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Evaluating Within-Person Change in Implicit Measures of Alcohol Associations: Increases in Alcohol Associations Predict Increases in Drinking Risk and Vice Versa

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Abstract

Aims: Implicit measures of alcohol associations (i.e. measures designed to assess associations that are fast/reflexive/impulsive) have received substantial research attention. Alcohol associations related to the self (drinking identity), the effects of alcohol (alcohol excite) and appetitive inclinations (alcohol approach) have been found to predict drinking cross-sectionally and over time. A critical next step in this line of research and the goal of this study is to evaluate whether increases in the strength of these associations predict increases in drinking and vice versa. These hypotheses were tested in a sample of first- and second-year US university students: a sample selected because this time period is associated with initiation and escalation of drinking, peak levels of alcohol consumption and severe alcohol-related negative consequences.
Short summary: This study's purpose was to evaluate whether increases in the strength of alcohol associations with the self (drinking identity), excitement (alcohol excite) and approach (alcohol approach) as assessed by implicit measures predicted subsequent increases in drinking risk and vice versa using a longitudinal, university student sample. Results were consistent with hypotheses.
Methods: A sample of 506 students' (57% women) alcohol associations and alcohol consumption were assessed every 3 months over a 2-year period. Participants' consumption was converted to risk categories based on NIAAA's criteria: non-drinkers, low-risk drinkers and high-risk drinkers. A series of cross-lagged panel models tested whether changes in alcohol associations predicted subsequent change in drinking risk (and vice versa).
Results: Across all three measures of alcohol associations, increases in the strength of alcohol associations were associated with subsequent increases in drinking risk and vice versa.

Conclusion: Results from this study indicate bi-directional relationships between increases in alcohol associations (drinking identity, alcohol excite and alcohol approach) and subsequent increases in drinking risk. Intervention and prevention efforts may benefit from targeting these associations.

INTRODUCTION

Implicit measures of alcohol associations (measures designed to assess associations that are fast/reflexive/impulsive) predict drinking behaviors cross-sectionally and prospectively, even after controlling for their explicit measure counterparts (i.e. measures assessing slower/more reflective cognitions; Reich *et al.*, 2010). Recent studies have also found that alcohol associations can predict changes in drinking behavior (Thush and Wiers, 2007; Lindgren *et al.*, 2016a). A critical next step is to evaluate the dynamic relationship between alcohol associations and consumption by examining whether *changes* in associations predict *changes* in consumption and vice versa. These dynamic relationships have only been studied in an early adolescent sample (Colder *et al.*, 2014). Thus, we evaluated whether changes in three well-validated implicit measures of alcohol associations were associated with changes in alcohol consumption in a sample of first- and second-year US university students.

Interest in alcohol associations is motivated by dual process models of alcohol misuse (e.g. Wiers *et al.*, 2007), which point to the importance of implicit and explicit cognitive processes in predicting drinking. Alcohol associations are commonly described as reflecting the extent to which alcohol becomes associated with other constructs in memory (see Stacy and Wiers, 2010). They are typically assessed indirectly—often by computer-based measures of reaction time in which the underlying cognitive process and content is inferred (see Nosek *et al.*, 2011). The current study makes use of such measures.

Although general theories of implicit cognition (Greenwald and Banaji, 1995; Nosek *et al.*, 2011) suggest that alcohol associations will strengthen in response to direct experience as well as to one's environment and should directly influence behavior, research evaluating how these associations develop over time is scant. Several studies have evaluated alcohol associations as prospective predictors of drinking or changes in drinking (e.g. Wiers *et al.*, 2002; Thush and Wiers, 2007; Gray *et al.*, 2011; O'Connor and Colder, 2015; Lindgren *et al.*, 2016a) but only one has addressed the relationship between *changes* in alcohol associations and *changes* in drinking. Colder *et al.* (2014) evaluated alcohol valence (good/bad) associations and alcohol consumption in a sample of 10–12 year-olds for 3 years. They found that alcohol associations became more neutral over time (initially, they were negatively valenced) and that alcohol consumption increased; however, these changes were not significantly associated with one another. These findings suggest that key tenets of implicit cognition theories—namely that changes in implicit cognitive processes should be associated with changes in behavior and vice versa—do not hold during this early developmental period.

