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Change in implicit alcohol associations over time: Moderation by drinking history and gender

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HIGHLIGHTS

- US college students' implicit alcohol associations increased over a 2-year period.
- Lifetime drinking history moderated changes in drinking identity associations.
- Greater increases were found in those without (vs. with) a history of intoxication.
- Gender moderated changes in implicit alcohol-excite associations.
- Greater increases were found in women (vs. men).

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ABSTRACT

Implicit measures of alcohol-related associations or implicit alcohol associations are associated with drinking outcomes over time and can be understood as vulnerability markers for problem drinking. Longitudinal research remains rare, leaving open questions about how implicit alcohol associations themselves change over time and what factors moderate that change. We examined these questions with data from a larger study of first and second year U.S. college students. We investigated how these implicit alcohol associations change over time and potential moderators of those changes (gender, lifetime drinking history, family history of problem drinking, and class standing). A sample of 506 students (57% women) completed baseline demographic measures and implicit measures (variants of the Implicit Association Test [IAT]) assessing associations with drinking and the self [drinking identity], alcohol and excite [alcohol-excite], and alcohol and approach [alcohol-approach]). IATs were completed at 3-month intervals for a total of 8 assessments. Results indicated small, but significant, change in alcohol-excite and alcohol-approach IAT scores over time, and mixed findings for hypothesized moderators. Drinking history moderated change in drinking identity IAT scores, with increases over time among individuals with no history of drinking or no history of intoxication and decreases among individuals with a history of intoxication. Gender moderated change in alcohol-excite IAT scores with greater change among women (vs. men). No significant moderators of change in alcohol approach IAT scores were found. Results point to the importance of evaluating implicit associations' trajectories and identifying additional factors that predict those trajectories and concomitant vulnerability to problem drinking.

1. Introduction

Research using indirect measures of alcohol-related associations that capture unintentional processing of alcohol-related cues, referred to as implicit alcohol associations for brevity, has increased exponentially. Generally, implicit alcohol associations predict unique

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variance in self-reported drinking outcomes after controlling for explicit/self-report measures (Lindgren et al., 2016; Reich, Below, & Goldman, 2010; Roefs et al., 2011; Rooke, Hine, & Thorsteinsson, 2008), consistent with the idea that these associations are unique vulnerability markers of problem drinking. Notwithstanding, longitudinal studies are rare, with few independent samples evaluating changes in implicit alcohol associations over time, and fewer that have more intensive repeated assessment or evaluate multiple types of implicit alcohol associations over time. Consequently, little is known about the development or change in implicit alcohol associations over time and the factors, including demographic characteristics, that moderate that change. Understanding these trajectories over time is important; doing so may elucidate periods when associations are more likely to increase and, in turn, confer increased risk for problem drinking. Looking downstream to identify factors that moderate changes in associations may identify subgroups at increased risk for problem drinking, which is important for prevention and intervention efforts. This study, which uses data from a larger study of U.S. first and second year college students (Lindgren et al., 2016, 2018), provides the first examination of the trajectory of implicit alcohol associations in a college student sample and tests moderators of changes therein. Four key demographic characteristics (family history of problem drinking, lifetime drinking history, gender, and class standing) were evaluated as potential moderators of change in those associations.

Our interest in change in implicit alcohol associations is motivated by theory and empirical findings. Multiple theories about the development of problem drinking point to the importance of implicit alcohol associations. Most have roots in dual process models of drinking and more recent dynamical systems perspectives (Bechara, 2005; Wiers et al., 2007, Wiers, Boelema, Nikolaou, & Gladwin, 2015). Common across these theories is the notion that repeated learning trials—-whether via direct or indirect experience—are crucial for the development of implicit associations and their theorized increasing influence on behavior.

The scant literature on changes in implicit alcohol associations is concentrated in studies of children and adolescents. Colder and colleagues (Colder et al., 2014; Meisel et al., 2018) evaluated change in implicit alcohol associations over time in a U.S. sample of children between the ages of 10 and 12, a period in which the majority of children have not initiated drinking and have limited access to alcohol. Their early work demonstrated that, over time, children's alcohol use increased and their implicit alcohol associations became less negative, but no significant relationship was found between changes in drinking and changes in implicit alcohol associations (Colder et al., 2014). Recent work with the same sample modeled between- and within-person implicit alcohol associations and found some support for changes in within-person implicit alcohol associations (specifically, for weaker negative alcohol associations) predicting subsequent increases in self-reported drinking (Meisel et al., 2018). Though the reciprocal relationship was tested, within-person changes in drinking did not predict subsequent changes in implicit alcohol associations. Collectively, direct drinking experience does not predict within-person changes in implicit alcohol associations in children, though those associations appear to change meaningfully. What factors *do* predict those changes and the nature of those changes in older samples in more alcohol-saturated environments remains unanswered.

