



Longitudinal relations between cognitive bias and adolescent alcohol use[☆]



Tim Janssen^{a,*}, Helle Larsen^a, Wilma A.M. Vollebergh^b, Reinout W. Wiers^a

^a University of Amsterdam, Research Priority Area Yield, Weesperplein 4, 1018 XA Amsterdam, The Netherlands

^b Utrecht University, Utrecht, The Netherlands

HIGHLIGHTS

- We examined whether cognitive biases and impulsivity predicted alcohol use.
- We examine interaction between impulsivity and alcohol on future cognitive bias.
- We found that attention bias predicted future alcohol use.
- We did not find that impulsivity, alcohol or interactions predicted cognitive bias.

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ABSTRACT

Introduction: To prospectively predict the development of adolescent alcohol use with alcohol-related cognitive biases, and to predict the development of alcohol-related cognitive biases with aspects of impulsivity.

Methods: Data were used from a two-year, four-wave online sample of 378 Dutch young adolescents (mean age 14.9 years, 64.8% female). With zero-inflated Poisson regression analysis we prospectively predicted weekly alcohol use using baseline cognitive biases. Additionally, multiple regression analyses were used to prospectively predict the emergence of alcohol-specific cognitive biases by baseline impulsivity and alcohol use.

Results: Zero-inflated Poisson analyses demonstrated that the Visual Probe Task reliably predicted weekly alcohol use at different time points. Baseline alcohol use and baseline impulsivity measures did generally not predict alcohol-specific cognitive biases.

Conclusions: The findings of this study indicated that while certain measures of alcohol-related attentional bias predicted later alcohol use in young adolescents, approach biases did not. Baseline measures of impulsivity and alcohol use did not predict later alcohol-related cognitive biases. We discuss implications for cognitive models on the development of cognitive biases and their role in early addictive behaviors.

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1. Introduction

Research in undergraduate populations have linked alcohol-related cognitive biases to alcohol use, with heavy drinkers reporting a stronger attentional bias (Field, Mogg, Zetteler & Bradley, 2004) and approach-bias (Field, Kiernan, Eastwood & Child, 2008) for alcohol compared to light drinkers. Alcohol-related cognitive biases are thought to promote drinking in a relatively automatic way (Gladwin, Figner, Crone & Wiers, 2011). Dual process theories of addiction (e.g. Bechara, 2005; Stacy & Wiers, 2010) emphasize interplay between on the one hand

relatively automatic or impulsive process such as selective attention and approach action-tendencies to alcohol-related cues, and on the other hand reflective, top-down processes that may moderate the impulsive alcohol-related reactions. While research has indicated that alcohol-related cognitive biases predicted alcohol use in heavy drinking adolescents (Field, Christiansen, Cole & Goudie, 2007; Field, Kiernan, Eastwood and Child, 2008; Peeters et al., 2012), little is known about the development of alcohol-related cognitive biases in early adolescence. For example, at present it is unknown whether early alcohol-related cognitive biases emerge as a consequence of alcohol use, or predate alcohol use as an alcohol-specific expression of more general pre-existing traits such as impulsivity. Therefore, the current study examined the development and interplay between alcohol-specific cognitive biases and emerging alcohol use in adolescence, and to what extent cognitive biases can be predicted by general impulsivity-related measures and alcohol use.

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* Corresponding author at: Department of Developmental Psychology, University of Amsterdam, Weesperplein 4, 1018 XA Amsterdam, The Netherlands. Tel.: +31 20 525 6729.

E-mail address: janssentim@gmail.com (T. Janssen).

It is generally accepted that adolescents experience a period of heightened sensitivity to reward and greater impulsivity resulting in greater risk taking, and that this period coincides with an increased likelihood of substance use onset. Specifically, studies suggest that risk taking shows an inverted U-shape pattern during adolescence, showing a decline after peaking in adolescence (Steinberg, 2004), and that this impulsivity prospectively predicts binge drinking, with binge drinking in turn also predicting a non-permanent increase in impulsivity (White et al., 2011). Animal studies further suggest that during this period, adolescents are conditioned to rewarding substances more rapidly (Brenhouse & Andersen, 2008). In humans, alcohol-related cognitive biases are believed to affect behavior through the interplay of dual processes. Current interpretations of dual process models (Gladwin, Figner, Crone and Wiers, 2011) suggest that this adolescent peak in impulsivity is represented as a delay in the development of top-down controlled, long term oriented motivation, and may coincide with the inverted U-shape pattern of impulsivity. This delay increases the likelihood of immediate responses being selected. A relevant example of top-down controlled, long term motivated decision making would be to hold off on going out with friends for a night of drinking because one has an important exam the following morning, which represents a deliberate effort to shift focus from immediate reward to long-term objectives. The strength of immediate responses may be influenced by reward learning that emphasizes the rewarding properties of the associated outcomes to these responses. These findings raise interest in examining the relation of alcohol-related cognitive biases and impulsivity to early substance use in human adolescents.

