Piloting the Alcohol Feedback, Reflection, and Morning Evaluation (A-FRAME) Program: A Smartphone-delivered Alcohol Intervention

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Abstract

Many college students engage in heavy drinking and experience negative consequences, but typically show little motivation to change their drinking behavior. Although personalized feedback interventions (PFIs) show promise, improved effect sizes, engagement, and potential for reach are needed. We developed and pilot-tested a theory-based, smartphone-delivered PFI for heavy-drinking college students that incorporated innovations, including a choice of feedback delivered in multiple doses that occur close in time to drinking events. In an open trial, we delivered the 4-week intervention to 18 heavy-drinking students, followed by individual interviews of participants' experience. Feasibility was demonstrated by high enrollment and response rates, and acceptability was demonstrated by positive participant ratings and interview responses. Results will inform efforts to continue to develop this novel and scalable mobile intervention for alcohol misuse among college students, with potential impact for the public health problem of high-risk drinking.

1. Introduction

The highest rates of drinking, heavy drinking, and alcohol use disorders occur among young adults (ages 18-29) relative to other age groups [1]. Those in college are at higher risk for heavy drinking compared to same-age, non-college peers [2] and experience a range of negative alcohol-related consequences, including memory loss, sexual assault, and injuries [3]. Heavy-drinking students typically show little motivation to change and continue to drink heavily in spite of negative consequences [4], and some will later progress to alcohol use disorders [5, 6]. As such, continued development of efficacious interventions is essential. The goal of the present study was to test the feasibility and acceptability of a mobile-delivered personalized feedback intervention (PFI) for heavy-drinking college students delivered the morning after drinking events.

The transtheoretical model (TTM) [7,8] highlights five stages through which individuals move with respect to changing behavior: Precontemplation (not thinking about change), Contemplation (aware of both pros and cons of drinking, ambivalent about change), Preparation (taking initial steps to change), Action (making change), and Maintenance (sustaining change). As most (67%) heavy drinking college students are in Precontemplation [9], one important goal of intervention is to move them toward later stages. Progression through early stages may occur via several processes, such as consciousness-raising (gathering new information), self-evaluation (considering consequences of the behavior to self), environmental evaluation (considering consequences to others), and social liberation (attending to social norms). The TTM also highlights changes in decisional balance (considering pros and cons of change) as an important marker of motivation. Interventions grounded in the TTM have used personalized feedback to promote these cognitive-affective processes.

Indeed, the most common and effective interventions used for college student drinkers provide brief personalized feedback on behavior (i.e., presentation of information derived from a recent assessment of the individual) [10, 11]. Feedback typically focuses on alcohol use levels, consequences, and norms for drinking. Personalized feedback is an effective behavior change technique because it engages several hypothesized mechanisms of change: enhancing motivation; increasing engagement with intervention content; changing attitudes/beliefs; presenting social norms; and providing information about risks, protective factors, and skills [12].

However, PFIs are not sought out or readily available to many individuals who may benefit from them [13], suggesting a need for improvement in reach and engagement. Even when utilized, effect sizes on alcohol use and consequences are small-to-medium [14,

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15], and short-term changes are not always maintained [15]. Possible explanations are that PFIs are typically delivered in a single dose [16], occur distal in time to actual drinking events, and provide feedback on broad patterns of behavior (e.g., drinks per week) rather than recent drinking episodes. These shortcomings suggest opportunities for future intervention development.

Advantages of web-based interventions include that they are convenient, private, easily disseminated, and preferred over in-person interventions by heavy-drinking college students [17, 18]. With promise of even greater convenience and dissemination, recent efforts use mobile phone technology for delivery. In the United States, 97% of young adults have smartphones [19], so this mode of intervention delivery fits well.

