Patterns of Change in Weekend Drinking Cognitions Among Non–Treatment-Seeking Young Adults During Exposure to a 12-Week Text Message Intervention

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ABSTRACT. Objective: We sought to identify patterns of response (latent classes) to a text-message (short message service) intervention based on weekend drinking cognitions (e.g., drinking plans, commitment to a low consumption goal), and to examine how the latent classes differed in baseline characteristics and alcohol consumption outcomes. **Method:** We conducted a secondary analysis of 384 non–treatment-seeking young adults with hazardous alcohol use randomly assigned to a 12-week short message service intervention. Responses to weekly short message service queries related to weekend drinking cognitions were categorized as (a) planned not to drink, (b) planned to drink but did not plan a heavy drinking episode (HDE), (c) planned to have an HDE but willing to limit alcohol consumption, (d) planned to have an HDE and not willing to limit alcohol consumption. We used repeated-measures

latent class analysis to identify distinct classes based on these categories and examined associations of the classes with baseline covariates and alcohol consumption outcomes through 6 months. **Results:** We identified the following three latent classes: planned not to drink (62%), willing to limit drinks (27%), and not willing to limit drinks (12%). The “not willing to limit drinks” class exhibited the least reductions in alcohol consumption and was more likely to include White individuals and those with higher baseline drinking severity. The “planned not to drink” class had the greatest reductions in alcohol consumption. **Conclusions:** Young adults who exhibited low likelihood of committing to goals to limit weekend drinking were less responsive to short message service intervention, suggesting the need for alternative interventions. (*J. Stud. Alcohol Drugs*, 77, 914–923, 2016)

HEAVY DRINKING EPISODES (HDEs), typically defined as consuming more than three drinks for women and more than four drinks for men over a period of 2 hours, are the most common pattern of excessive alcohol use in the United States (Centers for Disease Control and Prevention [CDC], 2012). Among young adults, HDEs are associated with a multitude of health and social problems (Hingson et al., 2009) including death, serious injury, homicides, and suicides (CDC, 2012). Brief in-person interventions have been shown to reduce alcohol consumption among young adults (Carey et al., 2007) but have not scaled to produce population-level effects (Clark & Moss, 2010). Compared to in-person interventions, computerized interventions can produce comparable reductions in alcohol consumption (Carey et al., 2009) but have potential for wider dissemination (Kypri et al., 2003).

Although most computerized interventions tested to date have been delivered through the web, kiosks, or personal computer format, they can also be delivered through text messaging (short message service [SMS]). SMS interven-

tions have been shown to be effective for a range of health issues (Orr & King, 2015). As opposed to computerized interventions delivered through web or personal computer formats, which typically provide one-time summary feedback, SMS interventions can be designed to efficiently interact with individuals over time, collecting contextual and time-varying data related to the behavior of interest and providing feedback through a series of “micro-interventions.” This format lends itself particularly well to addressing alcohol use, which is strongly influenced by temporal and contextual experiences (Witkiewitz & Marlatt, 2004) and requires ongoing patient self-management (McKay, 2005).

Our group has shown that an SMS intervention, Texting to Reduce Alcohol Consumption (TRAC), was effective in reducing alcohol consumption among at-risk young adults (Suffoletto et al., 2014, 2015). The TRAC intervention was informed primarily by the Theory of Planned Behavior (Ajzen, 1991), aiming to modify an individual’s drinking intentions—a known predictor of alcohol consumption (Cooke et al., 2016)—and targets weekends, given that they are a high-risk period for HDE among young adults (del Boca et al., 2004). The TRAC intervention was designed to function for individuals with a variety of levels of readiness to change, to accommodate shifting motivations from week to week, and to offer an action plan to anyone reporting likelihood of having an HDE over the weekend. This stands in contrast to traditional stage-of-change–based interventions that do not typically recommend offering action plans to individuals in the pre-contemplative stage. The TRAC

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intervention incorporates self-monitoring, goal-setting, and feedback strategies, which have been shown to be effective components of mobile behavioral interventions for reducing alcohol consumption (Garnett et al., 2015). Although a recent trial (Suffoletto et al., 2015) showed that, on average, young adults exposed to the TRAC intervention reported one less HDE per month compared with baseline up to 9 months post-enrollment (6-month post-intervention completion), there appeared to be heterogeneity in intervention effects, suggesting that certain individuals were less likely to show a positive response to the intervention.

This study's overall goal was to identify patterns of response to texted queries sent as part of the TRAC intervention with a focus on weekend drinking cognitions (e.g., drinking plans, willingness to commit to a low consumption goal), given the hypothesized linkage between intentions (Cooke et al., 2016) and goal commitment (Lozano & Stephens, 2010) with alcohol consumption outcomes. We examined categories of text responses over 12 consecutive weeks of intervention exposure to identify if and how responses changed over time using a repeated-measures extension of latent class analysis (LCA) (Lanza & Rhoades, 2013), following McCarthy et al. (2015). In particular, we hypothesized identification of a class that would have a high probability of being unwilling to limit its weekend alcohol consumption, which would subsequently be associated with less reduction in alcohol consumption through 6-month follow-up. We examined associations of the latent classes with baseline covariates (e.g., demographics, alcohol use severity) that have been shown to be associated with young adult HDEs (Siqueira & Smith, 2015). Study findings could inform the design of SMS interventions to maximize effectiveness, especially for those who are resistant to change.

Method

Data for this secondary analysis were drawn from a multi-site randomized clinical trial that examined the effects of the TRAC intervention on reducing alcohol use among young adults (Clinical trials registry: NCT 01688245). A total of 765 participants were randomized to one of the following conditions: a 12-week SMS-delivered intervention (TRAC: $n = 384$), 12 weeks of Sunday SMS drinking assessments ($n = 196$), or a minimally assessed control with no SMS ($n = 185$). All participants were offered a brochure describing local substance use treatment services. This study examines participants randomized to the TRAC intervention since it was the only condition to incorporate pre-weekend SMS queries regarding weekend drinking cognitions.

