly more than the risky students ($\chi^2(1) = 5.7$, $P < 0.05$). The risky group has usually needed more assistance from their friends to sober up than the safe group ($\chi^2(1) = 4.4$, $P < 0.05$). It is clear that students who have risky drinking habits are more likely to be in the situation that needs more careful attention. In general, the participants usually have been helped or have helped their friends sober up and will take each other home by car or walk.

4.1.4. Positive attitude toward a breathalyzer

Most of our participants had not used a breathalyzer before (N = 40, 95.2%). When we introduced the smart breathalyzer, the participants were interested and fascinated by the device, and they responded positively toward its appearance such as its design, size, and compactness.

To summarize the results of the initial survey and interviews, college students are more likely to drink in social settings and less likely to know how many drinks they need to consume for safe drinking. Obviously, students who have risky drinking habits are more likely to need help and attention from other people when they are drinking. Also, we found that they have positive attitude toward the smart breathalyzer.

4.2. Additional survey

4.2.1. Reliance on information from friends

Among the 44 participants, 28 students (63.6%) reported that they have received alcohol education. The education they received were from primary and secondary schooling (N = 15, 34%), college (N = 23, 52%), online (N = 10, 22.7%), and class presentations (N = 4, 9%). During alcohol education, negative consequences about drinking (N = 19, 68%) and binge drinking (N = 13, 46%) were strongly emphasized. However, when it comes to information about alcohol dependence, 24 (55%) participants relied on their friends for information rather than family (N = 11, 25%), alcohol education (N = 4, 9%), traditional media (N = 3, 7%) and other community sources (N = 1, 2%). This indicates that even though they received education about alcohol consumption, they are more likely to rely on their friends.

4.2.2. Alcohol consumption behaviors: high AUDIT vs. low AUDIT

Nearly 40% of 39 participants who have ever consumed alcohol before responded that they drink alcohol between 2–4 times a month. Most of the participants were female (N = 32, 82%). The AUDIT scores of 24 participants (62%) were less than 8, indicating they have reasonable drinking behaviors, while the scores of 14 participants (36%) were more than 8. Only one response was incomplete in the AUDIT questionnaire. Among those 14 participants with the high AUDIT scores, the scores of two participants are 16 and 18, which means they should monitor their drinking behavior seriously. In terms of drinking locations, the participants were more likely to drink at houses (mean: 4.33, SD: 0.77), apartment parties (mean: 3.92, SD: 1.22), and bars (mean: 3.79, SD: 1.58). The high-AUDIT group people usually consume alcohol at Greek society houses (mean: 1.79, SD: 1.48) more often than the low-AUDIT group (mean: 1.04, SD: 0.20); $t(36) = -2.45$, $P < 0.05$. When it comes to companions for drinking, it is clear that they usually drink with their friends (mean: 4.85, SD: 3.67). Between the high-AUDIT group and low-AUDIT group, the high-AUDIT group (mean: 2.21, SD: 1.63) usually consumed alcohol with Greek members significantly more often than the low-AUDIT group (mean: 1.35, SD: 0.83); $t(35) = -2.15$, $P < -0.05$. This indicates that heavy drinking behaviors could be associated with Greek life.

Overall, participants responded that they had engaged in risky behaviors under the influence of alcohol on less than a monthly basis. However, comparing the two AUDIT groups, the high-AUDIT score participants are significantly different in categories such as binge drinking ($\chi^2(3) = 17.5$, $P < 0.01$), illegal substances usage ($\chi^2(3) = 9.0$, $P < 0.05$), and blacking out ($\chi^2(3) = 13.2$, $P < 0.01$). This shows that heavy drinking habits could be associated with risky behaviors.

4.2.3. Perceiving peer alcohol consumption behaviors

Many participants reported that they are often aware of their peers' drinking behaviors. They have been aware that their peers binge drink either monthly (N = 16, 36.4%) or weekly (N = 16, 36.4%), or use illegal substances monthly (N = 10, 22.7%), weekly (N = 11, 25%), or even almost daily (N = 3, 6.5%). Also, about half of the participants have seen their peers blacked out or engage in sexual activity either monthly or weekly. There is only a significant difference between the risky and safe groups with perceiving their peer's binge drinking ($\chi^2(3) = 9.4$, $P < 0.05$). This result indicates that college students have awareness of the behaviors of people around them to some degree.

Overall, they reported they have been aware of others' risky behaviors relatively more than their own risky behaviors.

5. User study, app design, and evaluation

In this section, we report findings from the user study. These findings include the participants' drinking patterns collected from the breathalyzer recordings and the weekly survey responses, and user experience evaluations of the breathalyzer and the smartphone app. We then describe participants' perception and experience of using the breathalyzer, and how the current design helped or hindered their drinking behavior. Then, we propose our new design of the smartphone app for the breathalyzer and provide feedback from the design evaluation session.

