Impulsivity, Working Memory, and Impaired Control over Alcohol: A Latent Variable Analysis

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Abstract

Impaired control over alcohol is an important risk factor for heavy drinking among young adults and may mediate, in part, the association between personality risk and alcohol problems. Research suggests that trait impulsivity is associated with impaired control over alcohol; however, few studies of this association have included a range of impulsivity facets. The purpose of this study was to examine specific pathways from higher-order impulsivity factors to alcohol problems mediated via impaired control over alcohol. We also examined the moderating role of working memory in these associations. Young heavy drinkers ($N=300$) completed two multidimensional impulsivity measures (UPPS-P and BIS-11) along with self-report measures of impaired control over alcohol, alcohol use, and alcohol problems. Working memory was assessed using a computerized digit span task. Results showed that the impulsivity facets loaded onto two higher-order factors that were labeled *response* and *reflection impulsivity*. Response impulsivity predicted unique variance in self-reported impaired control and alcohol problems, whereas reflection impulsivity predicted unique variance in heavy drinking frequency only. Further, significant indirect associations were observed from response and reflection impulsivity to alcohol problems mediated via impaired control and heavy drinking frequency, respectively. Working memory and sensation seeking were not uniquely associated with the alcohol variables, and no support was found for the moderating role of working memory. The results help to clarify associations among impulsivity, impaired control, and alcohol problems, suggesting that impaired control may play a specific role in the pathway to alcohol problems from response impulsivity but not from reflection impulsivity.

Keywords

Loss of control; Disinhibition; Addiction; Executive Function; Personality

Introduction

Impaired control over alcohol is commonly endorsed by alcohol-involved youth and is associated with heavy drinking and alcohol-related problems (Chung & Martin, 2002;

Leeman, Patock-Peckham, & Potenza, 2012; McCusker, 2006; Nagoshi, 1999). Impaired control refers to the failure to follow through on intentions to abstain from alcohol as well as failed attempts to limit the amount of alcohol consumed during a drinking episode (Heather, Tebbutt, Mattick, & Zamir, 1993; Kahler, Epstein, & McCrady, 1995). Although impaired control is highly correlated with heavy drinking, it is a distinct construct that predicts unique variance in alcohol problems over and above levels of alcohol use (Leeman, Fenton, & Volpicelli, 2007; Nagoshi, 1999). Impaired control is conceptually related to the symptoms of alcohol use disorder that tend to have the earliest onset (Langenbucher & Chung, 1995; Leeman et al., 2014; Nelson, Heath, & Kessler, 1998), and impaired control is prospectively associated with alcohol problems (Leeman, Toll, Taylor, & Volpicelli, 2009). Thus, examining factors that contribute to impaired control in late adolescence may inform early intervention efforts.

Impulsivity and Impaired Control Over Alcohol

Trait impulsivity is strongly associated with heavy drinking and alcohol-related problems (Littlefield, Stevens, & Sher, 2014; Sher & Trull, 1994). Given that both impulsivity and impaired control over alcohol involve deficits in self-regulation of behavior (Leeman et al., 2012), impulsivity is clearly relevant to impaired control over alcohol. Indeed, it has been suggested that impaired control may represent a specific behavioral manifestation of impulsive personality (Patock-Peckham, King, Morgan-Lopez, Ulloa, & Moses, 2011). However, there is evidence that these constructs are distinct, with each predicting unique variance in alcohol problems (Nagoshi, 1999; Patock-Peckham & Morgan-Lopez, 2006). Leeman et al. (2012) suggested that there are important conceptual distinctions between impulsivity and impaired control. For example, not all components of impaired control over alcohol are synonymous with impulsivity (e.g., setting limits on alcohol consumption), nor do all individuals who experience impaired control over alcohol necessarily exhibit impulsive behavior in other domains (i.e., while not drinking; see Leeman et al., 2012).

Given that impulsivity and impaired control appear to represent distinct constructs, there may be utility in examining impulsivity as a predictor of impaired control. Indeed, there have been several studies that generally support the association between impulsive personality traits and impaired control (see Leeman et al., 2012). Furthermore, impaired control has been conceptualized as a mediator of the relationship between impulsivity and alcohol problems, a notion that has been supported empirically (Patock-Peckham & Morgan-Lopez, 2006, 2009). Thus, impaired control may represent an important target of interventions for impulsive individuals at risk for alcohol problems. However, given that impulsivity is not a unitary construct, it is not currently clear which facets of impulsivity may be associated with alcohol problems via impaired control over alcohol versus other pathways to alcohol problems (e.g., heavier drinking in general).

Hierarchical Structure of Impulsivity

It is widely acknowledged that impulsivity is a multifaceted construct comprised of several components (Evenden, 1999; Whiteside & Lynam, 2001). Multidimensional measures of impulsivity are commonly used in studies (e.g., UPPS-P; Lynam, Smith, Whiteside, & Cyders, 2006; Barratt Impulsivity Scale; BIS-11; Patton, Stanford & Barrat, 1995), and

distinguishing among impulsivity facets can be informative (Smith et al., 2007). However, given that these facets tend to correlate highly both within and across different measures, analyzing a range of impulsivity facets simultaneously as predictors of drinking behavior can be analytically problematic and can complicate the interpretation of associations (Coskunpinar, Dir, & Cyders, 2013). Hierarchical models of personality have been widely applied in both the normal and abnormal personality literatures (Digman, 1997; Markon, Krueger, & Watson, 2005). This approach models the structural relations among overlapping personality facets in a conceptually meaningful and parsimonious manner, while still providing a comprehensive representation of the full range of facets.