Participants

Participants were recruited between November 2012 and November 2013 at four urban hospital emergency depart-

ments (EDs). To be eligible for the study, participants had to be between 18 and 25 years of age and report hazardous drinking (Alcohol Use Disorders Identification Test–consumption (AUDIT-C) scores ≥ 3 for women or ≥ 4 for men) (Bradley et al., 2007). Drinkers were excluded if they were seeking treatment for substance use, had a history of substance abuse treatment, were receiving psychiatric treatment, were currently enrolled in high school, or did not own a cell phone with text messaging capability. Willingness to reduce drinking was not necessary for study participation.

Procedures

Study procedures (approved by the University of Pittsburgh Institutional Review Board) are detailed elsewhere (Suffoletto et al., 2013). In brief, randomization occurred after screening and the baseline assessment. Participants in the TRAC intervention arm received SMS queries on Thursday and Sunday for 12 consecutive weekends (see Supplemental Appendix A). Each Thursday at noon, participants were asked to report whether they planned on drinking that weekend and, if so, whether they were likely to have $>3/4$ (women/men) drinks on any occasion. If a weekend HDE was anticipated, participants were immediately asked if they were willing to commit to a goal to consume $<4/5$ (women/men) drinks per occasion over the weekend.

Based on willingness to commit to a drinking limit goal, real-time feedback messages were sent—drawn from a library of messages—which either expressed support for the low consumption goal or encouraged reflection on not setting a consumption goal. Each Sunday at noon, participants were asked to report the largest number of drinks they had consumed during a single occasion over the weekend. Based on drinking quantity reported, real-time feedback messages were sent, either supporting the low-risk drinking behavior or encouraging reflection on weekend HDE. Participants completed 81% of SMS on Thursdays overall, with 7% missing in Week 1 and 29% missing by Week 12. Retention was 78% at 3 months (end of intervention) and 63% at 6 months, similar to prior ED-based alcohol trials (D'Onofrio et al., 2012).

Measures

Baseline alcohol use severity. During screening, participants completed the AUDIT-C, which includes three questions about past-year alcohol consumption (Bush et al., 1998). Each question is scored 0 to 4 points. Scores ≥ 4 (men) and ≥ 3 (women) indicate positive screens for hazardous drinking (Reinert & Allen, 2002) and were required to be eligible for trial participation. Higher AUDIT-C scores are associated with alcohol use disorder severity (Rubinsky et al., 2013) and nonresponse to brief interventions (Gentilello et al., 1999).

Baseline marijuana use. During baseline assessments, participants completed the National Institute on Drug Abuse Modified Alcohol, Smoking and Substance Involvement Screening Test (ASSIST) (Humeniuk et al., 2008) to assess frequency of substance use in the past 3 months (coded 0 = *never* to 6 = *almost daily or daily*). We focused specifically on marijuana use as a relevant covariate, given the high rates of use in young adult ED populations (Woolard, 2003) and the association between marijuana and increased alcohol use (Yeomans-Maldonado & Patrick, 2015). Marijuana use in the past 3 months was recoded into a dichotomous variable (0 = *none*, 1 = *any*).

Demographics. At baseline, participants reported their age, gender, race/ethnicity, and whether they were currently enrolled in college. Race was recoded into a dichotomous variable (0 = *Black/Other*, 1 = *White*), combining Black and other race/ethnicity, because other race/ethnicity made up only 5.5% of the total sample. In the eight cases where a participant indicated both Black and White racial identity, the cases were coded as representing Black/Other race/ethnicity.

Weekend drinking cognitions. A four-level variable was created for each of the 12 weeks that represented categorical responses to Thursday SMS queries. Each weekend, a participant could be assigned to one of the following categories: (a) planned not to drink, (b) planned to drink but did not plan an HDE, (c) planned to have an HDE but willing to limit alcohol consumption, (d) planned to have an HDE and not willing to limit alcohol consumption. These categories are completely non-overlapping, meaning that a participant could exist in only one category each week. However, a participant could switch between these categories freely from week to week.

Alcohol consumption outcomes. Using the responses to the SMS queries sent each Sunday for 12 weeks regarding most number of drinks consumed on a single occasion over the weekend, we created a weekly outcome variable, HDE (0 = *none*, 1 = *any*). At 3 and 6 months post-enrollment, participants completed a web-based Timeline Followback (Sobell et al., 1996) calendar, reporting the number of drinks consumed each day in the past 30 days. Memory aids were used to enhance recall (e.g., visual calendar with key dates and holidays to serve as anchors for reporting drinking; a visual chart of standard drink sizes to reduce variability in quantity). Outcomes at 3 and 6 months included the number of HDE days in the past 30 days, any HDE (yes/no) in the past 30 days, and average number of drinks per drinking day (DPDD) in the past 30 days.

Data analysis

To identify patterns of weekend drinking cognitions from week to week, we conducted repeated-measures LCA (RM LCA), a person-centered analytic approach (Collins & Lanza, 2010). RM LCA models provided estimates of the

following parameters: latent class (profile) membership probabilities and item response probabilities for each class (i.e., the probability of “plan to have an HDE and not willing to commit to a drinking limit goal” conditional on most likely class assignment).

RM LCA analyses were run using Latent GOLD Version 5.0 (Vermunt & Magidson, 2005, 2013), using 16 random starts (models specifying 200 random starts yielded similar results), testing the fit of 1–6 latent classes. Full-information maximum likelihood estimation was used to handle missing data (Vermunt & Magidson, 2005). The best-fitting model was determined primarily by the Bayesian Information Criterion (BIC; lower value indicates better fit) (Henson et al., 2007), consideration of the distinctiveness of the class profiles (Collins & Lanza, 2010), and avoidance of classes with low prevalence (e.g., <10%). Other model-fit indices that were considered include sample size-adjusted BIC (aBIC; Sclove, 1987); bootstrap likelihood ratio test (BLRT; McLachlan & Peel, 2000); and entropy, a measure of classification quality (maximum = 1.00, indicating high classification quality).