We evaluated measures of three implicit alcohol associations—associations between drinking and self (drinking identity, Lindgren et al., 2013); alcohol and excitement (alcohol-excite, Lindgren et al., 2013; Wiers, van Woerden, Smulders, & de Jong, 2002); and alcohol and appetitive/approach inclinations (alcohol-approach, Ostafin & Palfai, 2006)—in a longitudinal study of first- and second-year U.S. college students (Lindgren et al., 2016). These associations – especially drinking identity – predicted drinking outcomes over time after controlling for their explicit measure counterparts. Additional analyses with these data indicated that increases in drinking risk were associated with subsequent increases in all three implicit associations and vice-versa (Lindgren et al., 2018). The larger study is unique because it included intense assessment of implicit alcohol associations. Each set of associations was measured eight times at three-month intervals, allowing for an investigation of the associations' trajectories over time and the evaluation of factors, including and in addition to individuals' drinking experiences, that moderate those trajectories. To date, this kind of investigation has not been conducted.

When considering potential moderators, one possibility is family drinking history. Theories of implicit alcohol associations conceptualize them as memory associations about alcohol that result from direct experience as well as mere exposure to alcohol-related cues and outcomes (Lau-Barraco & Dunn, 2009; Zack, Sharpley, Dent, & Stacy, 2009), including exposure to family members' drinking behaviors and outcomes (Van Der Vorst et al., 2013; Wiers et al., 2007). This conceptualization is analogous to long-standing findings that children develop beliefs about alcohol's effects (alcohol expectancies) long before ever trying alcohol; that parents' drinking behaviors (especially problematic drinking behaviors) influence children's expectancies; and that parents' behaviors influence the trajectory of children's alcohol expectancies and subsequent drinking behaviors (Brown, Tate, Vik, Haas, & Aarons, 1999; Kuntsche & Kuntsche, 2018). We know of a single study on the relation between family drinking history and implicit alcohol associations: findings indicated that adolescents' perceptions of their parents' alcohol use were positively correlated with their own implicit alcohol associations (Van Der Vorst et al., 2013). We propose to examine familial drinking history as a moderator of change in implicit alcohol associations. Because individuals with a family history of problematic drinking would likely have extensive prior exposure to alcohol cues and alcohol's effects, we predict that individuals with such a family history, compared to those without such, would have less change in their implicit alcohol associations.

A second potential moderator is one's personal drinking history. Though it has been established, including with this data set (Lindgren et al., 2018), that increases in young adults' drinking risk are associated with subsequent increases (at the next timepoint) in implicit associations, we know little about longer-term trajectories of implicit associations and how those trajectories differ as a function of levels of drinking experiences. Theory (Bechara, 2005; Wiers et al., 2007, 2015) and empirical findings from children (Colder et al., 2014) suggests that implicit alcohol associations would strengthen with more personal drinking experience. We predict that there is less room or opportunity for growth/increases in those associations among individuals with more experience (i.e., those with a history of intoxication or those with a history of drinking but not intoxication compared to individuals with no drinking history).

Class standing (i.e., one's year in college) is also a potential moderator of change in implicit associations. The U.S. college environment is alcohol-saturated, with increased access to alcohol, more unstructured time, and communal living, which are associated with greater risk for problematic drinking (Merrill & Carey, 2016). This environment readily provides multiple, repeated opportunities for direct and indirect alcohol exposure. Consequently, time spent in the college environment—for which class standing is a proxy—may contribute to or moderate the development of implicit alcohol associations. We expect that the college environment would have a greater impact on individuals with less prior exposure (i.e., lower class standing).

Finally, we have previously observed significant relationships with birth sex and baseline implicit associations with these data (Lindgren et al., 2018), suggesting that one's sex may also be related to the development of implicit associations over time. There is a dearth of theory about this possibility, and few studies have evaluated sex as a potential moderator (Lindgren et al., 2019). We thus, evaluate gender on an exploratory basis. Further, we elect to focus on gender, rather than sex, based on the expectation that gender would be a better proxy for representation of one's lived experience as a man, woman, or non-binary

individual.