5.1. Smart breathalyzer user study

5.1.1. Positive perception of breathalyzer usage

We inquired about the participants' attitudes on using the smart breathalyzer and the smartphone app in the post-survey using a 7-point Likert scale. There was one participant who did not answer this post-

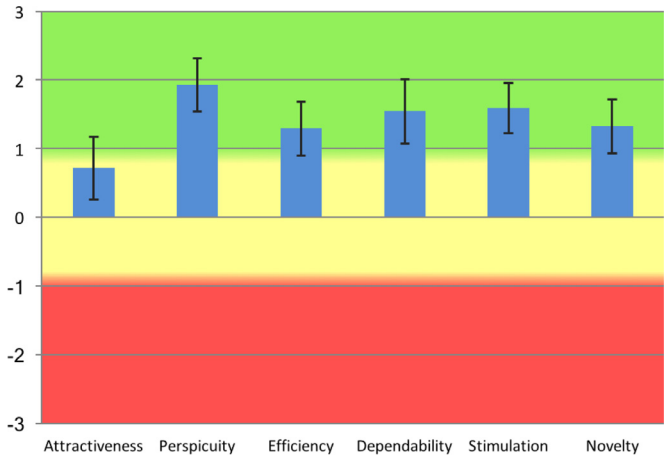

Fig. 4. Evaluation on six factors of user experience.

survey. Excluding this participant, the participants reported a neutral rating when asked if they thought the breathalyzer could be helpful for preventing excessive drinking (mean: 4.3, SD: 1.6). There was significant difference ($t(21) = 2.4$, $P < 0.05$) between the safe group (mean: 5.2, SD: 1.0) and the risky group (mean: 3.7, SD: 1.7). This shows that the safe group have better recognized and controlled their excessive drinking while using the breathalyzer than the risky group.

In terms of the user experience of the breathalyzer and the smartphone app, the UEQ results show that participants generally perceived the breathalyzer and the smartphone app positively. Other than attractiveness (0.7), which fell in the neutral range, all other factors were rated positively (perspicuity = 1.9, efficiency 1.3, dependability = 1.5, simulation = 1.6, novelty = 1.3). Fig. 4 shows the average ratings and range of the scales.

Although there is a need to evaluate and compare designs of breathalyzer devices more systematically, our participants were generally happy with the physical form factor of the breathalyzer design.

> *P-02 (Female, AUDIT = 12) "I thought the design is very sleek, not bulky"*

In addition, we compared our results with the benchmark data set collected from 9905 participants across 46 studies that evaluated other products (see Fig. 5) (Hinderks, 2016). The breathalyzer and the smartphone app was rated good or better in perspicuity, stimulation, dependability, and novelty than other products. This result meant that participants were able to enjoy using the breathalyzer without much difficulty.

Overall, the participants expressed positive user experiences about the breathalyzer. Most of them had never used a personal breathalyzer before, so the device was a novel product for them. The user-friendly hardware design may have also helped them feel less awkward when

Fig. 5. Comparison to the benchmark data set.

using it in public. Nearly all participants reported that they found the breathalyzer fun and exciting to use.

5.1.2. Social context of drinking and breathalyzer usage

During the study, the participants reported that they consumed alcohol with their friends (71.0%), social club members (12.9%), family (9.7%), and alone (6.5%). In terms of the locations, they drank at restaurants or bars (44.4%), home (22.2%), friend's house (20.0%), party (11.1%), and other places (2.2%).

> *P-06 (Female, AUDIT = 18) "I usually drink with my friends, because alcohol makes me relax, so we could talk more openly and comfortably with each other."*
> *P-07 (Female, AUDIT = 9) "The reason why I drink is... I just like it, and I just like drinking to forget my stress, and drinking with my friends is so fun."*
> *P-15 (Female, AUDIT = 17) "I enjoy drinking, I enjoy the atmosphere, and I feel excited when I drink with my friends."*

Overall, college students enjoy drinking with their friends for social purposes, and these responses corresponded with the initial survey and interview that showed college students have consumed alcohol in social settings.

In the interest of protecting participants' privacy, we report only the breathalyzer usage time and frequency in this paper. We grouped their device usage time into four time periods throughout the day: (1) midnight to 6am, (2) 6am to noon, (3) noon to 6pm, and (4) 6pm to midnight. Significant differences exist in two time slots: between 6pm to midnight (The safe group: mean = 1.1, SD = 1.2; The risky group: mean = 4.8, SD = 4.4; $t(17) = -3.1$, $P < 0.01$) and between midnight to 6am (safe group: mean = 0.1, SD = 0.3; risky group: mean: 3.8, SD = 4.5; $t(14) = -3.2$, $P < 0.01$). It is clear that the risky group used the device more frequently at night in Fig. 6, compared to the safe group, which showed relatively low usage.

For frequency of use, we analyzed how many times the participants used the breathalyzer (1) overall, (2) on their own, and (3) shared it with their friends during the two-week period. (1) The participants in the risky group (mean: 10.1, SD: 8.5), in particular, used the device much more than the safe group (mean: 2.1, SD: 2.4), and it is significantly different ($t(17) = -3.4$, $P < 0.01$). (2) When it comes to individual usage while alone, the safe group (mean: 2.1, SD: 2.4) and the risky (mean: 6.6, S.D: 4.4) were significantly different ($t(22) = -2.8$, $p < 0.05$). (3) Also, no one in the safe group shared the device with their friends, whereas the risky group reported sharing the device frequently with their friends (mean: 3.5 times, SD: 6.4). This difference between the two groups was significant ($t(14) = -2.2$, $P < 0.05$). Fig. 7 shows the difference in overall frequency of use among the groups.

In general, the risky group used the device and the app much more

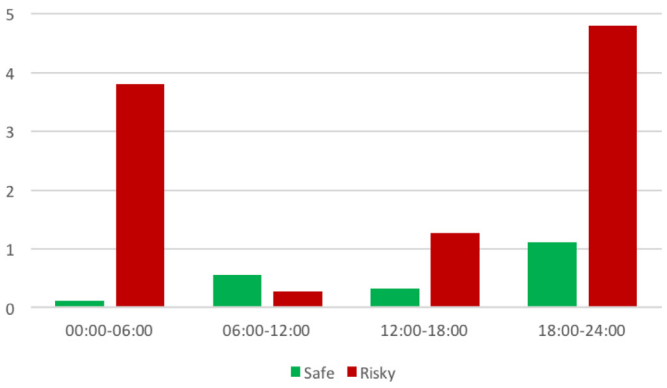

Fig. 6. Breathalyzer usage time (avg.) among the safe and risky groups during 2-week study.

