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Growth trajectories of alcohol information processing and associations with escalation of drinking in early adolescence

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Abstract

This longitudinal study provided a comprehensive examination of age-related changes in alcohol outcome expectancies, subjective evaluation of alcohol outcomes, and automatic alcohol associations in early adolescence. A community sample (52% female, 75% White/Non-Hispanic) was assessed annually for three years (mean age at the first assessment = 11.6 years). Results from growth modeling suggested that perceived likelihood of positive outcomes increased and that subjective evaluations of these outcomes were more positive with age. Perceived likelihood of negative outcomes declined with age. Automatic alcohol associations were assessed with an Implicit Association Task (IAT), and were predominantly negative, but these negative associations weakened with age. High initial levels of perceived likelihood of positive outcomes at age 11 were associated with escalation of drinking. Perceived likelihood of negative outcomes was associated with low risk for drinking at age 11, but not with changes in drinking. Increases in positive evaluations of positive outcomes were associated with increases in alcohol use. Overall, findings suggest that at age 11, youth maintain largely negative attitudes and perceptions about alcohol, but with the transition into adolescence, there is a shift toward a more neutral or ambivalent view of alcohol. Some features of this shift are associated with escalation of drinking. Our findings point to the importance of delineating multiple aspects of alcohol information processing for extending cognitive models of alcohol use to the early stages of drinking.

Early initiation of alcohol use is a robust predictor of alcohol abuse and dependence in adulthood (Grant & Dawson, 1998). Identifying factors involved in the early stages of drinking is important for targeting mechanisms of risk for early interventions. One such set of factors reflects how individuals process alcohol-related information. Many cognitive models of addiction distinguish between automatic and controlled information processing that operate as proximal predictors of alcohol use and mediate risk and protective factors from a variety of domains (Carter & Goldman, 2008; Gladwin, Figner, Crone, & Wiers, 2011; Sayette, 1999). Adolescence is a period of substantial change with respect to alcohol

use and motivation. Yet, there have been no comprehensive longitudinal studies of the development of automatic and controlled alcohol-related information processes during these formative years. Consequently, development of alcohol-related information processing is poorly understood, particularly during early adolescence (Windle et al., 2008). The goal of this study was to examine trajectories of automatic and controlled alcohol information processing, and their relation with the early stages of alcohol use in a community sample of adolescents.

Development of Alcohol Use

Initiation of substance use typically occurs during adolescence. Rates of alcohol use are very low prior to 12 years of age, and begin to increase at age 13 or 14 (Kandel & Logan, 1984). By the 8th grade, 29% of youth have tried alcohol (more than just a few sips), and by the end of high school the lifetime prevalence of alcohol use is 69% (Johnston, O'Malley, Bachman, & Schulenberg, 2013). Although alcohol use becomes more normative with age, there is considerable heterogeneity in age of onset and rate of increase in alcohol use (Colder, Campbell, Ruel, Richardson, & Flay, 2002).

Although the rise of alcohol use during adolescence is attributable to a complex web of etiological factors, (Windle et al., 2008; Zucker, Donovan, Masten, Mattson, & Moss, 2008), alcohol-information processing variables are thought to be central proximal determinants of drinking (Goldman, Darkes, Reich, & Brandon, 2006; Redish, Jensen, & Johnson, 2008). Moreover, not only does alcohol information processing influence drinking, but drinking influences alcohol information processing (Goldman, Reich, & Darkes, 2006). The dynamic nature of alcohol use and reciprocal associations with alcohol information processing during adolescence implies that alcohol information processing changes during this period. Yet no research has provided a comprehensive examination of the links between age-related changes in alcohol information processing and escalation of adolescent alcohol use. In examining such links, it is important to consider the complexity of alcohol information processing, including the distinction between controlled and automatic processing.

Controlled and Automatic Alcohol Information Processing

Appraisals of alcohol use are central to decisions to drink (e.g., Bandura, 1977, 1986; Goldman, Del Boca, & Darkes, 1999; Maisto et al., 1999; Sayette, 1999). Many cognitive models distinguish the role of *self-regulatory* (reflective) and *impulsive* processes on alcohol use (Chaiken & Trope, 1999; Deutsch & Strack, 2006; Devine, 1989; Evans, 2003; Evans & Coventry, 2006; see Sherman et al., 2008; Wiers et al., 2007). The self-regulatory process is thought to involve deliberative and conscious appraisals of available information and influence behavior via a *controlled process*. Expectations for alcohol's effects (outcome expectancies), representing propositional knowledge (e.g., **If I drink alcohol then ...**) have been conceptualized as an important domain of self-regulatory processes. Alcohol use outcome expectancies are typically assessed using self-report measures. Considerable evidence suggests that risk for alcohol use increases when the likelihood of positive outcomes (positive expectancies; e.g., I'll have fun) is perceived to be high and the

likelihood of negative outcomes (negative expectancies; e.g., I'll get sick) is perceived to be low (Carter & Goldman, 2008).

Subjective evaluation of outcomes in addition to expected likelihoods have also been considered an important domain of controlled alcohol information processing. Similar to outcome expectancies, subjective evaluations are typically assessed by self-report measures and represent the degree to which a particular outcome is viewed as desirable or undesirable, or good or bad. There is considerable variability in the desirability or value placed on certain outcomes associated with alcohol use (Fromme, Marlatt, Baer, & Kivlahan, 1994; Leigh, 1987), and studies have found that subjective evaluations of outcomes are associated with drinking above and beyond the effect of likelihood ratings, such that evaluating alcohol outcomes as positive or desirable is associated with increased alcohol use (Fromme & D'Amico, 2000; Fromme, Stroot, & Kaplan, 1993; Leigh, 1987).

The impulsive process is thought to involve spontaneous and reflexive appraisals of stimuli and influence behavior via an *automatic process*. Memory associations between behavior (e.g., drinking) and outcomes (e.g., fun) are thought to be activated by alcohol-related cues (e.g., smell of alcohol). Information that is readily or automatically activated is thought to be most strongly associated in memory and may be particularly relevant to in-the-moment decisions to drink (Goldman et al., 1999; Rather, Goldman, Roehrich, & Brannick, 1992). The inclination to drink or not drink is believed to depend on whether the automatically activated information is positively or negatively valenced, respectively. A variety of methods have been used to assess spontaneous activation of alcohol-related information including word association tests and reaction time tasks [e.g., the Implicit Association Test (IAT), semantic priming tasks]. Numerous studies have found that across methods, spontaneous activation of alcohol-related information and strong positive or weak negative alcohol-associations are related to high levels of drinking (for reviews see Reich, Below, & Goldman, 2010; Rooke, Hine, and Thorsteinsson, 2008).

