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Janssen, T.; Wood, M.D.; Larsen, H.; Peeters, M.; Vollebergh, W.A.M.; Wiers, R.W.

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Investigating the Joint Development of Approach Bias and Adolescent Alcohol Use

Tim Janssen, Mark D. Wood*, Helle Larsen, Margot Peeters, Wilma A. M. Vollebergh, and Reinout W. Wiers

Background: We investigated the joint development between implicit approach bias and early adolescent alcohol use, and examined whether the link between approach bias and alcohol use was moderated by working memory (WM).

Methods: The current study used data from a 2-year, 4-wave online sample of 378 Dutch early adolescents (mean age 14.9 years, 64.8% female). First, using latent growth curve modeling, we examined trajectories of approach bias and alcohol use over time. Second, we examined relations between baseline approach bias and WM and the development of alcohol use. Third, we examined the joint development of approach bias and alcohol use. Fourth, we examined whether the nature of this joint development varied for different levels of WM.

Results: Unconditional growth curve model analyses indicated that the functional forms of alcohol use and cognitive bias were best captured by quadratic and linear trajectories, respectively. We found that cognitive bias decreased over time. We found no significant relations between baseline predictors and observed increases in alcohol use. We found relations between the intercepts, but not to growth factors, in the joint development of alcohol use and approach bias. WM was not found to moderate relations between growth in approach bias and alcohol use in this sample.

Conclusions: While we observed evidence of association between approach bias and alcohol use at baseline, there was no evidence of relations between development trajectories of the two. These findings replicate prior research demonstrating a role of implicit approach bias in predicting early adolescent alcohol use but do not demonstrate, in a light drinking early adolescent sample, the importance of interrelations between changes in approach bias and alcohol use over time, or a moderating role of WM. It is important to consider the potential consequences of repeated online approach bias assessment (e.g., changes in stimulus valence) when interpreting these results.

Key Words: Approach Bias, Adolescent Alcohol Use, Growth Curve, Development Trajectories.

RESEARCH WITH EMERGING adults has associated alcohol-related cognitive biases to alcohol use, with heavy drinkers reporting stronger attentional (Field et al., 2004) and approach biases (Field et al., 2008) for alcohol compared to light drinkers. Alcohol-related cognitive biases are thought to promote drinking in a relatively automatic way (Gladwin et al., 2011). Dual-process theories of addiction (e.g., Bechara, 2005; Stacy and Wiers, 2010) emphasize the interplay between relatively automatic and reflexive processes (such as automatically triggered approach behavior) on the one hand, and reflective, top-down processes, supported by executive functions such as working memory (WM) and motivation to reduce drinking, on the other hand. While research has indicated that alcohol-related approach biases predict concurrent alcohol use in heavy drinking adolescents (Field et al., 2007, 2008), much less is known about the development of alcohol-related approach biases in early adolescence (Peeters et al., 2013). Specifically, it is presently unknown whether cognitive biases are found only in experienced drinkers or also in early adolescent normative drinkers, although it has been argued that cognitive biases do not play a large role in predicting normative adolescent alcohol use (Pieters et al., 2014). There is also little prior research examining growth in cognitive biases over time and the extent to which changes in cognitive bias may be associated with the normative increases in alcohol use that occur in adolescence. Finally, it is also unknown to what extent relations in the development of cognitive biases and alcohol use are moderated by individual differences in WM among early adolescents. Therefore, the current study examined bi-directional links in the joint development of alcohol-approach biases and alcohol use in early adolescence.

From the Department of Developmental Psychology (TJ, HL, RWW), University of Amsterdam, Amsterdam, the Netherlands; Department of Psychology (MDW), University of Rhode Island, Kingston, Rhode Island; Research Priority Area Yield (HL, RWW), University of Amsterdam, Amsterdam, the Netherlands; and Department of Social Sciences (MP, WAMV), Utrecht University, Utrecht, The Netherlands.