To date, a paucity of interventions have used mobile delivery of personalized feedback to target drinking behavior in young adults. Three mobile-delivered PFIs tested in randomized controlled trials (RCTs) have shown some promise. The first was delivered to heavy-drinking students, and involved assessment of past-week daily alcohol consumption, brief feedback and guidelines for hazardous drinking, and a relapse prevention skills training menu [20]. A second PFI targeted heavy drinking young adult emergency department patients, a version of which has been tested in three separate RCTs. This intervention includes goal selection and tailored personalized feedback based on brief surveys sent via text [21-23]. A third PFI [24] delivered via app over 2 weeks provided daily messages supportive of drinking reduction, normative feedback, and a blood alcohol concentration (BAC) calculator. Together, five RCTS on these three PFIs support the efficacy of mobile-delivered interventions incorporating personalized feedback, goal setting, and skills. However, results from these studies were mixed and only short-term effects were found, so further research is needed to develop interventions that can effectively reduce and maintain reductions in both alcohol use and consequences in young adults using a mobile platform. Only one of these interventions [24] incorporated personalized *normative* feedback (known to be an active ingredient). Only one other [21-23, 25] incorporated goal-setting; however, goals were provided *to* participants, rather than allowing participants to dictate their own goals, inconsistent with the theoretical importance of emphasizing choice and autonomy [26]. Importantly, only one RCT [25] tested effects of intervention relative to an intensive assessment control condition, leaving it unclear in the other studies as to whether changes observed were due to self-monitoring rather than the PFI. Finally, none of the interventions fully realized the potential of using daily, event-specific data to craft feedback reports, and none capitalized on the morning after drinking as an optimal time to deliver PFI.

The first thing most young adults (80%) do each morning is reach for their phone [27], suggesting the potential feasibility of intervention delivery at this time and through this mode. Further, students view the negative consequences of their drinking (e.g., hangover, blackouts) most negatively the next morning [28, 29] and may therefore be most motivated to change at that time. An intervention delivered when consequences are most salient may enhance motivation to change leading to reductions in risky drinking. This is consistent with the just-in-time intervention [30] concept of providing intervention when an individual is particularly receptive to re-evaluation of their behavior.

Intensive longitudinal data collection provides excellent opportunities for personalized and recent event-based links between behavior and its outcomes. For example, feedback using data collected at the event level can demonstrate that certain levels of alcohol use increased the likelihood of unwanted outcomes (e.g., hangover), whereas lower-level drinking events or those where protective strategies (e.g., drinking slowly) were used did not. Given within-person, day-to-day variability in alcohol use, consequences, and protective behavioral strategies (PBS), event-level data on drinking and outcomes provides an extraordinarily rich source of information to create innovative PFIs.

Guided by the TTM [7,8], we began to develop a mobile-delivered PFI for heavy-drinking college students, that relies on several intervention strategies (e.g., consciousness-raising, developing discrepancy) to target mechanisms of change (normative perceptions, PBS, motivation to change), in order to ultimately impact target behaviors (alcohol use, consequences). Our PFI has the following innovations: (a) delivery in multiple doses (b) at times when alcohol-related cognitions may be most salient and susceptible to modification (i.e., morning), (c) feedback that more closely links to recent drinking events, and (d) providing choice of what type of feedback one receives. The intervention, titled A-FRAME (Alcohol Feedback, Reflection and Morning Evaluation), was designed to provide feedback in six topic areas (see Methods). In earlier stages of development, focus groups (n = 15 heavy-drinking college students, 53% women) were used to gain end-user input on our intervention plan and prototypical feedback reports. At this stage, we found evidence that students liked the overall intervention idea, and participant suggestions were used to further refine the intervention protocol in order to address the present study aims.

The first aim of the present study was to examine feasibility of implementing the A-FRAME intervention

in an open pilot trial with a new sample of students. The following benchmarks for establishing feasibility were pre-specified: (1) targeted enrollment of 18 participants will be met, (2) 80% of eligible participants will consent, (3) 80% response rate to daily surveys, and (4) all intervention content will be delivered as planned. The second aim of this study was to determine intervention acceptability. The following benchmarks for establishing acceptability were pre-specified: (1) follow-up survey ratings of acceptability of the overall program will average between 3 and 5 (on a 5-point scale, from 1 to 5), and (2) no more than 10% of participants will withdraw. We also sought to gain a more complete understanding of participant preferences via post-intervention qualitative interviews.