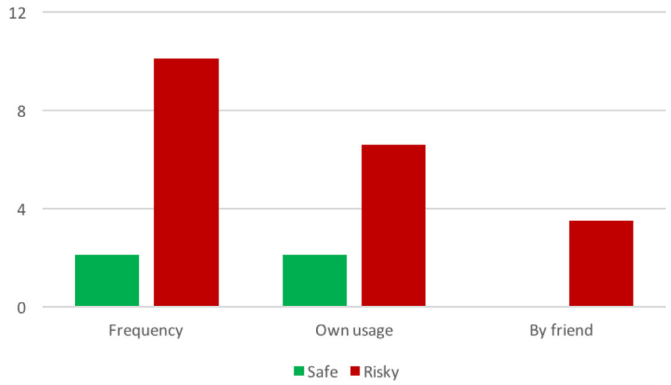

Fig. 7. Frequency of use (avg.) among the safe and risky groups during 2-week study.

actively than the safe group. Most of participants drank and used the device with their friends during the study. Socialization was an important factor contributing to drinking among our participants. Their usual companion for drinking were their friends, and most of them mentioned that they enjoyed drinking and using the device with their friends.

P-04 (Female, AUDIT = 15) "My friends really liked using the breathalyzer. The four of us used it at my friend's house. There was a small group of us."
P-06 (Female, AUDIT = 18) "I almost always drink alcohol with my friends. During the past 2 weeks, I used this about four times with my friends when we were drinking."
P-15 (Female, AUDIT = 17) "When my friends saw this, they looked curious. Some of them tried to use it and I felt that they controlled their drinking after BAC check."

These results indicate that college students' social relationship could be related to their motivation to drink. Moreover, we found that the participants and their friends voluntarily shared and used the device when they drank together. In our study onboarding, we did not ask them to share the breathalyzer and use it as frequently as possible. We did asked them to share with their family and friends only if they so desired.

5.1.3. Breathalyzer as a monitor for personal health and safety

Many participants considered the breathalyzer as an informational tool to monitor their drinking limits and whether it was safe to drive home.

P-07 (Female, AUDIT = 9) "I want to know what BAC level is dangerous to my health. I want to enjoy drinking but I don't want to feel sick when I accidentally drink too much."
P-22 (Female, AUDIT = 4) "This is helpful to monitor drinking. This could help me better understand how much I drink and whether it is harmful for my body."
P-02 (Female, AUDIT = 12) "I don't want to drive dangerously, so I want to use it to check if I am OK to drive."

The participants mentioned that the device was helpful for letting them and others know whether the user was intoxicated or not. If the device showed a high BAC level, the user's friends could ask her/him to stop drinking.

P-06 (Female, AUDIT = 18) "We didn't know my friend had drunk that much, but when we saw the high BAC level, we asked her to stop drinking."

We also found differences when it comes to taking care of drunken friends. Both female and male participants said that they usually take care of their friends if they are drunk or almost passed out. The participants mentioned that if their friend is drunk, they usually make her/him stop drinking, go out together to get fresh air, walk her/him home, or call a taxi/Uber to send their friends to home. Moreover, if they sent the friend home alone, they said they often check whether s/he has safely arrived. Both female and male participants mentioned that they are usually more careful when helping drunken female friends.

P-08 (Male, AUDIT = 20) "I am really careful when girls are drunk. Because I am a man, I might cause misunderstandings if I make even the smallest gesture that can be perceived as being inappropriate."
P-09 (Female, AUDIT = 13) "We don't care about male friends. They can go their home by themselves without much worry. But female friends are different. I cannot trust letting them go home alone if they're drunk. If my female friends drank too much, I'd let her sleep in my home."

In this sense, college students react differently about assisting their friends based on gender. They are more concerned about drunken female friends than drunken male friends because of possible risks such as sexual harassment and sexual assault.

5.1.4. Privacy and stigma of breathalyzer usage

Prior research reveals a stigma of using BAC detectors. One study that researched a wearable device with a transdermal sensor for monitoring BAC reported that device usage was negatively impacted by the perceived stigma associated with it, and many subjects reported hiding it from others (Gurvich et al., 2013; Marques and McKnight, 2007). This means that using an alcohol monitor could make users uncomfortable about the perceived stigma from their peers. However, participants in our study generally felt comfortable using the device around their friends and family (mean: 5.0, SD: 1.0). They also reported that bystanders did not react negatively when the participants used the breathalyzer in front of them (mean: 2.2, SD: 1.1).

P-01 (Female, AUDIT = 4) "My friends asked what it is. When I told them that it's a breathalyzer that measures the blood alcohol content, they were mostly interested rather than being negative.'

Only one participant mentioned that she felt uncomfortable about using the device in front of older family members.

P-10 (Male, AUDIT = 18) "When I met several older adults of the family, I didn't feel comfortable using it because I thought it would be inappropriate because they might think that I drink a lot."

In terms of both comfort level and reactions from others, there is no significant difference between groups. This shows that stigma is not a significant factor that could impede a wider adoption of breathalyzers for college students. Overall, both the post-survey and interview showed that participants and their friends and families all felt positive about using the breathalyzer. This result reveals that a smart breathalyzer with good design could be accepted by young people and be used without being negatively affected by stigma.