Regarding the relation between impulsivity and alcohol-related cognitive bias, a recent meta-analysis (Coskunpinar & Cyders, 2013) examined results from 13 studies, finding that there existed a consistent positive relation between both self-report and behavioral impulsivity on the one hand, and attentional bias on the other, with stronger findings for behavioral impulsivity. This study suggested a model relating impulsivity to attentional bias through both biasing of classical conditioning and affecting dopaminergic responses. Both these processes would serve to let aspects of impulsivity speed up the development of attentional biases given substance exposure. Although these findings pertained to attentional bias and were not exclusive to alcohol as a bias target, the implications from this model are that aspects of impulsivity, particularly behavioral as opposed to self-report, could be predictive prospectively of greater alcohol-specific cognitive bias. Incentive learning models suggest that this prospective prediction might be moderated by alcohol use, through the development of incentive sensitization (Berridge, Robinson & Aldridge, 2009), which could in humans be expressed in an attentional bias and approach bias (Berridge, Robinson & Aldridge, 2009; Stacy & Wiers, 2010). As mentioned in the meta-analysis (Coskunpinar & Cyders, 2013), all study data examined were cross-sectional, and there exists a need for causal and longitudinal data to effectively examine the precise nature of the interplay of these processes.

The current study was designed to investigate the role of alcohol-related cognitive biases and their relation to aspects of impulsivity as well as alcohol use in a sample of early adolescents in an online longitudinal study. Bias measures and alcohol use were measured at four six-month intervals, as well as self-reported impulsivity at baseline, allowing the examination of prospective relations between these measures. When predicting alcohol use, we hypothesized that later heavy drinkers would show greater baseline alcohol-related cognitive biases than later light drinkers, but only for those who were current drinkers. In accordance with dual process theory, we hypothesized that the interaction between impulsivity-traits and alcohol use would prospectively predict bias scores at later time points. We conducted two zero-inflated Poisson (ZIP) regression analyses to predict alcohol use after a short (6-month) and long (18-month) interval by bias measures on the one hand, and conducted multiple linear regression analyses to predict bias measures with impulsivity measures and drinking history on the other hand.

2. Methods

2.1. Participants

The current sample ($N = 378$, M age 14.9 years, $SD = 1.28$, range: 12–18 years, 64.8% female) is defined as those participants who successfully completed participation during at least one time point. Within this sample, 210 participants completed participation at Time 2, 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). Recruitment was presented as an opportunity to engage in a more elaborate online research project which was separate from and additional to the original classroom-based project. Details regarding the recruitment strategy for the online survey are described in detail in Janssen et al. (2014).

2.2. Procedure

Data for the study was collected online at four time points in 2010 and 2011 with six month intervals. At T1, 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. This form indicated that parents could object to participation by their child, which 37 parents did. 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.

2.3. Measures

2.3.1. Weekly alcohol use

At each time point, we measured alcohol use with a self-report scale where participants indicated the average number of alcohol units consumed on each weekday (Wiers, Hoogveen, Sergeant & Gunning, 1997), based on the Time-Line Follow Back method (Sobell & Sobell, 1992). Participants were informed that a single Dutch alcohol unit contains 10 g or 12.7 ml of alcohol.

2.3.2. Self-reported impulsivity

We measured two self-report aspects of impulsivity, Sensation Seeking and Impulsivity, using the Substance Use Risk Profile Scale (Woicik, Stewart, Pihl & Conrod, 2009), which consists of 23 items assessing participants' scores on personality traits associated with alcohol use. Impulsivity in this questionnaire is represented as the inability to inhibit rash action, whereas Sensation Seeking is represented as the desire for intense and rewarding experiences. Items in the SURPS took the form of statements (e.g. "I tend not to think before speaking"), about which participants were asked to indicate if they strongly disagreed, disagreed, agreed or strongly agreed on a four-point Likert scale. Cronbach's Alphas for reliability of the Sensation Seeking and Impulsivity scale were .70 and .61 respectively, which matches earlier studies (Woicik, Stewart, Pihl and Conrod, 2009).

2.3.3. Behavioral measures

All behavioral measures were programmed in ActionScript 3.0 and displayed in browser using Adobe Flash, with window size 1000×600 , and measured at each time point.

