Psychological distance intervention reminders reduce alcohol consumption frequency in daily life

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Citation Diversity Statement: Recent work in several fields has identified a bias in citation practices such that papers from women and other minority scholars are under-cited[1,2]. Here we sought to proactively consider choosing references that reflect the diversity of the field. First, we obtained the predicted gender of the first and last author of each reference by using databases that store the probability of a first name being carried by a woman[3,4]. By this measure (and excluding self-citations to the first and last authors of our current paper), our references contain 30% woman(first)/woman(last), 17% man/woman, 22% woman/man, and 31% man/man. This method is limited in that a) names, pronouns, and social media profiles used to construct the databases may not, in every case, be indicative of gender identity and b) it cannot account for intersex, non-binary, or transgender people. We look forward to future work that could help us to better understand how to support equitable practices in science.

Positionality Statement

Mindful that our identities can influence our approach to science, the authors wish to provide the reader with information about our backgrounds. With respect to gender, when the manuscript was drafted, nine authors self-identified as women, five as men, and one as non-binary. With respect to race, 13 authors self-identified as White, one as Asian, and one as Black.

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Abstract

Modifying behaviors, such as alcohol consumption, is difficult. Creating psychological distance between unhealthy triggers and one's present experience can encourage change. Using two multisite, randomized experiments, we examine whether theory-driven strategies to create psychological distance—mindfulness and perspective-taking—can change drinking behaviors among two samples of young adults without alcohol dependence via a 28-day smartphone intervention (Study 1, N = 108 participants, 5492 observations; Study 2, N=218 participants, 9994 observations). Study 2 presents a close replication with a fully remote delivery during the onset of the COVID-19 pandemic. During weeks when they received daily smartphone reminders, individuals in the psychological distance interventions drank less frequently than control weeks, and less than control participants. Intervention reminders reduced drinking frequency but did not impact amount. We find that smartphone-based mindfulness and perspective-taking interventions, aimed to create psychological distance, can change behavior. This approach requires frequent reminders, which can be delivered via smartphones.

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Behaviors like alcohol use, smoking, and unhealthy eating are leading contributors to preventable disease and morbidity[5]. Creating psychological distance[6] between unhealthy triggers and a person's present experience—temporally, spatially, or socially [7,8,9]—may be an effective way to change behavior[10]. For example, creating 'space' from alcohol[11], cigarette cues[12,13], and unhealthy foods[14], motivates healthier short-term choices in laboratory settings. Yet, in everyday life, unhealthy triggers are abundant[15–17]. What tools can help people to create distance from unhealthy triggers and pursue healthier options as they go about their lives? A growing body of research highlights the promise of smartphone-delivered health reminders[18]. Since smartphones are ubiquitous and often with people as they go about daily lives, they offer important opportunities to test how to effectively integrate theory-driven strategies from the laboratory into real-world settings[19]. Extending prior work, we focused on two popular psychological distancing strategies —mindfulness[20] and perspective-taking[21] to develop smartphone reminders. First, we designed theory-driven instructions that aim to create distance from alcohol cues. Then, we tested whether repeated reminders can change drinking behaviors in the everyday lives of young adults without alcohol dependence. Our study deployed two randomized experiments across two university sites: one shortly prior to and another during the onset of the COVID-19 pandemic.

Navigating many of today's leading public health challenges calls for behavior change within people's natural environments. One such important issue that affects individuals, communities and nations is alcohol use[5,22]. Across the globe, alcohol is the seventh leading risk factor of premature death and is a leading cause of premature death and disability for people aged 15-49 worldwide[23]. Alcohol harms individuals by increasing

behaviors that put people at risk for infectious and chronic diseases, as well as their communities through anti-social behavior, accidents, violence, and productivity losses[5]. Importantly, alcohol-related behaviors are not uniformly distributed across age; in the United States, alcohol use rates are some of the highest during the early twenties[24], and drinking is particularly pervasive on college campuses where 80% of students report consuming alcohol[25] as opposed to 64.8% in the general public [26]. Throughout the lifespan, drinking habits are most likely to develop in college [27] and continue to pose significant risks for alcohol dependence, cancer incidence and occupational problems a decade later [28,29]. Importantly, a growing body of work argues that even light and infrequent drinking can have substantive adverse effects on multiple areas of health, particularly cancers[30,31]. In response, recent work across 195 countries highlights a need to target light and moderate alcohol use to minimize harm[23]. Accordingly, research has sought to identify new preventative strategies to target young adults[32] and counter or divert the development of drinking habits. In this vein, we developed two interventions that use psychological strategies—mindfulness and perspective-taking—as two ways to create distance from alcohol cues and change drinking behavior in young adults without alcohol dependence.

The first popular strategy, mindfulness, involves creating space between a stimulus (e.g., an alcoholic drink) and a person's natural reaction to it[33]. Common mindfulness paradigms train individuals to take a step back and to accept their thoughts and feelings towards an unhealthy trigger without judgment or avoidance. Theoretically, taking a step back may re-orient attention away from reactive thought patterns and dissuade unhealthy choices, possibly by de-automatizing responses to triggers[20,34,35]. Meta-analyses suggest that mindfulness training can be a promising component of substance use interventions[36,37], for example in the context of alcohol use[38], tobacco use[39], and cannabis and opiate use[40,41], particularly among clinical populations and within laboratory contexts[42,43]. However, less

work has focused on non-clinical populations, such as healthy young adults, and within more ecologically valid contexts, such as throughout daily life. Among at-risk young adult drinkers, interventions that employ mindfulness have produced mixed effects at reducing drinking[44–48]. Some studies suggest that even a brief in-person mindfulness training can decrease short-term alcohol consumption[49,50]. Yet, others argue that a single shot mindfulness training is not sufficient to change drinking behaviors outside the laboratory and call for more frequent and higher intervention doses[48,51]. Overall, although distancing-based mindfulness strategies may be a promising path to improve health, more research is needed to examine how to effectively incorporate these strategies into the daily lives of young adults to possibly harness their preventative benefits[52].

The second strategy to create psychological distance involves perspective-taking[21], which is grounded in social learning theory[53]. Perspective-taking paradigms typically instruct individuals to imagine how a target person may think, feel, or behave in a given situation[54,55]. Imagining how a target individual would react, for example in response to an alcohol cue, can create distance by re-orienting attention away from a person's immediate reaction to a cue and towards a desired target's response. Separate bodies of work support this view. First, neuroimaging evidence suggests that adopting a target's perspective can shift neural responses to a stimulus to parallel the target's affective experience[56]. Second, behavioral work on modeling and social norms suggests that making salient viewpoints and habits of relevant health models, such as those of a health conscious peer, can encourage the adoption of healthy behaviors[12,57], possibly by calling into mind the subjective value of the peer's health habits[58,59] or by increasing perceived self-other overlap[60]. Together, these separate literatures motivate a test of whether approaching alcohol cues from the perspective of a lower drinking peer target, with the goal to create distance from alcohol cues, can reduce drinking behavior. In line with this possibility, correlational research suggests that individuals

who score higher on perspective-taking in general may be more likely to resist pro-drinking influences[61] and to report lower drinking[62]. Importantly, this research was cross-sectional and did not consider specific peers as perspective-taking targets, nor their perceived drinking behavior. Extending prior work, we suggest that experimentally prompting individuals to take the perspective of peers whom they perceive to drink less than themselves may offer an opportunity to create psychological distance from alcohol cues and provide a protective buffer from alcohol consumption in day-to-day life.

The evidence reviewed above suggests that mindfulness and perspective-taking strategies may reduce drinking by promoting different types of psychological distance[12,57.] However, less is known about how to effectively integrate these strategies into individuals' natural environments where pro-drinking influences may be present[15–17]. Indeed, current data is mixed, with some studies showing that a brief psychological distancing training in the laboratory can motivate healthier choices[49,50] and others showing that distancing trainings may not succeed in naturalistic environments without ongoing reminders[48,51]. To address the possibility that repeated exposure is critical for the effectiveness of health communications in-daily life[63], we conducted two randomized experiments. First, we developed theory-driven mindfulness and perspective-taking instructions designed to create psychological distance from alcohol cues. Then, we integrated them in the everyday lives of young adults via smartphones. In both studies, we used an ecological momentary assessment (EMA) design, which collects intensive repeated measures data in everyday settings[64]. This approach allowed us to embed an experimental intervention while preserving high ecological validity. In the first experiment, college students were recruited across two campuses and randomized to undergo a brief in-person mindfulness, perspective-taking, or control training on how to respond to alcohol cues in their everyday life. Next, they received two smartphone reminders according to their respective condition and reported their drinking twice daily. The second

experiment aimed to replicate the results with a larger sample, while also providing a fully remote intervention instead of an in-person training in a different context, during the onset of the COVID-19 pandemic.