Contrary to the positive attitude that the participants felt when they showed the device to others, they reacted negatively about sharing BAC levels on social media. We asked them about their thoughts on sharing BAC information on social networking service (SNS) platforms such as Facebook or Twitter. Most of the participants considered BAC levels as private information and did not want to share BAC information on social media platforms.

P-09 (Female, AUDIT = 13) "I don't want to boast to the public about how much I am drunk. It is my privacy."

On the other hand, they mentioned that they prefer to share the information selectively via text messages or personally directed messages.

P-07 (Female, AUDIT = 9) "I don't want to reveal my private information in public such as where I am drinking now. Rather, it would be good if I could control and select someone to share, like my friends."

P-09 (Female, AUDIT = 13) "I can send a message with the BAC information to my friend to show my states and ask him to come and help."

These answers show that they can share their BAC information with a person they trust, such as their friends.

5.2. Scenario-based app design evaluation

We conducted an iterative design process to improve the current existing smartphone app "BACtrack." Based on our findings and design implications from the surveys, interviews, and user study with the breathalyzer, we assessed users' needs and brainstormed design ideas. We then narrowed down and selected main concepts for designing, made storyboards and personas, and conducted an evaluation session with 21 students.

5.2.1. Scenario 1: Automatic message to get social support

The first scenario is as follows: When a user opens the app, it will ask how they will be getting home. The user will select one of the options (Car, Walk, Uber, or Staying at Home) and let the app know how she or he will return home after they drink. Later, when the user drinks and measures their BAC level before going home, it will note whether or not they should drive home in this situation. Also, the user's BAC level with additional information (e.g. "My BAC level is 0.15! I said I would drive home tonight.") is texted to the user's close friends and/or family immediately. The user's friends/family might decide to text back, call, or acknowledge what is happening.

This design concept provides an automatic message to the user's close friends and family members when a user reaches a high BAC level. Overall feedback was positive and there was no concern about stigma with this concept. For the participants, the function of an automatic message looked useful with mitigating concerns from their friends and family.

P-D02 "It looks nice to send a message to their close friend automatically. Ultimately, it might lessen worries of those friends and family about the user."

However, some participants mentioned that if a friend or family member who is a targeted receiver was not able to see the message or notification in real time, or if the targeted receiver was also drinking at the same time, the user might be not able to get help from them in that scenario.

P-D01 "Usually, people drink at night. The message receiver might sleep at that moment. You need to think about the situation of some people who are not able to see that notification in real time."

P-D02 "If they drink together, this function might not work.

Therefore, the system should also designed for the situation that some friends and family members miss a notification or message. In that case, there should be an alternative way to provide help to protect the user from dangerous situations.

Also, the participants in this session suggested a concept where a device or an app could be automatically aware of a user's level of intoxication and send an automatic notification or vibration to the user, which is the function of personalized and contextualized services that we considered in our discussion.

P-D03 "How about some function of automatic awareness? If the device notices the situation and give a notification and vibration to the user, that would be great."

P-D03"Also, if the system know that the user drank and are going home now, for example, by assuming based on the user's steps and time, they might send a notification such as 'If you will drive, please use the breathalyzer to check your BAC level.' "

Therefore, it could be concluded that increasing a user's recognition of risky drinking by providing personalized and contextualized functions is a desirable system for users.

5.2.2. Scenario 2: External rewards

The second scenario is as follows: When a user went to the bar at 8 pm and stays there for an hour, the app told him that he should check his BAC level. At that moment, he had not consumed alcohol yet, so his BAC level was 0. The app gave him 10 points, which can be redeemed later for discounts on things. However, he chose to stay longer and drank more at the bar. At 10 pm, the app alerted him again to ask him to check his BAC level. This time, his BAC level was 0.09, and he lost the points.

We suggested external rewards such as points or coupons that could be redeemed for some products. In this scenario, there would be points as a reward if a person used a breathalyzer and received a 0 or a low BAC level. On the other hand, if the user got a high BAC level such as over 0.08, then the points would be reduced. This concept is based on the idea of external rewards to motivate a college student to drink less. However, there were many concerns on misuse and negative effects. It is possible that the user might use the breathalyzer to earn the points even though she or he is not at a bar and did not drink at all. Also, there might be negative feelings caused by the subtracted points that could discourage users from using the device and the app.

P-D04 "It looks that the user might use the app to get more points even though she or he did not drink. However, I am concerned that if the user feels bad when their points reduced despite small an amount of points, they might not want to continue to use it anymore."

P-D04 "(To prevent misuse) The device should be aware of the place and know whether the user is at a restaurant or a bar."

Instead of external rewards, some participants suggested another motivation as an internal reward. In addition to providing preset goals, the app allows users to set their own goals and stimulations such as motivational phrases to prevent risky drinking.

P-D05 "I think the user who uses this service might have some willingness to prevent their bad drinking habits and behavior. How about making them write some phrases with their goal? That would be a stimulation to motivate the user. Then, if the device notices that the user did not use the device when they drank, the app shows that phrases to prick at their conscience."

Ultimately, the way to provide effective internal and external rewards should be carefully considered to prevent users from exploiting the reward system and causing negative impacts.

5.3. Design proposal

Focusing on ideas from our findings and feedback from design evaluation sessions, we designed new user interface screens and functions based on the current existing breathalyzer app "BACtrack" which was used for our user study. We designed the app not only to provide a more effective tracking system but also to offer a social support system considering the user's social network and social context of alcohol consumption.