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Reprint requests: Tim Janssen, PhD, Department of Developmental Psychology, University of Amsterdam, Weesperplein 4, 1018 XA Amsterdam, the Netherlands; Tel.: +31-20-525-6729; Fax: +31-20-525-6971; E-mail: janssentim@gmail.com

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Dual-process theories (Hofmann et al., 2008; Strack and Deutsch, 2004) posit that individuals may differ in their responses to rewarding stimuli when the impulsive tendency to approach or attend that stimulus differs from the reflective tendency to apply self-control. According to Hofmann and colleagues (2008), individuals may also differ in the strength of impulsive precursors based on earlier learning experiences, current needs, and genetic endowment (see also Wiers et al., 2009). Applied to alcohol use among adolescents, an alcohol-approach tendency is displayed in individuals where weaknesses in self-control and/or strength of impulsive precursors bias relatively automatic decisions in favor of alcohol consumption. Within the context of longitudinal changes in adolescent alcohol use and approach tendencies, the model predicts that displaying greater approach bias should be associated with higher alcohol use and lead to greater increases in alcohol use over time. Conversely, earlier alcohol use should lead to greater increases in the strength of impulsive precursors by sensitization to alcohol-related rewards from earlier learning experiences (Stacy and Wiers, 2010; Wiers et al., 2007). Such effects are expected to be moderated by self-control, such that the link between alcohol-approach tendencies and alcohol use are greater when self-control is low. This study focuses on the development of approach bias, and whether the individual differences predicted by the Hofmann and colleagues (2008) self-control model occur in normative early adolescents.

Adolescence is believed to be a period of critical vulnerability in the reflective system because during this time, the cortical regions supporting executive functions have not fully matured (Casey and Jones, 2010; Gladwin et al., 2011). Automatically triggered responses are suggested to be a part of the reflexive response, whereas reflective processes include the motivation to desist or limit a behavior such as drinking when drinking becomes a habit. This motivation might result from being faced with adverse consequences as a result of substance use. Gladwin and colleagues (2011) suggest that in addictive behaviors, the reflective system serves to extend the amount of time available to deliberate on the decision to engage in drug-related responses. During this deliberation, automatically triggered responses initially greatly increase motivation to engage in addictive behaviors. However, given extended time, higher order motivations and priorities (such as plans for the future) increase motivation to abstain. Thus, extended time of deliberation should decrease the likelihood of engaging in addictive behaviors. The ability to motivate oneself not to engage in addictive behaviors is thereby, at least in part, dependent on the ability to regulate responses using executive functions that operate the reflective system, especially when sensitization greatly increases the motivational value to engage in substance use.

Recent studies in young adults and adolescents have demonstrated that cognitive biases are associated with concurrent drinking (Field et al., 2007, 2008, 2011) and predictive of prospective drinking (Peeters et al., 2012, 2013; for a review, see Wiers et al., 2015). Further studies suggest that the link between cognitive biases and substance use is strongest when executive functions are weak (Grenard et al., 2008; Peeters et al., 2012, 2013; Thush et al., 2008; Van Hemel-Ruiter et al., 2014). However, the majority of findings supporting a moderating role of executive functions are from cross-sectional studies (Grenard et al., 2008; Thush et al., 2008; Van Hemel-Ruiter et al., 2014) or at-risk adolescents (Peeters et al., 2012, 2013). Only 1 longitudinal study with more normative early adolescents (Pieters et al., 2014) has been published, which observed inconsistent associations between baseline attentional and approach biases and adolescent alcohol use. Specifically, neither approach bias, attentional bias nor implicit memory bias had a main effect on alcohol use, nor did the interaction of any of these with WM capacity significantly predict alcohol use. There were, however, indications that approach bias interacted with negative expectations such that when negative expectancies were low, approach bias more strongly predicted changes in alcohol use. However, this study did not include repeated measures of cognitive bias, which prevented examination of the development of cognitive bias during adolescence.

Accordingly, the main aims of the current study were to examine developmental associations between cognitive bias and alcohol use among a normative sample of adolescents and investigate whether normative developmental increases in alcohol use were associated with growth in cognitive biases. First, regarding the trajectories of cognitive bias and alcohol use, we predicted that both approach bias and alcohol use increase over time. Second, consistent with dual-process model predictions and the cross-sectional research reviewed above, we predicted that a higher baseline cognitive bias would predict increases in alcohol use over time. Third, we predicted that approach bias and alcohol use would show joint development, such that increases in one are related to increases in the other. Fourth, we sought to examine whether the moderating role of executive function in cognitive bias–alcohol use relations observed in older and high-risk younger adolescents, would generalize to a normative sample of earlier adolescents. We examined these hypotheses using latent growth curve modeling, an analytic approach that is well suited for periods of developmental change (Bollen and Curran, 2006).