With respect to impulsive traits, different facets of impulsivity may be hierarchically organized into a few key higher-order constructs that reflect different mechanisms of impulsive behavior. For example, Leeman et al. (2012) suggested that several facets of impulsivity could be classified into domains labeled *response impulsivity* (difficulties inhibiting thoughts and behaviors, especially in the context of reinforcement) and *reflection impulsivity* (the tendency to make decisions without sufficiently gathering or evaluating relevant information; see also Verdejo-García, Lawrence, & Clark, 2008). The results of factor analytic studies of multidimensional impulsivity measures are generally consistent with this higher-order grouping of impulsivity dimensions. For example, Cyders and Smith (2007) conducted a confirmatory factor analysis on the UPPS-P and found that positive urgency and negative urgency (the tendency to act rashly in response to positive and negative emotions, respectively) both loaded on one higher-order factor, whereas lack of perseverance (difficulty following tasks through to completion) and lack of premeditation (the tendency to act without forethought) loaded on a separate higher-order factor. These factors are consistent with the concepts of response and reflection impulsivity, respectively. While the UPPS-P also contains a measure of sensation seeking (proclivity toward new and exciting experiences), sensation seeking tends not to load on the same factors as the other UPPS-P scales (Cyders & Smith, 2007) and is often considered to be a distinct construct (e.g., Magid, MacLean, & Colder, 2007).

Another widely used measure of impulsivity, the BIS-11 (Patton et al., 1995), is similarly comprised of facets that have been described in relation to response and reflection impulsivity (Leeman et al., 2012). Specifically, the non-planning scale (difficulties planning ahead and thinking about the future) clearly relates to reflection impulsivity. Also, the motor impulsivity scale contains items that primarily tap into acting without thinking and lack of perseverance, which closely align with reflection impulsivity. However, the third factor – attention impulsivity – contains elements of both response impulsivity (i.e., difficulty inhibiting thoughts and behaviors; e.g., “I can’t sit still during movies, or when I have to listen to people talk for a long time”) and reflection impulsivity (i.e., lack of perseverance and planning; e.g., “I change the things I like to do a lot”). In addition, this scale contains items that assess pure attention processes (e.g., “I do not pay attention”; see Coskunpinar et al., 2013; Leeman et al., 2012; Whiteside & Lynam, 2001).

Specific Associations Between Impulsivity Facets and Alcohol Outcomes

Importantly, facets of impulsivity appear to relate differentially with alcohol outcomes. Coskunpinar et al. (2013) conducted a meta-analysis of studies of the link between impulsivity and alcohol outcomes, classifying impulsivity measures (including the BIS-11) with respect to the UPPS-P facets. Their findings indicate that impulsivity facets consistent with reflection impulsivity and sensation seeking tended to be associated primarily with quantity of alcohol use and heavy drinking. In contrast, facets related to response impulsivity (specifically positive and negative urgency) had relatively stronger associations with alcohol problems. A similar meta-analysis by Stautz and Cooper (2013) yielded comparable findings.

However, there have been few studies examining differential relationships between impulsivity facets and impaired control over alcohol. Most published research to date has focused on a single global index of impulsivity (e.g., the Eysenck I7 scale) or has examined only a subset of impulsivity facets (see Leeman et al., 2012). While there is some evidence that urgency may be particularly relevant to impaired control over alcohol when compared with other UPPS-P facets (Wardell, Quilty, & Hendershot, 2015), the relative importance of different facets of impulsivity to impaired control remains unclear. Conceptually, both response and reflection impulsivity may be relevant to impaired control over alcohol. For example, drinking more than intended and/or failure to maintain intended abstinence could result from a general inability to inhibit responses and to act rashly with respect to reinforcing behaviors, which characterize response impulsivity. Moreover, the tendency to act without forethought and careful planning that is typical of individuals high on reflection impulsivity may make it difficult for them to adequately plan strategies to moderate or abstain from alcohol.

The Role of Working Memory

Theoretical perspectives such as cognitive motivation theory (Finn, 2002) and dual-process models (Bechara, 2005) contend that risk for problematic drinking is conferred by an interaction between strong motivational tendencies to approach reward (which characterize individuals high on impulsivity) and deficits in the ability to inhibit these motivational tendencies (i.e., deficits in executive functions). Working memory represents an important executive function that may play a role in the link between impulsivity and alcohol problems – impulsive individuals with low working memory capacity may be less able to keep distal, less salient negative alcohol consequences in mind when making decisions about drinking, thus strengthening the influence of impulsive personality on alcohol consumption behavior (Finn, 2002).

While there is some empirical evidence that working memory moderates associations between personality traits related to impulsivity and alcohol problems (Ellingson, Fleming, Vergés, Bartholow, & Sher, 2014; Finn & Hall, 2004), few studies of this moderation effect have been conducted, and results have been mixed. For instance, this moderation effect has been observed for some traits related to impulsivity but not others (Ellingson et al., 2014; Finn & Hall, 2004). Moreover, no studies to our knowledge have examined the interactive effects of impulsivity and working memory on impaired control over alcohol, which may be

a particularly relevant outcome in this model. That is, low working memory capacity may make it more challenging for individuals to keep their drinking intentions in mind while drinking (Lechner, Day, Metrik, Leventhal, & Kahler, 2016), which could exacerbate the effect of impulsivity on impaired control.