In one of the few studies of early adolescent drinking and automatic alcohol information processing, we used a single category IAT (SC-IAT) to examine the valence of automatic alcohol associations (O'Connor, Lopez-Vergara, & Colder, 2012). Results suggested that alcohol associations were predominantly negative in our early adolescent sample (10- to 12-year-olds), a finding that was not surprising given the young age of the sample. Importantly, weak negative automatic associations were associated with increased likelihood of alcohol use.

Development of Alcohol Information Processing

Knowledge of alcohol becomes increasingly elaborated as children age, with a faster rate of acquisition of positive than negative appraisals of alcohol during adolescence (Bekman, Goldman, Worley, & Anderson, 2011; Dunn & Goldman, 1998; O'Connor, Fite, Nowlin, & Colder, 2007). Thus, there is evidence that alcohol information processing changes with age. However, much of this research has not distinguished controlled and automatic processing and has been based largely on cross-sectional age comparisons.

With respect to controlled processing, there is evidence that alcohol outcome expectancies develop prior to use (Patel & Fromme, 2010). Early adolescents perceive negative outcomes (e.g., getting sick or getting in trouble) to be much more likely than positive outcomes (e.g., feeling happy or having fun with friends), however, with age, positive expectancies increase and negative expectancies decline (Beckman et al., 2011; Dunn & Goldman, 1998; O'Connor et al., 2007; Donovan, Molina, & Kelly, 2009; Miller, Smith, & Goldman, 1990). By late adolescence, although youth report both positive and negative outcome expectancies, positive outcomes are rated as more likely than are negative outcomes (Cameron, Stritzke, & Durkin, 2003; Dunn & Goldman, 1998; Schell, Martino, Ellickson, Collins, & McCaffrey, 2005). But likelihood ratings reflect only one component of controlled processing. No research to our knowledge has longitudinally examined developmental changes in subjective evaluations of outcome expectancies, and this remains a notable omission in the literature.

Much less is known about how automatic alcohol information processing might change with age. In prior work, with a sample of early adolescents (11–13 years old) we found evidence for positive alcohol associations assessed using a priming task (O'Connor et al., 2007). Furthermore, cross-sectional age comparisons suggested that the priming effect was not moderated by age, and thus, levels of activation of positive alcohol associations were similar across the younger and older adolescents. However, the small sample ($N=76$) likely limited our capacity to detect age differences. Although the data did not support an age effect, the pattern of means suggested that positive alcohol associations were more likely to be activated for older adolescents, and that automatic processing of alcohol-related information may shift with age during adolescence to favor drinking.

The Current Study

Although prior research has examined change in alcohol outcome expectancies, primarily positive expectancies, very little work has examined developmental change in subjective evaluations of alcohol outcomes or automatic associations. Thus, the current literature provides a limited understanding of the developmental dynamics between alcohol information processing and alcohol use during early adolescence. In this study, we examine trajectories of positive and negative alcohol outcome expectancies, the subjective evaluations of these outcomes, and automatic alcohol associations and how these trajectories relate to trajectories of alcohol use in early to middle adolescence. Consistent with prior research we hypothesized that with age, the perceived likelihood of positive alcohol outcomes would increase and perceived likelihood of negative outcomes would decline. Faster rates of increase and decrease in positive and negative outcome expectancies, respectively, were hypothesized to be associated with more rapid increases in alcohol use. Subjective evaluations of positive and negative outcomes were expected to become more positive (or less negative) over time. Increasing positive evaluations of positive outcomes and less negative evaluations of negative outcomes were expected to be associated with increases in alcohol use. Negative automatic alcohol associations were expected to become less readily activated over time with more rapid declines in negative automatic associations associated with more rapid increases in alcohol use. Finally, we examined potential associations between change in alcohol information processing variables to provide descriptive information on dynamic associations within this domain.

Method

Sample

Recruitment—The sample was recruited using a random-digit-dial (RDD) sample of telephone numbers from ASDE Survey Sampler, Inc., that was generated for Erie County, New York. Calls were made by trained telephone recruiter/interviewers utilizing scripts that explained the nature of study participation, eligibility criteria (an English speaking child between the ages of 10 and 12 years at the time of recruitment without any physical impairments or cognitive deficits that would preclude completion of the interview and a caregiver willing to participate), and the level of compensation for participation. Recruitment began in April 2007 and was completed in February 2009, and only one child per household was recruited. Participation rate was 47.3%, which is consistent with other large studies requiring intensive participation (Galea & Tracy, 2007).

Description—The final sample included 378 families. The sample was almost evenly split on gender (52% girls) and average age at each assessment was 11.6 ($SD = .88$), 12.6 ($SD = .89$), and 13.6 ($SD = .90$) years old at Waves 1–3, respectively. The majority of the sample was White/non-Hispanic (76%), 15% were Black/African-American, 3% Hispanic/Latino, 2% Asian/Pacific Islander, and 4% other (largely mixed racial/ethnic background). Most of the youth lived in two parent families (72%), and most parents completed college (58%). Median family income was \$60,000 and 7% of the sample received some form of public assistance income.

Missing Data—Retention was strong with 93% ($N=352$) and 94% ($N=354$) families completing the 2nd and 3rd assessments. Comparisons of participants with and without missing data on Wave 1 variables suggested no differences on demographic characteristics (family income, gender, adolescent age, minority status, parental education, and parental marital status) or on Wave 1 alcohol use, outcome expectancies, subjective evaluations, or automatic alcohol associations. The absence of differences suggests that missing data likely had a small impact on our findings. Moreover, our data analytic strategy (Full Maximum Likelihood Estimation, FIML) allowed us to include all cases in our analysis.