2. Methods

2.1. Participants

Inclusion criteria were (a) age 18-25, (b) university undergraduate student, (c) weekly heavy episodic drinking (HED; 4+[women] / 5+[men] drinks) over the past month, (d) at least one past-month negative consequence (of 10 commonly endorsed items) and (e) smartphone ownership and daily use. Exclusion criteria included (a) currently in treatment for a substance use disorder and (b) participation in the earlier (focus group) phase of the study. A total of 18 participants (56% women) were recruited.

2.2. Procedures

All procedures were approved by an Institutional Review Board. Participants were recruited using flyers around campus and advertisements in the university's morning e-mail. Interested participants completed an online screener. Those eligible attended an orientation session conducted via Zoom videoconferencing and indicated informed consent via an online form. Risks of participation were described in the study consent form, and included potential discomfort answering questions about or receiving feedback on one's drinking, potential breach of confidentiality, reactivity (i.e., increased drinking), and sanction due to responding to surveys during class or work. Participants were informed that they could exit out of surveys or withdraw from the study at any time, that drinking was not required to participate, and that we take several steps to protect their confidentiality. Next, they completed a baseline survey on demographics and past-month drinking behavior and practiced with daily feedback reports with support from research staff. Participants received a $25 electronic gift card to an online vendor for completing the session.

Surveys and feedback reports were administered daily for 28 days, with all participants starting on the same Monday. We used Qualtrics (a web-based survey system) to both collect and translate survey data into immediate feedback reports. Each day at 7am, a text message was sent to the participant's mobile phone with a link to the online survey, which participants were instructed to complete directly via their mobile phone using WiFi or their data plan. If not completed by noon, a reminder text message was sent. Participants were instructed to complete the survey as soon as they woke up and by 2pm; the survey was no longer available after 5pm. Entry into the survey required the participant's unique ID number and password combination. Upon submitting the final response of a given daily survey, if prior day drinking was endorsed, the survey seamlessly transitioned into the participant's personalized feedback report. As such, participants could view the feedback immediately from their mobile phone. Feedback drew on data collected by the Qualtrics survey at daily assessments and was sometimes integrated with baseline data. Participants were compensated based on their weekly compliance with these surveys, earning $25 per week for completion of all 7, $15 for 5-6, $10 for 3-4, and $5 for 1-2. Those completing all 28 surveys were entered into a raffle for an additional $100.

At the completion of the 28-day intervention, participants completed a brief survey on intervention acceptability and a 45-minute individual interview via videoconference. For completing the interview, participants were entered into a $100 raffle.

2.2.1. Intervention. Each feedback report began with a summary of drinks consumed relative to one's drinking goal established in the baseline assessment. Next, participants chose one topic for further feedback. Topics included: (1) BAC (calculation of estimated BAC from the prior night, information on factors that influence BAC, effects corresponding to estimated BAC in the typical drinker); (2) high-risk behaviors (information on the risk of pregaming, drinking games, shots, and simultaneous alcohol and marijuana use); (3) personalized normative feedback (comparison of last night's drinking to peer norms); (4) consequences (contrasting those reported the night before with consequences the participant indicated at baseline they would like to avoid); and (5) PBS; behavioral strategies for use before or during a drinking event to limit drinking or related harms). See Figure 1 for examples.

2.3. Measures

2.3.1. Baseline measures used to describe sample. Participants self-reported demographics. Standard drink

definitions were presented and past 30-day alcohol use was assessed with single items on both typical and peak drinks per drinking day (and hours over which consumed), and number of HED days (4+ standard drinks women/5+ men). Participants completed a weekly grid [31] of number of standard drinks and hours of consumption for each day in typical week.