2. Method

2.1. Participants

The sample comprised 506 full-time undergraduate students (57% women, 42% men, 1% transgender or declined to answer[1]) in their first or second year at a large Northwestern public university. Participants were ages 18 to 20 (M = 18.57, SD = 0.69) and fluent in English. They identified as White/Caucasian (52%), Asian (31%), more than one race (11%), Black or African American (1%), American Indian/Alaskan Native (1%), unknown (1%), or declined to answer (3%). Attrition occurred over the course of the study, such that 90% of participants completed Time point (T) 2, 76% T3, 76% T4, 77% T5, 72% T6, 67% T7, and 66% T8.

2.2. Measures

2.2.1. Implicit alcohol-related association

Three variants of the Implicit Association Test (IAT; Greenwald, McGhee, & Schwartz, 1998) were used to assess implicit associations between: (i) drinking and the self (the drinking identity IAT; Lindgren et al., 2013), (ii) alcohol and excitement (the alcohol-excite IAT; Lindgren et al., 2013; Wiers et al., 2002), and (iii) alcohol and approach (the alcohol-approach IAT; Ostafin & Palfai, 2006). IATs were completed at 3-month intervals for a total of 8 assessments.

IATs are computer-based reaction time tasks used to measure the strength of association between concepts. A target and attribute category (e.g., *me* and *drinker*) are paired on one side of the screen, with contrasting categories (e.g., *not me* and *nondrinker*) on the other side. Stimuli (words and/or pictures related to the category labels) are presented individually center-screen, and participants are asked to classify the stimuli (by pressing "e" for the categories shown on the left side and "i" for the categories on the right) as quickly and accurately as possible. Participants are alerted to incorrect responses, and they must correctly reclassify them before the next stimuli are presented. The target–attribute pairings are later switched. Faster, more accurate responding is expected when paired concepts are more congruent with a person's associations in memory. Scores were calculated using the D_1-scoring algorithm (Greenwald, Nosek, & Banaji, 2003) with higher scores indicating stronger associations between named concepts (e.g., *me* and *drinker* [vs. *nondrinker*] for the drinking identity IAT, *alcohol* and *excite* [vs. *depress*] for the alcohol-excite IAT, *alcohol* and *approach* [vs. *avoid*] for the alcohol-approach IAT). As recommended by Nosek, Greenwald, and Banaji (2007), scores were screened out if ≥10% of responses were faster than 300 ms.

2.2.2. Drinking history

Participants were asked about their history of drinking alcohol and their history of intoxication at baseline. Drinking history was dummy coded such that 0 = no drink history, 1 = history of drinking alcohol but no history of intoxication; 2 = history of intoxication.

2.2.3. Family history of problem drinking

Family history of problem drinking was assessed at baseline using items from the Comprehensive Drinker Profile (Miller & Marlatt, 1984). Participants were asked how many of their blood relatives—requesting separate counts for father, mother, brothers, sisters, grandfathers, grandmothers, uncles, aunts, male first cousins, and female first cousins—they regarded as being or having been "a problem drinker or an alcoholic." Scores for male and female relatives were calculated per Miller and Marlatt (1984). For the purposes of this study, biological familial risk of problem drinking was then dummy coded such that 1 = any risk (i.e., risk scores for any relatives were 1 or greater) and 0 = no risk.

2.3. Procedures

Participants were recruited via email from a randomly sampled list of full-time first- and second-year undergraduates, ages 18–20, obtained from the university's registrar's office. Invitations included a link and unique PIN to log in to the study webpage, where participants could learn more about the study, complete informed consent procedures, confirm eligibility requirements, and complete the baseline assessment. Follow-up assessments occurred every three months for two years. All assessments were similar in structure, with IATs interspersed among self-report questionnaires presented in a randomized order. Participants were compensated for each assessment completed. All procedures were approved by the university's institutional review board. See Lindgren et al. (2016) for additional details about procedures, measures, and the sample.

2.4. Data analysis

For each of the IATs, we fit a set of three multilevel growth models. Model 1 examined whether there was linear change in IAT scores across time.

$$IAT_{ij} = b_0 + b_1 time_{ij} + u_{0j} + u_{1j} time_{ij} + e_{ij}$$

where IAT_{ij} is the observed IAT score at time i for person j; $time_{ij}$ is the assessment point scaled so that baseline was 0 and increased by 1 across each assessment point; b_0 is overall intercept; b_1 is the rate of change; u_{0j} is a random intercept; u_{1j} is the random slope for time (i.e., person-specific rate of change)[2]; and e_{ij} is the residual. The random intercept and slope were allowed to correlate.