Procedure

Three annual surveys were completed by the target adolescent and one caregiver in our university research offices. After completing the consent (caregiver) and assent (adolescent) form procedures, the adolescent and caregiver were taken to separate rooms to enhance confidentiality and privacy during data collection. All adolescent and caregiver questionnaires were read aloud and responses were entered directly into a computer. To increase privacy and confidentiality, questions deemed “sensitive” (i.e., questions assessing alcohol use) were directly entered on the computer by the participant. We also obtained an NIH Certificate of Confidentiality and participants were told about the certificate. Interviews took approximately 2½ hours to complete. Interview procedures were the same at each wave of the study. Adolescents received a small prize for their participation and families were compensated \$75, \$85, and \$100 at Waves 1–3, respectively. Two months prior to the year anniversary of the first assessment, families were contacted for participation in the second

assessment. Most follow-up assessments were done within ± 2 months of the anniversary of the prior assessment (90%). The current study focuses on measures of alcohol information processing and alcohol use variables from the adolescent assessments.

Measures

Alcohol Outcome Expectancies (Waves 1–3)

Likelihood ratings: Alcohol outcome expectancies were assessed using a measure developed by O'Connor et al. (2007) for early adolescents with limited direct drinking experience. Participants were asked to imagine that they were at a party and had a drink of alcohol, even if this is something they would not do. Using an 11-point response scale (0 = 0% *no chance* to 10 = 100% *for sure*), they then reported their perceived likelihood of experiencing positive (10 items, e.g., “I’ll feel more happy”, “I’ll be more respected by other kids”) and negative (10 items, e.g., “I’ll get sick, I’ll feel out of control”) alcohol outcomes. The mean of the items was taken to form positive and negative likelihood scales scores at each assessment. Internal consistencies were high (Cronbach’s Alphas = .89–.91 for positive outcomes and .88 – .91 for negative outcomes).

Subjective Evaluations: The outcome items were repeated and participants were asked to report their subjective evaluation by rating whether each outcome was good or bad using a 5-point response scale (1 = *very bad* to 5 = *very good*). Items were averaged to form scale scores for positive and negative outcomes for alcohol use. Internal consistencies were high for the subjective evaluations scales (Cronbach’s Alphas = .93–.94 for positive outcomes and .87 – .88 for negative outcomes).

Confirmative factor analysis (CFA) of likelihood and evaluation items was conducted at each wave. Each model included 4 latent factors (positive and negative perceived likelihood factors, and positive and negative subjective evaluation factors), each indicated by 10 items. Caution is typically advised when interpreting fit indices of CFAs when a large pool of observed items is analyzed because many factor loadings are constrained to zero to impose a simple factor structure and these constraints may incorrectly lead to rejection of a plausible model (Borkenau & Ostendorf, 1990; Church & Burke, 1994). Nonetheless, fit indices from our models supported the four factor model (Wave 1 model: $\chi^2(731)=1043.22$, $p<.01$, CFI = .95, TLI=.94, RMSEA=.03; Wave 2 model: $\chi^2(731)=1044.25$, $p<.01$, CFI = .96, TLI=.94, RMSEA=.04; Wave 3 model: $\chi^2(731)=1232.67$, $p<.01$, CFI = .92, TLI=.91, RMSEA=.04). Moreover, all factor loadings were statistically significant and substantial (standardized loadings ranged from .41 to .88 at Wave 1, .46 to .82 at Wave 2, and .48 – .86 at Wave 3), further supporting the hypothesized 4 factor model.

Automatic alcohol associations: One of the most commonly used methods for assessing automatically activated alcohol associations is the IAT (Greenwald, McGhee, & Schwartz, 1998; Houben, Wiers, & Roefs, 2006; Reich et al., 2010). The IAT assesses the valence of automatically activated alcohol associations by comparing reaction times when an object category is paired with two evaluative categories (e.g., “positive” vs. “negative”). The original version of the task requires the target category (e.g., alcohol) and a contrast category (e.g., water, soda). Thus, the classic version of the task reflects relative activation of positive

vs. negative associations with alcohol relative to another object category. Several adaptations of the IAT have been developed (e.g., unipolar Single Target-IAT [ST-IAT], Thush and Wiers, 2007; unipolar IAT, Houben and Wiers, 2006). These tasks differ from the original IAT with respect to the object and/or the evaluative category features of the task. For example, the unipolar ST-IAT uses a single object category (e.g., alcohol), and one valenced category vs. a neutral category (e.g., positive vs. neutral). The unipolar IAT uses two object categories (e.g., alcohol vs. soda) and one valenced evaluative category vs. a neutral category (e.g., positive vs. neutral). Single Category IATs (SC-IATs, Karpinski and Steinman, 2006) are like the unipolar ST-IAT in that a single object category is used. However, unlike the unipolar tasks, the SC-IAT maintains the bivalent nature of the evaluative categories (e.g., positive vs. negative). Using a single object category may be particularly well suited for the assessment of alcohol associations given the lack of a naturally opposing category. In addition, the bivalent nature of the attitudinal associations (positive vs. negative) may have ecological validity for assessing attitudes about alcohol because drinking contexts typically include both positive and negative cues that compete for attention. Moreover, the SC-IAT is simple, and this was also deemed an important advantage over other IAT variants as we were administering the task to youth as young as 10 years old. Accordingly, the SC-IAT was used in the current study to assess automatic alcohol associations.

We are unaware of any studies that have formally compared a single category IAT to other IAT variants for alcohol. In the broader IAT literature (e.g., using the IAT to assess aspects of social cognition) the SC-IAT provides levels of reliability and validity similar that of the original dual categorization IAT (Karpinski & Steinman, 2006). Bar-Anan and Nosek (2012) compared 7 different variants of implicit association measures of social cognition. Results suggested that the SC-IAT had acceptable psychometric properties, and ranked in the middle of the 7 tasks after averaging across 23 evaluation criteria. These authors concluded that "...the present evidence suggests that the [SC-IAT] performs well, encouraging further usage, mostly for its unique procedural features [ease of use] (p. 360)".

