The Relationship Between Measures of Impulsivity and Alcohol Misuse: An Integrative Structural Equation Modeling Approach

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Background: Higher levels of impulsivity have been implicated in the development of alcohol use disorders. Recent findings suggest that impulsivity is not a unitary construct, highlighted by the diverse ways in which the various measures of impulsivity relate to alcohol use outcomes. This study simultaneously tested the following dimensions of impulsivity as determinants of alcohol use and alcohol problems: risky decision making, self-reported risk-attitudes, response inhibition, and impulsive decision making.

Methods: Participants were a community sample of nontreatment seeking problem drinkers (n = 158). Structural equation modeling (SEM) analyses employed behavioral measures of impulsive decision making (delay discounting task [DDT]), response inhibition (stop signal task [SST]), and risky decision making (Balloon Analogue Risk Task [BART]), and a self-report measure of risk-attitudes (domain-specific risk-attitude scale [DOSPERT]), as predictors of alcohol use and of alcohol-related problems in this sample.

Results: The model fits well, accounting for 38% of the variance in alcohol problems, and identified 2 impulsivity dimensions that significantly loaded onto alcohol outcomes: (i) impulsive decision making, indexed by the DDT; and (ii) risky decision making, measured by the BART.

Conclusions: The impulsive decision-making dimension of impulsivity, indexed by the DDT, was the strongest predictor of alcohol use and alcohol pathology in this sample of problem drinkers. Unexpectedly, a negative relationship was found between risky decision making and alcohol problems. The results highlight the importance of considering the distinct facets of impulsivity to elucidate their individual and combined effects on alcohol use initiation, escalation, and dependence.

Key Words: Impulsivity, Alcohol Use, Alcohol Problems, Delayed Reward Discounting, Risk-Taking.

INCREASED IMPULSIVITY HAS been repeatedly implicated in the development and maintenance of alcohol and other substance use disorders (e.g., Dawe and Loxton, 2004; Vitaro et al., 2001). The mechanisms underlying the association between alcohol use and impulsivity are complex and likely reflect multiple processes. For example, there is evidence that high levels of impulsivity may serve as a predisposing etiological factor, but also evidence that long-term exposure to drugs of abuse lead to impairment of neuronal mechanisms in the frontal cortex and striatum, thereby enhancing the potency of an impulse and diminishing the ability to exert inhibitory control over impulsive behaviors (for a review, see de Wit, 2009; Jentsch and Taylor, 1999). Traditionally defined, impulsivity includes facets such as poor planning, reduced response inhibition, and the preference for immediate rewards despite negative consequences. Based on a review of recent literature, however, impulsivity does not appear to be a unitary construct (de Wit, 2009; Dougherty et al., 2008; Evenden, 1999; Fernie et al., 2010). At least 2 distinct subcategories of impulsivity have been identified: (i) impulsive decision making and (ii) behavioral inhibition, also referred to as response inhibition (de Wit, 2009). The first, impulsive decision making, is defined as a form of suboptimal decision making that is often characterized by the preference for immediate gratification versus for more advantageous, albeit delayed, outcomes; this phenotype is traditionally measured using delayed discounting paradigms. A second facet of impulsivity, response inhibition, is defined as the suppression of reward-driven behavior or prepotent responses; it is routinely measured with Go/No-Go and stop signal paradigms (Aron, 2007; Olmstead, 2006). More recently, the propensity to make unduly risky decisions has emerged as yet another

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mechanistically distinct aspect of impulsive behavior/temperament (Fernie et al., 2010).

Numerous studies have identified associations between deficits in impulsivity and increased alcohol and substance use (for a review, see Verdejo-García et al., 2008). Alcohol-dependent and heavy-drinking individuals have been shown to exhibit increased rates of impulsive decision making as measured by delay discounting tasks (DDTs; MacKillop et al., 2010; Mitchell et al., 2005; Petry, 2001; Rubio et al., 2007; Vuchinich and Simpson, 1998). Higher scores on measures that have also been purported to assess impulsive decision making (IGT and Cambridge Gambling task) were associated with increased relapse rates after a 3-month follow-up in a sample of patients enrolled in a residential treatment program for alcoholism (Bowden-Jones et al., 2005) and were found to persist after a 6-year follow-up in an abstinent alcohol-dependent sample (Simulated Gambling Task; Fein et al., 2004). Taken together, these results suggest that increased impulsive decision making is associated with alcohol misuse and may maintain long-term abstinence among individuals with alcohol use disorders.