MATERIALS AND METHODS

Participants

The current sample (N = 378, M age = 14.9 years, SD = 1.28, range: 12 to 18 years, 64.8% female) included participants who successfully completed at least 1 full online survey assessment. Within this sample, 210 participants completed participation at Time 2 (1 participant's answer was undecipherable), 182 participants at Time 3, and 195 participants at Time 4. Participants were recruited from an earlier classroom survey for the Health Behaviors in School-aged Children-project (Van Dorsselaer et al., 2013). Details regarding the recruitment strategy for the online survey are described in detail in Janssen and colleagues (2014).

Procedure

Data for the study were collected online at 4 time points in 2010 and 2011 with 6-month intervals. At Time 1, directly after registration, the study website clarified that participation was volitional and that students could cease their participation at any point. Prior to the start of the study, parents of the candidate participants received a letter including a passive parental consent form. There were no exclusion criteria other than nonconsent. We invited 2,200 pupils to participate in the current study. Emails inviting pupils indicated that the current study was a high-intensity project that required continued participation to complete and was not related to the original survey. Parents of 37 children did not consent to their children's participation. The study protocol was approved by the Ethical Committee of the University of Amsterdam. All assessments were conducted online, and participants were free to perform the assessments at their location of choice. Each successfully completed assessment was rewarded with a 5 EUR gift voucher.

Measures

Weekly Alcohol Use. We measured alcohol use with a self-report scale where participants indicated the average number of alcohol units (defined in the Netherlands as containing 10 g of alcohol) consumed on each day of the week (cf., Wiers et al., 2007).

Behavioral Measures. Behavioral measures were programmed in ActionScript 3.0 (Adobe Systems, San Jose, CA) and displayed in the participant's browser using Adobe Flash (Adobe Systems), with window size 1,000 $\times$ 600 pixels, and measured at each time point. The order in which behavioral measures were administered was counterbalanced. The study originally included other measures of approach and attentional bias, namely the Alcohol Approach–Avoidance Task (Wiers et al., 2009), the Visual Probe Task (MacLeod et al., 1986), and the Alcohol Stroop Task (Cox et al., 2006). However, initial analyses revealed that the reliability for these tasks was too poor to justify growth curve analyses (Alcohol Approach–Avoidance Task: mean $r = 0.359$; Visual Probe Task: mean $r = 0.031$; Alcohol Stroop Task: mean $r = 0.151$). As described below, we observed greater reliability for the Stimulus–Response Compatibility (SRC) Task (Mogg et al., 2003) and thus elected to conduct Latent Growth Curve Modeling with this task. The tasks included in the current survey represent a selection of the complete test battery, which included a further 5 behavioral measures and 7 questionnaire blocks. The full test battery required approximately 1.5 hours to complete on average, and included both forced and recommended breaks to alleviate order effects on response accuracy.

SRC Task—We assessed approach bias with an SRC task. In this task, a manikin was presented below or above a stimulus. Stimuli were images of either alcohol-containing beverages or water. The task consisted of 2 blocks, each preceded by 8 practice trials. In one block, participants are required to move the manikin toward alcohol and away from water, and the instructions are reversed in the other block. This effect was counterbalanced between participants. Participants moved away from stimuli by pressing the arrow key matching the direction on screen. The 2 blocks each consisted of 32 trials with 8 alcohol and 8 water stimuli being displayed twice. The SRC effect was calculated as the mean reaction time on successful trials on the avoid-alcohol block minus the same for the approach-alcohol block. Even-odd reliabilities of the task (Eisinga et al., 2013) were moderate (Time 1: $r = 0.579$, Time 2: $r = 0.639$, Time 3: $r = 0.594$, Time 4: $r = 0.727$) but consistent with previous research (Field et al., 2011).

Self-Ordered Pointing Task (Petrides and Milner, 1982)—We assessed WM performance using a computer version of the Self-Ordered Pointing Task (SOPT). Pictures were simultaneously placed at different positions on screen, starting with a practice trial of 4 pictures followed by 5 trials with 6, 8, 10, 12, and 12 pictures. Participants were instructed to click each unique picture in each trial's set once, but never click the same location twice. When the participant clicked a picture, the location of the pictures on screen was shuffled randomly. The total SOPT score was calculated by taking the mean of the proportion of unique clicks for the 5 trials (Cragg and Nation, 2007). Internal consistency of the SOPT was 0.81, which is in line with earlier findings (Ross et al., 2007).