Our SC-IAT involved discriminating between an evaluative dimension (positive and negative words) and an object category (pictures of alcohol). Words were selected to be at a fourth grade reading level and were balanced across evaluative dimension on word frequency, length, and syllabic content. The evaluative words were presented auditorily and object categories were presented on the computer screen in picture format to decrease the lexical demands of the task. Participants were instructed to press the left-hand key (Z-key) on their keyboard when they heard a "good" word (e.g., beautiful) and to press the right-hand key (—/— key) when they heard a "bad" word (e.g., sickness). The object category (alcohol) was paired with the response key for bad words in one block and then with the response key for good words in another block. Each block consisted of 24 practice trials followed by 72 test trials. To limit response bias, the evaluative and object stimuli were not presented at equal frequency within block. When alcohol pictures were paired with good words 21 trials consisted of good words, 30 trials consisted of bad words, and 21 trials consisted of alcohol pictures. This resulted in relatively evenly balanced responses with 58% of correct responses being on the left key and 42% being on the right key. Likewise, when alcohol pictures were paired with bad words 30 trials consisted of good words, 21 trials

consisted of bad words, and 21 trials consisted of alcohol pictures. This resulted in 42% of correct responses being on the left key and 58% being on the right key. Thus, alcohol pictures were paired with good and bad words at equal rates across the task.

Stimuli were presented for 1500 millisecond (ms) and labels reminding the participants which key to press for the evaluative and object stimuli were presented in the lower left and right corners of the computer screen. The inter-trial interval during the test trials was 250 ms. Feedback indicating correct (green circle) and incorrect (red X) responses was presented for 250 ms after each trial. The trial timed-out after 1500 ms, and accordingly no response was recorded for these trials. Participants who did not respond within the allotted time were provided the following feedback for 250 ms: “Please respond more quickly”. Response times < 350 ms were considered anticipations, and excluded from analysis. On these trials, participants received the following feedback for 250 ms: “Please wait for the stimulus”. The task was the same across all three assessment Waves. Approximately 1% of the trials at each assessment were not analyzed because of non-response. Participants with error rates > 40% were excluded from analysis because the validity of their data was questionable. This resulted in the exclusion of two participants at Wave 1. No participants were excluded at Waves 2 and 3 because of high error rates.

A valid criticism of the IAT is that the traditional index of automatically activated memory associations from this task (the D-score) is influenced by a variety of cognitive processes, not just automatic processes, and thus, it is not “process pure” (Conrey, Sherman, Gawronski, Hugenberg, & Groom, 2005). In prior work we used the Quad model to distinguish four cognitive processes that influence performance on our IAT: activation of associations, guessing, overcoming bias, and ability to detect the stimulus. This allowed us to extract a more “process pure” index of automatically activated substance use associations from our IAT (O’Connor et al., 2012). We found that quad model index of automatically activated alcohol associations were predominantly negative, and provided better discrimination between young adolescent drinkers and abstainers than the traditional IAT D-score. That is, strong negative associations were linked with a low likelihood of drinking.

The quad model uses a multinomial processing tree to predict the likelihood of making correct/incorrect responses based on five parameters (automatic activation of negative alcohol associations, general activation of the positive evaluation category, guessing, overcoming bias for automatic activation, and ability to detect the stimulus) (see O’Connor et al., 2012 for more details). Using HMMTree software (Stahl & Klauer, 2007), we fit a saturated model to each individual’s observed probabilities of making correct/incorrect responses. A negative automatic alcohol association parameter was output for each participant at each wave of data collection. Values indicate the probability that the negative automatic alcohol association influenced IAT responding, and thus, high values indicate strong negative associations with alcohol. We included the other hypothesized parameters from the quad model as statistical control variables in our current analyses.

Alcohol Use (Waves 1–3)—Past year alcohol use was assessed at each assessment using two self-report items taken from the National Youth Survey (NYS; Elliott & Huizinga, 1983). These items assessed frequency and typical quantity of past year alcohol use with a

fill-in-the-blank response, and were multiplied to compute an index of total number of drinks consumed in the past year. As expected given the age of our sample, rates of alcohol use were low (22% at Wave 1, 27% at Wave 2, and 38% at Wave 3). Due to the non-normal distribution of the quantity by frequency index (Skewness = 4.8 to 8.2, Kurtosis = 26.8 to 72.4), an ordinal variable was created. We considered a variable number of categories and chose three categories (no use in the past year, one to three drinks in the past year, and more than three drinks in the past year) because adding additional categories created small cell sizes.

Results

Preliminary Analysis

Correlations and descriptive statistics for alcohol information processing variables are presented in Table 1. In general, stability correlations across Waves 1 to 3 were statistically significant and in the moderate range. The exception was modest stability among the automatically activated negative alcohol association variables. Correlations between perceived likelihood of positive and negative alcohol outcomes were generally weak, as were subjective evaluation ratings for the positive and negative outcomes. Negative automatic alcohol association variables were weakly associated with the likelihood and subjective evaluation outcomes. Perceived likelihood of positive outcomes was associated with subjective evaluations of both positive and negative outcomes, such that high perceived likelihood of a positive outcome was associated with more positive ratings of positive outcomes and more negative ratings of negative outcomes.

Means of the likelihood variables suggested that positive outcomes were perceived as less likely (20% to 30% likely) than negative outcomes (60% likely) and that this difference declined over time. Indeed, a repeated measures ANOVA with outcome *Type* (positive or negative) and *Wave* as within subjects factors suggested a significant *Type* $\times$ *Wave* interaction term with Greenhouse-Geiser adjusted *p*-value, $F(2, 688) = 34.67, p < .01$. A test of the effect of *Type* at each level of *Wave* suggested that positive outcomes were consistently viewed as less likely than negative outcomes (all *ps* $< .01$) and that the size of this difference declined over time, $\eta^2 = .66, .58$, and $.42$, at Waves 1, 2, and 3, respectively. Mean subjective evaluation ratings suggested that positive outcomes were viewed less negatively (on average “neither bad nor good”) than were negative outcomes (on average “Very Bad” to “Somewhat Bad”), and that this difference increased over time. Indeed, a repeated measures ANOVA suggested a significant *Type* $\times$ *Wave* interaction term with Greenhouse-Geiser adjusted *p*-value, $F(2, 688) = 4.55, p < .02$. A test of the effect of *Type* at each level of *Wave* suggested that positive outcomes were consistently viewed as less negative than negative outcomes (all *ps* $< .01$) and that the size of this difference increased over time $\eta^2 = .58, .63$, and $.70$, at Waves 1, 2, and 3, respectively.