The Present Study

This study examined the role of impulsivity and working memory in impaired control over alcohol among participants in late adolescence, a developmental period in which impaired control over alcohol has been identified as an important risk factor. We focused on young heavy episodic drinkers as this is a population at significant risk for alcohol problems and the development of alcohol use disorders. We used structural equation modeling (SEM) to estimate higher-order response and reflection impulsivity constructs from two widely used multidimensional measures of impulsivity. We hypothesized that both response and reflection impulsivity factors would be unique predictors of impaired control over alcohol, and that impaired control would mediate the associations of both impulsivity factors with alcohol problems. Also, we expected that reflection impulsivity and sensation seeking (but not response impulsivity) would be uniquely associated with heavy drinking frequency, and that heavy drinking frequency would mediate the associations of reflection impulsivity and sensation seeking with alcohol problems. Further, given that executive functions are conceptually relevant to both impulsivity and impaired control over alcohol, a secondary aim of this study was to examine the role of working memory in the hypothesized associations. We expected that the links between impulsivity and alcohol outcomes (including impaired control) would be stronger for individuals with lower working memory capacity.

Method

Participants

The sample consisted of young heavy episodic drinkers ($N=300$; $n=159$ women) who participated in a screening and assessment session as part of an experimental study. Because the experimental component involved alcohol administration procedures, all participants had volunteered to receive alcohol in the laboratory (pending eligibility to proceed to the experimental component). Participants indicated their ethnic/racial background by checking all applicable categories from the following list: Caucasian ($n=172$; 57%), Asian ($n=43$; 14%), Black/African American ($n=35$; 12%), East Indian ($n=28$; 9%), Hispanic/Latino ($n=26$; 9%), Native North American ($n=9$; 3%), Pacific Islander ($n=3$; 1%), and other ($n=39$; 13%). Forty-one (14%) participants endorsed more than one ethnic/racial category. Mean age was 19.75 years ($SD=1.02$; Range=18–25). The majority of participants ($n=227$; 76%) were full time students, 5% ($n=15$) were part time students, and 19% ($n=56$) were not enrolled as students. Two participants did not report student status. Participants reported drinking an average of 5.08 ($SD=2.29$) drinks per drinking day, on a mean of 19.10 ($SD=12.05$) drinking days in the past 90 days. The average number of heavy drinking episodes (defined as 4+ drinks for women/5+ drinks for men) was 11.08 ($SD=9.75$).

Recruitment and Procedure

Participants were recruited mainly through online advertisements on public and University websites aimed at social drinkers in Toronto, Canada. Consistent with the aims of the experimental component of the study, primary eligibility criteria included at least one heavy drinking episode in the past month, no prior alcohol treatment or current desire/attempts to reduce drinking, no current psychiatric medications or diagnoses requiring treatment, no recent illicit drug use except for cannabis, no contraindications for alcohol use, and no severe nicotine dependence. Detailed recruitment and eligibility screening procedures have been described elsewhere (masked for blind review). Eligibility screenings were conducted via telephone, and participants meeting eligibility criteria were scheduled for an assessment session. Data collected from this session were used for the present analyses. Additional results from this baseline session for a portion of the participants have been reported previously (masked for blind review). Based on eligibility and scheduling factors, roughly one third of participants in the current sample ultimately proceeded to begin the experimental component of the study (for additional details see [masked for blind review]).

Measures

Impaired Control Scale (ICS; Heather et al., 1993)—Part 3 of the ICS was used to assess beliefs regarding the ability to exert control over drinking behavior (10 items; e.g., “Even if I intended having only one or two drinks, I would end up having more”). Participants rated items on a 5-point scale (0=*never* to 4=*always*), and responses to items were summed to derive a total scale score. Part 3 of the ICS is more relevant than Parts 1 and 2 when assessing impaired control in young heavy drinkers, who are less likely to endorse a history of attempts to quit or cut down on drinking (Leeman et al., 2007). The ICS has been shown to have strong psychometric properties (Heather, Booth, & Luce, 1998). Cronbach’s α for Part 3 of the ICS was .88 in this sample.

Timeline Followback (TLFB; Sobell & Sobell, 1992)—Drinking behavior was assessed with the TLFB, a structured calendar-based method for assessing recent alcohol use. Past 90 day heavy drinking frequency was used in the analyses, and was calculated as the total number of days on which participants reported drinking 4 or more drinks for women or 5 or more drinks for men.

Rutgers Alcohol Problems Index (RAPI; White & Labouvie, 1989)—The RAPI was used to assess past-year alcohol-related problems. Participants rated the frequency with which they experienced 23 different indicators of alcohol-related problems (e.g., tolerance/withdrawal symptoms, academic problems, social/interpersonal consequences) on a scale from 0=*Never* to 4=*More than 10 times*. Responses to items were dichotomized to indicate whether the problem was present (1) or absent (0), and a total problem count was calculated. We removed three items that were redundant with the impaired control construct (“Kept drinking when you promised yourself not to”; “Tried to control your drinking by trying to drink only at certain times of the day or in certain places”; “Tried to cut down or quit drinking”). Cronbach’s α for the RAPI was .86.