Analysis Strategy

Using Mplus Version 7.2 (Muthen and Muthen, 2010), we conducted latent growth curve modeling using full informational maximum likelihood to determine the suitability of the cognitive bias measures (given reliability issues in this sample and prior research, see Ataya et al., 2012) and to examine the functional form of cognitive bias and alcohol use trajectories. These analyses followed a 2-step process (Bollen and Curran, 2006). In Step 1, we estimated separate unconditional (no predictors) models for each outcome over 4 waves to examine the fixed (means) and random (variances) effects of the outcomes. Specifically, we compared intercept-only models, with those including intercept and slope factors, and intercept, slope, and quadratic factors. In growth curve modeling, the intercept factor includes an estimate of the mean level of an outcome at a particular measurement period (baseline here) and a variance estimate indicating whether there is meaningful variability around the intercept. The slope factor represents linear change in the outcomes over time and also includes a variance estimate. The quadratic factor represents the exponential change in the outcome over time and the variability around this factor. We determined fit of these models using omnibus fit statistics (e.g., comparative fit index (CFI), root mean square error of approximation (RMSEA); see Bollen and Curran, 2006), chi-square difference tests, and by examining the significance of mean and variance estimates of the latent factors. Because alcohol use outcomes in the current sample were nonnormally distributed, we log10-transformed these outcomes.

In Step 2, to test the hypothesis that initial approach bias prospectively predicts substance use changes (and to replicate earlier findings on early adolescents from Pieters et al., 2014), we regressed baseline approach bias, baseline WM, and their interaction on the alcohol use growth curve selected from those compared in Step 1. To test the hypothesis that normative developmental increases in alcohol use were associated with growth in cognitive biases, we examined a dual growth curve model. In this model, we integrated the separate alcohol and cognitive bias growth curve models. Baseline age was included as a covariate. To examine relations between the initial levels of bias and alcohol use and the development over time, and to examine whether growth in one factor was associated with growth in the other, we also estimated associations between and across the intercepts and slopes of each curve.

Finally, to test the hypothesis that automatic associations would have a stronger effect on drinking behavior when executive functions are weaker, we examined whether baseline WM moderated relations between latent factors of the growth curves of weekly alcohol use and cognitive bias. We examined moderation by including the interaction between WM and initial bias. Two separate models estimated parameters for the role of these covariates in each of 2 pathways that were potentially moderated by WM: the prediction of initial alcohol use by initial bias and the prediction of growth of alcohol use by initial bias. We used separate models for each of these potential interaction effects to limit the number of parameters of each model.

RESULTS

Unconditional Means Models

To test our first prediction, regarding the functional form of approach bias and alcohol use, we examined assessment means at each time point as well as fit of different growth curve models. Table 1 contains means and standard deviations for approach bias, alcohol use, age, and gender at each time point. Counter to our expectations, while repeated measures analysis demonstrated that alcohol use increased significantly among drinkers, the mean for approach bias decreased over time. Table 2 contains fit criteria for each attempted growth curve model. Based on examination of fit indices and chi-square difference scores, it was concluded that the best functional form for the alcohol use trajectory was the model that included intercept, slope, and quadratic factors, although variance for the quadratic factor was fixed at zero due to nonconvergence in the initial quadratic model. This means that individual differences in exponential growth over time were not modeled and could not be predicted by other factors. Following parallel decision criteria, the intercept and slope factor model was selected as best capturing the cognitive bias trajectory. While the mean of the intercept was positive and significantly different than zero ($M = 42.7$, SD = 6.8, $p < 0.001$), the mean for the slope factor in this model was negative and significant ($M = -26.1$, SD = 12.5, $p = 0.037$) indicating negative average growth in cognitive bias. The mean for the quadratic factor was nonsignificant ($M = 6.0$, SD = 4.2, $p = 0.155$). The variances for the intercept and slope approach bias factors were not significant, indicating a lack of variability around both the initial mean level of approach bias and the significant mean decrease over time. However, it has been noted that subsequent inclusion of covariates often finds significant associations indicating variation as a function of the covariates with increased statistical power invoked as an explanation (Muthén, 2002). Accordingly, we elected to estimate conditional models without constraining the variances of the intercept and quadratic approach bias factors.