Univariate Growth Models

Next we tested mean change in alcohol information processing variables and alcohol use. Given our interest in age-related change and the age heterogeneity at our initial assessment, we estimated our growth models in Mplus version 6.1 (Muthén & Muthén, 1998–2010) with

individual varying times of observation where the time variable was continuous age. This approach allowed a clear interpretation of change with respect to age and avoids potential bias in growth factor variances that can occur when modeling growth using fixed time intervals with age heterogeneous samples (Mehta and West, 2000). This approach also accommodates variability in time intervals of follow-up assessments (i.e., not all participants were assessed at exactly the targeted one year interval). Growth models with individually varying times (or ages in our case) are similar to growth models estimated in Hierarchical Linear Models (HLMs) that include age as a continuous time-varying covariate. A disadvantage of this approach is that fit indices that are common for structural equation models are not provided. As such, the log likelihood was used for nested model tests to evaluate whether the addition of a random slope improved the model fit compared to an intercept only model. Given three repeated measures, linear trends of age were specified and our nested model test evaluated whether adding a random linear slope of age improved the model compared to a random intercept only model. Age was centered at 11 years, and so the intercept represents levels of the outcome at age 11. Robust maximum likelihood estimation was used to accommodate non-normal distributions of the observed information processing variables (see Table 1), and Weighted Least Squares Mean and Variance Adjusted (WLSMV) was used in our alcohol model to accommodate the ordinal nature of this outcome.¹

Growth in perceived likelihood of positive alcohol outcomes—Perceived likelihood of positive outcomes was correlated with positive and negative outcome valence ratings (see Table 1) and accordingly, positive and negative valence ratings were included as time-varying covariates. This allowed us to examine change in perceived likelihood above and beyond valence ratings. Nested model comparisons suggested that the addition of age improved model fit ($\chi^2(3) = 75.7, p < .01$). The fixed effects of both the intercept ($M = 3.11, p < .01$) and slope ($M = .44, p < .01$) of age were statistically significant. The variance of the intercept ($\sigma^2 = 1.52, p < .01$), but not the slope ($\sigma^2 = .07, p < .40$), was statistically significant. The model implied trajectory is plotted in Panel A of Figure 1. On average, 11-year-olds perceived positive outcomes as unlikely (about 20% likely to occur) and with age the perceived likelihood of positive alcohol outcomes increased. However, there was limited heterogeneity in this rate of change.

Growth in perceived likelihood of negative alcohol outcomes—Nested model comparisons suggested that the addition of age improved model fit ($\chi^2(3) = 13.7, p < .01$). The fixed effects of both the intercept ($M = 7.31, p < .01$) and slope ($M = -.17, p < .01$) of age were statistically significant. The variance of the intercept ($\sigma^2 = 2.10, p < .01$), but not the slope ($\sigma^2 = .04, p < .65$), was statistically significant. The model implied trajectory is plotted in Panel A of Figure 1. On average, 11-year-olds perceived negative outcomes as likely (about 60% likely to occur) and with age the perceived likelihood of negative alcohol

¹The number of observations at each age was $N=112, N=236, N=342, N=245, N=133$, and $N=16$ for ages 10, 11, 12, 13, 14, and 15, respectively. The reason for the limited number of observations at age 15 is that a small number of participants were 12 years old at recruitment, but then had a birthday by the time they came in for the first assessment. These youth were 15 years old at Wave 3. We did a sensitivity analysis by eliminating observations corresponding to age 15 and rerunning our growth models. Results did not change, suggesting that the small number of observations at age 15 did not have a strong influence on our findings.

outcomes declined. However, there was limited heterogeneity in this rate of change. Also notable in Panel A is that the perceived likelihood of positive and negative outcomes are converging with age, and this is consistent with repeated measures ANOVAs discussed above suggesting that the observed difference between positive and negative likelihoods declined over time.

Growth in subjective evaluation of positive alcohol outcomes—Subjective evaluations of positive outcomes were correlated with perceived likelihood of positive outcomes (see Table 1) and accordingly, we included positive likelihood as a time-varying covariate. Nested model comparisons suggested that the addition of age improved model fit ($\chi^2(3) = 39.7, p < .01$). The fixed effects of both the intercept ($M = 2.7, p < .01$) and slope ($M = .09, p < .01$) of age were statistically significant. Moreover, the variance of both the intercept ($\sigma^2 = .55, p < .01$) and the slope ($\sigma^2 = .04, p < .05$) was statistically significant. The model implied trajectory is plotted in Panel B of Figure 1. On average, 11-year-olds held a modestly negative view of positive alcohol outcomes (between “somewhat bad” to “neither bad or good”) and with age these outcomes were viewed as more neutral (or less negative). There was significant heterogeneity in this rate of change.

Growth in subjective evaluation of negative alcohol outcomes—Subjective evaluations of ratings of negative outcomes were correlated with perceived likelihood of positive outcomes (see Table 1) and accordingly, we included positive likelihood as a time-varying covariate. Nested model comparisons suggested that the addition of age improved model fit ($\chi^2(3) = 9.5, p < .05$). The fixed effect of the intercept ($M = 1.5, p < .01$) but not the slope ($M = .01, p < .80$) of age was statistically significant. However, the variance of both the intercept ($\sigma^2 = .19, p < .01$) and the slope ($\sigma^2 = .03, p < .05$), was statistically significant. The model implied trajectory is plotted in Panel B of Figure 1. On average, 11- to 15-year-olds held a negative view of negative alcohol outcomes (between “very bad” and “somewhat bad”). Although on average, the valence of negative outcomes did not change with age, there was significant variability in growth, suggesting that for some youth these valence ratings did change with age.

Growth in negative automatic alcohol associations—Parameters from the quad model that showed significant correlations with negative automatic alcohol associations (overcoming bias, discrimination, general reaction time) were included as time-varying covariates. Nested model comparisons suggested that the addition of age improved model fit ($\chi^2(3) = 48.2, p < .01$). The fixed effect of the intercept ($M = .06, p < .01$) and slope ($M = -.01, p < .01$) of age was statistically significant. The variance of the intercept ($\sigma^2 = .002, p < .01$), but not the slope ($\sigma^2 < .001, p < .15$), was statistically significant. The model implied trajectory is plotted in Panel C of Figure 1. On average, the likelihood that negative automatic alcohol associations influenced IAT responses was .06 among 11-year-olds, and the influence of such negative associations declined with age. There was limited heterogeneity in this decline.