Model 2 extended Equation 1 and included the following baseline predictors: drinking history (2 = history of intoxication, 1 = drink history with no intoxication, 0 = no drink history), family history (1 = any risk, 0 = no risk), gender (1 = woman, 0 = man), and class standing (1 = sophomore, 0 = first year). Drinking history was dummy-coded with two indicators and the no drink history group as the reference category. Model 3 added the two-way interactions between the baseline predictors and time. All models were estimated using mixed in Stata 16 (StataCorp., 2019).

3. Results

3.1. Descriptive statistics

Please see Table 1 for descriptive statistics of the baseline IAT scores and hypothesized moderators.

3.2. Drinking identity associations

Table 2 displays the results for the identity IAT. Model 1 suggested there was no change, on average, in identity. The random effects, however, suggested significant variability in the growth parameter across participants ($\hat{\sigma}_{u_1}$ = 0.032, p < 0.001). The pattern of random effects was identical across all three models. Model 2 indicated that both personal drinking history at baseline and gender were related to

[1] Because the subgroup of individuals identifying as transgender (n = 2) or who declined to report their gender (n = 2) was small in number, we were unable to include them in analyses.

[2] We used a likelihood ratio test to compare the fit of a model with a random intercept only to the model in Equation 1, which has a random intercept, a random slope, and covariance between the intercept and slope. For all three IATs, the model in Equation 1 significantly fit the data better.

Table 1
Descriptive statistics and bivariate correlations for baseline Implicit Association Test (IAT) scores and hypothesized moderators of IAT score growth.

	1	2	3	4	5	6	7	8
1. Drink Hx: No intox vs. otherwise	–	–	–	–	–	–	–	–
2. Drinking Hx: Intox vs. otherwise	−0.74***	–	–	–	–	–	–	–
3. Family Hx	−0.09*	0.15**	–	–	–	–	–	–
4. Gender	−0.01	0.04	0.10*	–	–	–	–	–
5. Class standing	−0.16***	0.14**	0.03	0.07	–	–	–	–
6. Drinking identity IAT	−0.24***	0.34*	−0.02	−0.12*	0.05	–	–	–
7. Alcohol-excite IAT	−0.14**	0.24***	0.13**	−0.12*	−0.02	0.13**	–	–
8. Alcohol-approach IAT	−0.20***	0.32***	0.03	−0.11*	−0.01	0.22**	0.39**	–
M (frequencies of No intox or intox)	144 (41%)	259 (55%)	0.59	0.57	1.50	−0.08	−0.11	−0.21
SD	N/A	N/A	0.49	0.50	0.50	0.45	0.46	0.40
n for the specified response	470	470	505	502	481	465	475	467

Note. $N = 506$. Sample size varies for individual analyses due to missing data. Data from 4 participants (2 who identified as transgender and 2 who declined to answer) are not included in analyses involving gender due to the small sample size. Drink Hx: No intox vs. otherwise; coded 1 = at baseline reported having history of drinking alcohol but no history of intoxication, 0 = otherwise Drink Hx: Intox vs. otherwise; coded 1 = at baseline reported history of intoxication, 0 = otherwise. Number of participants with no lifetime self-reported alcohol use at baseline = 67; history of use but not intoxication = 144; history of use and intoxication = 259. Family Hx = familial risk of problem drinking, assessed using items from the Comprehensive Drinker Profile; coded 0 = no risk, 1 = any risk. Gender was coded 0 = man, 1 = woman. Class standing was coded 0 = first year, 1 = sophomore. Drinking identity IAT = score on drinking identity IAT; higher scores indicate stronger association between *me* and *drinker* (vs. *nondrinker*). Alcohol-excite IAT = score on alcohol-excite IAT; higher scores indicate stronger association between *alcohol* and *excite* (vs. *depress*). Alcohol-approach IAT = score on alcohol-approach IAT; higher scores indicate stronger association between *alcohol* and *approach* (vs. *avoid*).
$^{*}p < 0.05$, $^{**}p = < 0.01$.

Table 2
Results of multilevel growth models predicting change in drinking identity IAT scores over time.