UPPS-P Impulsivity Scales (Lynam et al., 2006)—The UPPS-P assesses several facets of impulsivity: negative urgency (12 items; $\alpha = .87$; e.g., “When I feel bad, I will often do things I later regret in order to make myself feel better now”), positive urgency (14 items; $\alpha = .92$; e.g., “When I am in a great mood, I tend to get into situations that could cause me problems), lack of premeditation (11 items; $\alpha = .86$; e.g., “I don’t like to start a project until I know exactly how to proceed” [reverse scored]), lack of perseverance (10 items; $\alpha = .81$; e.g., “I generally like to see things through to the end” [reverse scored]), and sensation-seeking ($\alpha = .84$; e.g., “I generally seek new and exciting experiences and sensations”). Participants rated items on a 4-point scale (1=*disagree strongly* to 4=*agree strongly*). Scale scores were calculated by taking the mean of the items on each scale. The UPPS-P is a reliable and valid measure of these impulsivity facets (Cyders et al., 2007; Smith et al., 2007).

Barratt Impulsiveness Scale – Version 11 (BIS-11; Patton et al., 1995)—The BIS-11 is a widely used measure of impulsivity comprised of three primary facets: attention impulsivity (8 items; $\alpha = .71$; e.g., “I can’t sit still during movies, or when I have to listen to people talk for a long time”), motor impulsivity (11 items; $\alpha = .59$; e.g., “I do things without thinking”) and non-planning impulsivity (11 items; $\alpha = .76$; i.e., e.g., “I plan what I have to do” [reverse scored]). Items were rated on a 4-point scale (1=*Rarely/Never* to 4=*Almost Always/Always*), and items were summed to calculate total scores for each scale. The BIS-11 is among the most frequently used measures of impulsivity, and there are data to support its psychometric properties (Stanford et al., 2009).

Working Memory—We derived indices of working memory from a computerized version of the digit span task delivered via Inquisit 3.0 (Draine, 2009). The task is analogous to the digit span task found in the Wechsler Memory Scale (Wechsler, 1997) and was adapted from an auditory version of the task described by Woods et al. (2011). The task involves the forward and backward recall of lists of digits. Digits are presented one at a time on a computer screen (for one second each), and at the end of each list participants are asked to recall the digits in forward or backward order by using the number pad on the keyboard. All subjects are first presented a list of 3 digits; the list length then increases adaptively (as described in Woods et al., 2011) such that correct responses result in a one digit increase in list length on the next trial, while two consecutive incorrect responses result in a one digit reduction in list length on the next trial. The task consists of 14 trials of forward recall (i.e., in order of presentation) followed by 14 trials of backward recall (i.e., in reverse order of presentation). We focused on digits backward performance, as this reflects the ability to manipulate information in memory, which may be crucial for planning and thus broadly relevant to impulsivity (Ellingson et al., 2014; Schofield & Ashman, 1986).

We derived three related but distinct indices from the digit span task to serve as indicators of working memory performance: the mean span index, which represents the list length at which 50% of the trials are expected to be correct; the two-error total, which is the total number of trials before two consecutive errors at the same list length (Woods et al., 2011); and median response time across trials. The total response time for a given trial (i.e., the time between the offset of the list presentation and the completion of list recall) is a function of the list length as well as pauses before initiating a response and pauses between digits.

Working memory span tends to be positively associated with total response time for the longest list recalled (Cowan, 1992; Tehan & Lalor, 2000), and it has been argued that response time represents an informative index of working memory task performance (Cowan et al., 2003). Thus we used each participant's median response time across the digit span trials as an additional indicator of the latent working memory factor.

Data Analysis Plan

We first examined the distributional properties of all variables. One participant had an extreme outlying value (i.e., greater than 3.29 SD above the mean and notably disconnected from the distribution; Tabachnick & Fidell, 2007) on the heavy drinking variable, which was set to missing. Another participant had extremely slow RT on the digit span task (z -score=5.55) and so working memory data for this participant was excluded. The overall rate of missing data on the observed variables used in the SEM analyses was low (<1%). Most variables reasonably approximated univariate normal distributions (skewness = 1.00 and kurtosis = 2.00), except for the heavy episodic drinking variable (skewness=1.69, kurtosis=3.23). We used robust maximum likelihood estimation to accommodate missing values and non-normality.

To examine the hypothesized direct and indirect associations among impulsivity and alcohol variables, as well as the moderating role of working memory in these associations, we conducted SEM using Mplus version 7 (Muthén & Muthén, 2012). We specified a hybrid model, with the response impulsivity, reflection impulsivity, and working memory constructs modeled as latent variables, and impaired control, heavy drinking frequency, alcohol problems and sensation seeking modeled as observed variables. Consistent with previous work (Cyders & Smith, 2007), we expected the impulsivity facets to load onto two higher-order impulsivity factors that we labeled response impulsivity and reflection impulsivity. Indicators of the latent response impulsivity factor were the positive and negative urgency scales of the UPPS-P and the attention impulsivity scale of the BIS-11. Indicators of the latent reflection impulsivity factor included the lack of perseverance and lack of premeditation scales of the UPPS-P, and the non-planning, motor, and attention impulsivity scales of the BIS-11. It is important to note that we specified the BIS-11 attention impulsivity scale as an indicator of both response and reflection impulsivity, consistent with the results of Whiteside and Lynam (2001) and previous reviews of the literature that have grouped attention impulsivity with both urgency (response) and lack of planning (reflection; Coskunpinar et al., 2013). Also, given evidence that sensation seeking is a construct distinct from response and reflection impulsivity (Cyders & Smith, 2007; Smith et al., 2007), we modeled sensation seeking as a separate observed variable. Three indices derived from the backward digit span task (mean span, two-error total, median RT) were specified as indicators of a latent working memory factor.