Growth in alcohol use—Nested model comparisons suggested that the addition of age improved model fit ($\chi^2(3) = 79.0, p < .01$). The fixed effect of the intercept ($M = -3.13, p$

$< .01$) and slope ($M = .81, p < .01$) of age was statistically significant. The variance of both the intercept ($\sigma^2 = 7.16, p < .01$) and slope ($\sigma^2 = 1.15, p < .05$) was statistically significant. The likelihood of alcohol increased with age and there was significant individual variability in rates of change. Because our outcome was ordinal, this is a logit model and we have computed predicted probabilities across age (Hosmer & Lemeshow, 1989), which are plotted in Panel D of Figure 1.

Parallel Process Growth Models

Alcohol information processing and alcohol use—Parallel process growth models with alcohol information processing variables and alcohol use were estimated. A model with all variables was not feasible given the computational demands of growth modeling with individually varying times. Accordingly, separate models were run for each alcohol information processing variable. Univariate growth models suggested no variability in growth of perceived likelihood of positive and negative alcohol outcomes, and therefore, the variances of these slopes were set to 0 in the parallel process growth models. Of interest in these models is the covariation between alcohol use growth factors and the alcohol information processing growth factors. Covariances and correlations from the parallel process growth models are presented in Table 2. The alcohol slope was associated with both the likelihood of positive outcomes intercept and subjective evaluation of positive outcomes slope. High perceived likelihood of positive outcomes at age 11 was associated with a steeper than average increase in alcohol use. Steeper than average increases in subjective evaluations of positive outcomes were associated with steeper than average increases in alcohol use. The alcohol intercept was associated with the likelihood of negative outcomes intercept, such that high perceived likelihood of negative alcohol outcomes at age 11 was associated with increased alcohol use. Neither subjective evaluations of negative outcomes nor negative automatic alcohol association growth factors were associated with the alcohol growth factors.

Alcohol information processing—In our final analysis we examined associations between the growth factors of the information processing variables by estimating separate models for each pair of information processing variables. Associations between information processing growth factors are presented in Table 3. Most of the associations between growth factors are consistent with correlations among the observed variables presented in Table 1. For example, the correlations between perceived likelihood of positive and negative outcome observed variables were small (see Table 1) as was the correlation between the perceived likelihood of positive and negative outcome intercept growth factors (see Table 3). Correlations between perceived likelihood and subjective evaluation growth factors also mapped onto the observed correlations in Table 1. The correlations were in the moderate range for positive outcomes, and small for negative outcomes. Negative automatic association growth factor correlations were modest (see Table 3) as were the correlations between the observed negative automatic association variables and the other observed information processing variables (see Table 1). The slope factors for the subjective evaluation of positive and negative outcomes were correlated .47, suggesting that as evaluations of negative outcomes become less negative (or more positive) so do evaluations of the positive outcomes. This pattern is consistent with the trend in the correlations among

these observed variables such that the within time correlations increase across assessments (see Table 1, $r_s = .08, .13$, and $.33$ at Waves 1, 2, and 3, respectively).

Discussion

Adolescent alcohol use continues to be a significant public health concern (CASA, National Center on Addiction and Substance Abuse, 2011), and understanding the mechanisms of alcohol use provides an opportunity to develop more effective targeted interventions (Stewart et al., 2005). Cognitive models focus on how individuals process alcohol-related information and offer a useful framework for examining mechanisms (Carter & Goldman, 2008; Sayette, 1999). Early adolescence is considered a formative period with respect to alcohol attitudes and perceptions because it presages the onset and escalation of drinking (Bekman et al., 2011; Cameron et al., 2003). However, alcohol information processing is complex and involves both automatic and controlled processes (Wiers et al., 2007). This complexity has not been considered in prior longitudinal studies investigating development of alcohol information processing. This is a notable gap in the literature given the centrality of alcohol information processing in models of addiction. In this study, we examined age related change in positive and negative alcohol outcome expectancies, subjective evaluations of these outcomes, and automatic alcohol associations in a community sample of early adolescents, and how these changes were associated with trajectories of alcohol use.

Consistent with prior work (e.g., McCarthy, Pedersen, & D'Amico, 2008; Millstein & Halpern-Felsher, 2002; Schell et al., 2005), we found that the likelihood of positive outcomes from drinking was perceived as rare at ages 11 years (20% likelihood of occurrence), whereas negative outcomes were perceived to be more much more likely (60% likelihood). In terms of effect size, these perceived likelihood differences were large at the first assessment and diminished to the moderate range by the third assessment. With respect to subjective evaluations, 11-year-olds maintained a neutral view of positive outcomes ("neither bad nor good") and a negative view of negative outcomes ("somewhat bad" or "very bad") and differences in subjective evaluations of positive and negative outcomes were consistently large across all three assessments. These evaluations were complimented by negative automatic alcohol associations. This cognitive organization of alcohol appraisals suggests that both controlled and automatic processes may serve a protective function prior to adolescence, guarding against initiation and high levels of alcohol use. Indeed, alcohol use was rare prior to age 12.

Importantly, we found that appraisals of alcohol use shifted with age. Perceived likelihood of positive outcomes increased and perceived likelihood of negative outcomes decreased with age. These findings align with prior research (Colder, Chassin, Stice, Curran, & Curran, 1997; Cumsille, Sayer, & Graham, 2000; Sayer & Willett, 1998). We also found that subjective evaluations of positive outcomes became more positive with age, although on average these evaluations remained relatively neutral ("neither good nor bad"). On average, subjective evaluations of negative outcomes did not change and remained negative. Taken together our findings suggest that the gap between expected likelihood of positive and negative outcomes was closing and evaluations of positive and negative outcomes were becoming more polarized. To our knowledge no other longitudinal studies have examined

age-related changes in subjective evaluations, and thus, an important contribution of the present study is that we examined subjective evaluations as well as perceived likelihood of outcome. It appears that both aspects of controlled processing shift in favor of substance use as adolescents age.