Conditional Alcohol Growth Curve Model

To determine whether baseline approach bias, WM, and their interaction predicted alcohol use (per our second prediction), at baseline and the observed significant growth in alcohol use we regressed age, baseline approach bias, baseline WM, the interaction between baseline approach bias and WM, and age on the intercept and slope factors of the quadratic alcohol use curve described above. The main effects used to create the variable representing the interaction were centered (Aiken and West, 1991). Overall, model fit was good, RMSEA = 0.072, standardized root mean square residual (SRMR) = 0.031, CFI = 0.974. Figure 1 contains the standardized path estimates. Age was significantly and positively associated with both the intercept and slope of alcohol use (ps < 0.05), such that higher age at baseline was associated with greater levels of alcohol use at baseline and growth in alcohol use over time. Baseline approach bias, WM, and the Bias × WM interaction were not associated with initial levels of alcohol use or growth on this factor.

Dual Growth Curve Models

To determine whether there were relations between the development of approach bias and the development of alcohol use (per our third prediction), we estimated a dual growth curve model with cognitive bias and alcohol use, controlling for baseline age differences by estimating paths to both intercept factors (Fig. 2). Overall, model fit for the dual growth curve model was good, RMSEA = 0.033, SRMR = 0.066, CFI = 0.960. In this model, age was significantly and positively associated with initial level of alcohol use ($b = 0.571$, 95% CI = 0.489 to 0.653). The only significant pathway between the 2 latent growth curves was the one between the intercepts ($b = 0.444$, 95% CI = 0.004 to 0.982) indicating that, after controlling for significant age effects, baseline cognitive bias was associated with initial levels of alcohol. Results did not support any of the hypothesized relations to increases in alcohol use, nor were there significant relations associated with the observed decrease in approach bias over time. To determine whether order effects influenced results, we examined whether order of tests predicted changes in reliability in the SRC task based on the formula from Cohen and Cohen (1983, p. 54). This formula is used to determine significance of differences in reliability between those participants who completed the task very early, early, late, or very late in the test battery. Correcting for multiple testing, we found no significant relations

Table 1. Descriptive Statistics for Alcohol Use, Approach Bias Score, Age, and Gender

	Time 1 (N = 378)	Time 2 (N = 209)	Time 3 (N = 182)	Time 4 (N = 195)
Weekly alcohol use (% weekly drinker)[a]	23.2	29.5	40.1	58.5
Weekly alcohol use (M (SD))[b]	5.22 (5.22)	4.93 (4.34)	5.27 (5.32)	5.76 (5.27)
Approach bias reaction time (M (SD))	43.34 (132.48)	16.96 (136.16)	18.43 (149.92)	15.88 (150.19)
Mean age (M (SD) in years)	14.89 (1.28)	15.26 (1.20)	15.87 (1.25)	16.18 (1.26)
Gender (% female)	64.8	71.4	69.2	67.7

[a]This row indicates the percentage of participants that indicate weekly alcohol use above zero.
[b]Weekly alcohol use does not appear to increase over time, but a repeated measures analysis reveals that among those who already drank at Time 1, mean number of drinks increased linearly (M (SD) for Time 2: 5.27 (4.92), Time 3: 6.26 (6.27), Time 4: 7.36 (6.36), $F = 10.799$, $p < 0.01$).

Table 2. Model Fit and Variances for Growth Curve Models of Approach Bias and Alcohol Use

Outcome	Solution	Chi-square (df)	SRMR	CFI/TLI	Variance (i)[b]	Variance (s)[b]	Variance (q)[b]
Alcohol Use	Intercept-only	155.4 (8)***	0.204	0.444/0.583	7.269***	–	–
	Intercept + Slope	19.5 (5)**	0.075	0.945/0.934	6.276***	2.747**	–
	Quadratic	9.1 (4)	0.062	0.981/0.971	6.157***	2.748**	0[a]
Approach Bias	Intercept-only	13.8 (8)	0.085	0.389/0.542	2.690**	–	–
	Intercept + Slope	5.8 (5)	0.059	0.910/0.892	1.462	1.267	–
	Quadratic	4.1 (4)	0.056	0.994/0.991	1.496	1.301	0[a]

Model fit statistics for different growth curve solutions on 4-wave longitudinal data. CFI, comparative fit index; SRMR, standardized root mean square residual; TLI, Tucker–Lewis Index.
[a]Variances for the quadratic factor for both outcomes were fixed at zero because solutions failed to converge unless specified.
[b]Variances of "i," "s," and "q" refer to the standardized variances of intercept, slope, and quadratic factors, respectively.
$^{**}p < 0.01$, $^{***}p < 0.001$.