The early college/university years in the USA (typically age 18–20) is an important developmental period and has several characteristics that make it a good candidate for evaluating whether there is a bi-directional relationship between changes in drinking and changes in alcohol associations. The first 2 years are a time when drinking is becoming established (a sizeable proportion of college students transition from abstinence to drinking when they begin college, see Fromme *et al.*, 2008) and escalating (drinking is at its peak during the college years; see Naimi *et al.*, 2003). These years and the US college environment are also associated with increased access to alcohol (likely due to the drinking age in the US being 21 years and greater independence from being away from home), and there are high rates of severe, alcohol-related negative consequences, including emergency room admissions, blackouts and sexual assaults (Merrill and Carey, 2016). Consequently, these years are likely a time when alcohol associations increase in strength and when those increases should be associated with increases in subsequent drinking behavior (Wiers *et al.*, 2007). Further, increases in or initiation of drinking behavior should result in increases in alcohol associations because direct experience should strengthen implicit cognition processes.

Key associations to assess during this developmental period are drinking identity, excitement about alcohol and alcohol approach associations. These associations predicted drinking in college students in previous studies and link to psychological theories of drinking. First, drinking identity associations—associations with the self and being a drinker—link to theoretical models that suggest that identity (or self-concept) influences alcohol use and misuse and smoking (Lindgren *et al.*, 2016b), and cessation and treatment (Dingle *et al.*, 2015; Frings and Albery, 2015; Tombor *et al.*, 2015). These models stem from social psychological theories that suggest that groups can be powerful sources of identity and can motivate individuals to behave consistently with group norms (e.g. Tajfel and Turner, 1979). Second, alcohol excite associations are thought to reflect motivations for why individuals drink. They also can be thought of as implicit counterparts to enhancement drinking expectancies and motives, which are consistent, proximal predictors of drinking (see Cox and Klinger, 1988; Cooper *et al.*, 1995). Third, alcohol approach associations link to theoretical models suggesting that substance-related cues can elicit an appetitive response to approach and consume alcohol that, with repeated and increased use, become increasingly automatic and result in continued, compulsive use despite negative consequences (see Baker *et al.*, 2004; Berridge *et al.*, 2009). Empirically, all three associations predict drinking but are only weakly correlated with one another (Lindgren *et al.*, 2013a; 2016a); together, they provide a wide-ranging but non-redundant evaluation of key associations for this age group.

Study overview

Study data derive from a large, longitudinal study of implicit and explicit measures as predictors of drinking in a sample of first- and second-year university students (Lindgren *et al.*, 2016a). In this paper, we focus exclusively on implicit measures of alcohol associations to test a tenet of the dual process model and implicit cognitive theory that had not been tested in a young adult sample. Specifically, we evaluated the hypothesis that changes in alcohol associations (drinking identity, alcohol excite, and alcohol approach) would be positively associated with changes in drinking and vice versa.

METHODS

Procedures

The university's Institutional Review Board approved all procedures. Full-time students aged 18–20, who were in their first or second year, were approached at the beginning of the academic year via e-mail to participate. Participants completed each 50-min assessment online (assessments were hosted on the Project Implicit platform via a private study url). Each assessment included informed consent, three Implicit Association Tests (IATs; Greenwald *et al.*, 1998) to measure alcohol associations and self-report measures. There were eight assessments, occurring at 3-month intervals. Compensation was $25 for the first three assessments, $30 for the last five assessments, and bonuses of $5 upon completion of all of the first four assessments and $10 for all of the final four. A $5 incentive was added to the last assessment for those ineligible for the $10 bonus. See Lindgren *et al.* (2016a) for the full description of study procedures and additional detail about study participants.