In both studies, we manipulated whether participants received mindfulness or perspective-taking smartphone reminders (vs. control reminders) within-person over four alternating weeks and examined changes in drinking behaviors (See Fig. 1). We tested two competing hypotheses. First, psychological distance-based trainings, such as mindfulness and perspective-taking, may help individuals to integrate distancing strategies in their responses to alcohol and influence subsequent behavior[65], without the need for frequent reminders. If true, we expected the mindfulness and perspective-taking trainings to reduce drinking frequency and drinking amount irrespective of whether intervention reminders are present or absent. Specifically, we expected to observe similar drinking frequency and drinking amount on weeks when individuals received psychological distancing reminders versus control reminders, prompting them to respond to alcohol naturally. Second, and in contrast, distance-based trainings may not succeed in daily life without boosts from frequent distancing reminders, particularly in the moments when individuals are most likely to encounter alcohol cues in their everyday lives. In this case, we expected drinking frequency and amount to decrease on weeks when individuals received intervention reminders versus control reminders. Our study focused on effects of psychological distancing reminders in general, and we had no *a priori* hypothesis about the relative effectiveness of the mindfulness versus perspective-taking strategies. Consistent with prior work[66], we separately modeled the frequency of drinking occasions and the quantity consumed per occasion, as these variables are independently linked to drinking habits and alcohol-related health outcomes[67].

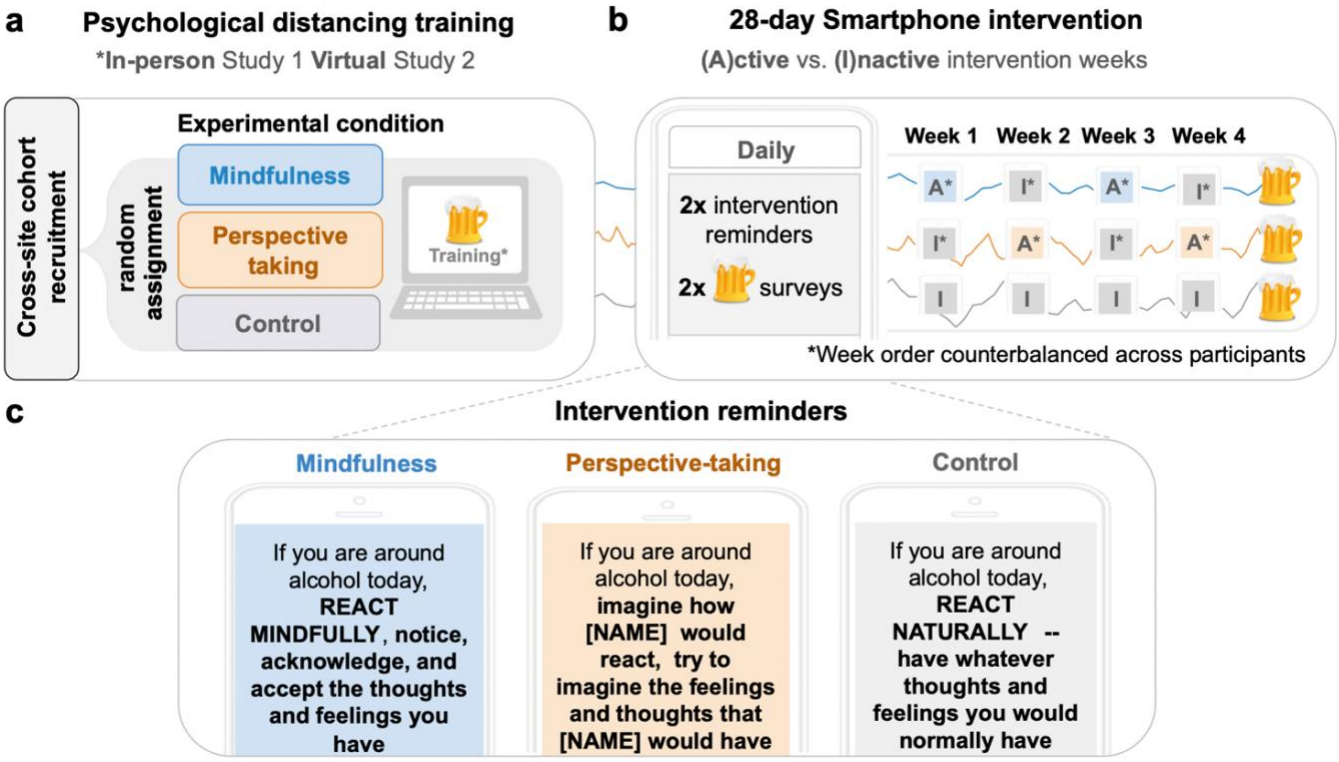

Fig 1. | Study procedure and intervention reminders. We conducted two experiments which we refer to as Study 1 and Study 2. a. Young adults (Study 1: $N = 108$; Study 2: $N = 218$), recruited across two different university sites, completed online surveys and were randomly assigned to one of three experimental conditions and completed psychological training (in-person Study 1; or virtual Study 2) on how to respond to alcohol cues. b. Following the training, participants underwent a 28-day smartphone intervention in which they received two intervention reminder texts a day and two texts assessing their alcohol use. Participants in the mindfulness and perspective-taking conditions, received active intervention reminders on one week and control reminders the following week, with week order counterbalanced across participants. c. Reminder text messages corresponding to condition assignment and week.

Results

Intervention compliance and alcohol consumption

In Study 1, participants were highly compliant with the study protocol responding to a median of 94.64% of 56 EMA alcohol surveys sent to each person over the 28 days (M = 91.02%, SD = 12.72). In total, in Study 1, we collected 5492 usable data points. Participants reported drinking on 15.36% of all assessments. The average participant reported having 3.12 (SD = 1.70) drinks per drinking occasion. Six participants (~6% of the sample) reported no drinking throughout the intervention period. In Study 2, participants were also highly compliant with the study protocol responding to a median of 91.07% of 56 EMA alcohol surveys sent (M = 82.13, SD = 24.80). In total, in Study 2, we collected 9994 usable data points. Participants reported drinking on approximately 10.12% of all assessments. The average participant reported having approximately 2.00 (SD = 1.13) drinks per drinking occasion. Seventy-eight participants (~35% of the sample) reported no drinking throughout the intervention period, which took place after students left campus during the COVID-19 pandemic. See Table 1 and Table S1 for descriptive statistics by intervention week and condition. Response rates did not vary by condition assignment: Study 1: $F(2, 105) = 0.64$, $p = .526$; Study 2: $F(2, 215) = 0.22$, $p = .801$. Participants in the mindfulness and perspective-taking conditions responded to more alcohol surveys on inactive weeks vs. active weeks in both studies: (Study 1 active weeks (M = 24.72, SD = 4.00) vs. inactive weeks *(*M = 25.72; SD = 3.84), $t(70) = -2.99$, $p = 0.024$; Study 2 active weeks (M = 22.41, SD = 7.46) vs. inactive weeks *(*M = 23.54; SD =7.42), $t(146) = -3.47$, $p = <.001$). To account for possible effects of differences in response rates, we controlled for the number of responses to alcohol prompts in all models (see Data analysis of the Methods section).

Within-person effects of daily reminders on alcohol consumption

We tested two competing hypotheses about the effects of intervention reminders on drinking. First, training individuals to create distance from alcohol cues, may help change drinking behavior without the need of frequent reminders, in which case we would expect no differences in drinking on active intervention weeks when psychological distance reminders are present versus inactive weeks, when individuals received control reminders. Second and in contrast, intervention reminders may help individuals to effectively integrate distancing strategies in daily life, in which case we would expect greater reductions in drinking on active intervention weeks versus inactive weeks. To assess whether drinking levels varied on active weeks versus inactive weeks, we specified two separate multilevel hurdle models: one for Study 1 and another for Study 2, comprising individuals assigned to the mindfulness and perspective-taking conditions, who underwent both active and inactive intervention weeks. The main predictor of interest was active week (intervention reminders) versus inactive week (control reminders). The two main outcomes of interest include frequency of drinking occasions and numbers of drinks per drinking occasion. Consistent with prior work[67], we modeled these two drinking outcomes separately (see Data analysis section of the Methods for information on covariates and modeling details). We report effects on drinking occasion frequency first and effects on drinking amount second. The results are visualized in Fig. 2. The data and analysis scripts for the main analyses reported in the manuscript are available (https://github.com/miajov/psych-distance-intervention) in addition to an R markdown notebook to view analyses (https://rpubs.com/jovanova_mia/916416).

Psychological distance reminders reduce drinking frequency. Examining both distancing strategies together (i.e., collapsing across mindfulness and perspective-taking conditions), we found a main effect of the intervention reminders such that participants in the mindfulness and perspective-taking conditions were less likely to drink following active

reminders relative to following inactive reminders in Study 1 (active week vs. inactive week: OR = 1.34, 95% CI [1.01 - 1.77], p = .041; Table 2). We replicate these findings in Study 2 (active week vs. inactive week: OR = 1.39, 95% CI [1.08 - 1.80], p = .011, Fig. 1; Table 2). These results were obtained from a zero-inflated hurdle model, to account for the fact that participants had zero drinks on some days. The zero-inflated sub-model of the hurdle model estimated the probability of an extra zero (no alcohol use) such that a positive odds ratio indicates more occasions with no alcohol use. For more details see Data Analysis section of the Methods. These results, consistent across both studies, offer support for the hypothesis that psychological distancing strategies, drawing on mindfulness and perspective-taking, may be contingent on frequent reminders to successfully reduce drinking frequency.