Using adjusted three-step modeling procedures in Latent GOLD Version 5.0 (Bakk & Vermunt, 2016), we selected the best-fitting RM LCA model, saved class assignment probabilities, and then related the probabilities of class assignment to external variables (covariates and outcomes), correcting for classification error to minimize bias. Baseline covariates included age, sex (0 = *female*, 1 = *male*), race/ethnicity (0 = *Black/Other*, 1 = *White*), AUDIT-C score, and marijuana use (0 = *no use*, 1 = *any use*). AUDIT-C was *z* score standardized. Site was not associated with the latent classes or outcomes (Suffoletto et al., 2014) and thus was not included as a covariate in the models.

We graphically examined the frequency distribution of weekend drinking cognitions reported through SMS in each of the latent classes each week to better understand the timing and magnitude of changes over the 12 weeks of intervention exposure. We also graphically examined the percentage of individuals reporting an HDE through SMS for each of the latent classes over the 12 intervention weeks. To explore whether there were differences in likelihood of HDE over the 12 weeks between the three latent classes, we used three-step modeling to compare growth (intercept, slope) in HDE over the 12 weeks across the three classes, adjusting for age, sex, race, AUDIT-C score, and marijuana use (see Supplemental Appendix B).

Last, we examined the relative strength of association of latent class with 3- and 6-month outcomes, focusing on number of HDEs and DPDD over the past month. We modeled each outcome as dependent (“distal outcome”) count variables using the Bolck–Croon–Hagenaars method, which is less sensitive to violations of distribution assumptions and accommodates variables of any scale type (Bakk & Vermunt, 2016; Bolck et al., 2004). Full-information

TABLE 1. Descriptive statistics for the TRAC intervention sample and by latent response class

Baseline	Total sample (<i>N</i> = 384)	Plan not to drink (<i>n</i> = 237)	Willing to limit drinks (<i>n</i> = 102)	Not willing to limit drinks (<i>n</i> = 45)
Age, in years, <i>M</i> (<i>SD</i>)	22.0 (2.0)	21.9 (2.1)	22.1 (2.0)	22.0 (2.0)
Female	65.4%	68.4%	59.8%	64.4%
Race				
White	49.5%	44.3%	53.0%	68.9%
Black/Other	50.6%	55.7%	47.0%	31.1%
Current college enrollment	42.2%	40.9%	45.1%	42.2%
AUDIT-C score, <i>M</i> (<i>SD</i>)	6.3 (2.2)	6.2 (2.0)	5.4 (1.8)	7.7 (2.2)
Daily or almost daily tobacco	59.9%	58.6%	59.8%	66.7%
Any cannabis	51.3%	47.7%	61.8%	46.7%

Notes: TRAC = Texting to Reduce Alcohol Consumption; AUDIT-C = Alcohol Use Disorders Identification Test—consumption.

maximum likelihood estimation was used to accommodate missing outcome data (Vermunt & Magidson, 2005). Although attrition was associated with less than college education and using tobacco, these variables were not significantly associated with the latent classes and were not included as covariates (however, we note that three-step models that included these variables as covariates resulted in similar findings for outcome variables). Parameters for each latent profile (membership probabilities, item response probabilities) were similar for unconditional and conditional (external variables included) models. Outcome analyses adjusted for baseline covariates.

Results

Sample descriptive statistics are reported in Table 1. Participants in the TRAC intervention arm (*n* = 384) had a mean age of 22.0 years and were mostly female (65%); almost half (49.5%) were White, and 42.2% were currently enrolled in college. At baseline, participants had an average AUDIT-C score of 6.3 (*SD* = 2.2), with 41% reporting drinking at least two times per week, 39% consuming more than five drinks on a typical drinking day, and 21% reporting consuming more than six drinks at least weekly. Comorbid cigarette and marijuana use were high (59.9% and 51.3%, respectively).

RM LCA model

The 12 weeks of weekend drinking cognitions were used to estimate RM LCA models with one to six classes. BIC indicated that the three-class solution had the best fit to the data (Table 2). Classification quality of the three-class model was satisfactory (entropy = .79, where the maximum = 1.00). Although Akaike Information Criterion and BLRT suggested improvement in model fit with additional classes, differences in BIC and aBIC indicated that improvements slowed after four to five total classes. The four- and five-class solutions essentially further subdivided individuals who tended to report no plan to drink, that is, the largest class in

the three-class model. To avoid classes with relatively small proportions (<10%), we chose a three-class model.

Figure 1 shows the distribution of drinking cognitions over 12 weeks, both overall and for each of the three classes. The largest class of individuals (planned not to drink; 62%) exhibited an increasing probability of reporting no plan to drink over 12 weekends and also seemed to make most of their changes in the first 6 weeks of intervention exposure. The next largest class (willing to limit drinks; 27%) exhibited a decreasing probability of planning weekend HDE over 12 weeks as well as a high willingness to limit their alcohol consumption. The smallest class (not willing to limit drinks; 12%) was composed of individuals who reported a high probability of planning weekend HDE and a low, yet moderately variable, probability of willingness to limit their alcohol consumption.

Covariate effects for the three-class model

We examined the association of the three latent classes with the following covariates: age, sex, race, AUDIT-C score, and any marijuana use. The differences in covariates between latent classes can be seen in Table 1. As shown in Table 3, for each point increase in AUDIT-C score (holding other variables constant), the odds of being in the “not willing to limit drinks” class are 2.72 times higher and the odds of being in the “willing to limit drinks” class are 1.54 times higher compared with the “planned not to drink” class. White race is associated with higher odds of being in the “not willing to limit drinks” class compared with the “planned not to drink” class. Marijuana use was associated with being in the “willing to limit drinks” class relative to the “planned not to drink” class.