Participants

Participants (N = 506, 57% female, age: M = 18.58, SD = 0.69) were undergraduates at a large public university in the Pacific Northwest. Fifty-two percent identified as White, 32% as Asian American, 11% as multiracial and the remaining 5% as Black or African American, American Indian or Alaskan Native, unknown or declined to answer. Eight percent of participants identified as Hispanic or Latino. Retention rates for Time 2 through Time 8 were 90%, 76%, 76%, 77%, 72%, 67% and 66%. Because both initiation and escalation of drinking were of interest, participants did not have to currently drink alcohol to be eligible for the study. Consistent with other studies of early college students (see Fromme *et al.*, 2008), 50% of participants reported no consumption at the first assessment, dropping to 24% at the last assessment.

Measures

Alcohol associations

Three variants of the IAT (Greenwald *et al.*, 1998) evaluated drinking identity, alcohol excite and alcohol approach associations. The IAT measures reaction times when classifying stimuli into categories as quickly as possible. Two target and two attribute categories are placed in pairs on the screen. In the drinking identity IAT, for example, participants classify stimuli representing the target categories 'me' and 'not me' and the attribute categories 'drinker' and 'non-drinker.' During each IAT trial, a stimulus appears at the center of the screen. Participants must classify it according to the categories displayed on the left or right side of the screen using a designated key (*e* for left and *i* for right). If an error is made, participants must correct it before proceeding to the next trial (no time penalty is applied to error trials and the reaction time for the corrected response is included in IAT scores). Each IAT includes seven blocks: three practice blocks and four test blocks. Practice blocks (1, 2 and 5) include either the target or attribute categories on each side of the screen. For example, Block 1 of the drinking identity IAT might start with 'me' on the left and 'not me' on the right, and participants classify stimuli representing those categories. Test blocks (3, 4, 6 and 7) pair one target category with one attribute category on each side of the screen. For example, Blocks 3 and 4 of the drinking identity IAT might pair 'drinker' with 'me' on the left and 'non-drinker' with 'not me' on the right. Thus, items fitting either the 'drinker' or 'me' categories are classified on the left, and items fitting either 'non-drinker' or 'not me' are classified on the right. The pairings would be reversed in Blocks 6 and 7: 'drinker' would be paired with 'not me' and 'non-drinker' would be paired with 'me.' The order in which category pairings are presented is counterbalanced across participants.

Participants' reaction times classifying stimuli in Blocks 3, 4, 6 and 7 (i.e. the paired category blocks) were used to calculate IAT scores following the *D*-score algorithm (Greenwald *et al.*, 2003). The *D*-score is a standardized difference score that reflects a participant's average reaction time for trials in each set of paired blocks (i.e. average reaction time for Blocks 3 and 4 is subtracted from Blocks 6 and 7). Scores were calculated such that higher scores indicated stronger associations (faster reaction times) with the categories in the IAT's name. For example, higher scores on the drinking identity IAT indicated faster reaction times when *drinker* and *me* are paired and thus a stronger association between *me* and *drinking* or a stronger drinker identity. The order in which the IATs were presented was randomized across participants and interspersed among the self-report measures to reduce fatigue. As per Nosek and colleagues' (2007) recommendations for screening, IAT scores were excluded when 10% or more trials were faster than 300 ms or when 30% or more trials included errors. Such exclusions rarely exceeded 10% across time points. Internal consistency for the IAT was calculated by correlating two *D*-scores: one for Blocks 3 and 6 and one for Blocks 4 and 7 (see Greenwald *et al.*, 2003). Consistencies typically range from 0.5 to 0.6 for these IATs (see Lindgren *et al.*, 2013a), rs: drinking identity = 0.58, alcohol approach = 0.55, alcohol excite = 0.57. IAT stimuli are reported in Lindgren *et al.* (2016a).

Alcohol consumption

The Daily Drinking Questionnaire (Collins *et al.*, 1985) assessed participants' self-reported alcohol consumption on each day of a typical week in the last 3 months. US standard drink equivalencies were provided. Following NIAAA guidelines (2017), participants were classified into three risk categories for developing an alcohol use disorder. Non-drinkers consumed zero drinks per week. Low-risk men and women consumed no more than 14/7 drinks per week and no more than 4 or 3 drinks on a single day, respectively. High risk men and women consumed more than 14 or 7 drinks per week or 4 or 3 drinks on a single day, respectively.