Psychological distance reminders do not impact drinking amount. Examining both distancing strategies together (i.e., collapsing across the two intervention conditions), we found no difference in the number of drinks consumed on alcohol use occasions following active intervention reminders, relative to following control reminders across both studies (Study 1 active week vs. inactive week; OR = 0.92, 95% CI [0.69 - 1.23], p = .575; Study 2: active week vs. inactive week: OR = 0.97, 95% CI [0.77 - 1.23], p = .816, Table 2) These results come from the portion of the hurdle model that examined how much alcohol is consumed, conditioned on drinking at all. Together, these results suggest that the intervention reminders reduced the overall drinking occasion frequency, however did not influence the amount consumed when drinking (Table 2).

Exploratory interaction effects of mindfulness vs. perspective-taking reminders type. We next explored whether the effects of the intervention reminders on drinking varied based on specific distancing strategy: mindfulness vs. perspective-taking. To examine this question, we added an interaction term between intervention condition and week in each multilevel hurdle model (for Study 1 and Study 2 separately). We found no significant

interaction between mindfulness (vs. perspective-taking) and intervention week in either study on drinking frequency (Study 1: active week vs. inactive week: OR = 0.93, 95% CI [0.62 – 1.41], p = .741; Study 2 active week vs. inactive week OR = 0.95, 95% CI [0.66 – 1.38], p = .796, Table 2). This finding, as well as inspection of both raw and winsorized means (Table S1), suggests that both mindfulness and perspective-taking strategies, with frequent reminders, may be similarly effective in reducing drinking frequency. However, exploratory inspection of the medians by condition and intervention week suggests that the effects in the mindfulness condition may be more robust in reducing drinking frequency (see Table S1). Further, we found no significant interaction between mindfulness (vs. perspective-taking) and intervention week in either study on drinking amount (Study 1: active week vs. inactive week: OR = 1.09, 95% CI [0.72 -1.65], p = .687; Study 2: active week vs. inactive week: OR = 1.27, 95% CI [0.89 – 1.80], p = .189), Table 2.

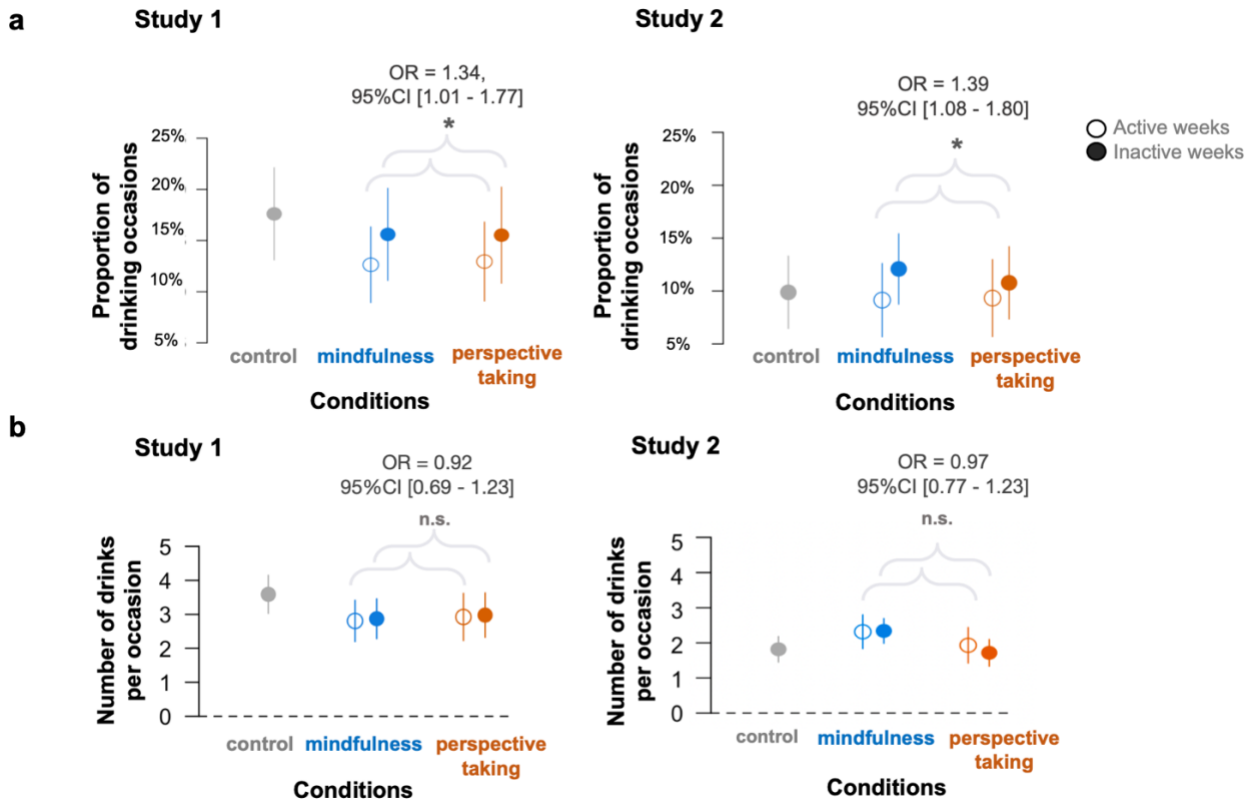

Fig 2. | Psychological distance reminders reduce drinking frequency but do not influence amount. a. Collapsing across experimental conditions, participants in the

mindfulness and perspective-taking conditions were less likely to drink following active intervention reminders relative to following control reminders in Study 1 (left) and Study 2 (right). b. We found no differences in the number of drinks consumed on alcohol use occasions following active intervention reminders, relative to following control reminders across both studies, Study 1 (left) and Study 2 (right). Note: figure presents raw data for illustration. Dots present the mean and the error bars present 95% confidence intervals.

Between-person effects of daily reminders on drinking frequency

Next, we conducted follow-up analyses to explore whether the effects of the psychological distance intervention reminders observed in both studies, i.e., the decrease in the drinking occasion frequency on active weeks versus inactive weeks, differed from non-intervention related changes we might expect in the absence of these reminders. Specifically, we asked whether the changes in drinking frequency among participants in the intervention conditions differed from changes among participants in the control condition in both studies. As part of the design, participants in the control condition only received control reminders throughout the entire study period, which prompted them to respond to alcohol naturally. Thus, we were interested in whether the intervention consistent changes in drinking frequency, differed from changes we may expect for participants monitoring their own alcohol use and completing other aspects of the protocol, but without the key psychological distancing components. To test for this possibility, for each control participant, we randomly labeled two of the four weeks as pseudo "active" and others as pseudo "inactive" (despite the protocol remaining the same for control participants throughout). This random assignment allowed us to match the two intervention designs as closely as possible. For the present analysis, we repeated this random assignment 100 times, and we compared the average pseudo-inactive-to-active-week change scores for the control group to inactive-to-active-week change scores for the intervention groups. Performing this comparison allowed us to

test whether the changes in drinking frequency among participants in the intervention conditions differ from changes in drinking frequency among participants who participated in all other aspects of the study but were not instructed to adopt psychological distance.

Psychological distance reminders reduce drinking frequency vs. control.

Examining both distancing conditions together (i.e., collapsing across mindfulness and perspective-taking conditions), we compared changes in drinking frequency in the intervention groups versus the control condition, using unpaired two-sided Wilcoxon tests to account for the non-normality of the data (see the Data Analysis section of the Methods for details). We found significant differences in behavior change, such that individuals in the intervention groups showed a greater decrease in drinking frequency from inactive weeks to active weeks relative to the control group, both in Study 1 (W^1 = 1002, Z = -2.013, p = .044, r = .194) and in Study 2 (W = 3733, Z = -3.487, p = <.001, r = .236; Fig. 3). We found parallel results when accounting for outliers (See Supplement C for more details). Together, these results further support the inference that the psychological distancing components reduced drinking frequency rather than extraneous factors unrelated to the psychological distancing intervention.

[1] W presents the test statistic for the Mann–Whitney–Wilcoxon test.

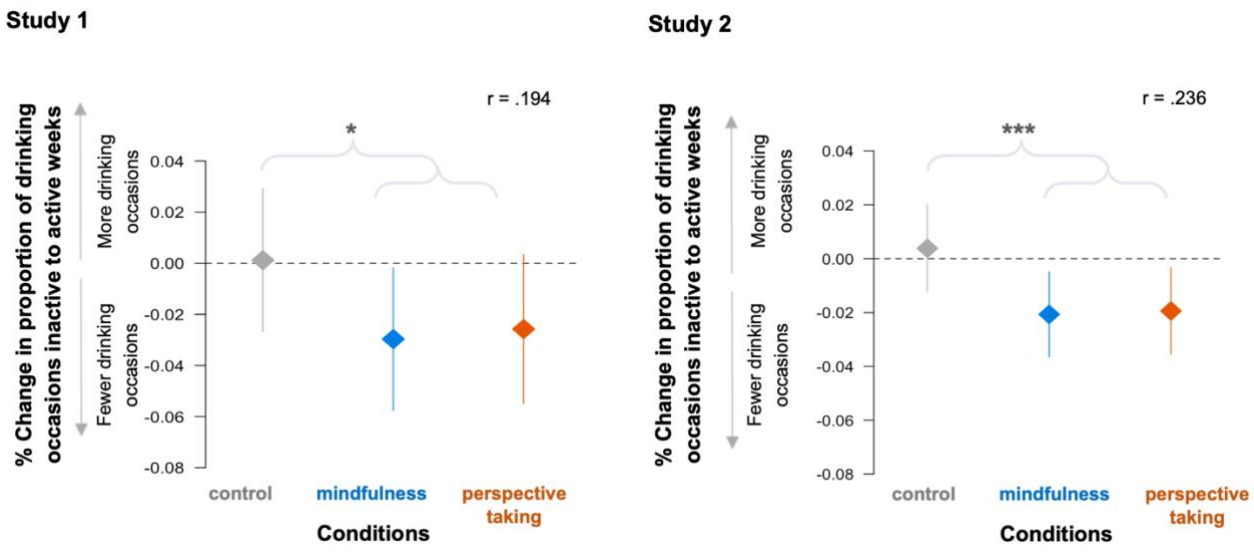

Fig 3. | Reminders change drinking frequency among participants in the intervention conditions vs. control. Participants in the distancing conditions—mindfulness and perspective-taking—tended to drink less frequently on active compared to inactive weeks relative to participants in the control condition in Study 1 (left) and Study 2 (right). Negative change scores suggest intervention consistent decreases in drinking occasion frequency.