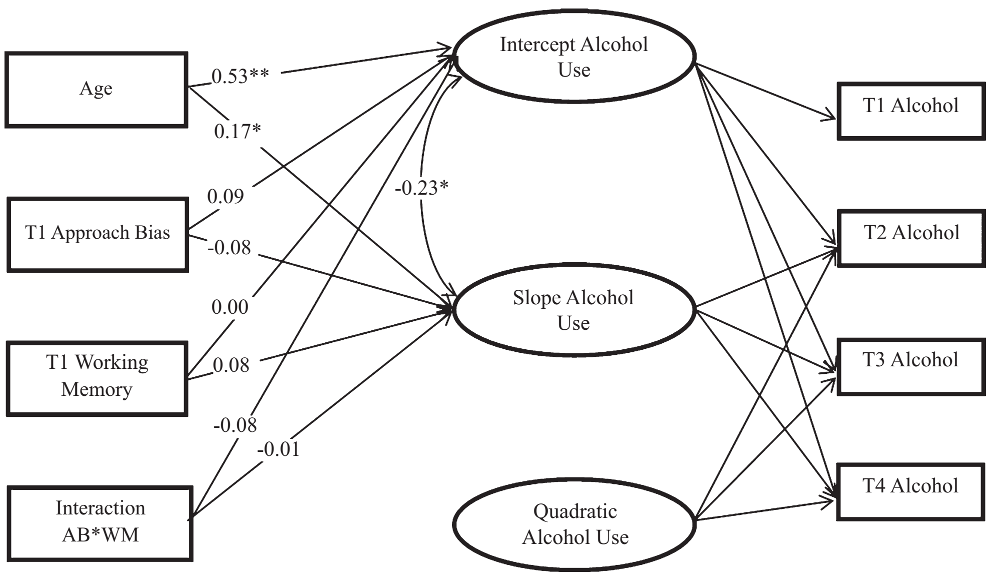

Fig. 1. Latent growth curve of alcohol use conditioned on baseline predictors. Figure represents a statistical model with 3 latent factors representing intercept, slope, and quadratic factors of alcohol use. Pathways estimate the relations between intercept and slope for alcohol use only, as variance on the quadratic factor was fixed at zero. Values are standardized coefficients. Interaction AB*WM represents a variable created as the product of standardized approach bias and working memory capacity. $^{*}p < 0.05$, $^{***}p < 0.001$.

between order and task reliability. Furthermore, we conducted a post hoc analysis to determine whether the found relation between intercepts of approach bias and alcohol use remained significant when correcting for order effects, which it did.

To address our fourth research question of potential moderation of approach bias–alcohol outcome relations by WM, we added WM and the interaction between WM and the intercept of bias to the model depicted in Fig. 2. Table 3 lists the estimated values for the main and interaction effects tested.[1] Findings demonstrated that none of the interaction effects or main effects using WM were associated with the intercept or slope of alcohol use. Accordingly, results from these models do not support the hypothesis that WM moderates relations between approach bias and alcohol use in a normative adolescent sample.

DISCUSSION

The present study examined relations between the development of alcohol use and the development of approach bias in a normative sample of young adolescents and examined whether the strength of these relations varied according to individual differences in executive functioning. First, unconditional latent growth models indicated that alcohol use increased while approach bias decreased over time. Second, baseline approach bias, WM, and their interaction did not predict initial level of alcohol use or its development over time. Third, results from dual growth models demonstrated that in the current sample, only the intercept of approach bias and the intercept of alcohol use were related. These results differ in that the intercept of approach bias reflects the stable level of approach bias measured across time

[1]Model fit and standardized model effects are not available because when creating interactions with a latent factor as one of the main terms, this term is dependent on values for the latent variable indicators (Muthén, 2002).