Data Analysis

We used cross-lagged panel models (Newsom, 2015) to examine the relationships among the alcohol associations (IAT scores) and the drinking risk categories. The IATs were treated as continuous variables and drinking category was treated as an ordered categorical variable with three levels (1 = No Risk, 2 = Low Risk, 3 = High Risk). We used drinking category as the outcome because it is not currently possible to implement a cross-lagged model with a zero-inflated negative binomial outcome. Although cross-lagged models would be possible by treating the drinking outcome as normally distributed, doing so is problematic generally (see Atkins *et al.*, 2013). Moreover, the distribution of the drinking in this sample has both a large number of zeros and is positively skewed. Consequently, we chose a middle-ground option where drinking is divided into categories of low and high risk. These categories were put forth by the US National Institute on Alcohol Abuse and Alcoholism (see NIAAA, 2017) as clinically, relevant distinctions. Further, one can use a latent variable formulation of categorical variables that allows them to be used in cross-lagged models (B. O. Muthén and Asparouhov, 2002).

The path model for the drinking identity IAT and drinking is depicted in Fig. 1; we used identical models for the alcohol approach and excite IATs. As indicated in Fig. 1, we estimated autoregressive and cross-lagged parameters. We estimated four key relationships in all models. For example, in the drinking identity model, the parameters were (a) an autoregressive relationship between identity at Time *t* and identity at Time *t* – 1; (b) an autoregressive relationship between drinking at Time *t* and drinking at Time *t* – 1; (c) a cross-lagged relationship between identity at Time *t* and drinking at Time *t* – 1; and (d) a cross-lagged relationship between drinking at Time *t* and identity at Time *t* – 1. Beginning with Time 2, we constrained the estimates to be constant across time because we did not have any predictions about time-related patterns. Further, from Time 2 onward the parameters represent relationships controlling for previous time points whereas from Time 1 to Time 2, there is no previous time point. Consequently, we estimated unique autoregressive and cross-lagged parameters from Time 1 to Time 2. The model also included birth sex and drinking history prior to Time 1 (1 = history of alcohol consumption, 0 = no history of alcohol consumption) as predictors of the IATs and drinking risk (Birth sex was controlled for in analyses due to long-standing evidence of sex differences in consumption among US college students (see Schulenberg et al., 2017) and evidence of sex differences in the distribution of men and women among the three drinking risk categories in six (of the eight) time points. The overall pattern of results does not differ if birth sex is not controlled for. Prior history of drinking was added as a covariate to test whether initial changes IAT scores were associated with bigger changes in risk (and vice versa) amongst those who were completely new to drinking. We thank an anonymous reviewer for this suggestion.). As with the other parameters, we estimated unique values for the covariates at Time 1 and then constrained them to be equal across time beginning at Time 2 (i.e. one value for each covariate from Time 2 to Time 8).

To fit this model, a latent variable formulation of drinking risk had to be used. The latent variable approach treats the observed categorical variable as a coarse measurement of an underlying continuous variable—in this instance, drinking category is a coarse measure of continuous drinking risk (Muthén and Asparouhov, 2002). Continuous drinking risk is divided into three parts, separated by two thresholds. Participants below the first threshold are in the no risk category; participants between the first and second thresholds are in the low risk category and participants above the second threshold are in the high-risk category. The cross-lagged models were estimated using Mplus (Muthén and Muthén, 1998–2017, Version 8.0) with the weighted least squares (WLSMV) estimator.