Association of latent classes with alcohol use

Figure 2 shows the proportion who reported any weekend HDE (yes/no) based on Sunday SMS report in each of the three classes across 12 weeks of intervention exposure. The

TABLE 2. Fit statistics for repeated-measures latent class analysis models specifying 1–6 classes

Latent classes	Log-likelihood	Parameters	AIC	BIC	Difference in BIC	aBIC	Difference in aBIC	Entropy	BLRT (p) ^a
1	-4,176.630	36	8,425.2609	8,567.4840	—	8,453.2611	—	1.00	—
2	-3,804.044	73	7,754.0894	8,042.4863	524.99	7,810.8676	642.39	0.77	<.001
3	-3,669.286	110	7,558.5719	7,993.1426	49.35	7,644.1281	166.74	0.79	<.001
4	-3,569.458	147	7,432.9167	8,013.6612	20.52	7,547.0240	97.11	0.78	<.001
5	-3,521.121	184	7,410.2422	8,137.1604	123.50	7,546.3145	0.71	0.78	<.001
6	-3,477.579	221	7,397.1586	8,270.2506	133.09	7,553.2755	6.97	0.78	<.001

Notes: AIC = Akaike Information Criterion; BIC = Bayesian Information Criterion; aBIC = sample size-adjusted BIC; BLRT (p) = bootstrap likelihood ratio test p value. BLRT p value indicates the significance of the difference in model fit with the addition of one more class. **Bold** indicates the class with the best fit to the data. ^a $p < .05$ indicates a significant change in model fit with an increase in the number of latent classes.

FIGURE 1. Frequency distribution of weekend drinking cognitions for each of the three latent classes and the total sample over the 12 intervention weeks. Gray = planned not to drink; diagonal stripe = plan to drink but did not plan a heavy drinking episode (HDE); white = planned to have an HDE but willing to commit to a low consumption goal; black = planned to have an HDE and not willing to commit to a low consumption goal. The four panels show, for each latent class and the total sample, the frequency distribution of pre-weekend drinking cognitions (assessed on Thursday) for each of the 12 intervention weeks. The depicted frequency distribution is based on “hard classification” of cases into the most likely class and depicts cases with relevant data at a given time point, although analyses to derive the three latent classes used full-information maximum likelihood estimation to accommodate incomplete data over the 12 weeks.

TABLE 3. Latent class membership baseline predictors (reference group = planned not to drink)

Baseline covariate	Willing to limit drinks OR [95% CI]	Not willing to limit drinks OR [95% CI]
Age	1.22 [0.93, 1.61]	1.23 [0.85, 1.79]
AUDIT-C score	1.54 [1.15, 2.06]***	2.72 [1.84, 4.02]***
Sex (0 = female, 1 = male)	1.01 [0.55, 1.85]	0.70 [0.30, 1.62]
Race (0 = Black/Other, 1 = White)	1.62 [0.92, 2.85]	3.10 [1.36, 7.05]***
Any marijuana (0 = no, 1 = yes)	1.82 [1.03, 3.22]*	1.03 [0.48, 2.21]

Notes: OR = odds ratio; CI = confidence interval; AUDIT-C = Alcohol Use Disorders Identification Test–consumption.

* $p < .05$; *** $p < .001$.

“planned not to drink” class had a lower proportion reporting any HDE in Week 1 (24% vs. 53% in “willing to limit drinks” and 64% in “not willing to limit drinks” classes) and showed the greatest reduction in HDE prevalence over 12 weeks (from 24% in Week 1 to 6% in Week 12). Among the classes, the “not willing to limit drinks” class had a high and largely unchanged proportion reporting HDE over the 12 weeks (range from 76% in Week 3 to 46% in Week 12), whereas the “willing to limit drinks” class showed intermediate values (range from 55% in Week 2 to 31% in Week 8).

Exploratory analyses (see Supplemental Appendix B) comparing growth (intercept, slope) in HDE across the three classes—adjusting for baseline covariates of age, sex, race, AUDIT-C score, and marijuana use—indicated that the “not willing to limit drinks” class was more likely to report HDE at Week 1 (HDE growth model in which intercept was set to 0 at Week 1) than the “planned not to drink” class ($p < .05$). A separate exploratory analysis indicated that the “not willing to limit drinks” class also was more likely to report HDE

at Week 12 (HDE growth model in which intercept was set to 0 at Week 12) than the “planned not to drink” class ($p < .05$). The “willing to limit drinks” class did not differ from the other two classes in HDE at Week 1 or Week 12. There was no difference across the three latent classes in rate of change in HDE over the 12 weeks.

As shown in Table 4, HDE and DPDD at 3 and 6 months were lowest in the “planned not to drink” class and highest in the “not willing to limit drinks” class, with the “willing to limit drinks” class showing intermediate levels of HDE and DPDD. As shown in Table 5, when we controlled for baseline covariates, the “planned not to drink” class and the “willing to limit drinks” class differed from the “not willing to limit drinks” class in HDE and DPDD at 3 months (e.g., for HDE, Wald statistic = 44.59, $p < .001$; for DPDD, Wald statistic = 21.10, $p < .001$).

Specifically, the “planned not to drink” class was estimated to have 1.45 fewer HDE days, and the “willing to limit drinks” class was estimated to have 0.34 fewer HDE days,

FIGURE 2. Percentage reporting a heavy drinking episode through short message service text intervention for each of the three latent classes over the 12 intervention weeks. Plan not to drink class ($n = 237$); willing to limit drinks class ($n = 102$); not willing to limit drinks class ($n = 45$).