	(1) Drinking Identity	(2) Drinking Identity	(3) Drinking Identity
Fixed effects:			
Time	0.0052	0.0064*	0.024**
	[−0.00095,0.011]	[0.00024,0.013]	[0.0059,0.042]
No Intox		0.033	0.053
		[−0.049,0.12]	[−0.048,0.15]
Intox		0.26***	0.33***
		[0.18,0.34]	[0.23,0.43]
Family Hx		−0.033	−0.0084
		[−0.086,0.021]	[−0.074,0.057]
Gender		−0.13***	−0.13***
		[−0.18, −0.078]	[−0.20, −0.070]
Class standing		0.0099	0.0059
		[−0.044,0.064]	[−0.060,0.072]
No Intox × Time			−0.0070
			[−0.026,0.012]
Intox × Time			−0.023*
			[−0.041, −0.0056]
Family Hx × Time			−0.0083
			[−0.021,0.0041]
Gender × Time			0.0021
			[−0.010,0.014]
Class standing × Time			0.0013
			[−0.011,0.014]
Intercept	−0.068***	−0.13**	−0.19***
	[−0.10, −0.034]	[−0.21, −0.052]	[−0.28, −0.090]
Random Time	0.032***	0.031***	0.028***
	[0.024,0.043]	[0.022,0.042]	[0.020,0.040]
Random Intercept	0.31***	0.27***	0.27***
	[0.29,0.35]	[0.25,0.31]	[0.24,0.30]
Corr(Time,Int)	−0.55***	−0.48***	−0.47***
	[−0.69, −0.38]	[−0.64, −0.28]	[−0.64, −0.26]
Residual	0.30***	0.29***	0.29***
	[0.29,0.31]	[0.28,0.30]	[0.28,0.30]
N	2496	2450	2450

Note. Data from 4 participants (2 who identified as transgender and 2 who declined to answer) are not included in analyses involving gender due of the small sample size. Model (1) tested for linear change in IAT scores across time; (2) also included baseline predictors; (3) also included the 2-way interaction between baseline predictors and time. Tables report parameters, with 95% confidence intervals in brackets. No intox = baseline lifetime drinking history of no intoxication; coded 1 = history of drinking alcohol but never been intoxicated, 0 = otherwise. Intox = baseline lifetime drinking history of intoxication, coded 1 = lifetime history of intoxication, 0 = otherwise. Family Hx = familial risk of problem drinking, assessed using items from the Comprehensive Drinker Profile; coded 0 = no risk, 1 = any risk. Gender was coded 0 = man, 1 = woman. Class standing was coded 0 = first year, 1 = sophomore. $^{*}p < 0.05$, $^{**}p < 0.01$,$^{***}p < 0.001$.