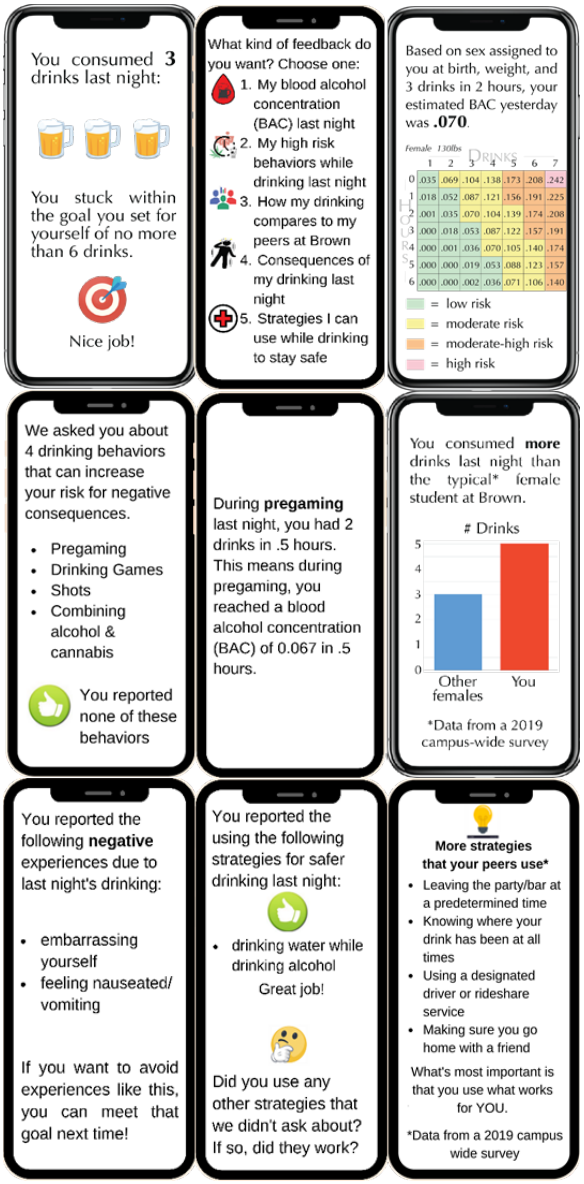

Figure 1. Example Personalized Feedback

2.3.2. Baseline measures for intervention input. Weight and sex were collected at baseline in order to calculate estimated BACs both at baseline (for typical and peak drinking) and from daily data. Prior to setting a drinking goal, participants were given National Institute of Alcohol Abuse and Alcoholism guidelines for "low-risk drinking" for both single day (<4 drinks women, <5 men) and weekly limits (< 7 women, <14 men). Next, using participant data, they were presented with the text, "On a typical week, the number of drinks you consume when you drink ranges from ____ to ___", followed by, "Please set a goal for your drinking over the next few months. Over the next few months, my goal is to consume no more than ____drinks on a day that I drink." Next, participants indicated which of a list of consequences they wished to avoid over the next 30 days. These included: embarrassing self, becoming rude/obnoxious, hurting/ injuring self by accident, feeling nauseated/vomiting, behaving aggressively, neglecting school-related obligations, having a romantic/sexual experience that I later regret, forgetting what I said or did, and hangover [32].

Finally, a list of strategies was displayed, and students indicated which they found useful in the past for limiting alcohol use or consequences. Strategies included determining in advance not to exceed a set number of drinks, alternating alcoholic and nonalcoholic drinks, asking a friend to let you know when you've had enough, drinking water while drinking alcohol, stopping at a predetermined time**,** choosing not to play drinking games, choosing not to take shots of liquor, avoiding mixing different types of alcohol, drinking slowly**,** avoiding trying to keep up with or out-drink others**,** and eating before or while drinking.

2.3.3. Daily measures. Each day, participants reported whether or not they used alcohol the day before. For drinking days, participants reported the number of standard drinks and the total time over which those drinks were consumed. Additionally, they reported whether they participated in high-risk behaviors, which included: pregaming ("did you drink before going to a main social event?"), playing drinking games, consuming shots, and using cannabis. If participants endorsed pregaming, they reported the number of drinks and time period over which they were consumed during pregaming. If participants endorsed cannabis use, they reported whether or not they were under the influence of cannabis and alcohol at the same time. Next, lists of strategies and consequences (identical to baseline) were presented, and participants were asked to report whether any applied to the night prior. For each consequence endorsed, participants rated their experience on a 7-point Likert scale (-3 = "extremely negative", 0 = "neutral", +3 = "extremely positive"). Immediately after submitting their survey, the PFI was delivered.