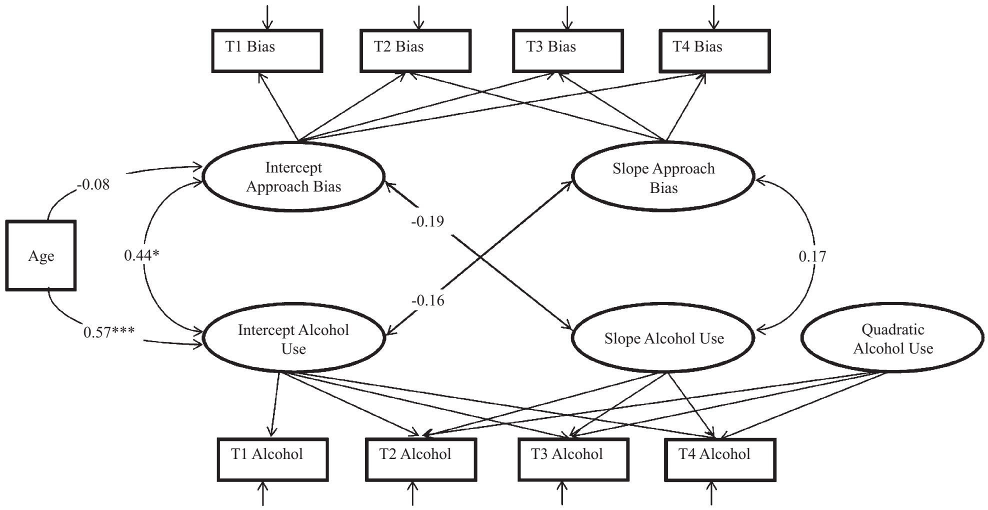

Fig. 2. Dual-Process Growth Curve of Approach Bias and Alcohol Use. Figure represents a statistical model with 4 latent factors representing the intercepts and slopes, that is, stable levels and growth, of alcohol use and approach bias at 4 time points. Pathways estimate the relation between intercepts and slopes for alcohol use and approach bias. As variance for the quadratic factor of alcohol use was fixed at zero, no relations between this factor and other factors are estimated. Scores are the standardized coefficients and standard errors for the specified relations. *$p < 0.05$, ***$p < 0.001$.

Table 3. Unstandardized Coefficients from the Regression on Latent Variables with Interaction Effects

Dependent	Independent	Coefficient (SE)
Intercept Alcohol	Age	0.323 (0.046)***
	Intercept Bias	0.007 (0.006)
	WM	0.086 (0.055)
	Intercept Bias × WM	−0.002 (0.001)
Slope Alcohol	Intercept Alcohol	0.039 (0.084)
	Intercept Bias	7.195 (27.325)
	WM	0.048 (0.149)
	Intercept Bias × WM	−0.001 (0.004)

Results from regression on latent variables listed as dependent, in 2 separate models. Bias is assessed with the Stimulus–Response Compatibility task. WM, Working Memory assessed with the Self-Ordered Pointing Test.
***$p < 0.001$.

points, compared to the less reliable use of only the baseline measurement (where measurement error plays a larger role; see Cunningham et al., 2009). There were no significant relations between changes in either measure over time, and no indications that alcohol use and approach bias co-develop in early adolescence. Fourth, in the current sample, relations between the development of alcohol use and the development of approach bias did not differ between those scoring low on WM versus those scoring high on WM.

As noted, most other studies in the field of adolescent substance use and cognitive biases thus far examined cognitive biases in heavy or social drinking adolescents, or college students. The current study differed in that it examined changes in cognitive biases among early light drinking adolescents. Only 1 other recent study examined prospective prediction of alcohol use, but did so with baseline cognitive biases (Pieters et al., 2014). This study found no evidence for a main effect of cognitive bias in the prediction of alcohol use. Pieters and colleagues (2014) demonstrated that while explicit motivation was the strongest predictor of adolescent alcohol use, approach bias was only predictive when negative expectancies were low. Because we did not assess negative expectancies in the current sample, we cannot replicate this finding. However, the lack of overall prediction by baseline cognitive biases of alcohol use is in line with the current study, as is the lack of an effect of poor WM capacity on this relation. Regression analyses from Pieters and colleagues (2014). did not distinguish between initial level and change in alcohol use during the study period, nor did it include repeated measures of approach bias over time. The sample from that study was otherwise of similar age, and measures of alcohol use, approach bias, and WM were identical. Other cross-sectional studies using heavier drinking adolescents have supported the association between cognitive biases and alcohol use more consistently (Field et al., 2004, 2007), and more recent longitudinal studies have demonstrated that among selected at-risk subpopulations, the development of alcohol use and the development of cognitive biases are associated (Peeters et al., 2012, 2013). In this at-risk population, where executive functions are below levels in the current sample (Peeters et al., 2015), it was shown that this developmental relation only occurred among those scoring below the median on inhibition skills, in line with earlier cross-sectional findings on the role of WM (Grenard et al., 2008; Thush et al., 2008). Integrating the results from the current study and those of Pieters and colleagues (2014) with results from research with at-risk adolescent population (Peeters et al., 2012, 2013) suggests compromised executive functioning may be a necessary prerequisite for the development of cognitive biases to be associated with the development of alcohol use in early adolescence. Additionally, there may be other factors of potential importance in which these subpopulations differ, such as socioeconomic status, home environment, and history of drug use among family members that may affect relations between cognitive bias and alcohol outcomes. Regardless, executive functions in the current sample may be generally too high compared to such samples, so that implicit effects that have been observed when executive functions are low, are occluded in the current sample.