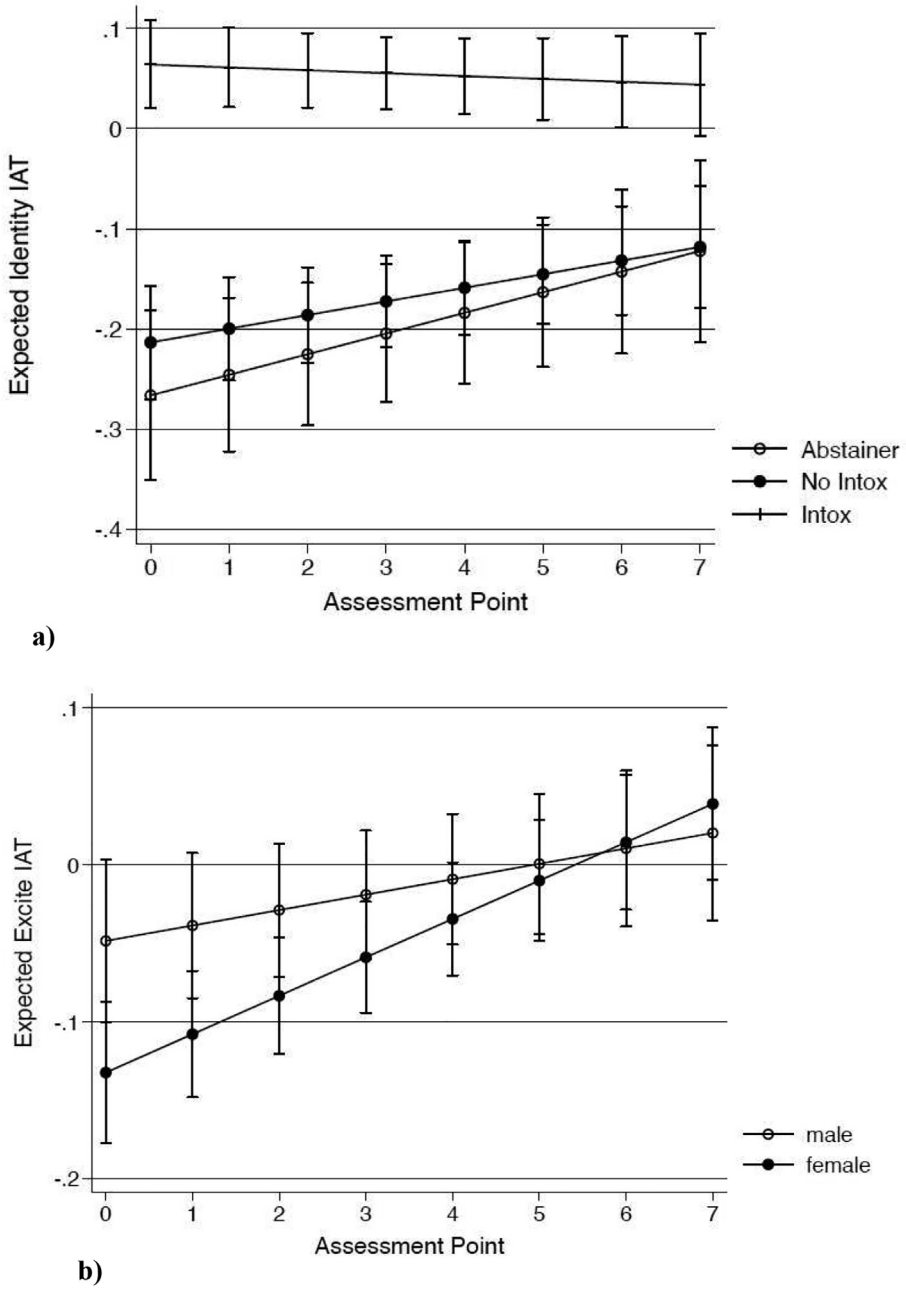

Fig. 1. Change in Implicit Association Test (IAT) scores over time as a function of baseline lifetime history of drinking (Panel a) and gender (Panel b).

drinking identity over time. Specifically, those with a history of intoxication at baseline had higher identity scores across time than those with no drinking history ($b = 0.26, p < 0.001$). Likewise, women had lower drinking identities than men across time ($b = -0.13, p < 0.001$). The growth parameter estimate was significant in Model 2, suggesting a small positive increase in identity over time after controlling for the covariates ($b = 0.006, p < 0.05$). Finally, Model 3 indicated that there was a significant interaction between history of intoxication versus no history of drinking and time ($b = -0.023, p < 0.05$). Fig. 1 displays the nature of the interaction. Those with a history of intoxication began the study with higher identity scores than either those with no history of drinking or those with a history of drinking but no history of intoxication. Further, those with a history of intoxication had a slight decrease in identity scores across time, whereas the other two groups showed an increase.

3.3. Alcohol-excite associations

Table 3 displays the results for the alcohol-excite IAT. Model 1 suggested there was, on average, small, positive, change in alcohol-excite IAT scores ($b = 0.018, p < 0.001$). The random effects suggested significant variability in the growth parameter across participants ($\hat{\sigma}_{u_1} = 0.036, p < 0.001$), and this pattern was identical across all three models. Model 2 indicated that those with a history of intoxication had higher excite scores across time than those with no history of drinking ($b = 0.24, p < 0.001$). The growth parameter remained significant. Model 3 showed a significant interaction between gender and time ($b = 0.015, p < 0.05$). Fig. 1 displays the nature of the interaction. At baseline, women had lower alcohol-excite IAT scores than men. Further, women's growth in excite scores was steeper than men's.

Table 3
Results of multilevel growth models predicting change in alcohol-excite IAT scores over time.

	(1) Alcohol-excite	(2) Alcohol-excite	(3) Alcohol-excite
Fixed effects:			
Time	0.018***	0.018***	0.022*
	[0.011,0.024]	[0.012,0.025]	[0.0029,0.041]
No Intox		0.083	0.10
		[−0.00011,0.17]	[−0.0070,0.21]
Intox		0.24***	0.28***
		[0.16,0.32]	[0.17,0.38]
Family Hx		0.034	0.061
		[−0.020,0.089]	[−0.0084,0.13]
Gender		−0.039	−0.084*
		[−0.093,0.016]	[−0.15,−0.015]
Class standing		−0.024	−0.031
		[−0.079,0.031]	[−0.10,0.039]
No Intox × Time			−0.0056
			[−0.026,0.014]
Intox × Time			−0.013
			[−0.032,0.0065]
Family Hx × Time			−0.0083
			[−0.022,0.0051]
Gender × Time			0.015*
			[0.0012,0.028]
Class standing × Time			0.0019
			[−0.012,0.016]
Intercept	−0.088***	−0.23***	−0.24***
	[−0.12,−0.053]	[−0.31,−0.15]	[−0.35,−0.14]
Random Time	0.036***	0.035***	0.035***
	[0.028,0.046]	[0.027,0.046]	[0.027,0.045]
Random Intercept	0.32***	0.29***	0.29***
	[0.29,0.35]	[0.26,0.32]	[0.26,0.32]
Corr(Time,Int)	−0.58***	−0.58***	−0.57***
	[−0.70,−0.43]	[−0.70,−0.42]	[−0.70,−0.41]
Residual	0.31***	0.31***	0.31***
	[0.30,0.32]	[0.30,0.32]	[0.30,0.32]
N	2565	2517	2517