We began by first estimating a measurement model that included only the three latent variables, which were allowed to freely covary with one another. Covariances among indicator error terms were constrained to zero. We first evaluated the fit of the measurement model, and examined the pattern of factor loadings to determine whether the indicators loaded as hypothesized. While there are no universally accepted cut off values for goodness

of fit indices in SEM, model fit is often considered acceptable if root-mean square error of approximation (RMSEA) < .08, the comparative fit index (CFI) > .90, and the standardized root mean square residual (SRMR) < .08; model fit can be considered good if RMSEA < .06, CFI > .95, and SRMR < .05 (Bentler & Bonett, 1980; Browne & Cudeck, 1993; Hu & Bentler, 1999).

After confirming the fit of the measurement model, we next examined the structural model. Based on our hypotheses, we estimated paths from both response and reflection impulsivity (but not sensation seeking) to impaired control, as well as paths from both reflection impulsivity and sensation seeking (but not response impulsivity) to heavy drinking frequency. In turn, impaired control and heavy drinking frequency were specified as predictors of alcohol problems. Paths from working memory to all three alcohol outcomes were freely estimated given that we did not forward hypotheses regarding specific associations with working memory. We next examined whether including the direct paths from the impulsivity factors and sensation seeking to alcohol problems resulted in model fit improvement to determine full vs. partial mediation, and planned to retain significant direct paths in the model. Also, in order to provide a thorough test of the hypothesized unique associations between the impulsivity variables and the alcohol variables, we determined whether the inclusion of the non-hypothesized paths led to any improvements in model fit.

Further, to test the hypothesis that working memory would moderate the associations between impulsivity and alcohol outcomes, paths from working memory to all of the alcohol variables were included in the model. Then, in a subsequent step, latent variable interactions between working memory and the impulsivity variables (response, reflection, sensation-seeking) were entered into the model. We planned to trim any interactions and non-hypothesized paths that were not statistically significant in order to achieve a parsimonious model. Finally, bootstrapping was used to calculate 95% confidence intervals for the indirect pathways from impulsivity factors to alcohol problems mediated via impaired control and heavy drinking frequency.

Results

Table 1 shows the means, standard deviations, and bivariate correlations among all variables. As expected, longer RT on the digit span task was associated with better performance on the task. Also, mean span on the digit span task was negatively correlated with the non-planning subscale of the BIS-11. Further, most of the impulsivity facets (other than sensation seeking) were significantly correlated with self-reported impaired control over alcohol, and all impulsivity facets (including sensation seeking) were significantly correlated with alcohol problems. However, fewer facets were correlated with heavy drinking frequency. Of note, many of the impulsivity facets across both measures were moderately intercorrelated with one another. Moreover, the BIS-11 scales were significantly correlated with the UPPS-P scales, with the exception of a null association between UPPS-P sensation seeking and BIS-11 attention and non-planning scales.

We next examined the results of the SEM models. The hypothesized measurement model provided adequate fit to the data, scaled $\chi^2(31)=86.24$, $p<.001$, RMSEA=.08, CFI=.94,

SRMR=.05. All factor loadings were statistically significant (all p s < .01). Further, the response and reflection impulsivity factors were significantly correlated with one another (β =.57, p <.001), and the working memory factor was negatively correlated with the reflection impulsivity factor (β =-.15, p =.025), but not the response impulsivity factor (β =-.08, p =.282).

Next, we estimated the hybrid model including the latent impulsivity factors, the latent working memory factor, and observed sensation seeking scale as predictors of impaired control and heavy drinking frequency, which in turn were specified as predictors of alcohol problems. The hypothesized model with paths from response and reflection impulsivity to impaired control and from reflection impulsivity and sensation seeking to heavy drinking frequency did not fit the data well, scaled $\chi^2(64)$ =204.73, p <.001, RMSEA=.09, CFI=.89, SRMR=.06. However, inclusion of the direct paths from the impulsivity factors and sensation seeking to alcohol problems resulted in significant improvement in model fit, scaled $\chi^2(3)$ =19.73, p <.001. Inspection of the coefficients revealed that the direct path from response impulsivity to alcohol problems was statistically significant (p =.001), suggesting that impaired control did not fully mediate the relationship between response impulsivity and alcohol problems. Thus, this direct path was retained in the final model. However, the direct paths from reflection impulsivity and sensation seeking to alcohol problems were not significant (p s>.107) and were trimmed to obtain a more parsimonious model. This model provided adequate fit to the data, scaled $\chi^2(63)$ =186.92, p <.001, RMSEA=.08, CFI=.91, SRMR=.06. Further, inclusion of the non-hypothesized paths from response impulsivity to heavy drinking and from sensation seeking to impaired control did not improve model fit, scaled $\chi^2(2)$ =0.11, p =.946, and neither of these additional paths were statistically significant (all p s > .750). Thus, these paths were not retained in the model.