2.3.4. Follow-up measures and interview. Intervention acceptability was assessed with items used in our prior work [33], asking how acceptable, convenient, interesting, informative, and relevant the intervention was overall, with each assessed on a 5-point

scale from "not at all" (1) to "very" (5). Participants were also asked to rate how interesting and relevant each of the six feedback topic areas were, using the same scale. Following a semi-structured agenda, interviews began with broad questions about what participants liked and disliked. Several questions then assessed the acceptability of specific program features, including topic choice, goal-setting, and compensation. The interviewer used the unique feedback reports that were delivered to each participant to get direct feedback from participants on what they viewed during the trial.

3. Results

3.1. Drinking descriptives

Table 1. Baseline and Daily Survey Descriptives

	n/% or Mean (*SD*)
Age	20.17 (1.20)
Biological Sex	
Male	8 (44%)
Female	10 (56%)
Gender Identity	
Male only	8 (44%)
Female only	8 (44%)
Non-binary/Genderqueer	2 (12%)
Year in School	
First year	4 (22%)
Sophomore	5 (28%)
Junior	4 (22%)
Senior	5 (28%)
Race/Ethnicity	
White	12 (67%)
Asian	5 (28%)
Hispanic/Latino	1 (6%)
Baseline Drinking Behavior	
Average drinks on typical day	5.08 (1.83)
eBAC on typical day	.10 (.06)
Peak drinks on typical day	9.31 (2.87)
eBAC on peak day	.21 (.08)
Total drinks on a typical week	15.44 (7.20)
HED days in past 30 days	6.56 (3.18)
Max Drink Goal	5.17 (2.12)
Daily Survey Drinking Behavior	
Drinking days (of 28)	9.39 (6.10)
Drinks per drinking day	2.34 (1.59)
eBAC	.03 (.03)
Drinking days with any cons	34 (20%)

Note: HED = heavy episodic drinking (4+ drinks for women, 5+ for men); eBAC = estimated blood alcohol concentration; cons = consequences

Descriptive data from baseline and daily surveys are shown in Table 1. On daily surveys, we observed a total of 169 drinking events, representing 34% of all days assessed. All participants set a goal for max drinks per event that was lower than their personal peak drinks reported at baseline, which was supportive of harm reduction. Goals were met on 94% of drinking days, and 78% of participants met their goal on all drinking days.

3.2. Feasibility and acceptability benchmarks

All feasibility benchmarks were met. We recruited our target sample of 18 within 12 days, over which 219 people screened and 43 (20%) were eligible. All but one of 19 participants scheduled for orientation attended, and all 18 attendees consented. Compliance with daily surveys was 99% across the 28 days (499 out of 504 possible), and 89% of participants (n=16) completed all 28. Average time of completion was 9:47 am, supporting feasibility of morning assessment. Additionally, feedback reports were delivered on all self-reported drinking days. Surveys took less than one minute, and the combination of the survey and PFI took an average of 2.5 minutes following drinking days.

Table 2. Overall intervention and topic area acceptability ratings

	M	*SD*
Overall acceptability	4.89	0.32
Overall convenience	4.17	0.71
Overall interesting	3.28	0.96
Overall informative	3.56	1.04
Overall relevant	3.44	1.10
Would recommend	3.67	0.91
Interesting		
Drinks vs goal	3.06	1.11
BAC	4.35	0.79
High-risk behaviors	3.50	1.41
Peer norms	4.12	0.93
Consequences	3.11	1.36
Strategies	3.86	1.22
Relevant		
Drinks vs goal	3.33	0.84
BAC	3.94	0.83
High risk behaviors	2.87	1.46
Peer norms	3.59	1.12
Consequences	2.89	1.36
Strategies	3.71	0.76

Note: All scales from 1-5; Overall program and drinks: n=18; BAC: n=17; High-risk: n=8; Norms: n=17; Consequences: n=9; Strategies: n=7

On average, participants found the intervention to be very acceptable. Ratings for the overall intervention and acceptability and relevance of each feedback topic are presented in Table 2. We met our first acceptability benchmark for ratings falling between 3 and 5 on average. For overall acceptability, the program was rated "5" and "4" by 89% and 11% of the participants, respectively. No participant asked to withdraw from the study, and all completed the full set of procedures, meeting our second acceptability benchmark.