Discussion

Changing behavior is difficult. Yet, changing from unhealthy to healthy choices in day-to-day life can improve long-term quality of life and longevity. Across two studies, we leveraged smartphone technology to administer two theory-driven interventions to change an important health behavior—alcohol consumption—as a preventative measure among young adults without alcohol dependence. We found that reminders, focused on creating psychological distance from alcohol cues, were key to the success of the interventions to reduce drinking frequency, highlighting the value of administering health interventions through smartphone technologies that are integrated in people's day-to-day lives. In both studies, drinking frequency decreased about 2% on average on weeks when participants received daily psychological distancing reminders versus control reminders. In Study 1,

drinking occasion frequency decreased from once every 6 days to once every 8 days when intervention reminders were present versus control reminders. In Study 2, drinking occasion frequency reduced from once every 9 days to once every 11 days, on average. Importantly, this behavior change was specific to individuals who were randomly assigned to receive psychological distance reminders. Together, these reductions in drinking frequency suggest a meaningful change, and are particularly compelling for society's broader goals of health behavior change in light of evidence linking light and infrequent alcohol with cancer risk incidence[68–71].

Overall, a large body of research highlights the promise of psychological distance interventions to change health behavior mainly among clinical samples[36]. In parallel, a growing body of research highlights the promise of mobile-phone based health interventions to administer health interventions[18,72]. However, mixed findings in the literature have been observed with respect to the effectiveness of regulatory strategies to reduce drinking via mobile-phones as preventative efforts— particularly among young adults[44–47,73]. Our two randomized experiments examined the effectiveness of repeated smartphone reminders that promote two different kinds of psychological distance from alcohol cues–mindfulness and perspective-taking– in everyday life. We examined effects on drinking frequency and drinking amount over 28 days among young adults. Within-person, we tested whether individuals in the mindfulness and perspective-taking conditions drank less frequently and consumed fewer drinks when drinking on active intervention weeks relative to inactive weeks. Across both studies, we found that participants in the psychological distance intervention conditions reported fewer drinking occasions on active weeks, relative to inactive, or control, weeks. These reductions in drinking frequency replicated across both studies, and are consistent with prior work showing that the effectiveness of smartphone-administered drinking interventions may be contingent on frequent reminders. For example,

Witkiewitz *et al*., found that randomizing young adults into a 14-day smartphone intervention did not significantly reduce drinking. However, among individuals who were randomized to the smartphone intervention, receiving more vs. less frequent personalized feedback modules, was associated with a lower likelihood of drinking during the 14-day assessment period[51]. Consistent with broader literature on nudging healthy choices[74], psychological distance reminders may help offload cognitive effort when evaluating health-related options[75], particularly in key moments when individuals encounter alcohol cues in day-to-day-life. Specifically, distancing reminders may make healthier options more salient, e.g. by re-orienting attention away from immediate reactions to triggers, or towards a healthier peer's perspective, and thus help de-automatize habitual reactions to alcohol cues[76]. Reminders may also be effective by helping people notice when there is a need to regulate and/or how they can go about doing so[77].This, in turn, may replace an unhealthy choice with a healthier option and thus facilitate behavior change.

We did not find a significant interaction between the two types of psychological distancing interventions and active vs. inactive week on alcohol consumption. Instead, both the mindfulness and perspective-taking reminders reduced the likelihood of drinking occasions on active vs. inactive weeks to a similar degree. It is possible that different types of psychological distancing strategies, with frequent reminders, may be similarly effective in reducing the frequency of drinking occasions relative to an individual's own baseline. Further, it is plausible that both interventions leverage a parallel psychological distance mechanism, though our data do not speak to this possibility directly. For example, neuroimaging research suggests that different forms of psychological distance are encoded similarly in the brain[78,79]. However, future research that investigates these parallels in the drinking intervention context[80] can help further clarify the mechanisms through which psychological distancing strategies can facilitate behavior change.

The current results should be interpreted in light of several strengths and limitations. First, study strengths include the employment of theory-driven interventions within an ecologically valid EMA design. This design allowed us to capture intervention effects in participants' natural environments over 28 days and overcome common retrospective biases often introduced in questionnaires that ask participants to recall and aggregate information about longer periods of time (e.g., amount of alcohol consumed in the previous 30 days[81]). Next, the within-person manipulation allowed us to detect intervention effects while considering individuals' personal drinking baselines[82]. We employed this repeated measures design across two different samples of students and across two campuses, thereby increasing the generalizability of our findings. Although intensive assessment often raises data compliance concerns, we observed little evidence of non-compliance in our data. The intensive sampling approach produced high response rates (approximately 95% median response rate in Study 1, with an in-person training component, and 91% median response rate in Study 2 with a fully remote delivery and a doubled sample size). These high response rates speak to the feasibility of applying this approach for evaluating health interventions among young adults. With respect to limitations, it is important to note that our data cannot speak to long-term intervention effects on drinking beyond the length of 28 days and our results may not generalize to samples beyond young adults without alcohol dependence who are part of social groups. Specifically, we recruited students from pre-existing social groups on two college campuses (and included groups in which 80% or more expressed interest), with higher proportions of women than men. Although we controlled for non-independence of observations in statistical modeling, the non-independence may have confounded intervention effects in unmeasurable ways (e.g., spillover effects or social influence). As such, it is important for future work to examine the effectiveness of psychological distancing interventions, administered via smartphones, in new samples. Finally, when interpreting

results, it is important to note that the psychological distancing reminders did not explicitly instruct individuals to decrease the quantity of alcohol consumed. As such, future work could test more explicit instructions to possibly elicit stronger reductions in drinking amount. Finally, to reduce concerns over self-reported drinking, future research could incorporate measures of passive transdermal sensors[83] or blood alcohol content reports via smartphones[84].

Conclusion

The present study responds to calls to develop more effective, theoretically-guided behavior change interventions[18,85]. The two mobile-health interventions that we tested here contribute to a growing literature on how to leverage mobile technology to administer psychological behavior change interventions among young adults. In two multi-site, randomized experiments with two different samples of college students without alcohol dependence, we found that psychological distance-based reminders—drawing on mindfulness and perspective-taking—and delivered via smartphones, decreased the frequency of drinking occasions over the course of a month, both prior and during the onset of the COVID-19 pandemic. These intervention reminders specifically reduced drinking frequency but had no impact on the amount consumed per occasion. Future research may expand the use of psychological-distancing interventions employed via smartphones to elicit behavior change outside the lab.

Methods

We use data from two different cohorts of college students from the Social Health Impact of Network Effects (SHINE) Study which we refer to as Study 1 and Study 2. Details of the design, data preparation, and data analysis can be found in Supplement A. All research was conducted in accordance with the Human Subjects Electronic Research Application (HSERA) Institutional Review Board (IRB) at the University of Pennsylvania and

acknowledged by the Human Research Protection Office of the Department of Defense. All participants provided informed consent before taking part in the study and all participants were financially compensated.

Participants

Our Study 1 sample comprised 108 individuals (65 female, 42 male, and 1 other/non-binary) in Study 1. The participants were aged between 18 and 28 years (M=20.54, SD=1.70) and identified as white (53.7%), Asian (29.6%), Hispanic/Latino (4.6%), African American/Black (1.9%), and multiracial/other (10.2%). Our Study 2 sample comprised 218 new individuals (157 female and 48 male; 13 did not respond) aged between 18 and 42 years (M=20.6, SD=2.1). Participants in Study 2 identified as white (37.2%), Asian (31.7%), African American/Black (7.8 %), Hispanic/Latino (5.0%), multiracial/other (12.8%), and missing information (5.5%). In both studies, we recruited undergraduate students who were part of on-campus social groups (e.g., sports teams, arts groups, Greek life, etc.) across two college sites. Diagrams of enrollment and retention can be found in Supplement A, Fig S1 and Fig S2.