RESULTS

Figure 2 shows the distribution of each IAT over time and Fig. 3 shows the distribution of the drinking risk categories over time for the entire sample. See Supplemental Table 1 for descriptive statistics and zero-order correlations for study baseline variables. At the sample level, the IATs were relatively static across time. For example, median values varied slightly across time, but generally stayed just

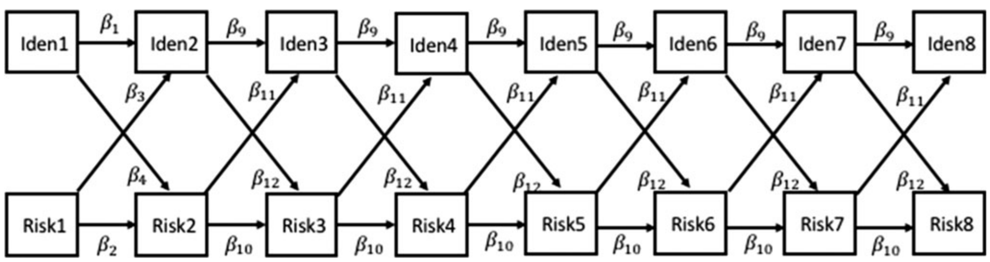

Fig. 1. Path diagram for the cross-lagged model relating drinking identity and drinking risk. Comparable models for approach and excite were also estimated. All models included birth sex and drinking history prior to Time 1 as covariates as well as covariance among the residuals at each time point. Iden = Implicit Drinking Identity; Risk = Drinking Risk Category.

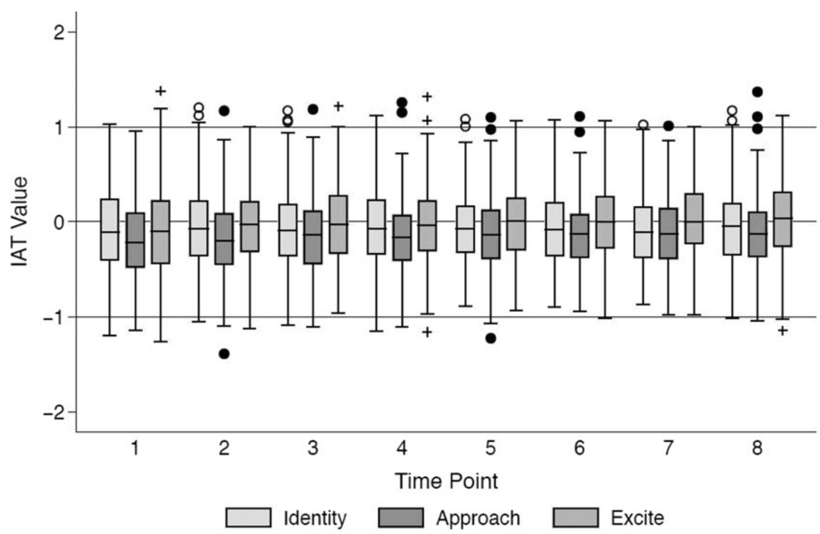

Fig. 2. Distribution of each IAT over time. Identity refers to the drinking identity IAT, approach to the alcohol approach IAT and excite to the alcohol excite IAT. IAT values are *D*-scores. IAT = Implicit Association Test.

below zero. Likewise, the range of IAT scores stayed fairly consistent across time. The distribution of risk categories changed more over time. Specifically, the number of people in the no risk category decreased substantially from Time 1 to Time 8 whereas the low risk and high-risk categories fluctuated.

Table 1 presents the parameter estimates and model fit statistics for the cross-lagged models for each IAT. Model fit was good for all three models: the comparative fit index ranged between 0.95 and 0.97, the Tucker–Lewis index ranged between 0.94 and 0.96, and the root mean square error of approximation ranged between 0.06 and 0.07. Findings from all three models suggested that changes in IAT scores predicted later changes in drinking risk and that changes in drinking risk predicted later changes in IAT scores, holding constant birth sex and history of drinking.