3.3. Topic choice

All participants received feedback on how the number of drinks reported compared to their goal, and then they were instructed to choose at least one additional topic on which to receive feedback. However, due to a programming error, one participant bypassed this option after eight drinking occasions, and two additional participants did so on one occasion each (n=10 days; 6%). The modal number of topics selected was 1 (n=147 days; 87%). The percentage of participants who chose each topic at least once were: 100% for norms, 94% for BAC, 61% for consequences, 56% for strategies, and 50% for high-risk behaviors. The percentage of drinking events on which each topic was chosen were 38% for BAC, 25% for norms, 15% for consequences, 12% for strategies and 11% for high-risk behaviors. Consistent with these survey results, in interviews, participants described strongest interest in the BAC and peer norms feedback. Participants were less interested in viewing or repeatedly viewing consequences and risk behaviors.

3.4. Positive feedback on the prototype

Interviews revealed that participants were very satisfied with the compensation ($25/week for all 7 surveys), and 100% noted that they would continue to participate for much longer if asked. They agreed that morning was the best time to complete the daily surveys, and that the receipt of immediate feedback (rather than at some point later that day) was ideal. When asked a general, introductory question on what they liked about the prototype, spontaneous responses included: ease of surveys and the routine nature of completing them daily; non-judgmental nature of feedback; ability to self-monitor, self-reflect, and raise awareness; provision of interesting information; goal-setting and positive reinforcement for achieving goals; the element of topic choice; and personalization (Table 3). Due to the potential that feedback the morning after drinking events could result in negative emotions (e.g., shame), we queried emotional reactions to the feedback. A couple of participants saw the potential that this could occur, but typically participants described more simply feeling neutral, surprised, and/or curious.

3.5. Suggestions for improvement

Participants were also asked what they did not like about the prototype and for suggestions for improvement (Table 4). Here we learned that they wanted more topic choices and reduced redundancy in the feedback reports. They found the recapping of survey responses (e.g., "you used these strategies last night") much less useful than any calculations/expanded feedback provided (e.g., BAC based on drinks, hours, sex and weight). Although participants noted the value of daily feedback (e.g., "*getting the option to see it daily was good because you don't know when you would want to know about your drinking the previous night*", ID1007; Male), providing aggregate/trend data was an was an additional suggestion that was repeatedly identified as of interest by participants. Finally, participants were asked whether the program should allow a user to change their goal, and most noted that this might be a valuable feature to add. Though not described in detail here, we received numerous suggestions for how to improve the feedback formatting, wording, and visual appeal, each of which will be taken into consideration in the next iteration.

3.6. Additional topic options

Participants were asked about interest in a range of additional feedback topic choices not included in this iteration. Due to time constraints, not all participants received these interview questions. Of those asked, 100% were interested in feedback on caloric intake (13/13), sleep (15/15), and spending (14/14); 93% (13/14) were interested in mood; 75% (6/8) were interested in peer consequence norms, and 50% (5/10) were interested in peer approval of drinking behaviors.

4. Discussion

Few interventions have been designed to provide personalized feedback to heavy-drinking college students via mobile phone, and none have capitalized on the use of daily data to inform event-level feedback. Our goal was to provide initial evidence that such an approach would be feasible and acceptable. Across several benchmarks, we found support for this novel mobile intervention involving daily assessment and personalized feedback.