While there are interesting theoretical implications to the current study's findings, there are also potential methodological explanations. First, from a methodological perspective, the finding that approach bias decreased over the study period was unexpected but may potentially be explained by the nature of repeated measures assessment. The current study's test battery included a large number of behavioral measures which may have affected participants' motivation. Furthermore, aside from their use in Peeters and colleagues (2013), there are few previous examples of repeated assessment of bias measures among adolescents. Together, these factors suggest that behavioral measures of cognitive bias may be influenced by repeat administrations. We have investigated changes in the reliability of our approach bias measure over time and in task order and found no significant relations of reliability to either. This suggests that other methodological factors than just reliability may have affected results. Aside from differences in reliability, the repeated administration of the SRC task may have changed the valence of the stimuli so that they were re-coded into sets specific to the task, losing their representative value as images of real-life alcohol opportunities. Alternately, as we elected to use images of water glasses as contrast, it is possible that there was an initial difference in salience between target and contrast images such that the bias score calculated as the difference in approach speed between the 2 reflects a general tendency to approach high-valued stimuli rather than alcohol-images specifically (cf., Van Hemel-Ruiter et al., 2011). In this scenario, a decrease in mean approach bias might reflect aging of the participants and a general maturing-out of sensation seeking, as has been noted in the past (Steinberg et al., 2008). Second, from a theoretical perspective, there exists the possibility that a lack of general association of cognitive bias to the development of alcohol use indicates that cognitive biases require specific circumstances or a more consistent intake of alcohol to develop. A lack of predictability of the change in cognitive bias suggests that possibly, the light amount of drinking observed in the current sample is not enough to affect dopamine pathways to create "wanting" to the degree suggested by incentive sensitization theory, therefore not creating automatic response tendencies that meaningfully impact behavior. From this perspective, the development of alcohol use among early adolescents may be more strongly predicted by explicit motivation and reflective processes not included in the current study (but more thoroughly included in Pieters et al., 2014), context (e.g., peers), or a combination of these factors. In contrast to this, the intercepts of approach bias and alcohol use were associated in the current study, indicating that even among a normative sample of early adolescents, cognitive bias is etiologically relevant in the prediction of alcohol use. Larger sample sizes and longer follow-up periods may be necessary to conduct stronger tests of our study questions.

Some strengths are that the present study was one of the first to longitudinally assess cognitive bias among normative early adolescents using repeated measures. This allowed us to examine to what degree these measurements were suitable for longitudinal analyses and examine the developmental relations of approach bias in relation to alcohol use. Second, we employed latent growth modeling, which allowed the prediction of change across a period of time based on repeated assessments of 2 processes. Third, we ensured that relations between approach biases and alcohol use did not result from initial differences in age by covarying all latent factors with age. Some limitations are that we did not examine the effect of changes in WM during the study period. Because of the limited sample size and attrition, we used only baseline WM data. Second, sample size limitations prevented us from examining the role of interactions on all growth relations simultaneously.

Moving forward, we suggest that further research on early adolescents feature larger samples to compensate for a lower prevalence rate of alcohol use in such samples. At a more basic level, it appears that validation is required of behavioral measures of cognitive bias to confirm measurement variance across levels of population separated by age, prior alcohol use, and repeated assessments. On a positive note, new and more reliable indices are currently being developed and tested for attentional bias (Zvielli et al., 2014). Given reliable and valid means of measurements as well as longer study periods, future research may determine how the development of early adolescent substance use relates to cognitive biases from early adolescence into college age. Potentially, bias measures are more effective at predicting substance use among heavy drinkers whose drinking behavior is more entrenched. These things taken into account, the current study replicates a growing body of research indicating a role for implicit bias in early adolescent alcohol use, by means of a significant association between stable levels of approach bias and alcohol use. Additionally, the current study casts broad potential implications for the field in terms of the validity and representation of aspects of alcohol-approach tendency as measured by the SRC. Finally, however, it offers no support for the notion that the changes in cognitive biases and alcohol are consistently related among light drinking early adolescents, unlike among heavier or at-risk drinkers.

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CONFLICT OF INTEREST

None of the authors have conflicts of interest to declare.

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