Procedure

First, participants completed a Qualtrics survey containing demographics and social network questionnaires on perceived peer drinking, and other measures beyond the scope of the present report. Next, a subset of interested participants were randomized into three intervention conditions—mindfulness, perspective-taking, and control—and were invited to attend an in-person (Study 1) or a virtual (Study 2) training session. Participants underwent a 5-7 minute long instruction training on how to respond to alcohol cues in daily life according to their respective conditions. More information about the instruction language development and training can be found in Supplement B. Following the training, participants began a 28-day ecological momentary intervention and assessment protocol. Participants received two

reminders daily on how to respond to alcohol cues in daily life and responded to two surveys a day measuring their alcohol use among other factors, for a total of 4 signals daily over 28 days. Data collection for Study 2 replicated Study 1 but was modified to be completed fully remotely. See Fig 1 for Study Procedure.

Measures

We used participant reports of drinking during the 28-day ecological momentary assessment period. Participants were asked: "Since your EVENING/MORNING survey, have you consumed any alcohol? ("No" or "Yes" response option). Participants who responded "Yes", were asked to enter the number of standard servings of beer, liquor, and wine consumed since the previous survey using a numeric entry. Responses for each beverage category were summed to obtain the total servings of alcohol consumed for each assessment (see Refs.[86] [87,88] for previous uses of these scales to capture alcohol use during daily life). When participants responded "No" to having consumed alcohol, they answered questions about physical activity, caffeine use, and water consumption. These questions were matched for length with the follow-up alcohol questions to reduce the possibility that participants would report no alcohol use in order to minimize survey completion time. To select low drinking peer targets for participants randomized in the perspective-taking condition, we used peer nominations from the baseline social network questionnaire in response to: "Who in your group drinks the least?". In cases when individuals nominated more than one peer who drinks less than them, targets were selected by picking peer who was also nominated as close ("Who are you closest to?") and who had the highest self-reported drinking difference from the individual.

Data preparation

Drinking was defined as the number of total alcohol servings consumed at each assessment over the 28-day period. In Study 1, the three largest, improbable values of drinks

per drinking occasion (24, 36, 60) were winsorized to the next largest value—16 drinks per occasion. This step applied to 7 signals across 3 individuals out of 5492 observations in total. No outliers were observed in Study 2.

Data analysis

To account for the nature of the alcohol use data which are often positively skewed and include many observations at zero, we used multilevel hurdle models. Hurdle models include a logistic regression to model the zeroes in the data as well as a count regression (in this case negative binomial) to model the counts. All the zeroes (not alcohol use occasions) are modeled with the logistic regression and nonzero-counts (alcohol use occasions) are modeled by a truncated negative binomial (i.e., truncated as it does not contain zero). Thus, these models allowed us to independently model whether a person drinks or not (logistic regression) at a given occasion and number of drinks when an individual drinks (count regression). We estimated hurdle models[89] using glmmTMB[90] in R (Version 4.0.3) using the RStudio interface (Version 1.3.1093).

We specified two models (one for Study 1 and another for Study 2) to assess whether drinking frequency and amount vary among participants in the mindfulness and perspective-taking conditions (within-person) on weeks when intervention reminders were present or absent. The main predictor of interest was active vs. inactive week and the outcomes were frequency of drinking occasions and drinking amount. To further explore if the effectiveness of the reminders varied by condition type (mindfulness vs. perspective-taking), we also included an interaction term: condition type x active week (vs. inactive week). Given that observations are nested within participants, who are in turn nested within non-independent social groups, all multilevel models accommodated the nested nature of the data and intercepts were allowed to vary randomly across people. In all models presented in the main manuscript, we controlled for the following covariates: social weekend (defined as Thursday,

Friday, or Saturday), due to differences between weekend and weekday drinking among college students[91]; participant response rates, given observed differences in response rates on active versus inactive weeks in both studies; and signal count in the study given overall decreases in drinking over time. We observed no differences from the main findings presented when removing covariates. Additional models controlling for demographic variables including age, gender, and race are presented in the Supplement C (Table S2). We observed no differences from the main findings presented when controlling for age, gender and race.

Exploratory analyses. To explore whether the changes in drinking occasion frequency (on active weeks versus inactive weeks) among the intervention groups differed from non intervention-related changes among participants in the control condition, we compared drinking frequency change scores. We calculated change scores to capture the difference in the average proportion of drinking occasions on active intervention weeks versus inactive weeks throughout the 28-day study period. To do this, we first calculated the average proportion of drinking occasions on active weeks and inactive weeks separately, by dividing the number of drinks reported throughout the active and inactive intervention period by the individual's number of responses to alcohol reminders during the same time period. Next, we created change scores by subtracting the proportion of drinking occasions on active weeks from the proportion of drinking occasions on inactive weeks. In Fig 2, we flipped the change scores for ease of interpretation such that more negative change scores indicate greater intervention-consistent reductions in drinking frequency from inactive to active weeks.

To obtain change scores for participants in the control condition, who did not undergo a within-person active-to-inactive week manipulation as part of the protocol, we randomly assigned two of the four weeks in the study period as pseudo "active" and remaining two as

pseudo “inactive” weeks. To counterbalance week order, as done in the active treatment groups, we randomly split half of the participants in an ABAB design, or a BABA design, which allowed us to match the two intervention designs as closely as possible. We repeated this random assignment 100 times to stabilize the estimates. Next, we averaged the change scores in drinking frequency (from pseudo-inactive to pseudo-active weeks) for the control participants across all iterations and compared the control group change scores to the intervention groups’ change scores. We first checked whether the proportion of drinking occasions were significantly non-Gaussian using the Shapiro Wilk test of normality and chose to perform non-parametric Mann–Whitney–Wilcoxon tests instead of t-tests because of nonnormality. We performed this comparison using unpaired two-sided Wilcoxon tests. Calculations were performed in RStudio (https://www.Rproject.org).

Table 1. Descriptive Statistics

Study 1										
Conditions	Mindfulness				Perspective-taking				Control	
Intervention Weeks	Active Weeks		Inactive Weeks		Active Weeks		Inactive weeks		N/A	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Percentage of EMA responses	89.96%	13.49%	91.22%	13.61%	86.44%	15.15%	92.54%	13.99%	92.86%	13.32%
Percentage of drinking occasions	12.63%	9.24%	15.59%	12.88%	12.94%	13.14%	15.53%	15.80%	17.61%	12.39%
Drinks per occasion	2.81	1.81	2.87	1.65	2.92	1.72	2.98	1.53	3.59	1.86

Study 2										
Conditions	Mindfulness				Perspective-taking				Control	
Intervention Weeks	Active Weeks		Inactive Weeks		Active weeks		Inactive weeks		N/A	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Percentage of EMA responses	81.48%	22.39%	85.33%	24.03%	78.57%	30.55%	82.78%	29.02%	82.27%	23%
Percentage of drinking occasions	9.14%	15.02%	12.08%	15.54%	9.33%	14.80%	10.77%	15.00%	9.88%	12.07%
Drinks per occasion	2.39	1.81	2.46	1.42	1.93	0.97	1.71	1.16	1.83	1.05

Table 2. Within-person effects of reminders on drinking on active vs. inactive weeks

	Study 1			Study 2		
	Zero-inflated sub-model					
Fixed Effects	OR	95%CI	*p*	OR	95%CI	*p*
Intercept	1.77	[.26-11.8]	.558	10.4	[2.96-36.5]	<.001
Active week (vs. inactive)	1.34	[1.01-1.77]	.041	1.39	[1.08-1.80]	.011
Perspective condition (vs. mindful)	1.21	[.71-2.05]	.489	1.06	[0.60-1.87]	.845
Signal count	1.01	[1.01-1.02]	<.001	1.00	[0.99-1.00]	.458
Number of responses	1.03	[0.99-1.07]	.149	1.02	[1.00-1.04]	.109
Social weekend (vs. week)	0.50	[0.40- .61]	<.001	0.54	[0.45-0.65]	<.001
Perspective condition (vs. mindful) *active week (vs. inactive)	0.93	[0.62- 1.41]	.741	0.95	[0.66-1.38]	.796
Random effects	Variance		SD	Variance		SD
Intercept						
Participant ID* Group ID	<.011		.938	.200		.447
Participant ID	<.001		<.001	.079		.282
	Conditional sub-model					
Fixed Effects	OR	95%CI	*p*	OR	95%CI	*p*
Intercept	3.56	[0.93-13.7]	.065	1.79	[0.87-3.68]	.111
Active week (vs. inactive)	0.92	[0.69-1.23]	.575	0.97	[0.77-1.23]	.816
Perspective condition (vs. mindful)	1.02	[0.69-1.51]	.919	.054	[0.38-0.76]	<.001
Signal count	1.00	[0.99-1.00]	.158	1.01	[1.00-1.01]	.041
Number of responses	0.99	[0.96-1.01]	.284	0.99	[0.98-1.01]	.353
Social weekend	1.56	[1.26-1.93]	<.001	1.27	[1.06-1.53]	.009
Perspective condition (vs. mindful) *active week (vs. inactive)	1.09	[.72-1.65]	.687	1.27	[0.89-1.80]	.186
Random effects	Variance		SD	Variance		SD
Intercept						
Participant ID* Group ID	229		.478	1.879		1.371
Participant ID	.028		.167	.738		.859

Note. Study 1: 3577 observations nested within 71 participants across 10 groups; Study 2: 6729 observations nested within 147 participants across 23 groups. The zero-inflation sub-model of the hurdle model estimates the probability of an extra zero (no alcohol use) such that a positive estimate indicates a higher chance of no alcohol use. Perspective = perspective-taking; mindful = mindfulness.