2.3.3.1. Stimulus Response Compatibility (SRC; De Houwer, Crombez, Baeyens & Hermans, 2001). We assessed approach bias with an SRC task. In this task, a manikin is presented below or above a stimulus. Stimuli are images of either alcoholic drinks or water. The task consisted of two blocks, each preceded by 8 practice trials. One block requested

participants to move the manikin towards alcohol and away from water, another block requested participants to do the opposite. Participants moved away from stimuli by pressing the arrow key matching the direction that would carry the manikin away from the stimulus on screen, in relation to the manikin's location. The two blocks each consisted of 32 trials with eight alcohol stimuli and eight water stimuli being displayed twice per block. The SRC effect was calculated as the median RT on successful trials on the avoid-alcohol block minus the same for the approach-alcohol block. Even-odd reliability of the task, reported as Spearman–Brown prophecy coefficient (Eisinga, Grotenhuis & Pelzer, 2013), ranged from moderate to acceptable at .579 (Time 1), .639 (Time 2), .594 (Time 3), and .727 (Time 4).

2.3.3.2. Alcohol Approach-Avoidance Task (AAT; Wiers, Rinck, Dictus, & Van Den Wildenberg, 2009). The Alcohol-AAT assesses approach bias by measuring whether participants are quicker to approach alcohol images compared to water images, while participants react to a feature of the stimulus unrelated to its contents. Participants were presented with 20 alcohol stimuli and 20 neutral stimuli, each tilted once to the left and once to the right, for a total of 80 trials. Participants were instructed to approach (press the up-arrow-key three times) stimuli tilted to the left, and avoid (press the down-arrow-key three times) stimuli tilted to the right. When participants pressed the up- or down-arrow-key, the image displayed grew or shrunk, simulating an approach or avoidance action tendency (Rinck & Becker, 2007). Error trials were repeated after a 3 second delay to stimulate serious performance (cf. Greenwald, Nosek & Banaji, 2003). Trial RTs represented the time required to complete the approach (three keypresses). Scores on the Alcohol-AAT were calculated as the median RT for alcohol-avoid trials minus the median RT for alcohol-approach trials (Rinck & Becker, 2007; Wiers, Beckers, Houben, & Hofmann, 2009), which are less sensitive to outliers than mean scores. Even-odd reliability of the task, reported as Spearman–Brown prophecy coefficient, ranged from low to moderate at .227 (Time 1), .342 (Time 2), .388 (Time 3), and .480 (Time 4).

2.3.3.3. Visual probe task (MacLeod, Mathews & Tata, 1986). The visual probe task assesses attentional bias for alcohol. Participants are presented with two stimuli for 1000 ms, one on the left and one on the right side of the screen, one of which was alcoholic while the other was water-themed. After this time, a probe in the form of an arrow pointing up or down is presented on screen. Participants were required to press the Up-arrow key if the arrow is pointing up and the Down-arrow key if the arrow is pointing down. The arrow was presented at the former location of either the left or right stimulus at random. 80 trials were presented, during half of which the arrow appeared behind the alcoholic stimulus. The visual probe effect was calculated as the median reaction time when the arrow probe appeared behind the water stimuli, minus the median reaction time when the arrow probe appeared behind the alcoholic stimuli. Even-odd reliabilities for the visual probe task were calculated as the correlation between the visual probe effect for even trials and the visual probe effect for odd trials, reported as Spearman–Brown prophecy coefficient where appropriate, and were exceptionally poor, at $-.060$ (Time 1), $.138$ (Time 2), $-.184$ (Time 3), and $.075$ (Time 4). It is not appropriate to apply correction to negative reliabilities.

2.3.3.4. Emotional Stroop task (Williams, Mathews & MacLeod, 1996). A basic Emotional Stroop task adapted for measuring attentional bias to alcoholic word stimuli was used. Participants were presented with either alcoholic or neutral words presented in one of four colors. Participants must use one of four keys to identify the color in which the stimulus is presented. First, two practice blocks of 20 trials allowed participants to overlearn the link of each color (red, yellow, green, blue) to their corresponding key ('E', 'F', 'J', 'I'). During the first 20 trials, the key letters were displayed in the associated color. After that, the key letters were displayed in black and errors resulted in the key letters displayed in the associated color as a reminder. Following practice, the

experimental block consisted of 64 trials in which 8 alcohol stimuli and 8 neutral stimuli (office supplies) were each presented 4 times. Presentation was in random order, meaning that carry-over effects were an aspect of measurement (for more discussion, see Franken, Kroon, Wiers & Jansen, 2000; Waters, Sayette & Wertz, 2003). Even-odd reliability of the task, reported as Spearman–Brown prophecy coefficient, was low at .231 (Time 1), .110 (Time 2), .153 (Time 3), and .108 (Time 4).