TABLE 4. Alcohol consumption outcomes at 3- and 6-month follow-up for each of the three latent classes

Variable	Total sample <i>M (SD)</i>	Planned not to drink <i>M (SD)</i>	Willing to limit drinks <i>M (SD)</i>	Not willing to limit drinks <i>M (SD)</i>
3-month follow-up	(<i>N</i> = 290)	(<i>n</i> = 174)	(<i>n</i> = 77)	(<i>n</i> = 39)
No. of days with a heavy drinking episode	3.15 (4.28)	1.67 (2.85)	4.27(4.65)	7.51 (5.21)
Drinks per drinking day	3.50 (2.00)	3.05 (1.90)	3.47 (1.58)	5.33 (2.10)
6-month follow-up	(<i>N</i> = 234)	(<i>n</i> = 143)	(<i>n</i> = 58)	(<i>n</i> = 33)
No. of days with a heavy drinking episode	2.91 (3.83)	1.84 (3.33)	3.79 (3.51)	5.97 (4.43)
Drinks per drinking day	3.52 (2.28)	3.06 (2.12)	3.49 (1.85)	5.37 (2.68)

Notes: Unadjusted means, based on classification of cases into the most likely class, are reported. No. = number.

relative to the “not willing to limit drinks” class. Further, at 3 months, the “planned not to drink” class was estimated to have 0.41 fewer DPDD, and the “willing to limit drinks” class was estimated to have 0.33 fewer DPDD, relative to the “not willing to limit drinks” class. At 6 months, the “planned not to drink” class and the “willing to limit drinks” class had fewer DPDD compared with the “not willing to limit drinks” class (Wald statistic = 16.76, $p < .001$). For HDE at 6 months (Wald statistic = 15.19, $p < .001$), the “plan not to drink” class was estimated to have 0.92 fewer HDE days relative to the “not willing to limit drinks” class. However, the “willing to limit drinks” class did not significantly differ ($p = .35$) from the “not willing to limit drinks” class on HDE at 6-month follow-up.

Discussion

This study revealed that heterogeneity in response to a text message intervention could be described by three latent classes in a sample of non-treatment-seeking young

adults. A large class of young adults reduced their weekend drinking intentions over 12 weeks (“planned not to drink”), and another class reported a decreasing likelihood of HDE over 12 weeks as well as a high stable willingness to limit their alcohol consumption (“willing to limit drinks”), which together constituted the vast majority of participants (88%). Both of these classes reduced their alcohol consumption over weekends during the intervention and up to 3 months after intervention completion, supporting the idea that the effects of the text message intervention reported in prior trial manuscripts (Suffoletto et al., 2014, 2015) were likely driven by the two “responder” classes. The different classes of response to texted queries that we found are comparable to those reported in a study examining an in-person brief alcohol intervention for an older adolescent ED population (Becker et al., 2012). In their study, the authors described three classes of response based on frequency of drinking over time, including a “moderate use, decreaser” class (57%), a “heavy use, decreaser” class (11%), and a “heavy use sustainer” class (33%). This is the first study to exam-

TABLE 5. Association of latent classes with 3-month and 6-month outcomes (reference group = not willing to limit drinks)

Variable	<i>b (SE)</i>	<i>z</i>	Wald (<i>df</i>)
No. of HDE days at 3 months			
Intercept	1.69 (0.16)	10.76***	115.72 (1)***
Planned not to drink	-1.45 (0.22)	-6.62***	44.59 (2)***
Willing to limit drinks	-0.34 (0.16)	-2.08*	
DPDD at 3 months			
Intercept	1.69 (0.08)	20.71***	428.75 (1)***
Planned not to drink	-0.41 (0.10)	-4.29***	21.10 (2)***
Willing to limit drinks	-0.33 (0.08)	-3.89***	
No. of HDE days at 6 months			
Intercept	1.51 (0.16)	9.36***	87.54 (1)***
Planned not to drink	-0.92 (0.24)	-3.75***	15.19 (2)***
Willing to limit drinks	-0.15 (0.16)	-0.94	
DPDD at 6 months			
Intercept	1.83 (0.12)	15.49***	239.91 (1)***
Planned not to drink	-0.46 (0.11)	-4.08***	16.76 (2)***
Willing to limit drinks	-0.33 (0.12)	-2.82***	

Notes: *N* = 384. no. = number; HDE = heavy drinking episode; DPDD = drinks per drinking day. The coefficients reported reflect adjustment for covariates, which included sex (0 = female, 1 = male), race/ethnicity (0 = other race/ethnicity, 1 = White), Alcohol Use Disorders Identification Test-consumption score, and marijuana use (0 = no use, 1 = any use).

* $p < .05$; *** $p < .001$.

ine patterns of response over exposure to a text message intervention.

The changes in weekend drinking intentions among the “plan not to drink” class are supportive of our hypothesized intervention model based on the Theory of Planned Behavior. Specifically, it aligns with prior work showing that changes in drinking intentions are a key mechanism of subsequent change in alcohol consumption (Cooke et al., 2016). The finding that intentions not to drink increased over time suggests that young adults exposed to the intervention may substitute drinking plans with nondrinking activity plans or change their expectations of heavy drinking weekends to ones with moderate drinking. It also suggests the possibility that sending support messages when an individual declares no intention to drink could act to reinforce those intentions in future weeks. This would be in line with prior research illustrating that provision of feedback is an element common to successful brief interventions for alcohol use disorders (Bien et al., 1993). Our finding that the changes appeared to take place over the first 6 weeks suggests that the SMS program may have a positive effect if conducted for shorter periods.