5.3.1. Location-awareness

In our design, we aim to increase a user's awareness of breathalyzer usage using a contextualized function. Our suggested design is that the app could recognize a user's location and provide contextualized services based on their location. For example, if the user is staying near or at a bar, the app will automatically ask the user whether she or he will drink. This automated system could help the user recognize possible negative consequences to drinking such as drunk driving (See the 1st line of Fig. 8).

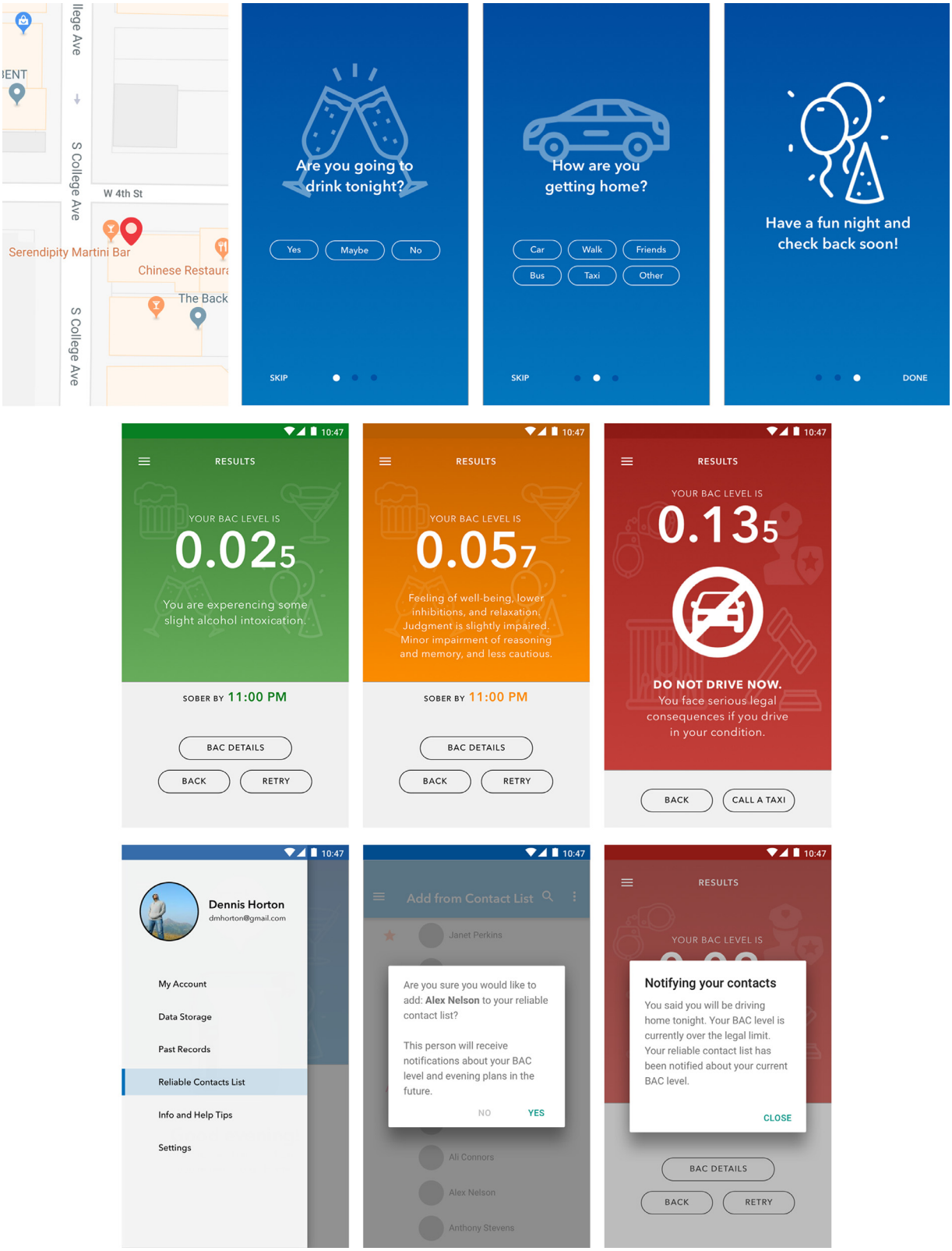

Fig. 8. Example of function and screen design - 1st line: Location-awareness and checking a user's status and plan for drinking - 2nd line: BAC level with different colors (0.00–0.04: green / 0.041–0.079: orange / 0.08+: red) - 3rd line: Reliable Contact List (When a user needs social intervention, a notification will show.). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

5.3.2. Checking the users status

As an extension of the function of increasing user awareness, our new design suggests that the app could keep checking the user's level of intoxication and their plan to get back home (e.g. car, walk, tax, bus, etc.). This function will be operated based on the user's location or if the user turns on the app. Also, it will recommend using the breathalyzer at the end of the night if the user answered that they will drink and have to drive home. This automated system could continuously help the user

recognize possible dangers and prevent them from happening (See the 1st line of Fig. 8).

5.3.3. Intuitive BAC results

The current existing app mainly shows flat colors with a white background and blue text. Considering one's cognitive ability when one is drinking, our proposed design provides different colors and icons based on the user's BAC level to increase their recognition of their current level of intoxication. For example, if the user reaches BAC levels over 0.08, the app will display a larger red background with bold texts of "DO NOT DRIVE NOW" and a car crossed out graphically. This visual element could help the app convey important information quickly. The user can recognize their drinking status intuitively based on the colors and boldly displayed BAC level. They also will be able to see when they will be sober, which potentially will prevent drunk driving. The second line of Fig. 8 shows an example of screens with different BAC levels.