Before interpreting the main effects, we next entered the latent variable interactions between working memory and the impulsivity factors and sensation seeking to examine whether any of the paths in the model were moderated by working memory. However, none of these interactions were statistically significant (all p s > .325), so they were removed from the model to simplify interpretation of the main effects. Also, none of the paths from the working memory factor to the three alcohol outcomes were significant (all p s > .067), so these were also trimmed. However, there was a significant negative covariance between working memory and reflection impulsivity (p =.019); thus, the covariances among WM and the impulsivity factors were retained in the model. Further, contrary to our hypothesis, sensation seeking was not uniquely associated with heavy drinking (β =.09, SE =.06, p =.103), nor was the sensation seeking scale significantly associated with the latent impulsivity or working memory factors (all p s > .219). Given that sensation seeking was not associated with any variables in the model, we removed sensation seeking to achieve a more parsimonious model. The model fit indices for this final model ranged from adequate to good fit, scaled $\chi^2(57)$ =127.85, p <.001, RMSEA=.06, CFI=.94, SRMR=.05.

Figure 1 shows the final SEM model. With respect to unique paths from the impulsivity factors to the alcohol variables, we observed the hypothesized unique association from the response impulsivity factor to impaired control over alcohol. Also as expected, reflection impulsivity was uniquely associated with heavy drinking frequency. However, contrary to

our hypothesis, the reflection impulsivity scale did not predict unique variance in impaired control over alcohol ($p=.276$). Furthermore, both impaired control and heavy drinking frequency predicted unique variance in alcohol problems.¹

Also as hypothesized, there was a significant indirect association between response impulsivity and alcohol problems mediated specifically through impaired control over alcohol ($\beta=.25$, 95%CI [.17, .35]). This suggests that impaired control was a partial mediator of this association given that the direct path from response impulsivity to alcohol problems was also statistically significant. In addition, the indirect association between reflection impulsivity and alcohol problems mediated by heavy drinking frequency was statistically significant ($\beta=.04$, 95%CI [.01, .07]), whereas the indirect pathway from reflection impulsivity to alcohol problems mediated by impaired control was not ($\beta=.04$, 95%CI [−.03, .10]). Given that the direct association from reflection impulsivity to alcohol problems was not significant, these findings suggest that this association was fully mediated by heavy drinking frequency.

Discussion

Through applying a hierarchical structure to several overlapping facets of impulsivity, this study helps to provide some conceptual clarity to the associations among impulsivity factors, impaired control over alcohol, heavy drinking, and alcohol problems. We found some support for hypothesized unique associations between high-order response and reflections impulsivity factors and different alcohol outcomes, as well as hypothesized specific indirect pathways from impulsivity factors to alcohol problems mediated via impaired control vs. heavy drinking. Given that the response and reflection impulsivity factors were highly correlated, these results suggest that the variance that was unique to each factor is relevant for understanding different pathways to alcohol problems. In contrast, sensation seeking was not uniquely associated with the alcohol outcomes in the model, nor did we find evidence that working memory moderated links between impulsivity and alcohol outcomes. The findings advance our understanding of the association between impulsivity and impaired control over alcohol and suggest avenues for future work in this area.

The measurement model largely supported our hypotheses regarding the hierarchical structure of impulsivity, confirming that the BIS-11 and UPPS-P scales (other than sensation seeking) loaded on two higher-order impulsivity factors reflecting response and reflection impulsivity constructs. As few previous studies have examined the interrelationships among the scales across these two measures, these findings help to clarify the empirical and conceptual associations of the impulsivity facets that comprise these widely used measures.

¹Research shows that personality and alcohol use may have bi-directional associations (Littlefield et al., 2012; Quinn et al., 2011). Given the cross sectional nature of the present study, we were not able to empirically establish the temporal ordering of the variables in the model. So, we also examined a model in which the direction of the paths from the impulsivity factors to the alcohol outcomes was reversed for comparison with the model that we specified a priori. The fit of this reversed model was comparable (AIC=9.23, BIC = 9.23), and the significance of the paths was largely similar. Thus, the cross-sectional data reported here support both a model in which impulsivity factors are specified as predictors of alcohol outcomes and a model in which alcohol variables are specified as predictors of impulsivity. The only notable difference was that the path from impaired control to reflection impulsivity was statistically significant in this reversed model ($\beta=.32$, $SE=.06$, $p<.001$), whereas the path from reflection impulsivity to impaired control was not significant in the model shown in Figure 1. However, this difference was expected given that the model in Figure 1 controls for response impulsivity when predicting impaired control from reflection impulsivity.

An interesting finding was that the BIS-11 attention impulsivity scale loaded on both response and reflection impulsivity factors, which was expected given that this scale contains items that reflect both difficulty maintaining attention (consistent with reflection impulsivity) and difficulty inhibiting thoughts (consistent with response impulsivity; see Leeman et al., 2012).

We hypothesized that response impulsivity would predict unique variance in impaired control over alcohol, which was supported by the data. Because the two urgency scales had stronger loadings on the response impulsivity factor than the attention impulsivity scale, the results suggest that rash action and difficulty inhibiting behavior, particularly in emotional contexts, may play an important role in impaired control over alcohol. Given that alcohol has prominent mood-altering effects and is often used in the context of mood regulation (Cooper, Frone, Russell, & Mudar, 1995; Simons, Dvorak, Batien, & Wray, 2010), it is not surprising that individuals high on urgency may have difficulty moderating alcohol consumption or maintaining abstinence despite pre-existing intentions to do so. Impaired control, in turn, partially mediated the association between response impulsivity and alcohol problems, suggesting that impaired control may be one mechanism through which response impulsivity may lead to alcohol problems. In contrast, we did not observe the hypothesized unique association between reflection impulsivity and impaired control. While it might be expected that individuals high on reflection impulsivity may have difficulty formulating and effectively implementing plans to control their drinking – thereby increasing the likelihood of experiencing impaired control – these data do not lend support this notion. Perhaps individuals high on reflection impulsivity are less likely to form intentions to moderate alcohol consumption in the first place (a process that involves planning ahead), which makes impaired control a less relevant outcome for them. Future research that examines specific mechanisms and isolates different components of impaired control (i.e., intention formation and planning vs. violations of drinking intentions) will be necessary in order to clarify the processes underlying the associations of different domains of impulsivity with impaired control over alcohol.