The relatively high probability of reported drinking plans in the “willing to limit drinks” class throughout the 12 weeks suggests that this group did not simply replace drinking events with nondrinking events. The willingness to limit alcohol consumption below HDE thresholds suggests that these individuals may learn to self-regulate during drinking occasions. It also supports the use of just-in-time text message reminders to reinforce commitment to support goal attainment (Lagoa et al., 2014). The association we found between any marijuana use and the “willing to limit drinks” class is of unclear meaning. In general, all classes had higher rates of marijuana use (>47% in each class) than those documented among young adults in the National Survey of Drug Use and Health (19.6%) (Center for Behavioral Health Statistics and Quality, 2015). One possibility is that young adults who use cannabis are more amenable to reducing their alcohol consumption than non-cannabis users, but another possibility is that young adults may be replacing one drug with another.

As hypothesized, we identified a class that showed little change in willingness to limit alcohol use (“not willing to limit drinks” class). This was the smallest class, which showed little interest in reducing their weekend drinking or setting drinking limit goals over the 12 weeks of intervention exposure. This class had negligible reductions in both the probability of reporting weekend HDE during intervention exposure and alcohol consumption through 6 months of follow-up. This suggests that when recruiting non-treatment-seeking young adults, one can expect a minority (around 12% in this sample) to be less responsive to this type of SMS intervention. Compared with the responder classes, individuals in this group were more likely to report high

baseline alcohol use severity. This finding is reflected in prior research showing that heavier drinkers respond less to brief interventions (Carey et al., 2007; Gentilello et al., 1999) and supports federal guidelines advising that those with more severe drinking be referred directly to treatment (National Institute on Alcohol Abuse and Alcohol, 2007).

Another interpretation is that brief interventions need to be more responsive to heavier drinkers’ needs. For example, instead of prompting these heavier drinking individuals to commit to a low-quantity drinking goal (i.e., <4/5 drinks per occasion), mobile interventions could include adaptive-graded goal commitment, whereby individuals are prompted to set goals closer to their current drinking level. Setting more attainable goals could facilitate goal achievement, with reinforcement of successively closer approximations to the desired behavior (Lamb et al., 2004). Compared to the “planned not to drink” and “willing to limit drink” classes, individuals in the “not willing to limit drinks” class were also more likely to report being White. This finding mirrors our initial trial findings showing that, compared with White individuals, Black individuals had fewer HDEs (incident rate ratio = 0.85, 95% CI [0.77, 0.95]) and were more likely to report having no HDEs (odds rate ratio = 2.42, 95% CI [1.53, 3.82]) at 3-month follow-up (Suffoletto et al., 2014). This result also reflects national survey data showing that White young adults tend to report greater alcohol consumption than Black young adults (Center for Behavioral Health Statistics and Quality, 2015).

Study limitations

Although we used prospective SMS reports of pre-weekend drinking cognitions as the repeated indicator of latent classes, which should minimize recall bias and preserve a temporal precedence to outcomes, data could still be subject to reporting biases. The latent classes that were identified should be considered “heuristic” patterns of intervention response, and they warrant replication. There was an increasing amount of missing data from Week 1 to Week 12, although participation rates were relatively high and comparable to other SMS interventions (Irvine et al., 2012; Weitzel et al., 2007). Participants lost to follow-up were less likely to self-identify as being White and were more likely to use tobacco and not have a college education. Although analyses accommodated incomplete data over follow-up, study results need to be interpreted in the context of attrition over follow-up. Methods to enhance engagement with SMS intervention over time are needed.

We were not able to directly examine response to other intervention components (e.g., provision of information on alcohol-related health risks in response to reporting a weekend heavy drinking), which may have affected drinking behavior. In addition, other correlates of treatment response, such as readiness to change, and mediators specific

to the Theory of Planned Behavior (i.e., attitudes, subjective norms, and perceived behavioral control) were not examined here. Future work also might consider the predictive utility of weekly goal intentions above and beyond initial intentions to reduce drinking. Given that this study focused on young adult hazardous drinkers who were identified in an ED setting, findings may not generalize to other populations and settings.

Conclusions

Results from RM LCA indicated distinct and meaningful patterns of response to texted queries in an SMS alcohol intervention among non-treatment-seeking young adults, including differences in the timing and rate of change in drinking cognitions among groups. Latent class membership was related to known baseline risk factors for hazardous drinking and was associated with drinking outcomes. The text message alcohol intervention had maximum impact for those who reported plans not to drink on weekends, had moderate impact on those who planned weekend HDEs but were willing to commit to low consumption goals, and was least effective for those who were not willing to limit their alcohol consumption. Future text message and mobile communication technology interventions should be designed to adapt intervention content to different subgroups to optimize effectiveness.

Conflict of Interest Statement

Brian Suffoletto has received royalties for a copyright for a text message intervention that has been licensed to HealthStratica LLC.