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Supplementary information

The following document contains supplementary information for *Jovanova et al*. Psychological distancing interventions reminders reduce drinking frequency in daily life.

Supplement A presents information on participant enrollment and study procedures. Supplement B includes information on pilot data collected to help develop the intervention language. Supplement C includes descriptive statistics, sensitivity analyses accounting for demographic covariates, and robustness checks.

Supplementary Methods and Materials A

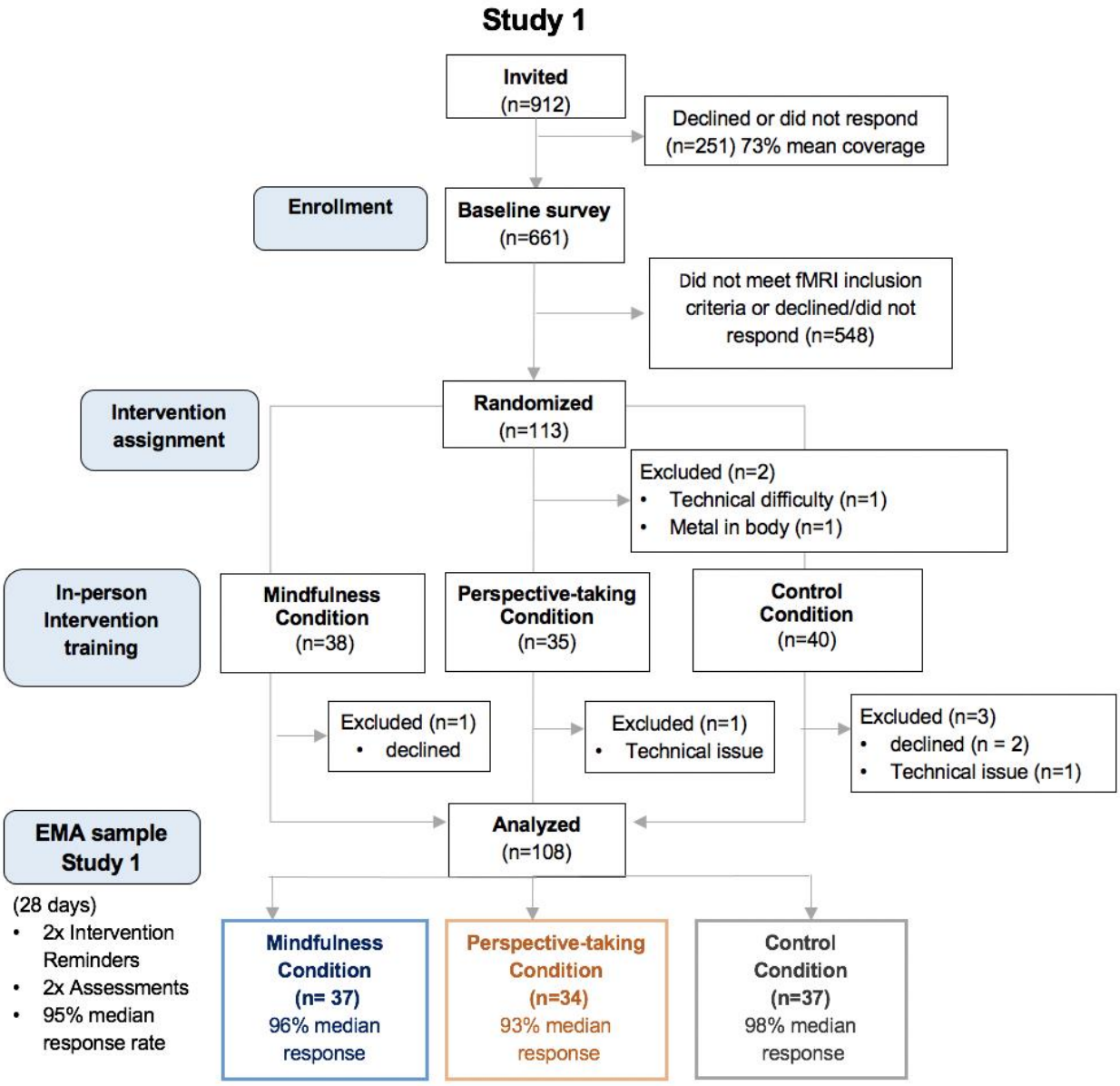

Fig S1. Participant enrollment and retention in Study 1.

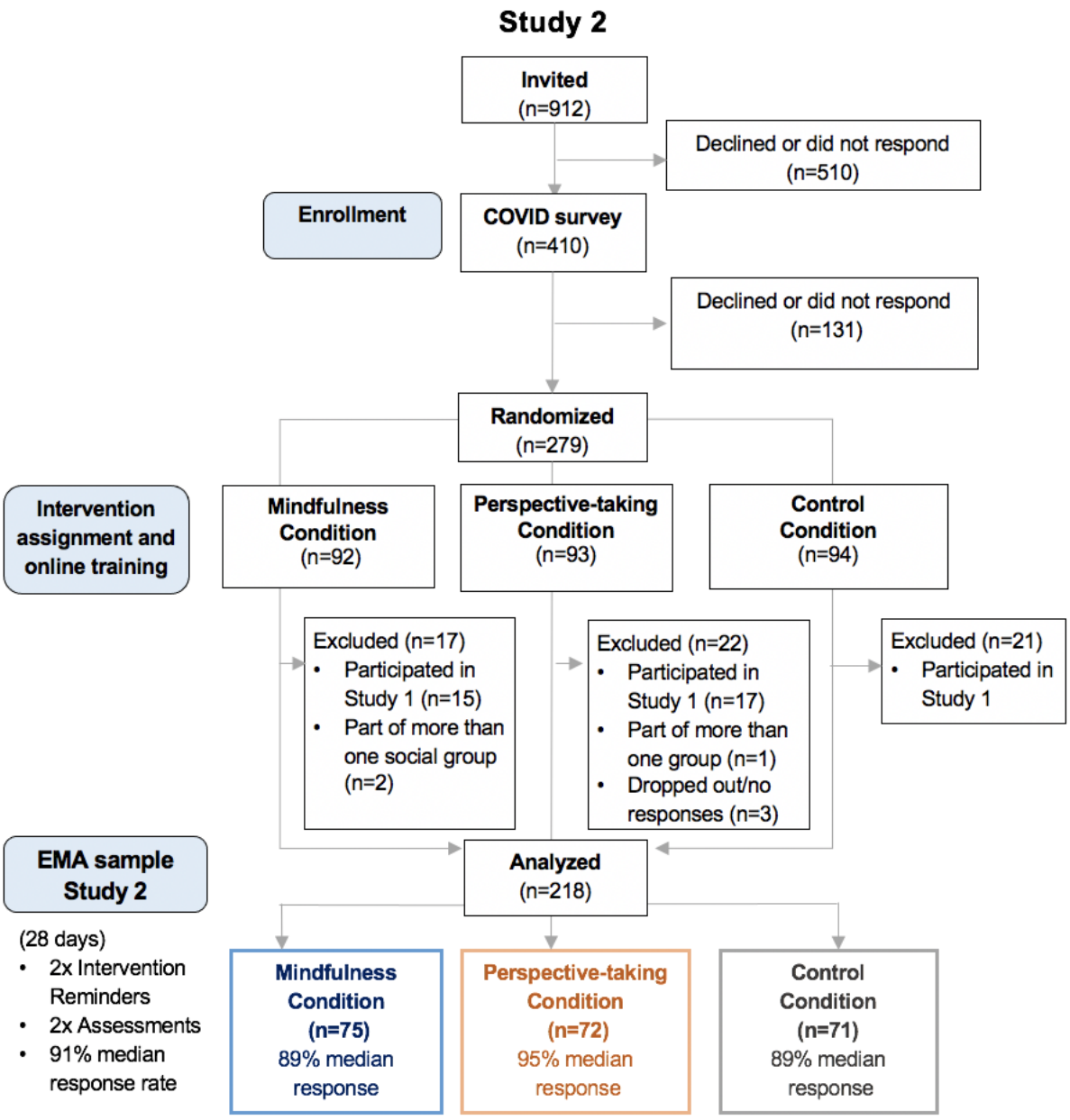

Fig S2. Participant enrollment and retention in Study 2.

Recruitment

Recruitment materials advertised a study titled "Social Health Impact of Network Effects Study (SHINE)" to undergraduate students who were members of on-campus social groups across two Northeastern universities in the United States. The study was advertised through flyers, university websites, and email communication. To reach students, researchers contacted group leaders and further employed a snowball sampling approach, such that participating students could share recruitment information with their peers who were members of on-campus social clubs or sports teams. The data collection for Study 1 began on February 2nd, 2019 and ended on April 7th, 2020, thus including time primarily on campus and as participants transitioned home at the start of the COVID-19 pandemic. The data collection for Study 2 began on May 30, 2020 and ended on October 27, 2020.