Drinking identity

From Times 1 to 2, drinking risk predicted increases in drinking identity ($\hat{\beta}_3 = 0.06$, $P < 0.01$), holding constant Time 1 identity ($\hat{\beta}_1 = 0.45$, $P < 0.001$), birth sex ($\hat{\beta}_5 = -0.14$, $P < 0.01$) and history of drinking ($\hat{\beta}_7 = 0.25$, $P < 0.01$). In contrast, Time 1 identity did not predict Time 2 risk ($\hat{\beta}_4 = -0.42$, ns), holding constant Time 1 risk

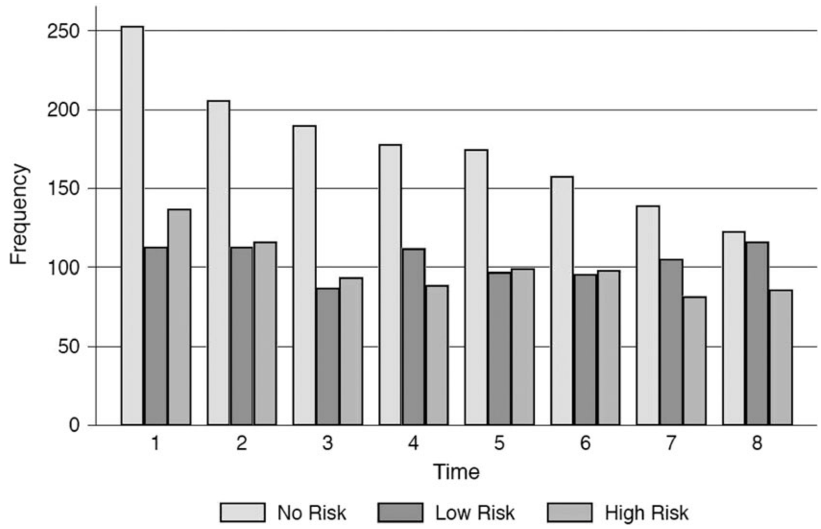

Fig. 3. Distribution of drinking category over time. No risk, low risk, and high risk refer to NIAAA drinking categories. No risk drinkers consumed zero drinks per week. Low-risk men/women consumed no more than 14/7 drinks per week and no more than 4/3 drinks on a single day. High risk men/women consumed more than 14/7 drinks per week or 4/3 drinks on a single day.

Table 1. Results of cross-lagged panel models testing changes in implicit alcohol associations and changes in drinking risk category

		Identity	Approach	Excite
Time 1				
$IAT_1 \rightarrow IAT_2$	$\hat{\beta}_1$	0.45***	0.43***	0.44***
$Risk_1 \rightarrow Risk_2$	$\hat{\beta}_2$	1.88***	1.90***	1.79***
$Risk_1 \rightarrow IAT_2$	$\hat{\beta}_3$	0.06**	0.03	0.06**
$IAT_1 \rightarrow Risk_2$	$\hat{\beta}_4$	−0.42	−0.49	0.12
Birth sex → IAT_1	$\hat{\beta}_5$	−0.14**	−0.11**	−0.12**
Birth sex → $Risk_1$	$\hat{\beta}_6$	0.06	0.06	0.09
History → IAT_1	$\hat{\beta}_7$	0.25***	0.22***	0.2**
History → $Risk_1$	$\hat{\beta}_8$	1.84**	1.83***	1.83***
Time 2–8				
$IAT_{t-1} \rightarrow IAT_t$	$\hat{\beta}_9$	0.76***	0.74***	0.78***
$Risk_{t-1} \rightarrow Risk_t$	$\hat{\beta}_{10}$	0.9***	0.91***	0.92***
$Risk_{t-1} \rightarrow IAT_t$	$\hat{\beta}_{11}$	0.02***	0.01***	0.01***
$IAT_{t-1} \rightarrow Risk_t$	$\hat{\beta}_{12}$	0.35**	0.45*	0.39***
Birth sex → IAT_t	$\hat{\beta}_{13}$	−0.04***	−0.02*	0.001
Birth sex → $Risk_t$	$\hat{\beta}_{14}$	0.17**	0.24*	0.14**
History → IAT_t	$\hat{\beta}_{15}$	−0.04*	−0.01	0.02
History → $Risk_t$	$\hat{\beta}_{16}$	0.25*	0.16**	0.24*
Model fit	CFI	0.97	0.95	0.96
	TLI	0.96	0.94	0.96
	RMSEA	0.06 (90% CI = 0.05, 0.07)	0.07 (90% CI = 0.06, 0.08)	0.06 (90% CI = 0.05, 0.07)

Note. *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$; $N = 501$ (5 of the 506 participants did not provide a response to the item assessing lifetime drinking history); IAT, Implicit Association Test; Risk, drinking risk category (higher categories = higher risk of alcohol use disorder); History, drinking history prior to Time 1; CFI, Comparative Fit Index; TLI, Tucker–Lewis Index; RMSEA, root mean square error of approximation; CI, confidence interval.