2.3.3.5. Brief Implicit Attitude Test (Sriram & Greenwald, 2009). We intended to measure implicit attitudes between alcohol and the concepts of 'Arousal' versus 'Sedation' to examined whether participants implicitly associated alcohol with these concepts. The version of the Brief Implicit Attitude Test used differs from an ordinary Implicit Attitude Test (Greenwald, McGhee & Schwartz, 1998) in that it has no separate training blocks, only two different test blocks and a third of the usual amount of trials. The test blocks show only one of two attribute categories per block. It was found that the Brief IAT confused participants, who were unclear as to what classification to make and reported frustration about the task. For this reason, subsequent waves of the study did not include the Brief IAT and the current study does not report results from the task.

2.3.3.6. Delay Discounting Task (Richards, Zhang, Mitchell & Wit, 1999). In the Delay Discounting task, the participant was required to choose between accepting an immediate virtual reward and choosing a delayed, but greater reward. The delay ranged from one to seven time points: a day, a week, a month, six months, a year, five years and 25 years. In the computerized version of this task, this choice was repeated six times for each delay period, and the immediate reward was adjusted based on the participant's previous choice (cf. Richards, Zhang, Mitchell and Wit, 1999). Scores on the Delay Discounting Task were calculated as the value of the 'Area under the Curve' (Myerson, Green, & Warusawitharana, 2001). Internal consistency (Cronbach's α) of the seven indifference points was .88.

2.4. Analysis strategy

We first examined descriptive statistics for alcohol data, gender, and age at each time point. Furthermore, we examined correlations between cognitive bias tasks and impulsivity-related measures, and examined Spearman correlations from tasks to alcohol use at time points 1 and 2. We studied relations to missing data by correlating instances of missing data with study-relevant predictors. We found that there were no significant relations between behavioral indicators and instances of missing data. We used Full Information Maximum Likelihood to deal with missing data, which is a frequently used method to deal with missing data (Newman, 2003). Descriptive statistics revealed that, as expected for the current sample, the distribution of alcohol use in the current sample contains an excess of indications of zero use. Given this distribution, it is appropriate to conduct regression analyses appropriate for such forms of non-normality. ZIP regression (Böhning, Dietz & Schlattmann, 1997) is a method suitable to handling data where the outcome variable has a distribution with a high zero count. ZIP regression assumes two subpopulations; one subpopulation of non-drinkers, who solely produce zero observations (structural zeroes), another subpopulation, the drinkers, producing observations in a certain range including zero (sampling zeros). Sampling zeros represent participants who may have been part of the drinker population, but who did not drink at the specific time point for reasons other than being a non-drinker. For easier understanding, compare this to two groups of people, one of whom went fishing while another did not. Among those who went fishing, there are those who caught zero fish, but still had opportunity to do so. To analyze this distribution, two regressions are typically estimated: A logistical regression to separate participants who solely produce structural zeroes and those who not, and a Poisson regression to predict the amount of alcohol consumed by those who had the opportunity to do so. When

predicting bias, we used linear regression as bias measures were normally distributed.

2.4.1. Predicting alcohol use

Using ZIP regressions with Time 2 (6-month interval), Time 3 (12-month interval) and Time 4 (18-month interval) alcohol use as a short- and long-term outcome measure, we examine two models. In the first model, alcohol use onset and escalation is predicted using background variables Age and Gender, as well as Time 1 cognitive bias measures. In the second model, we examine whether earlier predictors also predict the change in alcohol use by including Time 1 alcohol use as a predictor. ZIP models were estimated using Mplus 7.2 and R. For reference, we also provide the ZIP regression results for the regression of impulsivity traits on later alcohol use. These may be found in the online supplemental materials.

2.4.2. Predicting bias

We examine whether Time 4 alcohol-related cognitive bias (measured by AAT, SRC, Visual Probe and Emotional Stroop) can be predicted by earlier impulsivity-related measures in four two-step hierarchical linear regressions. In the first step, we predict Time 4 bias using impulsivity traits controlled for background variables (age and gender) where significant, as well as Time 1 alcohol use. In the second step, we control this regression for the Time 1 measurement of the predicted bias, to examine whether impulsivity measures and alcohol use predict changes in bias scores between Time 1 and Time 4. In the third step, we include interactions between impulsivity traits and alcohol use. Linear regression models were estimated using SPSS Statistics 20.0. For reference, results from the prediction of the four bias measures at Time 2 and 3 are available in online supplementary materials.