References

- Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, 50, 179–211. doi:10.1016/0749-5978(91)90020-T.
- Bakk, Z., & Vermunt, J. K. (2016). Robustness of stepwise latent class modeling with continuous distal outcomes. *Structural Equation Modeling: A Multidisciplinary Journal*, 23, 20–31. doi:10.1080/10705511.2014.955104
- Becker, S. J., Spirito, A., Hernandez, L., Barnett, N. P., Eaton, C. A., Lewander, W., . . . & Monti, P. M. (2012). Trajectories of adolescent alcohol use after brief treatment in an emergency department. *Drug and Alcohol Dependence*, 125, 103–109. doi: 10.1016/j.drugalcdep.2012.03.021
- Bien, T. H., Miller, W. R., & Tonigan, J. S. (1993). Brief interventions for alcohol problems: A review. *Addiction*, 88, 315–336. doi:10.1111/j.1360-0443.1993.tb00820.x
- Bolck, A., Croon, M., & Hagenaars, J. (2004). Estimating latent structure models with categorical variables: One-step versus three-step estimators. *Political Analysis*, 12, 3–27. doi:10.1093/pan/mp001.
- Bradley, K. A., DeBenedetti, A. F., Volk, R. J., Williams, E. C., Frank, D., & Kivlahan, D. R. (2007). AUDIT-C as a brief screen for alcohol misuse in primary care. *Alcoholism: Clinical and Experimental Research*, 31, 1208–1217. doi:10.1111/j.1530-0277.2007.00403.x
- Bush, K., Kivlahan, D. R., McDonell, M. B., Fihn, S. D., & Bradley, K. A. (1998). The AUDIT Alcohol Consumption Questions (AUDIT-C): An effective brief screening test for problem drinking. *Archives of Internal Medicine*, 158, 1789–1795. doi:10.1001/archinte.158.16.1789
- Carey, K. B., Scott-Sheldon, L. A., Carey, M. P., & DeMartini, K. S. (2007). Individual-level interventions to reduce college student drinking: A meta-analytic review. *Addictive Behaviors*, 32, 2469–2494. doi:10.1016/j.addbeh.2007.05.004
- Carey, K. B., Scott-Sheldon, L. A., Elliott, J. C., Bolles, J. R., & Carey, M. P. (2009). Computer-delivered interventions to reduce college student drinking: A meta-analysis. *Addiction*, 104, 1807–1819. doi:10.1111/j.1360-0443.2009.02691.x
- Center for Behavioral Health Statistics and Quality. (2015). *Behavioral health trends in the United States: Results from the 2014 National Survey on Drug Use and Health* (HHS Publication No. SMA 15-4927, NSDUH Series H-50). Retrieved from <http://www.samhsa.gov/data/sites/default/files/NSDUH-FRR1-2014/NSDUH-FRR1-2014.htm>
- Centers for Disease Control and Prevention. (2012). Vital signs: Binge drinking prevalence, frequency, and intensity among adults—U.S., 2010. *Morbidity and Mortality Weekly Report*, 61, 14–19. Retrieved from http://www.cdc.gov/mmwr/preview/mmwrhtml/mm6101a4.htm?s_cid=mm6101a4_w
- Clark, D. B., & Moss, H. B. (2010). Providing alcohol-related screening and brief interventions to adolescents through health care systems: Obstacles and solutions. *PLoS Medicine*, 7(3), e1000214. doi:10.1371/journal.pmed.1000214
- Collins, L. M., & Lanza, S. T. (2010). *Latent class and latent transition analysis with applications in the social, behavioral, and health sciences*. Hoboken, NJ: John Wiley & Sons.
- Cooke, R., Dahdah, M., Norman, P., & French, D. P. (2016). How well does the theory of planned behaviour predict alcohol consumption? A systematic review and meta-analysis. *Health Psychology Review*, 10, 148–167. doi:10.1080/17437199.2014.947547
- D'Onofrio, G., Fiellin, D. A., Pantalon, M. V., Chawarski, M. C., Owens, P. H., Degutis, L. C., . . . O'Connor, P. G. (2012). A brief intervention reduces hazardous and harmful drinking in emergency department patients. *Annals of Emergency Medicine*, 60, 181–192. doi:10.1016/j.annemergmed.2012.02.006
- Del Boca, F. K., Darkes, J., Greenbaum, P. E., & Goldman, M. S. (2004). Up close and personal: Temporal variability in the drinking of individual college students during their first year. *Journal of Consulting and Clinical Psychology*, 72, 155–164. doi:10.1037/0022-006X.72.2.155
- Garnett, C., Crane, D., West, R., Brown, J., Michie, S. (2015). Identification of behavior change techniques and engagement strategies to design a smartphone app to reduce alcohol consumption using a formal consensus method. *JMIR Mhealth Uhealth*, 3(2), e73. doi:10.2196/mhealth.3895
- Gentilello, L. M., Rivara, F. P., Donovan, D. M., Jurkovich, G. J., Daranciang, E., Dunn, C. W., . . . Ries, R. R. (1999). Alcohol interventions in a trauma center as a means of reducing the risk of injury recurrence. *Annals of Surgery*, 230, 473–480, discussion 480–483. doi:10.1097/0000658-199910000-00003
- Henson, J. M., Reise, S. P., & Kim, K. H. (2007). Detecting mixtures from structural model differences using latent variable mixture modeling: A comparison of relative model fit statistics. *Structural Equation Modeling*, 14, 202–226. doi:10.1080/10705510709336744
- Hingson, R. W., Edwards, E. M., Heeren, T., & Rosenbloom, D. (2009). Age of drinking onset and injuries, motor vehicle crashes, and physical fights after drinking and when not drinking. *Alcoholism: Clinical and Experimental Research*, 33, 783–790. doi:10.1111/j.1530-0277.2009.00896.x
- Humeniuk, R., Ali, R., Babor, T. F., Farrell, M., Formigoni, M. L., Jittiwutikarn, J., . . . Simon, S. (2008). Validation of the alcohol, smoking and substance involvement screening test (ASSIST). *Addiction*, 103, 1039–1047. doi:10.1111/j.1360-0443.2007.02114.x
- Hingson, R. W., Zha, W., & Weitzman, E. R. (2009). Magnitude of and trends in alcohol-related mortality and morbidity among U.S. college