Some support has also been found for decreased response inhibition in alcohol dependence, as measured by commission errors in the continuous performance task and Go/No-Go tasks (Bjork et al., 2004; Kamarajan et al., 2005), and by measures of time required to stop a response in stop signal inhibition tasks (SSTs; Goudriaan et al., 2006; Lawrence et al., 2009). Response inhibition has also been successfully studied using a variant of the SST within a neuroimaging paradigm. Abstinent alcohol-dependent patients were found to have decreased dorsolateral prefrontal cortical activation during response inhibition, decreased medial orbitofrontal cortical activity (an area implicated in prediction error signaling and the detection of contingency change), decreased amygdala activation, and decreased activity in bilateral parietal cortices and the rostral anterior cingulate cortex during task decisions, suggesting that impulsive task decisions elicit less cortical and subcortical activation in individuals with alcohol dependence relative to controls (Li et al., 2009). Additionally, patients within the type II alcoholism category, characterized by a dense family history of alcoholism, earlier onset, and antisocial traits, were found to display greater impairments in inhibitory control than those classified as type I (Bjork et al., 2004).

Nevertheless, studies of social drinking samples have found inconsistent associations between decreased response inhibition and alcohol consumption. For instance, associations were found with heavy social drinking in women but not men (Nederkoorn et al., 2009), and null findings have been reported (Fernie et al., 2010). The mixed results obtained across varying samples of alcohol users suggest that the relationship between response inhibition and alcohol use requires further specification and that sample characteristics ought to be carefully considered.

As risk-taking was conceptualized initially as synonymous with impulsivity, few studies have assessed risk-taking as an isolated predictor of alcohol use. Using a task designed to emphasize the relative risk/reward contingencies, Bjork and colleagues (2004) found both increased impulsivity and increased risk-taking in an alcoholism treatment sample, relative to controls. Further, there is some evidence of genetic vulnerability for alcoholism that is mediated by the brain's response to the negative consequences associated with risky decision making. Reduced feedback error-related negativities, a component of the human event-related brain potential hypothesized to index the impact of reward prediction error signals (Holroyd and Coles, 2002) elicited during the Balloon Analogue Risk Task (BART; Lejuez et al., 2002), were found in alcohol-dependent patients with higher family density of alcohol problems versus those with little or no family history of alcoholism (Fein and Chang, 2008). In a sample of social drinkers, risky decision making measured with the BART predicted alcohol use after controlling for gender and remained significant after controlling for response inhibition (Fernie et al., 2010). Similar results were obtained in a prospective study of early adolescents such that increases in risky decision making over time predicted alcohol use at follow-up (MacPherson et al., 2010). These results suggest a positive relationship between risk-taking and alcohol use; however, further consideration of developmental issues, sample characteristics, and the definition of risk-taking itself is needed before stronger conclusions can be drawn. Moreover, these studies highlight the need to concomitantly assess the various facets of impulsivity to determine their relative contribution to alcohol use and abuse phenotypes.

This study seeks to address discrepancies in the impulsivity and alcohol use literature by simultaneously testing 3 dimensions of impulsivity (risk-taking, response inhibition, and impulsive decision making) as determinants of alcohol use and alcohol problems in a sample of nontreatment seeking problem drinkers. Structural equation modeling (SEM) analyses employed behavioral measures of impulsive decision making (DDT), response inhibition (SST), and risky decision making (BART), as well as a self-report measure of risk-attitudes (domain-specific risk-attitude scale [DOSPERT]), as predictors of alcohol use and of alcohol-related problems in a sample of problem drinkers. Consistent with the recognition of the multidimensionality of impulsivity, this study seeks to advance the literature by providing a more integrative evaluation of various subtypes of impulsivity and their relative contribution to alcohol use and alcohol problems by testing an a priori model of impulsivity and alcohol outcomes. Based on the available literature on the multifaceted nature of impulsivity, the a priori model allowed for each dimension to form its own latent structure, which in turn were used as determinants of alcohol use and alcohol problems separately. It was hypothesized that all factors would be associated with alcohol use and alcohol problems and that impulsive decision making would have the strongest association with alcohol outcomes based on effect sizes obtained in a recent meta-analysis of delayed reward discounting and addiction (Pryor and MacKillop, 2009).

MATERIALS AND METHODS

Participants

Nontreatment seeking problem drinkers ($n = 155$) were recruited from the Los Angeles community through flyers, print, and online advertisements, as part of a larger alcohol administration study. Inclusionary criteria were (i) age between 21 and 65; (ii) self-identification of problems with alcohol; and (iii) telephone endorsement of consuming a minimum of 48 standard drinks per month. The exclusion criteria were (i) current treatment for alcohol problems, history of treatment in the 30 days prior to enrollment, or currently seeking treatment; (ii) not having an alcoholic drink within 21 days of the telephone screening interview; or (iii) history of bipolar or psychotic disorder, or a positive evaluation for these disorders during a structured diagnostic interview (see Table 1 for sample demographics).