Note. Data from 4 participants (2 who identified as transgender and 2 who declined to answer) are not included in analyses involving gender due of the small sample size. Model (1) tested for linear change in IAT scores across time; (2) also included baseline predictors; (3) also included the 2-way interaction between baseline predictors and time. Tables report parameters, with 95% confidence intervals in brackets. No intox = baseline lifetime drinking history of no intoxication; coded 1 = history of drinking alcohol but never been intoxicated, 0 = otherwise. Intox = baseline lifetime drinking history of intoxication, coded 1 = lifetime history of intoxication, 0 = otherwise. Family Hx = familial risk of problem drinking, assessed using items from the Comprehensive Drinker Profile; coded 0 = no risk, 1 = any risk. Gender was coded 0 = man, 1 = woman. Class standing was coded 0 = first year, 1 = sophomore.
*$p < 0.05$, ***$p < 0.001$.

3.4. Alcohol-approach associations

Table 4 displays the results for the alcohol-approach IAT. Model 1 suggested there was, on average, small, positive, change in alcohol-approach IAT scores ($b = 0.016$, $p < 0.001$). The random effects suggested significant variability in the growth parameter across participants ($\hat{\sigma}_{u_1} = 0.025$, $p < 0.001$), and this pattern was identical across all three models. Model 2 indicated that those with a history of intoxication had higher approach scores across time than those with no history of drinking ($b = 0.21$, $p < 0.001$). Likewise, women had lower approach scores than men across time ($b = -0.086$, $p < 0.001$). The growth parameter remained significant and none of the interactions was significant.

4. Discussion

This study is the first we know of to evaluate predictors of changes in implicit alcohol associations over time in a college sample. Drinking identity, alcohol-excite, and alcohol-approach associations were assessed eight times over a period spanning two academic years. Findings were generally consistent with the hypothesis that the early college years are a period in which alcohol-related associations would strengthen: alcohol-excite and alcohol-approach associations increased over time. Drinking identity associations did not change significantly on average, but there was evidence of change as a function of personal drinking history. Those with no drinking history and no history of intoxication increased over time and those with a history of intoxication decreased, suggesting potential boundary conditions for growth among this age group.

We tested key demographic and drinking experience factors as potential predictors of change over time. We reasoned that the college environment—via repeated opportunities for direct and indirect exposure to alcohol—might impact change in implicit alcohol associations for individuals with less previous alcohol exposure. Findings were mixed. Personal drinking history, specifically history of intoxication (vs. abstaining) predicted baseline differences in all three IATs. It did predict changes in implicit associations over time, with increases among individuals with no or less history of drinking, but that prediction was limited to drinking identity associations. Further, slight decreases in drinking identity associations were observed among individuals with a history of intoxication. Though the effect being specific to identity associations was not predicted, it is not altogether surprising that personal history would be most closely tied to changes in identity: both the personal drinking history moderator and drinking identity variable describe the individual, whereas alcohol-excite and -approach associations describe alcohol.

Class standing and family history of problem drinking did not significantly predict change in implicit associations. Prior research

Table 4
Results of multilevel growth models predicting change in alcohol-approach IAT scores over time.

	(1) Alcohol-Approach	(2) Alcohol-Approach	(3) Alcohol-Approach
Fixed effects:			
Time	0.016***	0.016***	0.020*
	[0.0098,0.021]	[0.010,0.022]	[0.0028,0.037]
No Intox		0.056	0.067
		[−0.017,0.13]	[−0.023,0.16]
Intox		0.21***	0.26***
		[0.15,0.28]	[0.18,0.35]
Family Hx		−0.0018	0.011
		[−0.048,0.045]	[−0.047,0.068]
Gender		−0.086***	−0.11***
		[−0.13, −0.039]	[−0.17, −0.051]
Class Standing		0.011	−0.015
		[−0.036,0.058]	[−0.073,0.043]
No Intox × Time			−0.0042
			[−0.022,0.013]
Intox × Time			−0.017
			[−0.034,0.00010]
Family Hx × Time			−0.0042
			[−0.016,0.0075]
Gender × Time			0.0083
			[−0.0035,0.020]
Class Standing × Time			0.0090
			[−0.0029,0.021]
Intercept	−0.19***	−0.28***	−0.29***
	[−0.22, −0.16]	[−0.35, −0.21]	[−0.38, −0.21]
Random Time	0.025***	0.025***	0.023***
	[0.017,0.037]	[0.017,0.037]	[0.015,0.036]
Random Intercept	0.25***	0.22***	0.22***
	[0.23,0.28]	[0.20,0.25]	[0.20,0.25]
Corr(Time,Int)	−0.49***	−0.41**	−0.39**
	[−0.66, −0.27]	[−0.61, −0.15]	[−0.61, −0.12]
Residual	0.29***	0.29***	0.29***
	[0.28,0.30]	[0.28,0.30]	[0.28,0.30]
N	2552	2505	2505