The findings provide further support for specificity in the associations of higher-order impulsivity constructs with alcohol outcomes. Consistent with previous research (Coskunpinar et al., 2013; Stautz & Cooper, 2013), we found that the reflection impulsivity factor was associated uniquely with heavy drinking frequency, whereas the response impulsivity factor was a unique predictor of alcohol problems, even after accounting for heavy drinking and impaired control. Conceptually, individuals high on response impulsivity may be more prone to alcohol-related problems irrespective of frequency or quantity of drinking because they drink in risky ways or have difficulty inhibiting drinking behavior at inopportune times (Smith et al., 2007). This may increase risk for alcohol problems irrespective of levels of consumption. In contrast, individuals higher on reflection impulsivity may be less likely to go into drinking contexts with a clear plan to limit their alcohol consumption, which may result in heavier drinking. Further, our data suggest that heavy drinking frequency fully mediated the relationship between reflection impulsivity and alcohol problems, as there was no direct association between reflection impulsivity and alcohol problems. In other words, the risk for alcohol problems associated with reflection impulsivity appears to be accounted for by a tendency to engage in more frequent heavy

drinking. While these interpretations are limited by the cross-sectional design (see below), the differential associations observed here suggest that future studies should consider different mediators of the link between different impulsivity factors and alcohol outcomes.

In addition, despite showing significant correlations with alcohol problems and a few of the impulsivity facets in bivariate analyses, sensation seeking was not uniquely associated with any of the other constructs in the multivariate context of the SEM model. While this lack of association was somewhat unexpected given that sensation seeking has been shown to correlate with other facets of impulsivity, there have been some discrepancies in these associations across studies (Cyders et al., 2007; Smith et al., 2007). Conceptually, sensation seeking reflects a tendency to seek out new and exciting experiences, but not necessarily disinhibition or unplanned action in the context of these experiences, making it distinct from response and reflection impulsivity. Further, we expected sensation seeking to be associated with heavy drinking based on the results of meta-analytic studies (see Coskunpinar et al., 2013; Stautz & Cooper, 2013). However, in most of the studies reviewed in these meta-analyses, the association between sensation-seeking and heavy drinking frequency was examined in a general sample that was not restricted to heavy episodic drinkers. Thus, it is possible that sensation seeking has a less pronounced relationship with frequency of heavy drinking among regular heavy episodic drinkers, which may in part reflect a restriction in the range of sensation seeking and heavy drinking frequency observed in this population. Another consideration is that the effect estimates in these meta-analyses were based largely on bivariate associations between impulsivity facets and drinking variables, without taking into account the overlapping variance among the impulsivity constructs as was done in the present study. Moreover, differences in the measures used could also be partially responsible for inconsistent findings across studies.

Another contribution of the present study is that we examined the moderating role of working memory in the associations between impulsive traits and impaired control over alcohol. Theory suggests that individuals with low working memory capacity have greater difficulty keeping the negative consequences of alcohol use in mind when making decisions about drinking, which may increase the influence of impulsive processes in these decisions (Finn, 2002). Thus, we expected that high impulsivity combined with relatively lower working memory performance would predict increased impaired control, as well as heavier drinking and greater alcohol problems. However, we did not find support for this hypothesis, as working memory did not moderate any of the paths from the impulsive traits to the alcohol outcomes, nor was working memory a unique predictor of any of the alcohol outcomes. While this finding is not consistent with some prior research (Ellingson et al., 2014; Finn & Hall, 2004), there have been relatively few studies directly testing the interaction between working memory and impulsivity in relation to alcohol outcomes. Further, the available studies have tended to find that the moderating effects of working memory are specific to some narrow facets of personality that are conceptually related to impulsivity (e.g., the social deviance scale of the Tridimensional Personality Questionnaire), but not to other facets of impulsivity (e.g. Ellingson et al., 2014). The present study is the first study to our knowledge to examine working memory as a moderator of the relationship between higher-order impulsivity factors comprised of several facets of impulsivity and alcohol-related outcomes. That we did not observe a significant moderating effect of

working memory in this context suggests that more research is needed to clarify the role of working memory in the associations between impulsivity and alcohol outcomes.

Still, despite the lack of significant moderation effects and unique associations between the latent working memory factor and alcohol outcomes in the SEM model, it is notable that we observed a statistically significant negative correlation between the working memory factor and the reflection impulsivity factor (see Figure 1). This finding is consistent with the notion that deficits in working memory may be correlated with a tendency to act with little forethought and planning (Romer et al., 2011; Whitney, Jameson, & Hinson, 2004), which characterize individuals high on reflection impulsivity. Thus, the results support the potential importance of considering executive functions in studies of impulsivity.