($\hat{\beta}_2 = 1.88, P < 0.001$), birth sex ($\hat{\beta}_6 = 0.09$, ns) and history of drinking ($\hat{\beta}_8 = 0.25, P < 0.01$). As expected, from Times 2 to 8, increases in drinking identity were associated with increased drinking risk at the following time point ($\hat{\beta}_{12} = 0.35, P < 0.01$), holding constant previous drinking risk changes ($\hat{\beta}_{10} = 0.9, P < 0.001$), birth sex ($\hat{\beta}_{14} = 0.17, P < 0.01$) and history of drinking ($\hat{\beta}_{16} = 0.25, P < 0.05$). The model also suggested that increases in drinking risk were associated with increased identity at the following time point ($\hat{\beta}_{11} = 0.02, P < 0.001$), holding constant previous identity changes ($\hat{\beta}_9 = 0.76, P < 0.001$), birth sex ($\hat{\beta}_{13} = -0.04, P < 0.001$) and history of drinking ($\hat{\beta}_{15} = -0.04, P < 0.05$).

Alcohol approach

From Times 1 to 2, drinking risk did not predict changes in alcohol approach or vice versa. In contrast, from Times 2 to 8, increases in alcohol approach were associated with increased risk at the following time point ($\hat{\beta}_{12} = 0.45, P < 0.05$), holding constant previous drinking risk changes ($\hat{\beta}_{10} = 0.91, P < 0.001$), birth sex ($\hat{\beta}_{14} = 0.24, P < 0.05$) and history of drinking ($\hat{\beta}_{16} = 0.16, P < 0.01$). Likewise, increases in drinking risk were associated with increased alcohol approach at the following time point ($\hat{\beta}_{11} = 0.01, P < 0.001$), holding constant previous alcohol approach changes ($\hat{\beta}_9 = 0.74, P < 0.001$), birth sex ($\hat{\beta}_{13} = -0.02, P < 0.05$) and history of drinking ($\hat{\beta}_{15} = -0.01$, ns).

Alcohol excite

From Times 1 to 2, alcohol excite did not predict changes in drinking risk. However, risk did predict increases in alcohol excite ($\hat{\beta}_3 = 0.06, P < 0.01$), holding constant Time 1 alcohol excite ($\hat{\beta}_1 = 0.44, P < 0.001$), birth sex ($\hat{\beta}_5 = -0.12, P < 0.05$) and history of drinking ($\hat{\beta}_7 = 0.2, P < 0.01$). From Times 2 to 8, increases in alcohol excite were associated with increased drinking risk at the following time point ($\hat{\beta}_{12} = 0.39, P < 0.001$), holding constant previous drinking risk changes ($\hat{\beta}_{10} = 0.92, P < 0.001$), birth sex ($\hat{\beta}_{14} = 0.14, P < 0.01$) and history of drinking ($\hat{\beta}_{16} = 0.24, P < 0.05$). Likewise, increases in drinking risk were associated with increased alcohol excite ($\hat{\beta}_{11} = 0.01, P < 0.001$), holding constant previous alcohol excite changes ($\hat{\beta}_9 = 0.78, P < 0.001$), birth sex ($\hat{\beta}_{13} = 0.001$, ns) and history of drinking ($\hat{\beta}_{15} = 0.02$, ns).