Psychological distance training

In the next section, we provide details about the psychological distance instructions training. Study 1 and Study 2 followed similar procedures. Participants were invited to complete an introductory training on how to approach alcohol cues they encounter in their everyday environments, either in-person (Study 1) or online (Study 2). Consistent with past work on regulation of alcohol craving, participants viewed images of alcohol (beer, wine, and liquor) to elicit craving[1] and were trained to respond to these alcohol cues using different strategies according to the three randomized conditions: mindfulness, perspective-taking, and control. In Study 1, a researcher guided participants through the instructions on how to respond to alcohol on a computer screen in the lab and verbally checked participant comprehension. In Study 2, participants viewed standardized training videos on how to respond to alcohol on their mobile devices. To verify comprehension, participants were required to pass comprehension checks on

their personal devices via Qualtrics during the training. A researcher examined the responses and verified participant comprehension of the training. The training lasted around 5-7 minutes.

Intervention training components

Mindfulness. Participants viewed different images of alcohol beverages paired with text instructions, piloted across 14 Mechanical Turk studies prior to the study (See Mindfulness piloting below). On different trials, the text instructed participants to either approach the alcohol image mindfully, by mentally taking a step back in order to observe the situation and their responses in an impartial and non-judgmental manner (mindfulness trials) or to react naturally (control trials). During mindfulness trials, participants were further asked to pay attention to their reaction without getting caught up in it. In contrast, on control trials, participants were asked to approach the alcohol image as they normally would approach alcohol in their daily life, by reacting naturally or to have whatever thoughts and feelings they would normally have. By alternating mindful and natural responses to alcohol stimuli, the training intended to instruct participants to differentiate between creating psychological distance from their responses to alcohol vs. having a natural response to alcohol.

Perspective-taking. Parallel to the mindfulness condition, participants in the perspective-taking condition were presented with images of an alcoholic beverage paired with different instructions. On different trials, the text instructed individuals to either respond to the image from the perspective of their two lowest-drinking peers (perspective-taking trials), or were asked to respond to the image naturally from their own perspective (control trials). On perspective-taking trials, a peer's name was prompted on the screen and participants were asked to imagine the thoughts and feelings of their selected peer in response to the alcohol cue. Peer names were selected based on the participant nominations of group members whom they perceived to drink

less than themselves. On control trials, participants were asked to approach alcohol from their own perspective. By alternating peer- and self-focused responses to alcohol stimuli, the training intended to train participants to differentiate between taking their peers' and their own perspective when they encounter alcohol.

Control. The third group completed the same task, for the same time period, without any regulatory strategy suggested. All participants viewed images of alcoholic beverages (e.g., bottle of beer), and were asked to respond naturally as they normally would in their everyday life.

Ecological momentary intervention protocol

Following the psychological distancing instructions training, participants began a 28-day ecological momentary intervention and assessment period delivered via smartphones. Participants received two intervention prompts, one at 2:00 pm and the second at 9:00 pm each day over 28 days. The content of the prompts varied according to the three assigned conditions: the control message stated "If you are around alcohol today, REACT NATURALLY — have whatever thoughts and feelings you would normally have"; the mindfulness message stated "If you are around alcohol today, REACT MINDFULLY — notice, acknowledge, and accept the thoughts and feelings you have"; the perspective-taking message stated "If you are around alcohol today, IMAGINE HOW [NAME] WOULD REACT — try to imagine the thoughts and feelings that [NAME] would have", where [NAME] contained the name of the lower-drinking and closest nominated peer. Participants in the control condition consistently received the control message for these prompts. For participants in the mindfulness and perspective-taking conditions, prompts reinforced the mindfulness and perspective-taking prompts respectively) on two weeks and for the other two weeks the control message was received in the prompt (ABAB or BABA order counterbalanced across participants).

Ecological momentary assessment

As part of the 28-day protocol, participants answered two daily surveys in addition to the intervention prompts. A morning survey was sent at 8:00 am and an evening survey was sent at 6:00 pm. The surveys assessed alcohol consumption, and additional measures not the focus of the present report such as mood, conversations about alcohol, and others.

Supplementary Methods and Materials B

Mindfulness piloting

To inform the language used in the initial instructions and the smartphone intervention, we explored nine different variations of mindfulness-related instructions. We conducted a series of online studies via Amazon's Mechanical Turk (total n = 700). Consistent with past work on alcohol regulation, participants viewed images of alcohol (beer, wine, and liquor[1]) paired with manipulated instructions across different trials and rated their alcohol craving on a scale from 1-5 after each trial. In each pilot, participants viewed one of 9 different versions of mindfulness instructions on some trials and control instructions on other trials. Three of the pilots emphasized instructions related to psychological distancing, whereas the remaining versions emphasized different components, such as attention to the present moment, focus, awareness, or acceptance and contained no distancing language.

We ran multilevel models using lmer[2] in R (Version 4.0.3) using the RStudio interface (Version 1.3.1093) to compare craving ratings on trials after participants viewed mindfulness intervention instructions vs. control instructions. The pilot data suggested a trend such that instruction trials that emphasized psychological distancing (Fig S3A, replicated in B and C) directionally decreased alcohol craving vs. instruction trials which instead emphasized other components of mindfulness (Fig S3D–I). While more experimental work is needed, these data highlight that psychological distancing may be an important mechanism to help down-regulate responses to alcohol cues. See Fig S4 for one of the nine example instructions without distancing and other instructions that include distancing (as well as the final instructions used in the mindfulness condition).

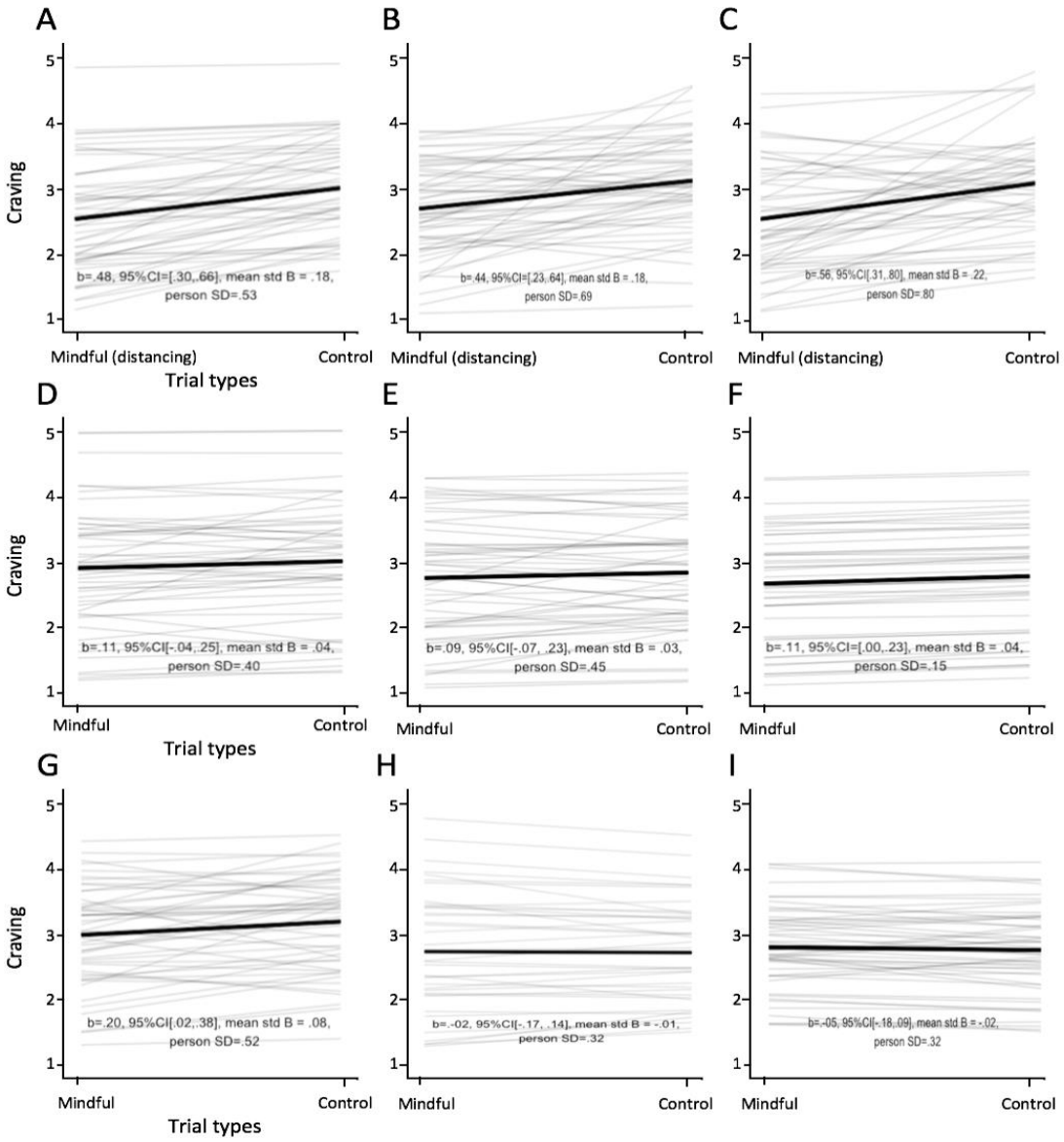

Fig S3. Effects of different mindfulness instructions on alcohol craving across instruction versions with varying emphasis on psychological distancing from alcohol cues. Across this series of pilot studies, the data indicate that mindfulness instructions emphasizing distancing (A-C) may be more effective in reducing craving than instructions emphasizing other components of mindfulness (D-I). Further, mindfulness instructions that contained no distancing language had near zero effect on reducing craving.