Each of the BAC results will also have additional "BAC Details" that give more explanation of what that specific BAC level means for the person. When the result is above 0.08, it will also show only the BAC level and an option to call a taxi if the user noted that they will be driving that evening.

5.3.4. Reliable contact list

We designed and propose a social support system that uses social contexts and network around the user. This function regards one's desire to be safe and willingness to share information based on trust in close family members and friends. In our designed system, the user can setup a Reliable Contact List on the app by adding from their contact list on their phone. If the user receives a BAC level higher than 0.08, the app will automatically send a message to people on the reliable contact list (See the third line of Fig. 8). The message will include not only the level of BAC but also the location of the user if the user is set to share it with people on the reliable list. Then, those people will be able to know the user's drinking status, contact the user, and ask the user whether she or he needs help such as providing a ride.

To test feasibility of our design ideas, we utilized BACtrack API sources and developed a prototype that works with the breathalyzer and a user's smartphone. Fig. 9 shows our testing for the social support system. When the app detected a BAC level higher than 0.08 through the breathalyzer, a message with BAC level and location was automatically sent to a person who was registered on Reliable Contact List.

6. Discussion

In this paper, we explored college students' practices and social contexts of alcohol consumption as well as their perception and experience of drinking while using a breathalyzer that is paired with a smartphone app over a period of two weeks. Early alcohol awareness is especially important at an early age. It is important to provide proper monitoring and intervention techniques to college students so they are able to establish safe and responsible drinking habits. Since there is little research on breathalyzer usage in general, our research contributes to this public health issue by reporting insights on college students' perception, usage preferences, and concerns regarding stigma and privacy of breathalyzer usage. Our findings provide insights for designing effective technological interventions for promoting safe drinking behaviors among college students. In this section, we review our results and discuss design considerations.

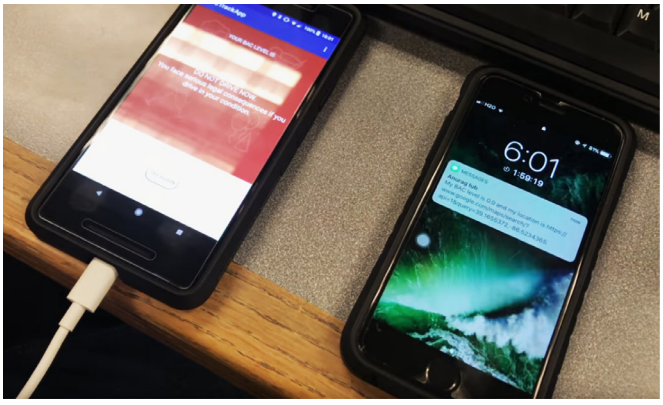

Fig. 9. Example of the app prototype testing the function of automatic message when over 0.08 BAC level is detected.

6.1. Social support system within a trusted network

6.1.1. The influences of social environments

Our surveys and interviews indicate that it is crucial to consider the influences of social contexts on college students' drinking behaviors. We found that the participants often drink with friends in a public setting, and they have been affected by their peers in terms of information sources, drinking practices, and help such as sobering up. Current literature has identified social relationships to be an important factor in drinking. Peer drinking is significantly correlated to college students' alcohol consumption patterns (Hussong, 2003; Mallett et al., 2009). College students' perceived social networks and peer acceptability could influence and change their drinking behavior, such as initiation and maintenance of their alcohol reduction (Reid et al., 2015). From our surveys and interviews, we found that college students' perception and drinking habits are closely related to their social environments. Specifically, the risky group in our study spent much more time drinking with their friends than the safe group. Participants of the risky group answered that they enjoy drinking with their friends due to its role in making social connections. Since drinking is seen as a social agent, the valuation of friendship is an important consideration when designing intervention systems that encourage safe drinking behavior.

In the context of the U.S., the Greek life could be a critical factor that is associated with drinking behaviors. The Greek life refers to fraternities and sororities, or Greek Letter Organizations (e.g. Phi Beta Kappa, Alpha Delta Pi, etc.). These are social organizations of students in colleges and universities in North America, which have been established to meet specific academic and cultural needs (Whipple and Sullivan, 1998). Most of the members of these organizations often live together and build their group norms. However, many have established risky drinking norms, and the members of the Greek life have more chances to experience negative consequences of excessive drinking (Cashin et al., 1998). Current studies have discussed social norms, protective strategies, and negative influences that are associated with peer pressure from fraternity and sorority members on college students' drinking behaviors. Members of fraternity and sorority members could be at extreme risk of developing unhealthy drinking behavior patterns (Brown-Rice et al., 2015; Page and O'Hegarty, 2006; Soule et al., 2013). These findings accord with our result that shows the participants who have risky drinking habits are more likely to consume alcohol with Greek members.

Therefore, we could assume that the social context and the college campus drinking atmosphere influenced the participants' drinking patterns. Understanding the social context around drinking would be necessary when researching ways to encourage college students to drink more responsibly.

6.1.2. Perceiving & concerning about peers' behaviors

In terms of the perception of peers' behaviors, the participants answered that they have been more likely to notice their peers' risky behaviors rather than their own risky behaviors. The reasons could be that they have not behaved dangerously, they were incapable of knowing their behaviors, or they have an unconscious stigma, which could make one understate their drinking behavior (Waterton and Duffy, 1984). Also, this result shows that they have watched the

behaviors of their peers. This finding provides us the insight that peers could play a role in caring about each other when they are hanging out and drinking together.