Table 3. Aspects of the prototype intervention participants liked

Aspect	Representative Quotes
Ease	I definitely liked how convenient it was. Having a link texted to me every morning was very helpful. (ID1012; Male)
Routine	I liked this survey popping into my message every morning. I'd do it, would get my day going – I got one thing done and so let's keep going – it was a nice way of starting the day. (ID1005; Male)
Non-judgmental	I felt like it was pretty non-judgmental (ID1018; Female)
Self-reflection	I generally enjoyed the time for a little reflection and thinking about my drinking habits. (ID1017; Gender-fluid Female)
Interesting	It was really interesting to go through. I thought I wouldn't be interested and would feel repetitive with all the other alcohol studies and training I'd done, but I found it to be really interactive. (ID1002; Female)
Goal-setting	I really liked setting the goal at the beginning – if someone is using the daily reports to meet a certain goal, it can be very beneficial. (ID1013; Male)
Topic choice	I liked the option to choose a lot. It put me more in control about what I am learning about my decisions. (ID1001; Female)
Personalization	It's personalized and takes into account your own answers and responds to you accordingly, so I think it's a great resource to have. (ID1014; Male)

Table 4. Suggestions for improving the intervention

Suggestion	Representative Quotes
Add more topic choices	The options were the most important part so I would like to see more of them. (ID1007; Male)
Reduce redundancy	Some of [the feedback] was identical every time and that could be because my responses on those days were the same but sometimes I wished there was a "learn more" link where I could go deeper into a topic. (ID1006; Non-binary Female)
Don't just recap survey answers	I think it's cool that you can stay accountable and recognize what happened, but seeing the behaviors you put into the survey isn't providing any additional information. (ID1013; Male)
Provide trend/aggregate data	I just wish I didn't have to analyze the trends myself – not that I minded but it would have been more helpful if the study noticed that you tend to have these negative things associated with higher number of drinks. (ID1016; Female)
	If the survey is designed for long-term participation, seeing more cumulative weekly or biweekly patterns would be good. I am curious about what long-term health impacts this kind of drinking has. (ID1010; Male)
Allow goal changes or separate weekday and weekend goal-setting	If you started a new medication that lowered tolerance for example, you may want to lower your goal. If you include an option to change goal, allow for it only once a month and request the user provide a reason. (ID1002; Female)
	Depending on the situation, your goal could change. In school, your goal might even vary between weekdays and weekends. I probably would have set my weekday goal to maybe 2, and weekend goal to 4-5. (ID1015; Female)

Supporting feasibility, we quickly recruited our target sample size, and the intervention was delivered on all self-reported drinking days. Further, compliance with the daily reports was exceptional (99%). In order for feedback reports to be delivered, completion of each report is necessary. As such, it will be important to maintain the brevity of these surveys and the ability to complete them at a time that is convenient for users. Of note, as participants in this study were paid up to $25/week for completing the daily reports, so it will be important to examine compliance in the absence of monetary compensation in future work.

Ratings on the extent to which the A-FRAME intervention was acceptable, convenient, and informative show promise for continued development of this platform. Morning reports were completed on nearly all days with no adverse effects. Participants appreciated several specific features of the intervention, such as the ease and routine of engaging with the platform each morning, provision of feedback that was informative and allowed for self-reflection, ability to set

and track one's own goals, positive reinforcement, and the ability to choose which areas were most of interest for each feedback report. Each of these features of A-FRAME will be retained and/or further maximized during ongoing development.

Participants also had several recommendations for modifications to the intervention. They were interested in having even more topic choices, with particular interest in how mood, sleep, spending, and caloric intake may each relate to drinking behavior. Additionally, they endorsed the potential value of allowing users to change their goal throughout the program. Most notably, participants desired less "recapping" of survey responses, and more data interpretation and aggregation.

Based on this feedback, the next iteration of A-FRAME will include additional feedback topics and will allow users to change goals during intervention. These additional elements of choice will be consistent with theories of motivation and intervention tailoring by supporting autonomy and self-determination [34]. Additionally, in future steps, we will explore exactly what data points should be aggregated, over what time frames (e.g., weekly, monthly), and how this information would best be presented to users.