Note. Data from 4 participants (2 who identified as transgender and 2 who declined to answer) are not included in analyses involving gender due of the small sample size. Model (1) tested for linear change in IAT scores across time; (2) also included baseline predictors; (3) also included the 2-way interaction between baseline predictors and time. Tables report parameters, with 95% confidence intervals in brackets. No intox = baseline lifetime drinking history of no intoxication; coded 1 = history of drinking alcohol but never been intoxicated, 0 = otherwise. Intox = baseline lifetime drinking history of intoxication, coded 1 = lifetime history of intoxication, 0 = otherwise. Family Hx = familial risk of problem drinking, assessed using items from the Comprehensive Drinker Profile; coded 0 = no risk, 1 = any risk. Gender was coded 0 = man, 1 = woman. Class standing was coded 0 = first year, 1 = sophomore.
$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

indicating a relation between family history of problem drinking and implicit alcohol associations was conducted with adolescents. It may be the association between family drinking history and change in implicit associations is specific to earlier developmental time periods (childhood and adolescence) when familial influences may be particularly strong because the person is (likely) still living at home. It may also be that family history predicts initial levels of childhood/adolescent implicit alcohol associations but once those associations are more established, changes therein are more strongly guided by personal or non-familial, interpersonal factors.

Gender was also evaluated as an exploratory predictor. Findings were mixed. Across the implicit associations, men, on average, had significantly stronger alcohol-related associations than women. However, gender only interacted with time when predicting change in alcohol-excite associations, with significantly greater change in alcohol-excite associations observed among women compared to men. This finding may reflect some component of the decreasing gender gap in college men and women's drinking; the greater increase in women's alcohol-excite scores could reflect that women's drinking increases more rapidly than men's drinking during this critical period (Schulenberg et al., 2018).

Finally, we note the finding for random effects for growth across all of the implicit associations measured, indicating significant individual differences in change over time. This effect reflects both measurement error and meaningful individual differences. The former is a known limitation of IATs and implicit measures; they typically have lower reliabilities compared to self-report measures (Lindgren et al., 2016; Nosek, Hawkins, & Frazier, 2011). The latter may reflect meaningful variations in those associations across individuals, perhaps related to person-specific changes in drinking or other variables (e.g., mood changes).

Study strengths include more intensive longitudinal assessment of a relatively large sample of individuals who range from abstainers to heavy drinkers and who are at the beginning of a developmental period associated with substantial change in drinking. Nonetheless, the study has limitations. The study design is correlational, precluding causal claims about the relation between predictors and the implicit alcohol-related associations. Findings, which rely on a sample from the U.S. Pacific Northwest, may not generalize to other geographic regions or college campuses with different drinking cultures. Evaluating how change in implicit associations relates to changes in other cognitive vulnerability factors (drinking motives, alcohol expectancies) and other possible moderators of the change process (race and ethnicity) will be important. Future work might also take a data-driven approach via machine learning that optimizes the predictive power of multiple moderators.

This study provides a rare examination of the trajectories of implicit alcohol associations and moderators of those trajectories. Results

indicated small, but significant, changes in associations over time. Personal drinking history (for drinking identity) and gender (for alcohol-excite) emerged as important, potential influences of their trajectories.

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Conflict of interest

B. Teachman has a significant financial interest in Project Implicit, Inc., which provided services for hosting data collection for this project under contract with the University of Washington. All other authors declare that they have no conflicts of interest.

CRediT authorship contribution statement

Kristen P. Lindgren: Conceptualization, Methodology, Writing - original draft, Writing - review & editing, Funding acquisition. **Scott A. Baldwin:** Software, Formal analysis, Visualization, Writing - original draft, Writing - review & editing. **Kirsten P. Peterson:** Project administration, Writing - original draft, Writing - review & editing. **Reinout W. Wiers:** Conceptualization, Writing - review & editing. **Bethany A. Teachman:** Conceptualization, Writing - review & editing.

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