Therefore, as college students value their social relationships and care about their peers' behaviors, this attitude would facilitate their support for friends. Our results from the user study show that most of the participants were not uncomfortable when they shared their device and BAC information with their friends and family members when they were drinking together. Also, they are more willing to share BAC information with close friends and family members for safety reasons. Although the peer-based support among AA members is more carefully dealt with because of strong concerns about stigma and safety (Rubya and Yarosh, 2017; Yarosh, 2013), there can be a different type of peer-based support for college students who are building drinking habits with their peers. There is a design opportunity to create a peer-support system to facilitate safer drinking behaviors. For example, if a user's BAC level is higher than the user's typical average level, the app could send notifications to authorized friends or family members who are registered on the app (Min et al., 2018). Our design proposal of the reliable contact list can implement this function via the app. If the user's BAC level is higher than 0.08, a message is sent to the people on the preset list to ask them for help. In addition to the reliable list, this peer-support system could be improved to generate tailored notification messages based on the distance between the user and the registered person. For example, if the user is intoxicated at a bar, a family member who is at home might receive information about the bar, such as phone number and location, while a friend who is at the same bar or nearby might receive an alert with information about immediate solutions to help lower her/his friend's BAC level.

6.1.3. Extending support network

In addition to the peer support network, this support network might need to be extended. Considering the feedback at the design evaluation session, it is possible that a student and all of her/his peers can be drunk late at night. In this case, it could be difficult to get support from their close friends and family. Thus, the system might need to consider a larger support network that includes a certified person who can be responsible for the caring of the students. For instance, this person can be a bartender or staff member at a restaurant/bar, and they can get a notification that ask them to help the students not drink too much. However, there should be issues of privacy and safety. Regarding this, the system could be designed to share temporal information with a certified person at a restaurant/bar, and expire it after a reasonable time frame.

6.2. Personalization & contextualization

6.2.1. Different awareness & understanding of drinking

Our survey and interviews reveal that the participants showed a lack of knowledge or perception of their drinking behaviors as well as legal limits. This lack of understanding has coincided with the purpose of SBI, which is utilized to raise an individual's awareness of their drinking behaviors and knowledge about the risks of excessive alcohol consumption (Community Preventive Services Task Force, 2013). Moreover, only about half of the participants received education about alcohol consumption. As the education on the risks of drinking could be associated with college students' perceptions of drinking norms and their own alcohol-related risk (Perkins et al., 2005), it is crucial to provide appropriate knowledge about excessive alcohol consumption and its risks. Therefore, the future system should provide scaffolding mechanisms that are personalized based on a user's current level of understanding of alcohol consumption that includes risks and negative results of excessive drinking, and meaning of each BAC level and Driving Under the Influence (DUI).

Our interview results from the user study showed that gender could be influencing an individual's perceived safety or risks of alcohol consumption. The system should be customized based not only on a social group but also on gender differences in an individual's network. Current studies revealed that there are gender differences in drinking behaviors in Greek organizations (Brown-Rice and Furr, 2015; Brown-Rice et al., 2015). Social norm interventions on alcohol consumption also should be altered depending on gender (Lewis and Neighbors, 2004). Further research should consider gender differences and Greek life, and focus on what aspects of the social support system should be prioritized.

6.2.2. Different physical & cognitive capabilities

Each person has a unique body composition, mental status, preference to certain things, and personality. Each individual could possess a different tolerance level to alcohol. Although BAC level is an objective measure, people can feel very differently at the same BAC level (Min et al., 2018). This means that the some users might not trust the BAC level on the app because they might feel that the app does not precisely indicate their risk level. This difference could be inferred from their AUDIT scores. Some participants who have low AUDIT scores could be more sensitive to the effects of alcohol compared to those with high AUDIT scores, and the app could allow the users to adjust the BAC level threshold based on their own personal preferences (up to the regional legal limit).

Additionally, it would be important to consider a one's cognitive status when she or he is drinking. If she or he is highly intoxicated, they may find it difficult to use a device or see a screen on a smartphone because of their low cognitive ability. In this sense, technology should be contextualized with a user's cognitive status and provide proper interventions to prevent more risky situations. For example, if the device could notice a user's level of intoxication or the number of drinks they consume, it could stimulate users with haptic technology to check their level of intoxication such as BAC level, or the app could show more intuitive graphics to make them realize their state. Regarding the method to measure one's drinking status, current research has examined the smartphone sensors that detect how much alcohol a user has consumed (Bae et al., 2018; 2017) or how much a user has been drunk (Mariakakis et al., 2018). Our design proposal is one possible solution that reflects this aspect to deliver the user's BAC result more intuitively. Depending on the level of BAC, the screen shows different colors and images. If the user's BAC level is over 0.08, the red color and icon could intuitively warn the user not to drive.

Future technology should provide personalized and contextualized functions, information and feedback based on their physical and cognitive conditions, drinking environments, etc. to effectively encourage safe drinking. This should carefully consider people who are more prone to consume alcohol regularly or frequently due to a higher possibility of risky behaviors.

6.3. Active self-reflecting rather than passive tracking

In the user study, most of the participants said they are not concerned about their accumulated records, but more worried about if they drank too much at that moment when they checked their BAC levels. We assume this is because our target population is young college students who are not yet problematic drinkers, and they do not perceive themselves as recovering alcoholics. Thus, they are not concerned about accumulated information about their drinking, and they aim to prevent them from becoming drinkers with harmful drinking behaviors down the road.