Though not initially conceptualized in this way, the A-FRAME intervention is a type of behavior change support system [35]. More specifically, it may be described as a persuasive technology – interactive information technology with the goal of changing or shaping one's attitudes or behavior without using coercion or deception [36, 37]. The Persuasive Systems Design model [38] suggests the importance of three phases of development: (I) understanding fundamental issues behind persuasive systems, (II) analyzing the context for persuasive systems (e.g., recognizing the intent), and (III) designing and evaluating the actual system qualities.

Within Phase I, several key postulates behind persuasive systems have been described [38], and here we reflect on the extent to which our work is in line with these postulates. One postulate is that people like their views about the world to be organized and consistent, and systems that support making commitments may result in more effective persuasion. Our efforts to (a) allow users to set their own goals and (b) highlight inconsistencies in perceived versus actual norms both were in line with this postulate. Our future plan to allow users to change their goals throughout use of the system is in line with ideals that persuasive systems involve a process rather than an act, and should be able to adapt to changes in the user that occur during the process of persuasion. A third postulate implies that users are most interested in persuasive messages when they have high motivation and ability; our attempt to engage the user in the morning after drinking events (when motivation to change is assumed to be highest) fit with this postulate. A fifth postulate is that persuasion is incremental; we believe that the provision of feedback in small doses (by virtue of being asked to choose only a single feedback topic each time) aligns with this principle. Additional postulates suggest that the system should be unobtrusive, useful, and easy to use, and we received feedback from our users on how to improve in these areas.

With respect to Phase II, one thing we acknowledge regarding the intent of A-FRAME is that it was designed to prompt motivation to change among those who likely are not already considering change. As such, it will remain important that we, as the stakeholders, allow users to personalize their goals, and to emphasize voluntariness of attitude or behavior change [38, 39]. Phase III (design of system features) will be an ongoing process, particularly as we hope to ultimately transition from a text-message delivered "survey" to a more functional mobile application. As such, we will have many more opportunities to define the system requirements and ways in which those requirements should be implemented across several key design principles related to primary task support (e.g., tailoring, self-monitoring), dialogue support (e.g., praise, reminders), and credibility support (e.g., trustworthiness, verifiability) [39]. These efforts should ultimately maximize the persuasiveness of the A-FRAME intervention and therefore its impact on both alcohol use attitudes and behaviors.

4.1. Limitations

Several qualifications to our findings should be considered. First, the intervention tested in this study was a prototype version, programmed using commonly available survey software and without ideal formatting or interface. Participant feedback will be used to further refine the visual appeal of the intervention. Second, this pilot was conducted with students from a single university. Although this is appropriate at this early stage of intervention development in which we prioritized homogeneity of our sample, it will be important to determine whether pilot findings generalize to students from other universities. Further, not all participants received all follow-up interview questions, depending on which parts of the intervention they had viewed during the pilot.

It is also important to note that this pilot was conducted during the COVID-19 pandemic. Although participants were recruited both before and after being asked to depart campus, all study procedures (orientation, 28 days of surveys and feedback, and follow-up interviews) were conducted while students were engaged in remote learning only. Relative to other

surveys conducted on this campus, typical drinking patterns were not observed, which we attribute to the fact that many students moved home with parents and were engaged in social distancing from peer groups. Indeed, many participants noted that the feedback itself and the way they interacted with the intervention (e.g., topic choices) could have been quite different had they still been on campus. Due to the unique conditions under which this pilot took place, results may be biased. As such, additional pilot work with students who are under typical drinking conditions is needed.

4.2. Conclusions and future directions

We demonstrate initial evidence that a mobile-delivered PFI based on event-level data is feasible and acceptable to heavy-drinking students. As intervention development is not a linear but rather a recursive process, additional iterations of our initial prototype, based on feedback received in this study, should be piloted. Subsequently, the intervention will be tested in a randomized controlled pilot in which mobile PFI is compared to daily assessment only. Given the basis of our PFI in the Transtheoretical Model, the extent to which our PFI promotes movement through the stages of change will be measured, and continued attention will be paid to key concepts for behavior change support systems. Ultimately, this intervention could transition to a mobile app-based format, with the potential to reduce heavy drinking among college students.

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