DISCUSSION

The study evaluated questions of change in alcohol associations and change in drinking risk in a sample of US students in their first or second year of college—a time of increased initiation and escalation of drinking and increased drinking risk. The study's purpose was to test a key—yet rarely tested—tenet of implicit cognition theories; that increases in the strength of alcohol associations would be associated with subsequent increases in drinking and vice versa. This is the second study we know of to test for bi-directional relationships between changes in alcohol associations and changes in drinking and the first study to find evidence of such relationships. Bi-directional relationships were observed for all three associations in this study—drinking identity, alcohol excite and alcohol approach. Notably, study results differ from those of Colder *et al.* (2014), which found no evidence of reciprocal effects with a sample of US children and early adolescents. A related study that evaluated a slightly older sample of Dutch adolescents and focused on a different type of implicit cognitions (Janssen *et al.*, 2015) also found no evidence of reciprocal effects. Collectively, findings from these studies may indicate the moderating influence of age, developmental stage, the university/college environment, availability of alcohol and/or one of many other factors that vary when examining drinking from a developmental perspective. Research that expands the current model to include such factors and other hypothesized moderators of impulsive processes (e.g. self-regulatory processes, see O'Connor and Colder, 2015) will be crucial for providing a more comprehensive understanding of when and why changes in alcohol associations become predictive of changes in drinking and vice versa.

Implications

The current results point to the importance of measuring change processes. Earlier analyses from the larger parent study (Lindgren *et al.*, 2016a) did not find that a static measure of alcohol approach associations predicted change in drinking behaviors at the next time point (though drinking identity and alcohol excite associations were predictive), while the present study found that change in each of the alcohol associations was predictive. Although the analyses were not directly comparable in other ways, the distinct results raise the possibility that measuring absolute level of alcohol associations may only tell part of the story of individual risk. A dynamic assessment strategy may, instead, be needed to determine when an individual is becoming more at risk.

More generally, although causal claims cannot be made with these data, results support assertions that targeting alcohol associations in prevention and intervention efforts may be helpful (see Wiers *et al.*, 2006). Some progress has been made on this front via computer-based tasks that seek to modify alcohol associations (see Wiers *et al.*, 2011), but these tasks have yielded null results in US college samples (see Lindgren *et al.*, 2015) and a recent meta-analysis (Cristea *et al.*, 2016) raised concerns about the tasks' efficacy (though there is disagreement about how to interpret the negative findings; Wiers *et al.*, in press). Taken together, this suggests the importance of developing strategies that can target alcohol associations in college student populations. Developing interventions that seek to strengthen the influence of slower, reflective processes and override the alcohol associations may also be helpful.

Limitations and future directions

Several limitations should be noted. First, the variables representing drinking risk, while based on NIAAA guidelines, were categorical and so are relatively coarse measures. Second, when using categorical variables in cross-lagged models, we needed to treat them as latent variables, meaning we could not make inferences about the probability of being in a given category. Third, the study sample, while relatively large, focuses on a single sample of undergraduates from a single university, and there was attrition over time. We also note that other alcohol associations (e.g. alcohol and valence [good/bad]) have been shown to predict drinking (Wiers *et al.*, 2002) and could be evaluated in future studies. Finally, we note the lower split-half reliabilities of the IATs used in the study. While they are similar to the reliabilities observed when using these IATs in other studies (see Lindgren *et al.*, 2013a) as well as IATs used in other studies (see Greenwald *et al.*, 2003), IATs and implicit measures in general tend to have lower internal consistencies than explicit measures (see Bar-Anan and Nosek, 2014). This is a general challenge for the field. Despite this limitation, there are many examples of the IAT's predictive validity generally (Bar-Anan and Nosek, 2014) and in alcohol research specifically (Reich *et al.*, 2010; Lindgren *et al.*, 2013b).

Conclusion

Despite these limitations, this study is an important step toward evaluating changes in alcohol associations and drinking. It is the first study to find a bi-directional relationship between increases in the strength of alcohol associations and increases in drinking risk in a sample of students in the early college years, and findings are consistent with theories of implicit cognition. They provide additional evidence that alcohol excite, alcohol approach and drinking identity are important factors to consider in cognitive models of alcohol use and misuse.

SUPPLEMENTARY MATERIAL

Supplementary data are available at *Alcohol And Alcoholism* online.

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CONFLICT OF INTEREST STATEMENT

None declared.

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