a. Mindfulness instruction with distancing (Final version used in the current project)

Another way you can relate to these situations is by *mentally taking a step back* in order to observe the situation and your response to it in an impartial and nonjudgmental manner. You may simply notice your thoughts and feelings about these situations, perhaps with some curiosity. That way, you can actively pay attention to your reaction and *see it as just a passing pattern of thoughts and feelings, without getting caught up in it.*

If you see a picture of beer, you can *mentally distance yourself* by observing the situation, and your response to it, with a more impartial, nonjudgmental, or curious mindset. When you see the word MINDFUL, it is critical that you *mentally take a step back from the situation, so that you observe the situation and your response to it without getting caught up in it.*

b. An example mindfulness instruction without distancing

Another way you can relate to these situations is by *actively noticing how they make you feel* in order to observe the situation and your response to it in an impartial and nonjudgmental manner. You may simply notice your thoughts and feelings about these situations, perhaps with some curiosity. That way, you can actively pay attention to your reaction and *observe your thoughts and feelings without judging your response.*

If you see a picture of beer, you can *notice any thoughts, sensations, and cravings or lack of cravings that arise.* When you see the word MINDFUL, it is critical that you *look at the photo and simply notice and observe any sensations you experience, so that you simply attend to what is felt, without making any judgment of the "goodness" or the "badness" of that sensation.*

Fig S4. Examples of pilot mindfulness instructions with (a) or without psychological distancing-related language (b).

Supplement C. Table S1. Descriptive statistics across interventions.

Study 1															
Condition	Mindfulness						Perspective-taking						Control		
Intervention Week	Active weeks			Inactive weeks			Active weeks			Inactive weeks			N/A		
	M	*M_win*	*Median*	*M*	*M_win*	*Median*	*M*	*M_win*	*Median*	*M*	*M_win*	*Median*	*M*	*M_win*	*Median*
% EMA responses	89.96%	89.96%	96.43%	91.22%	91.44%	96.43%	86.45%	86.87%	%	92.54%	93.20%	96.43%	92.86%	94.81%	98.21%
% Drinking occasions	12.63%	10.3%	10.71%	15.6%	14.63%	14.29%	12.95%	8.8%	9.56%	15.53%	14.3%	7.28%	17.61%	14.82%	14.55%
Drinks per occasion	2.61	2.34	2.29	2.87	2.77	2.69	2.92	2.60	2.86	2.98	2.95	2.90	3.56	2.78	3.1
Study 2															
Condition	Mindfulness						Perspective-taking						Control		
Intervention Week	Active weeks			Inactive weeks			Active weeks			Inactive weeks			N/A		
	M	*M_win*	*Median*	*M*	*M_win*	*Median*	*M*	*M_win*	*Median*	*M*	*M_win*	*Median*	*M*	*M_win*	*Median*
% EMA responses	81.48%	81.09%	89.29%	85.33%	91.94%	96.43%	78.57%	77.92%	92.86%	82.79%	92.55%	94.64%	80.53%	88.78%	89.29%
% Drinking occasions	9.14%	5.82%	3.71%	12.08%	8.91%	7.41%	9.33%	6.14%	3.70%	10.77%	7.89%	3.70%	9.87%	7.69%	4.76%
Drinks per occasion	2.31	1.87	1.70	2.34	2.02	2.25	1.93	1.86	1.92	1.72	1.57	1.50	1.94	1.07	1.82

Note: *M* = raw means; *M_win* = winsorized means (winsorized to +/- 2 standard deviations).

Supplementary Analyses C

In the subsequent section, we provide results from robustness checks and sensitivity analyses. First, we conducted two multilevel hurdle models, one for Study 1 and another for Study 2 to examine if the within-person effects of the psychological distance reminders on drinking frequency, presented in the main manuscript, remain robust when controlling for additional demographic variables. To test this, we ran parallel multilevel models to those presented in the main manuscript, but we also included gender, age, and race as covariates. Next, we explored whether the between-person effects on changes in drinking frequency, presented in the main manuscript, are robust to possible effects of outliers. To explore this question, we ran parallel tests to those presented in the main manuscript, winsorizing outliers to +/- 2 standard deviations from the mean.

Psychological distance reminders reduce drinking frequency controlling for demographics. Consistent with the main results presented in the manuscript, we observed parallel effects when controlling for age, gender, and race. Within-person, in both studies, we observed a lower probability of drinking on active weeks when individuals were instructed to adopt a mindful approach or to take their lower drinking peer's perspective, relative to inactive weeks, when they received control prompts, which instructed them to respond to alcohol naturally (Study 1: OR = 1.34, 95% CI [1.01-1.77], p = .042); Study 2: OR = 1.34, 95% CI [1.04 – 1.74], p = .025; Table S2). Similar to our results in the main manuscript, we observed no significant intervention effects on drinking amount, and no intervention week (active vs. inactive) x condition (mindfulness vs. perspective-taking) interaction effects in either study when accounting for demographics (Table S2).

Psychological distance reminders reduce drinking frequency vs. control. As a robustness check of the potential influence of outliers, we repeated the same analyses from the main manuscript comparing changes in drinking frequency between the intervention groups

(change from inactive to active weeks) and the control group (change from pseudo-active to pseudo-inactive weeks). Here, we winsorized drinking frequency change scores +/- 2 standard deviations from the mean. Consistent with the finding reported in the main text, we found significant differences in behavior change between the two groups; such that individuals in the intervention groups showed a greater decrease in drinking frequency from inactive weeks to active weeks relative to the control group, both in Study 1 (W = 984.5, Z = -2.146, p = .032, r = .206) and in Study 2 (W = 3750.5 Z = -3.475, p = =.001, r = .235; Fig. 3). These results reduce the likelihood that the observed between-person differences in behavior change between the intervention and control groups may be driven by outliers.

Table S2. Within-person effects of reminders on drinking on active vs. inactive weeks controlling for demographic variables

	Study 1			Study 2		
	Zero-inflated sub-model					
Fixed Effects	OR	95%CI	*p*	OR	95%CI	*p*
Intercept	59.6	[1.34-2653]	.004	103	[0.74-14,349]	.066
Active week (vs. inactive)	1.34	[1.01-1.77]	.042	1.34	[1.04-1.74]	.025
Perspective condition (vs. mindful)	1.12	[0.6- 1.89]	0.67	0.96	[0.55-1.67]	.890
Signal count	1.01	[1.01-1.02]	<.001	1.00	[0.99-1.01]]	.991
Number of responses	1.03	[0.99-1.06]	.165	1.01	[0.99-1.04]	.324
Social weekend (vs. week)	0.50	[0.40-0.61]	001	0.53	[0.44-0.64]	<.001
Age	0.85	[0.74-0.98]	.028	0.89	[0.71-1.10]	.280
Gender	0.91	[0.55-1.48]	690	1.50	[0.69-3.25]	.305
Race	0.98	[0.81-1.19]	.838	0.91	[0.75-1.11]	.357
Perspective condition (vs. mindful) *active week (vs. inactive)	0.93	[0.62-1.41]	.743	1.05	[0.72-1.54]	.783
Random effects	Variance	SD		Variance	SD	
Intercept						
Participant ID* Group ID	<.011	.902		1.599	1.265	
Participant ID	<.001	<.001		.781	.884	
	Conditional sub-model					
Fixed Effects	OR	95%CI	*p*	OR	95%CI	*p*
Intercept	9.89	[0.58-167]	.112	161	[9.27-2,793]	<.001
Active week (vs. inactive)	0.94	[0.70-1.26]	.669	0.95	[0.75, 1.22]	.699
Perspective condition (vs. mindful)	1.04	[0.71-1.54]	.828	0.48	[0.34, 0.68]	<.001
Signal count	1.00	[0.99-1.00]	.184	1.01	[1.00, 1.01]	.061
Number of responses	0.98	[0.96-1.01]	.169	0.99	[0.98, 1.01]	.302
Social weekend	1.56	[0.26-1.93]	<.001	1.32	[1.09, 1.61]	.005
Age	0.99	[0.89-1.09]	.778	0.84	[0.74, 0.96]	.009
Gender	0.76	[0.54-1.09]	.141	.62	[0.43, 0.90]	.013
Race	0.95	[0.83-1.08]	.414	.95	[0.86, 1.05]	.314
Perspective condition (vs. mindful) *active week (vs. inactive)	1.07	[0.71-1.61]	.758	1.41	[0.96, 2.08]	.076
Random effects	Variance	SD		Variance	SD	
Intercept						
Participant ID* Group ID	.205	.453		.1569	.396	
Participant ID	.033	.182		.058	.241	

Note. Study 1: 3577 observations nested within 71 participants across 10 groups; Study 2: 6301 observations nested within 138 participants across 23 groups. The zero-inflation sub-model of the hurdle model estimates the probability of an extra zero (no alcohol use) such that a positive estimate indicates a higher chance of no alcohol use. Perspective = perspective-taking; Mindful = mindfulness.

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