Prior research has found similar age-related shifts such that perceived likelihood of positive alcohol outcomes increased and perceived likelihood of negative outcomes decline with age (Goldberg, Halpern-Felsher, & Millstein, 2002; O'Connor et al., 2007), but these studies were based on cross-sectional age comparisons. Cameron et al. (2003) found evidence for concurrent positive and negative alcohol expectancies in children, and argued that this pattern reflected ambivalence in appraisals of alcohol outcomes, characterized by equally strong positive and negative expectancies. Memory network models also suggest concurrent activation of both positive and negative alcohol expectancies in early adolescence (Dunn & Goldman, 1998, 2000). In the context of these studies, our findings may be indicative of increasing ambivalence in that perceived likelihood of positive and negative outcomes are converging with advancing age and polarized subjective evaluations of positive and negative outcomes. The weakening of negative automatic associations may also suggest a shift toward ambivalence.

Several motivational models emphasize ambivalence regarding decisions about alcohol use (Breiner, Strizke, & Lang, 1999; Cox & Klinger, 2002). Ambivalent attitudes tend to be more pliable by persuasive communication and are held with less confidence (Armitage & Conner, 2000; Conner & Sparks, 2002; Maio, Bell, & Esses, 1996). Thus, as adolescents age, increasing ambivalence may render them more open or willing to initiate drinking. This may be particularly true during early adolescence when social contexts are shifting (e.g., increases in autonomy and more time spent with peers).

In addition to examining developmental changes in controlled and automatic alcohol information processing, we also examined whether these changes were related to alcohol use trajectories. Of particular interest is whether information processing at age 11 prospectively predicted increases in alcohol use. Findings revealed that associations with drinking depended on the specific facet of alcohol information processing. The likelihood of alcohol use increased with age with significant individual variability in rates of change. High perceived likelihood of positive outcomes from drinking at age 11 was associated with more rapid escalation in the likelihood of drinking. This is consistent with several studies that have found that positive outcome expectancies prospectively predict drinking (Aas, Leigh, Anderssen, & Jakobsen, 1998; Christiansen, Smith, Roehling, & Goldman, 1989; Cranford, Zucker, Jester, Puttler, & Fitzgerald, 2010). Although perceived likelihood of negative outcomes was not associated with change in alcohol use, there was evidence of a cross-sectional association, such that high perceived likelihood of negative outcomes was associated with low likelihood of drinking at age 11. In a large nationally representative sample, Leigh and Stacy (2004) compared associations between outcome expectancies and alcohol use across different age groups, and found evidence that positive expectancies may be a stronger predictor of adolescent alcohol use compared to negative expectancies. Our finding that early negative expectancies were not associated with increases in drinking are consistent with this conclusion.

Subjective evaluations of positive and negative outcomes and automatic negative alcohol associations at age 11 were not associated with trajectories of alcohol use. In general, youth maintained negative or neutral evaluations of the alcohol outcomes. Even for what are typically considered positive outcomes in the expectancies literature were viewed as “neither bad or good”. Moreover, an examination of the descriptive statistics of the subjective evaluations of negative outcomes, suggests that these outcomes were viewed negatively with limited variability. Moreover, the predominant association with alcohol on the IAT was negative. Taken together, evaluations of alcohol reflect a generally negative view of alcohol outcomes in our sample, and thus, subjective evaluations may not be particularly strong correlates of alcohol use in early adolescence. As is evident in our growth model for alcohol use, drinking was rare at ages 10 and 11, and increased with age. Subjective evaluations may change as youth experiment with alcohol and experience its effects, and so at later ages in middle or late adolescence, subjective evaluations may be more strongly associated with alcohol use. Indeed, increases in subjective evaluations of positive alcohol outcomes were associated with increases in alcohol use, suggesting that these evaluations were changing in parallel with drinking. Moreover, as subjective evaluations of positive outcomes became more positive so did evaluations of negative outcomes, suggesting that evaluations of positive and negative outcomes travel together with age.

Associations between alcohol information processing variables and alcohol use were generally modest. This suggests that other risk factors in addition to alcohol information processing are involved in the early stages of alcohol use (e.g., peer use, availability of alcohol, Hawkins, Catalano, & Miller, 1992). It is possible that as alcohol use progresses to heavy drinking and alcohol-related memory networks become more crystalized, associations between alcohol-related cognition and drinking increase in strength (Bekman et al., 2011).

Limitations and Conclusions

It is important to consider some limitations of this study when interpreting our findings. First, our findings should not be generalized beyond early adolescents who have relatively limited experience with alcohol. Alcohol information processing depends on accumulation of experience with alcohol (Goldman et al., 1999), and we would expect that developmental changes in alcohol information processing variables to be different in early compared to late adolescence as levels of use increase. As such, our study is best thought of as delineating developmental patterns relevant to the early stages of alcohol use. Second, automatic processes were represented by automatic memory associations that are thought to reflect implicit attitudes about alcohol use, and this is only one aspect of the broader domain of automatic processes. Other aspects of automatic alcohol information processing may show different patterns of age-related change and associations with alcohol use, and it would be fruitful to consider other aspects of automatic processing, such as automatic action tendency to approach alcohol or attentional bias for alcohol stimuli in future research (Stacy & Wiers, 2010). Third, we observed limited individual variability in growth in some of our alcohol information processing variables. Unlike prior research, several of our growth models included time-varying covariates, which undoubtedly reduced the variability in growth. In this regard, our study was more rigorous than prior research. However, the young age of our sample and the relative inexperience with alcohol, particularly in the early assessments,

likely also contributed to low individual variability. Limited individual variability, however, does not negate the fact that we observed change in the aggregate in most domains of alcohol information processing. Finally, we did not examine potential predictors of change in alcohol-information processing as this was beyond the scope of our study. However, this is an important direction for future research as understanding factors that influence the development of alcohol-information processing may have important implications for prevention.