3. Results

3.1. Descriptives

Table 1 details descriptive statistics for the current sample's alcohol use, age and gender. It demonstrates that the proportion of alcohol use in the current sample increases throughout the study period from 23% at Time 1 to 59% at Time 4. Repeated measures analysis shows that average weekly alcohol use increases significantly over time among those who already drank at Time 1 ($F = 10.799$, $p < .01$). Furthermore, we examined relations between missing data, gender and age occur and found only that age was slightly higher among drop-outs at Time 4 ($T2\ t = -.797$, $p > .05$; $T3\ t = 1.461$, $p > .05$; $T4\ t = -2.137$, $p < .05$). Chi-square analysis revealed no significant relations of missingness to gender (Time 2 $\chi^2 = 2.197$, $p > .05$; Time 3 $\chi^2 = .011$, $p > .05$; Time 4 $\chi^2 = .508$, $p > .05$).

Table 2 lists Spearman correlations between alcohol use at each time point and cognitive bias measures at Time 1. Table 3 shows correlations between alcohol-related cognitive bias measures at T4, and impulsivity-related measures at Time 1. Together, these tables demonstrate that there were no significant correlations between alcohol use and cognitive bias measures. Only age and gender were significantly directly associated with weekly alcohol use.

Table 1
Descriptive statistics for alcohol use, age and gender.

	T1 (N = 378)	T2 (N = 209)	T3 (N = 182)	T4 (N = 195)
Onset of 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)
Mean age (M (SD) in years) ^c	14.89 (1.28)	15.26 (1.20)	15.87 (1.25)	16.18 (1.26)
Gender (% female) ^c	64.8	71.4	69.2	67.7

Note. ^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 T1, mean number of drinks increased linearly (M (SD) for T2: 5.27 (4.92), T3: 6.26 (6.27), T4: 7.36 (6.36), $F = 10.799$, $p < .01$). ^c Age and gender did not significantly predict drop-out at any time point.

Table 2
Associations between implicit bias measures and alcohol use.

		T1 weekly alcohol use	T2 weekly alcohol use	T3 weekly alcohol use	T4 weekly alcohol use
T1 bias measures	SRC	.105	.099	.120	-.009
	AAT	-.048	-.093	.008	.099
	Visual Probe	.064	.007	-.021	.013
	Emo. Stroop	-.006	.029	.068	-.017
Background	Gender ^a	2.27*	1.89	1.92	1.90
	Age	.492***	.470***	.558***	.441**

Note: Spearman non-parametric correlations reported. AAT refers to the Alcohol Approach-Association Task. SRC refers to the Stimulus-response Compatibility Task. ^at-test statistic for independent samples t-test reported, equal variances not assumed.

* $p < .05$.

** $p < .01$.

*** $p < .001$.

3.2. Predicting alcohol use

Table 4 details regression results from each step of the ZIP regression on Time 2, Time 3, and Time 4 alcohol use for the full sample. Results show that the Visual Probe Task and the SRC do significantly predict the amount of alcohol consumed at Time 2, that the SRC task significantly predicts whether or not participants drink when prior alcohol use is controlled for, that the Visual Probe and Emotional Stroop task predicted amount of alcohol consumed at T3, and that the Visual Probe Task predicts alcohol consumed at Time 4 in the count-part of the ZIP model. To ascertain whether these significant findings were reliable, and because there exists no consensus on the number of participants required to robustly demonstrate meaningful prediction in ZIP regression, we calculated unstandardized bootstrapped confidence intervals for the T4 model coefficients in R using the percentile method and the bias-corrected and accelerated method (DiCiccio & Efron, 1996) with 1200 samples drawn. These confidence intervals indicate that of the bias predictors, only the prediction of Time 4 alcohol use in model 1 (no prior alcohol) and model 2 (prior alcohol included as predictor) by the Visual Probe Task is robust given percentile confidence intervals (model 1 95% CI 0.002–0.011, model 2 95% CI 0.003–0.012) as well as bias-corrected and accelerated confidence intervals (model 1 BCA CI 0.001–0.011, model 2 BCA CI 0.002–0.011). Table S1 in the online supplementary materials contains results of the prediction of Time 2, Time 3 and Time 4 alcohol use by impulsivity measures. These results indicate that self-reported impulsivity predicts alcohol use at Time 3, and that delay discounting and self-reported sensation seeking predict drinking at Time 4. These predictions remain significant when controlling for alcohol use at Time 1.