- students ages 18-24, 1998-2005. *Journal of Studies on Alcohol and Drugs, Supplement 16*, 12-20. doi:10.15288/jsads.2009.s16.12
- Irvine, L., Falconer, D. W., Jones, C., Ricketts, I. W., Williams, B., & Crombie, I. K. (2012). Can text messages reach the parts other process measures cannot reach: An evaluation of a behavior change intervention delivered by mobile phone? *PLoS ONE*, 7(12), e52621. doi:10.1371/journal.pone.0052621
- Kypri, K., Saunders, J. B., & Gallagher, S. J. (2003). Acceptability of various brief intervention approaches for hazardous drinking among university students. *Alcohol and Alcoholism*, 38, 626-628. doi:10.1093/alcalc/agg121
- Lagoa, C. M., Bekiroglu, K., Lanza, S. T., & Murphy, S. A. (2014). Designing adaptive intensive interventions using methods from engineering. *Journal of Consulting and Clinical Psychology*, 82, 868-878. doi:10.1037/a0037736
- Lamb, R. J., Kirby, K. C., Morral, A. R., Galbicka, G., & Iguchi, M. Y. (2004). Improving contingency management programs for addiction. *Addictive Behaviors*, 3, 507-523.
- Lanza, S. T., & Rhoades, B. L. (2013). Latent class analysis: An alternative perspective on subgroup analysis in prevention and treatment. *Prevention Science*, 14, 157-168. doi:10.1007/s11121-011-0201-1
- Lozano, B. E., & Stephens, R. S. (2010). Comparison of participatively set and assigned goals in the reduction of alcohol use. *Psychology of Addictive Behaviors*, 24, 581-591. doi:10.1037/a0021444
- McCarthy, D. E., Ebssa, L., Witkiewitz, K., & Shiffman, S. (2015). Paths to tobacco abstinence: A repeated-measures latent class analysis. *Journal of Consulting and Clinical Psychology*, 83, 696-708. doi:10.1037/ccp0000017
- McKay, J. R. (2005). Is there a case for extended interventions for alcohol and drug use disorders? *Addiction*, 100, 1594-1610. doi:10.1111/j.1360-0443.2005.01208.x
- McLachlan, G. J., & Peel, D. (2000). *Finite mixture models*. New York, NY: Wiley.
- National Institute on Alcohol Abuse and Alcoholism. (2007). *Helping patients who drink too much: A clinician's guide*. Bethesda, MD: Author.
- Orr, J. A., & King, R. J. (2015). Mobile phone SMS messages can enhance healthy behaviour: A meta-analysis of randomised controlled trials. *Health Psychology Review*, 9, 397-416. doi:10.1080/17437199.2015.1022847
- Reinert, D. F., & Allen, J. P. (2002). The Alcohol Use Disorders Identification Test (AUDIT): A review of recent research. *Alcoholism: Clinical and Experimental Research*, 26, 272-279. doi:10.1111/j.1530-0277.2002.tb02534.x
- Rubinsky, A. D., Dawson, D. A., Williams, E. C., Kivlahan, D. R., & Bradley, K. A. (2013). AUDIT-C scores as a scaled marker of mean daily drinking, alcohol use disorder severity, and probability of alcohol dependence in a U.S. general population sample of drinkers. *Alcoholism: Clinical and Experimental Research*, 37, 1380-1390. doi:10.1111/acer.12092
- Selove, L. S. (1987). Application of model-selection criteria to some problems in multivariate analysis. *Psychometrika*, 52, 333-343. doi:10.1007/BF02294360
- Siqueira, L., & Smith, V. C., & the Committee on Substance Abuse. (2015). Binge drinking. *Pediatrics*, 136, e718-e726. doi:10.1542/peds.2015-2337
- Sobell, L. C., Brown, J., Leo, G. I., & Sobell, M. B. (1996). The reliability of the Alcohol Timeline Followback when administered by telephone and by computer. *Drug and Alcohol Dependence*, 42, 49-54. doi:10.1016/0376-8716(96)01263-X
- Suffoletto, B., Callaway, C. W., Kristan, J., Monti, P., & Clark, D. B. (2013). Mobile phone text message intervention to reduce binge drinking among young adults: Study protocol for a randomized controlled trial. *Trials*, 14, 93. doi:10.1186/1745-6215-14-93
- Suffoletto, B., Kristan, J., Callaway, C., Kim, K. H., Chung, T., Monti, P. M., & Clark, D. B. (2014). A text message alcohol intervention for young adult emergency department patients: A randomized clinical trial. *Annals of Emergency Medicine*, 64, 664-72.e4. doi:10.1016/j.annemergmed.2014.06.010
- Suffoletto, B., Kristan, J., Chung, T., Jeong, K., Fabio, A., Monti, P., & Clark, D. B. (2015). An interactive text message intervention to reduce binge drinking in young adults: A randomized controlled trial with 9-month outcomes. *PLoS ONE*, 10(11), e0142877. doi:10.1371/journal.pone.0142877
- Vermunt, J. K., & Magidson, J. (2005). Latent variable. In B. Everitt & D. Howell (Eds.), *Encyclopedia of Statistics in Behavioral Science*. New York, NY: John Wiley & Sons, Inc. doi:10.1002/0470013192.bsa339
- Vermunt, J. K., & Magidson, J. (2013). *Latent GOLD 5.0 upgrade manual*. Belmont, MA: Statistical Innovations, Inc.
- Weitzel, J. A., Bernhardt, J. M., Usdan, S., Mays, D., & Glanz, K. (2007). Using wireless handheld computers and tailored text messaging to reduce negative consequences of drinking alcohol. *Journal of Studies on Alcohol and Drugs*, 68, 534-537. doi:10.15288/jsad.2007.68.534
- Witkiewitz, K., & Marlatt, G. A. (2004). Relapse prevention for alcohol and drug problems: That was Zen, this is Tao. *American Psychologist*, 59, 224-235. doi:10.1037/0003-066X.59.4.224
- Woolard, R., Nirenberg, T. D., Becker, B., Longabaugh, R., Minugh, P. A., Gogineni, A., . . . Clifford, P. R. (2003). Marijuana use and prior injury among injured problem drinkers. *Academic Emergency Medicine*, 10, 43-51. doi:10.1197/aemj.10.1.43
- Yeomans-Maldonado, G., & Patrick, M. E. (2015). The effect of perceived risk on the combined used of alcohol and marijuana: Results from daily surveys. *Addictive Behaviors Reports*, 2, 33-36. doi:10.1016/j.abrep.2015.05.004