Activity trackers, such as FitBit, promote one's self-reflection by recording user activities automatically. Even though there is a gap of time between the moment of data collection and the moment the user checks, users usually look and check the data after their activity. For example, a Fitbit user usually tracks the number of steps at the end of the day, instead of checking their steps in real-time. Many alcohol-related apps rely on more passive self-reporting, similar to the function of

a diary or a survey-based questionnaire (Mariakakis et al., 2018; Zheng et al., 2017). However, the passive tracking aspect might not be the best method for preventive technologies that aim to encourage college students to have responsible drinking behaviors. To be safer, it should more actively promote the user's self-reflection. It should be more intrusive, and it would be more beneficial for the user to monitor their amount of drinking or the level of intoxication in real-time. In this sense, the technology should focus more on the function of active monitoring to give them immediate stimulation rather than the passive tracking such as a diary to reflect upon. Our design proposal includes checking a user's status, and we plan one of the designs that consider the user's active monitoring and their self-reflection of their alcohol consumption. The automatic notifications, which keep asking the user to input their plan for drinking and returning home, and to use the breathalyzer, could make the user continuously recognize possible excessive drinking and risky behaviors.

On the other hand, it could be expected that there might be issues with motivating participants to actively use the technology. Even though the activity tracker is a relatively passive technology, users might not use it continuously because of issues of remembering, design, data management, etc. (Shih et al., 2015). Also, depending on personal characteristics, users may have different styles of using the tracker (Rooksby et al., 2014). This means that the technology as an active monitoring tool can be challenged by personal motivations to use it. College students might have diverse personalities and social contexts while they are drinking and using technology. Therefore, further research should identify various types of college students and discuss what factors could motivate each college students to use it actively and continuously.

6.4. Enjoy stopping drinking

Optimistically, we saw that the participants of the user study and their friends and family members enjoyed using the device and had positive attitudes toward it. We assume that "fun" could be a crucial factor in motivating young college students to use the breathalyzer. However, fun factors of the drinking-related device and app could also negatively influence young college students. Even though it might be designed to help college students to monitor their levels of intoxication, some people could consider it a competitive game and drink more to "win" (Gajecki et al., 2014). Our participants in the design evaluation also addressed their concerns about adverse consequences of gamified functions. Thus, the way to offer effective internal and external rewards should be carefully considered to prevent users from exploiting the reward system. Gamified factors should thus be carefully dealt with when the goal of the design is not only for entertainment. Without providing another factor for enjoyment, it would be difficult to make college students lose their enjoyment of drinking. Some people who love to drink might not feel a need to reduce their drinking and want to be drunk even though they know the risks of excessive alcohol consumption.

Further research should consider how to offset one's enjoyment of drinking by providing enjoyment of stopping drinking through preventive technology. For example, rather than displaying the level of BAC, it would be better to show changes in other aspects that might be influenced by drinking, such as GPA or a body condition, such as weight. External rewards could be considered as well as internal rewards in one's mind. For instance, participants could have the option to collect external rewards when they stop drinking.

6.5. Limitations

Our research has a few limitations. The user study was conducted with a relatively small sample size (24 students) and the short usage period (two weeks). The issues from the participants could not be generalized because we could not cover all types of backgrounds. For instance, we did not specifically investigate Fraternity or Sorority members. If our study were to focus on this population, there might be different issues and insights for future technological interventions. Future research could focus on specific populations such as Greek organizations or freshmen, along with the role gender differences play in drinking culture and behaviors.

Also, we could not test our prototype with college students. Even though we reflected ideas and feedback from the surveys and interviews, we could not deploy the prototype because of a lack of resources. Our future research should have a plan to conduct a deployment study to receive feedback to improve the current prototype.

Another limitation is that we did not utilize devices such as wearable devices. When we conducted the user study, wearable devices to detect BAC level had not yet been released. Even though we did not utilize it, our study provides implications for future designs of technological interventions that could prevent college students from risky drinking. Future research could design wearable devices for technological interventions and explore different user experience and effectiveness.

7. Conclusion

This research explored current drinking contexts of college students and suggested design insights for future technological interventions that could encourage safe and responsible drinking behaviors in this population. We conducted surveys, interviews, a two-week user study with a personal breathalyzer, and an iterative design process with users testing a proposed design idea.

Our study contributes to the understanding of current college students in terms of their alcohol consumption practices, attitudes, and perceptions of their own and peers' drinking. Also, we could explore how the user considered and experienced the smart breathalyzer, which has been understudied in the perspectives of HCI and technology design for supporting healthier lifestyles. Through several surveys and interviews, we confirmed that college students' social relationships and contexts have influenced their drinking behaviors and practices. As their social bond is strong, they care about each other when they are drinking. Opposite to our expectation, students enjoy using the smart breathalyzer and its app for their health and safety. They are open to sharing their alcohol-related information to the close people in their network for their safety. On the other hand, they are not much worried about the potential stigma that is related to breathalyzer use in public. We also identified that college students have a lack of understanding of their capabilities and knowledge of excessive alcohol consumption. Based on our findings, we extracted encouraging insights to continue designing effective technology for young college students. We suggest four main insights on roles of future mobile technology including personal breathalyzers— (1) establishing a social support system for safety by connecting the students to others within their trusted social network, (2) providing personalized and contextualized functions, (3) focusing on active and live self-reflecting, and (4) balancing enjoyable factors.

Future research should consider additional issues that we have mentioned and how to utilize more effective and beneficial technology to encourage safer drinking behavior for college students on a longer-term perspective. Our study was limited to a personal smart breathalyzer, but other new technologies, such as wearable devices, also have a lot of yet-to-be explored and untapped potential. Based on our findings, insights, and limitations, we plan to explore more specific social contexts, to deploy our prototype, and to examine the systems' impacts on safer and more responsible alcohol consumption and environments for college students.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to

influence the work reported in this paper.

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