Despite these limitations, this study makes meaningful contributions to our understanding of the development of alcohol information processing in adolescence. Cognitive models of addiction posit that both reflective/controlled and impulsive/automatic information processing are involved in the initiation, escalation, and maintenance of alcohol use (e.g., Reich, Dietrich, & Martin, 2011; Wiers et al., 2007). Understanding the age-related changes in both types of alcohol information processing is crucial for extending current cognitive models of alcohol use to be more developmental in their focus. This point is highlighted by the small to moderate associations we observed across different domains of alcohol information processing, and it has important implications for prevention, with respect to identifying potential targets for and timing of preventive intervention. The majority of alcohol information processing research has focused on positive expectancies in part because these expectancies show a strong and robust association with drinking (e.g., Goldman et al., 1999). However, there is evidence that negative expectancies, subjective evaluations, and automatic processing of alcohol information add to the prediction of adult and adolescent alcohol use (e.g., Fromme et al., 1993; Reich et al., 2011). Moreover, negative expectancies play an important role in an individual's motivation to refrain from drinking (Jones & McMahon, 1994) and negative expectancies in particular may play an important role in the initiation of alcohol use (Wiers, Gunning, & Sergeant, 1998). Thus, it is important to consider the broad domain of alcohol information processing. To our knowledge ours is the first comprehensive study of age-related changes in alcohol information processing during adolescence, a time when alcohol is typically initiated and begins to escalate. Overall, findings suggest that at ages 10 and 11, youth maintain largely negative attitudes and perceptions about alcohol, but with the transition into adolescence, there is a shift toward a more neutral or ambivalent view of alcohol, and some features of this shift are associated with escalation of drinking. Ambivalence about alcohol use has been posited to be a psychological context that leaves adolescents vulnerable and willing to initiate alcohol use (Cameron et al., 2003) and our findings point to the importance of considering multiple aspects of alcohol information processing that may underlie this ambivalence and vulnerability.

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Figure 1.
Model Implied Growth Trajectories of Alcohol Information Processing Variables

Table 1
Correlations and Descriptive Statistics of Alcohol Information Processing Variables

Variable	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.
1. W1 Pos. Likelihood	1.96														
2. W2 Pos. Likelihood	.44	2.01													
3. W3 Pos. Likelihood	.41	.59	2.07												
4. W1 Neg. Likelihood	.12	-.05	-.04	2.12											
5. W2 Neg. Likelihood	-.06	.00	-.12	.38	2.18										
6. W3 Neg. Likelihood	-.06	-.13	-.12	.29	.47	1.90									
7. W1 Pos. Subj. Eval.	.18	.18	.23	-.14	-.11	-.04	.98								
8. W2 Pos. Subj. Eval.	.14	.39	.36	-.11	-.12	-.17	.45	.94							
9. W3 Pos. Subj. Eval.	.19	.42	.55	-.08	-.11	-.22	.36	.62	.96						
10. W1 Neg. Subj. Eval.	.19	.09	.15	.02	-.13	.03	.08	.02	.08	.57					
11. W2 Neg. Subj. Eval.	.16	.23	.18	-.14	-.17	-.08	.01	.15	.13	.40	.53				
12. W3 Neg. Subj. Eval.	.25	.27	.35	.02	.12	.12	.14	.18	.33	.26	.40	.56			
13. W1 Neg. AAA	.04	.02	-.04	.00	.07	-.02	-.09	-.10	-.07	.05	.11	-.00	.07		
14. W2 Neg. AAA	-.02	.02	.01	.07	.02	-.05	-.03	-.06	-.02	.02	.01	-.02	.28	.06	
15. W3 Neg. AAA	-.06	-.09	-.08	.12	.02	-.05	-.05	-.04	-.07	.02	.00	.02	.21	.22	.05
Mean	2.41	2.72	3.34	6.17	6.23	5.87	2.80	2.78	2.98	1.52	1.48	1.53	.06	.05	.04
Skew	.84	.53	.03	-.47	-.44	-.23	-.29	-.37	-.55	2.63	2.50	2.01	1.36	1.49	1.51
Kurtosis	.41	-.28	-.86	-.14	-.23	.14	-.84	-.60	-.42	9.41	10.2	6.52	1.01	1.97	1.93

Note. W = Wave, Pos. = Positive, Neg. = Negative, Subj. Eval. = Subjective Evaluation, AAA = Automatic Alcohol Association. $|r| > .10$ statistically significant at $p < .05$, $|r| > .13$ statistically significant at $p < .01$. Standard deviations on the diagonal. Bolded values are stability correlations.

Table 2
Bivariate Associations With Alcohol Use Growth Factors From Parallel Process Growth Models.

	Alcohol Intercept	Alcohol Slope
	Cov. (Corr.)	Cov. (Corr.)
Positive Outcomes		
Likelihood Intercept	0.11 (0.04)	0.38* (0.34)
Likelihood Slope ^a		
Subjective Evaluation Intercept	0.41 (0.21)	-0.18 (-0.23)
Subjective Evaluation Slope	-0.10 (-0.21)	0.11* (0.54)
Negative Outcomes		
Likelihood Intercept	-1.10 [†] (-0.34)	-0.16 (-0.13)
Likelihood Slope ^a		
Subjective Evaluation Intercept	-0.02 (-0.01)	-0.01 (-0.03)
Subjective Evaluation Slope	-0.01 (-0.02)	0.04 (0.20)
Negative Automatic Alcohol Associations		
Intercept	-0.03 (-0.20)	0.01 (0.24)
Slope	0.01 (0.12)	-0.01 (-0.12)

Note. Cov. = covariance; Corr. = correlation;

^a variance and covariance of this slope factor set to 0.

* $p < .05$,

[†] $p < .01$.

Table 3
Covariances and Correlations Between Alcohol Information Processing Growth Factors.

	1.	2.	3.	4.	5.	6.	7.
1. Positive Outcome Likelihood Intercept	1.70[†]	-0.08	0.30	0.35	0.23	0.23	-0.05
2. Negative Outcome Likelihood Slope	-0.12	1.56[†]	-0.18	-0.08	-0.02	-0.20	-0.03
3. Positive Outcome Evaluation Intercept	0.30 [†]	-0.16	0.58[†]	-0.57	0.13	-0.02	-0.17
4. Positive Outcome Evaluation Slope	0.11 [†]	-0.02	-0.10 [†]	0.05*	-0.14	0.43	0.14
5. Negative Outcome Evaluation Intercept	0.14*	-0.01	0.04	-0.01	0.20[†]	-0.68	0.14
6. Negative Outcome Evaluation Slope	0.05*	-0.03	-0.00	0.02*	-0.05*	0.03*	-0.04
7. Negative Automatic Associations Intercept	-0.02	-0.01	-0.04	0.01	0.02	-0.00	<0.01[†]

Note: Variances on the diagonal (bolded), covariances below the diagonal, and correlations above the diagonal.

* $p<.05$.
[†] $p<.01$.