It is important to acknowledge that because of the cross-sectional design, this study does not permit examination of the direction of the associations between impulsivity and impaired control. In our model, we specified the impulsivity factors as predictors of impaired control and alcohol outcomes based on our conceptual framework and prior research showing that impulsivity facets prospectively predict alcohol outcomes (e.g., Cyders, Flory, Rainer, & Smith, 2009; Settles, Cyders, & Smith, 2010). However, research shows that personality and alcohol use may have bi-directional associations (Littlefield, Vergés, Wood, & Sher, 2012; Quinn, Stappenbeck, & Fromme, 2011). Moreover, when we reversed the direction of the paths in our cross-sectional model, the relative fit of the model was not markedly different and the pattern of associations was largely the same. Thus, we must use caution in interpreting the findings of this study and cannot draw any conclusions about the temporal ordering of the variables in this study. Future longitudinal studies will be necessary to address questions of directionality among the constructs examined here.

Another limitation of the present study is that our index of executive function was derived exclusively from working memory performance, as measured by the digit span task. While the digit span task provides a valid assessment of working memory and has been used in prior studies examining the role of working memory in the links between impulsivity and alcohol use (Ellingson et al., 2014; Finn & Hall, 2004), it has been argued that this task assesses only one domain-specific component of working memory (see Conway et al., 2005; Ellingson et al., 2014). Thus, more research is warranted to clarify the role of working memory in impaired control over alcohol, including studies that incorporate a variety of working memory tasks. Similarly, other indicators of executive functioning (e.g., response inhibition) may play a role in the associations between impulsivity and impaired control, pointing to avenues for future research. Moreover, this study was limited by a reliance on self-report measures of impulsivity. A number of behavioral measures of impulsivity are available (Dick et al., 2010), and combining self-report and behavioral assessments of impulsivity in a multitrait, multimethod approach could help to improve construct validity (Campbell & Fiske, 1959). Finally, the sample was limited to a relatively narrow population of young adult heavy drinkers; although this is a population in which impaired control is an important risk factor, the generalizability of the findings to other populations is limited.

In summary, this study provides new insight into the association between impulsivity and impaired control over alcohol, with evidence that response impulsivity relates uniquely to

impaired control, while reflection impulsivity, sensation seeking, and working memory do not. The results highlight the need for future research that examines specific mechanisms of the associations between impulsivity domains and impaired control over alcohol. In addition, future work could examine the potential clinical implications of these findings. For example, behavioral interventions aimed at helping young heavy drinkers exercise more control over their drinking could be targeted toward individuals who are high on response impulsivity. Further, that response impulsivity, but not reflection impulsivity, was related to impaired control suggests that it may be important for such interventions to focus on strategies for inhibiting urges to drink in the context of reinforcement.

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Figure 1.

Final SEM model of the associations among latent response and reflection impulsivity factors, impaired control over alcohol, past 90 day heavy episodic drinking frequency, and past year alcohol problems. Standardized parameter estimates are shown. Errors are omitted from the figure for ease of presentation. Solid arrows denote statistically significant associations and dashed arrows denote nonsignificant associations. UPPS-P and BIS-11 labels specify the self-report questionnaire from which the indicator is derived.

Digits=backward digit span task; NU=Negative Urgency; PU=Positive Urgency; LPM=Lack of Premeditation; LPS=Lack of Perseverance; NP=Non-planning; Mot=Motor Impulsivity; Att=Attention Impulsivity; MS=Mean Span; TET=Two-Error Total; RT=Response Time.

* $p < .05$; ** $p < .01$.

Table 1

Means, standard deviations, and correlations among observed variables in the model.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Digits: MS	-													
2. Digits: TET	.74**	-												
3. Digits: RT	.46**	.39**	-											
4. UPPS-P: NU	-.08	.04	-.15**	-										
5. UPPS-P: PU	-.08	.00	-.13*	.68**	-									
6. UPPS-P: LPM	-.10	-.04	-.06	.21**	.13*	-								
7. UPPS-P: LPS	-.06	-.03	.05	.30**	.14*	.39**	-							
8. UPPS-P: SS	.07	.04	-.01	-.03	.18**	.10	-.21**	-						
9. BIS-11: Att	-.07	.01	.02	.49**	.40**	.30**	.39**	.08	-					
10. BIS-11: NP	-.15**	-.08	-.10	.45**	.35**	.54**	.43**	-.07	.44**	-				
11. BIS-11: Mot	-.06	-.01	-.10	.39**	.38**	.37**	.23**	.18**	.53**	.44**	-			
12. Impaired Control	-.06	-.01	-.04	.50**	.50**	.13*	.16**	.06	.32**	.37**	.30**	-		
13. Heavy Drinking	-.10	-.07	-.04	.14*	.11	.16**	.08	.08	.05	.25**	.15*	.40**	-	
14. Alcohol Problems	.01	.02	-.02	.48**	.43**	.18**	.14*	.12*	.33**	.26**	.26**	.67**	.35**	-
Mean	6.34	5.70	10.60	2.33	1.93	1.99	2.06	3.07	17.85	24.24	22.83	1.99	11.08	6.74
SD	1.55	2.32	4.96	0.58	0.60	0.49	0.48	0.56	4.02	5.13	4.09	0.73	9.75	4.71

Note. Digits = Backward digit span task; MS= Mean Span; TET=Two-Error Total; RT=Median Reaction Time (s); NU=Negative Urgency; PU=Positive Urgency; LPM=Lack of Perseverance; SS=Sensation Seeking; Att=Attention; NP=Non-planning; Mot=Motor Impulsivity; Pairwise deletion used for missing data;

* p<.05,

** p<.01.