3.3. Predicting bias

Table 5 shows linear regression results from the prediction of the four bias measures at Time 4. Analyses were controlled for age and gender; however, age and gender did not significantly predict bias in any step of the analyses for any of the biases, and were therefore excluded from the final models. Explained variance for all biases was low ($R^2 = .069$, .049, .058 and .029 for Visual Probe Task, SRC, AAT and Emotional Stroop task, respectively). Furthermore, the included predictors

Table 3
Correlations between implicit bias measures and impulsivity measures.

	1	2	3	4	5	6	7
SRC	–	–.032	–.029	–.143	–.008	–.080	.049
AAT		–	.077	.070	.009	.143	.102
Visual Probe			–	.058	–.027	.097	–.056
Emo. Stroop				–	–.143	–.041	.018
Sensation Seeking					–	.159*	–.026
Impulsivity						–	–.102
Delay Discounting							–

Note: Reported are Pearson correlations between T4 bias measures and T1 impulsivity measures.

* $p < 0.01$.

did not meaningfully improve prediction over an intercept-only model, with none of the impulsivity-related predictors significantly predicting T4 bias. In the second step of the model, it was shown that baseline alcohol use did not significantly predict T4 bias when impulsivity-related measures were included in the model. Finally, the interactions between the impulsivity measures and alcohol use were also not significant.

4. Discussion

We investigated the interplay between alcohol-related cognitive biases and early adolescent alcohol use by examining whether biases predicted later alcohol use, and whether alcohol-related cognitive bias was prospectively predicted by general impulsivity-related measures. Results indicate consistently that biases did not predict whether participants initialized alcohol use or not, however, prediction of the amount of alcohol use by alcohol-related cognitive biases in those who drink was more consistent, revealing that attentional bias predicted quantity of drinking at later time points. Conversely, we predicted that cognitive biases would be predicted by impulsivity-related personality traits and/or previous alcohol use as well as their interactions. These predictions were not confirmed, suggesting that alcohol-related cognitive biases were not meaningfully predicted by earlier impulsivity or its interaction with alcohol use. Alcohol-related cognitive biases were also not meaningfully related to earlier alcohol use in the current sample. In terms of interacting dual processes, this suggests that while adolescence may be a period of reward sensitivity where adolescents are more likely to act on quickly retrieved motives and associations resulting in cognitive biases, it does not appear that the strength of these cognitive biases is prospectively predicted by the adolescent's impulsivity in the timeframe examined.

Table 4
Zero-inflated Poisson regression results for alcohol use as outcome.

T1 predictors	T2 weekly alcohol use		T3 weekly alcohol use		T4 weekly alcohol use	
	Not drinker	Amount if drinker	Not drinker	Amount if drinker	Not drinker	Amount if drinker
	(Est/S.E.)	(Est/S.E.)	(Est/S.E.)	(Est/S.E.)	(Est/S.E.)	(Est/S.E.)
Gender	0.052	–2.837*	–0.020	–3.694**	0.234	–2.240
Age	–4.916*	2.258	–3.893**	6.187**	–4.958**	2.750*
Visual Probe	–0.071	2.296	0.694	2.159*	–0.49	2.921*
SRC	0.872	2.803*	–1.357	2.894	0.428	0.01
Emo. Stroop	0.643	–0.618	0.177	3.500*	–0.411	–0.160
AAT	0.550	0.742	1.320	1.781	0.029	1.580
Gender	0.168	–2.722*	–0.054	–3.529**	–0.278	–1.897
Age	–3.037*	0.271	–2.583	4.700**	–3.144*	1.250
Visual Probe	0.373	3.147*	0.809	2.376	–0.169	3.022*
SRC	2.021	0.744	–1.197	2.319	0.383	–0.438
Emo. Stroop	0.178	–1.224	0.063	2.663	–0.266	–0.466
AAT	1.012	1.687	0.402	2.259	–0.198	2.431
Time 1 Alc	–2.016*	3.934**	–1.488	4.838**	–1.403	2.355

Note: Results are represented as standardized coefficients from the two-part prediction of drinking behavior, where 'Not drinker' represents predicting whether participants show structurally no drinking or any drinking (structural zeroes) and 'Amount if drinker' represents predicting whether alcohol consumed if not a member of the no drinking category.

* $p < .01$.

** $p < .001$.

Table 5
Linear regression results of prediction of T4 bias.

	T1 predictors	Visual Probe (beta)	AAT (beta)	SRC (beta)	Emo. Stroop (beta)
Step 1	Sensation seeking	–0.023	–0.010	–0.004	–0.061
	Impulsivity	0.100	0.157	–0.077	–0.015
	Delay discounting	–0.029	0.132	0.047	0.043
Step 2	Sensation seeking	–0.024	–0.007	–0.002	–0.056
	Impulsivity	0.098	0.164	–0.066	–0.002
	Delay discounting	–0.031	0.138	0.053	0.058
Step 3	Alcohol use	0.019	–0.039	–0.059	–0.088
	Sensation seeking	–0.010	0.000	–0.027	–0.059
	Impulsivity	0.068	0.165	–0.065	0.024
	Delay discounting	–0.058	0.115	0.039	0.092
	Alcohol use	0.216	–0.036	–0.013	–0.265
	SS * Alc	0.116	0.127	0.098	–0.033
	Imp * Alc	–0.073	–0.029	–0.167	0.184
	DD * Alc	–0.327	–0.052	0.045	0.085

Note: Results from linear regression with scores on the Visual Probe task, Alcohol-Approach Task, Stimulus Response Compatibility Task and the Emotional Stroop as dependent variable. Sensation Seeking and Impulsivity refer to self-reported traits as measured with the Substance Use Risk Profile Scale. SS * Alc, Imp * Alc, DD * Alc refer to the interaction terms with T1 alcohol use of Sensation Seeking, Impulsivity and Delay Discounting respectively.

We demonstrated for alcohol-related cognitive biases that in the current sample of early adolescents, attentional bias as measured by the Visual Probe Task predicted later alcohol use. However, no evidence was found that an approach bias predicted later alcohol use. These results are dissimilar to findings by Peeters et al. (2013) who found that approach bias as measured by the AAT predicted later alcohol use in impulsive high-risk youth. Importantly, in that study a sample from special education took part, containing adolescents already designated as at risk for substance use and adverse outcomes at a group-level, while the present sample were non-selected adolescents from the general population. Results are more in line with findings by van Hemel-Ruiter, de Jong, and Wiers (2011) who found that approach bias as measured by an Affective Simon Task was not stronger for heavy drinkers than for light drinkers, although the small sample in their study consisted entirely of young adolescents already engaged in drinking behavior. Compared to these studies, the current study's population was more often alcohol-naïve at baseline and generally drank less. We did not replicate the findings from Field, Kiernan et al. (2008) and Field, Caren et al. (2011) that heavier drinkers scored higher on approach bias as measured by the SRC, which might be due to the fact that the participants of those studies were older and generally drank

in much greater quantity. This opens up the possibility that alcohol-related cognitive biases, particularly approach biases, play a greater role in the development and maintenance of consumption of greater amounts of alcohol use as well as long-term addictive behaviors, and not so much in the development of early drinking.

The lack of replication of previous results regarding cognitive biases may be extended to findings regarding the role of aspects of impulsivity. Previous research (Coskunpinar & Cyders, 2013) indicated that behavioral aspects of impulsivity in particular, but also self-reported aspects of impulsivity, were associated with cognitive bias across a range of studies. While the current study is the first to examine the relation between cognitive bias and impulsivity in a longitudinal context, the lack of significant prospective prediction by aspects of impulsivity may be attributable to reasons other than the study's longitudinal setup. The current sample consisted of early adolescents who demonstrated relatively little alcohol use as compared to previous studies. It is possible that (prospective) relations between aspects of impulsivity and cognitive bias are apparent only when sufficient substance use is in evidence for the related cognitive biases to develop through substance exposure and associated learning processes.

The present study had several limitations and strengths worthy of discussion. Regarding limitations, first, it was beyond the scope of the current study to detect significant relations in a full cross-lagged structural equation model, given the large amount of different bias-related predictors included (two measures of attentional bias, and two measures of approach bias). Secondly, reliability for most of the assessments of alcohol-related cognitive bias was low, with the notable exception of the SRC. The low reliability of the AAT as compared to the SRC matches findings from previous studies (Krieglmeier & Deutsch, 2010). Indeed, in a similar study by Fernie et al. (2013), the SRC and visual probe were eventually excluded from further analysis because of low reliability. It is remarkable that in the present study, the reliability of the SRC was moderate to acceptable whereas other measures demonstrated low reliability. Also, in line with Fernie et al. (2013), in the current study we found negative associations between behavioral impulsivity measure (Delay Discounting) and not drinking alcohol at T4, and there were positive associations between self-reported impulsivity and alcohol use at T3 and T4. However, relations between behavioral impulsivity and alcohol use were not as consistent as in the study by Fernie and colleagues. The zero-inflated distribution of alcohol use in the current sample may potentially explain these discrepancies. It is possible that the lack of reliability found in cognitive bias measures contributed to the lack of meaningful prediction by alcohol use and impulsivity-based predictors of alcohol-related cognitive bias, although the more successful Visual Probe task was not the most reliable task included in the study. Thirdly, it is relevant to note that despite a lack of significant correlation to alcohol use, the Visual Probe task, SRC and AAT did at certain points significantly predict the amount of alcohol use in the ZIP regression. However, we included additional bootstrapping analyses which demonstrate that the significant effects found for the Visual Probe task, though not for the SRC, did robustly predict the amount of alcohol use after short and long delays. Statistically, the validity of unreliable tasks has been drawn into question (Ataya et al., 2012). Despite suggesting predictive validity of cognitive bias tasks, we consider the development of more reliably behavioral measures a priority. A fourth limitation is the noteworthy exclusion of the Brief Implicit Attitude Test in the analysis. The test was considered frustrating by participants. This effect was potentially compounded by the online environment in which the test was conducted, since no research assistants were available to offer insight. Based on this, we consider the Brief Implicit Attitude Test not recommended for online assessment in youth. Fifth, we found that age was associated with drop-out at Time 4. We used full information maximum likelihood as a model estimator (Asparouhov & Muthén, 2010), which is an appropriate method in the event that observed variables are indicators of missing data. Finally, due to sample size limitations, we were unable to examine all possible

predictive relations in the prediction of alcohol use in a single model. Regarding strengths, one notable strength is that both alcohol-related cognitive biases and alcohol use were measured longitudinally, allowing us to predict both alcohol-related cognitive bias and alcohol use prospectively, as well as predict change in alcohol use and alcohol-related cognitive bias scores by including Time 1 scores as a predictor. Furthermore, we included two different assessments for approach bias and attentional bias each, allowing us to examine whether demonstrated effects held for each assessment and cognitive bias type. Finally, the present study used a longitudinal two-year format to investigate the emergence of alcohol-related cognitive biases in adolescence.

The current study gave no indication that alcohol-related cognitive biases occur as an alcohol-specific proxy of general impulsivity traits, nor was there robust indication that these biases arose as a consequence of earlier alcohol use. Future studies aiming to investigate the etiology of alcohol-related cognitive biases may benefit from the inclusion of tasks specifically designed to maximize reliability or to choose analysis types that are more suited to deal with behavioral data with large amounts of error variance (Zvielli, Bernstein & Koster, 2014). Furthermore, observing alcohol consumption during larger intervals spanning across puberty might allow researchers to investigate the onset of alcohol use and alcohol-related cognitive biases in an entirely alcohol-naïve population. Finally, greater sample sizes would permit researchers to examine cross-lagged models of the interplay between cognitive bias and alcohol use. Our findings that attentional bias predicted subsequent alcohol use seem to be partly in line with incentive motivation and dual process models, although it is difficult to explain why alcohol use, in turn, did not predict changes in cognitive biases. Regarding consequences for incentive motivation and dual process models, we can conclude that hypotheses regarding the emergence of biases were not supported by the data. One reason could be the relatively weak internal consistency of the bias measures (although here reliability of the SRC was reasonably good). Further notable regarding the current data, our sample consisted of relatively light drinking adolescents. One potential explanation for the lack of findings in prediction of cognitive bias, therefore, may be found in a lack of repeated administrations of alcohol. In this scenario, cognitive biases may emerge only as a consequence of more long-term, more intense use of alcohol. If this is the case, we would expect results to be different in older samples and among at-risk populations. Indeed, Peeters et al. (2013) did find reciprocal relationship between approach bias measured with the AAT and adolescent alcohol use in an at-risk sample.

In conclusion, the current study furthers contributes to literature on cognitive biases in two key ways. First, it contributes to our understanding of the role of cognitive biases in the prospective prediction of alcohol use, showing that cognitive biases do not distinguish between drinkers and non-drinkers on the one hand, but showing that attention bias does predict the amount consumed by drinkers on the other hand. Second, the current study addresses a pressing issue regarding the relationship between aspects of impulsivity and alcohol use by examining prospective prediction of cognitive bias by aspects of impulsivity. The current study, perhaps surprisingly, shows that there were no prospective relations between impulsivity and cognitive bias. The study's sample of relatively light drinkers of early adolescent age may be relevant in explaining the lack of relations discovered.

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Contributors

All authors have materially participated in manuscript preparation. Tim Janssen, Helle Larsen and Reinout Wiers have contributed to the study design, study execution, statistical analyses and manuscript preparation. Wilma Vollebergh has contributed to the study design and manuscript preparation.

Conflict of interest

All authors declare that they have no conflicts of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <http://dx.doi.org/10.1016/j.addbeh.2014.11.018>.

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