Procedures

Interested individuals called the laboratory and completed an initial telephone screening interview to assess for the inclusion and exclusion criteria outlined earlier. During this telephone interview, participants were asked about their alcohol use (quantity and frequency) to assess whether they met the criteria for problem drinking. They were also asked whether they had ever been diagnosed with bipolar disorder or a psychotic disorder, and whether they were interested in receiving any treatment now or have received any treatment for alcohol problems (including formal treatment and/or use of self-help groups) in the past 30 days. Treatment seekers were excluded as a later phase of the study included an alcohol administration. Those who did indicate a desire for treatment were provided with a list of referrals. Eligible participants were invited to the laboratory for a face-to-face assessment session, which included the BART, DDT, SST, and DOSPERT. Prior to the assessment procedures, all participants provided written informed consent upon receiving a complete explanation of the study. Blood alcohol concentration (BAC) equal to 0.00 g/dl, as verified by a Breathalyzer test (Dräger, Telford, PA), was required before assessment commenced. Participants were compensated with \$40 for participation in the face-to-face assessment procedure, as well as up to an additional \$5 based on performance on the BART (outlined later). All procedures were approved by the Institutional Review Board of the University of California, Los Angeles.

Table 1. Sample Demographics

Variable	Percent or mean (SD)
Age	30.29 (10.49)
Sex: Male (%)	71.9
Ethnicity (%)	
White	46.7
African American	20.4
Asian	6.6
Latino	11.8
Other/mixed	11.2
Not specified	3.3
Education	14.8 (2.26)
ADS score	15.69 (7.02)
Males	16.05 (7.27)
Females	14.88 (6.42)
Cigarettes per day (%)	
0	43.1
1 ≤ 10	40.3
>10	16.6

ADS, Alcohol dependence scale.

Measures

Demographic information was collected from all participants, including age, sex, ethnicity, and education. In addition, multiple self-report and behavioral measures were obtained as described below.

Alcohol Use. The 30-day timeline follow-back (TLFB) interview (Sobell and Sobell, 1980) was used to assess drinking behavior including detailed data on the quantity and frequency of alcohol use over a 30-day period. An alcohol binge was defined as consuming 4 or more drinks within a given episode for a woman and 5 or more drinks for a man. The following measures of alcohol use were derived from the 30-day TLFB and used in the analyses: (i) average drinks per drinking day (DRINKS) and (ii) percent binge drinking days (BINGE).

Alcohol Problems. Alcohol dependence and the exclusionary psychiatric diagnoses were assessed using the structured clinical interview for DSM-IV (SCID; First et al., 1995) by bachelor's degree-level interviewers or graduate students under the training and supervision of a licensed clinical psychologist (LAR). DSM-IV symptoms of alcohol abuse and dependence were recorded, for a total of 11 possible symptoms (4 of abuse and 7 of dependence) comprising the indicator variable COUNT. In addition, participants completed the alcohol dependence scale (ADS), a 25-item self-report quantitative measure of the severity of alcohol dependence symptoms (Skinner and Allen, 1982). The ADS items cover alcohol withdrawal symptoms, impaired control over drinking, awareness of a compulsion to drink, increased tolerance to alcohol, and salience of drink-seeking behavior, occurring within the past 12 months. A total ADS score was tabulated for each participant and included in the model as the indicator variable ADS. Last, the Drinker Inventory of Consequences (DrInC)—a self-administered 50-item questionnaire designed to measure adverse consequences of alcohol abuse in the following 5 areas, interpersonal, physical, social, impulsive, and intrapersonal—was administered (Miller et al., 1995). The 5 subscale scores were summed to provide a single indicator variable of negative drinking consequences (DRINC). Thus, the 3 indicator variables for the alcohol problems latent variable include (i) alcohol dependence symptom count (COUNT), (ii) alcohol dependency score (ADS), and (iii) negative drinking-related consequence (DRINC).

Risky Decision Making. A modified version of the BART (Lejuez et al., 2002) was administered to assess risky decision making. Participants were presented with a picture of a balloon on a computer screen (via MATLAB, v7.5; The MathWorks Inc., Natick, MA) and instructed to press 1 of 2 keys: 1 to inflate the balloon ("pump"), and 1 to end the trial ("cash out") and move on to the next trial. With each pump, the balloon would near-instantly inflate by a small amount on the screen, and a minute amount of money (\$0.003) was continuously tallied. Participants chose at each pump whether to continue to inflate the balloon, or to press the "cash out" key to end the trial, add the tallied money to the guaranteed "bank," and begin the next trial. However, a certain amount of risk is applied to each pump, such that inflation to a certain point will cause the balloon to visibly explode on the screen resulting in a loss of money earned so far on that trial. Risk of balloon explosion was distributed following a normal distribution with a mean at the midpoint of possible pumps (32 of 64 possible pumps) and a standard deviation of 20. Each session consisted of 72 trials. As the inclusion of pumps made in trials that resulted in explosions may negatively bias the mean, the adjusted mean pumps (AMP) was used as a primary variable of risky decision-making propensity (Lejuez et al., 2002). The average number of pumps on trials immediately following a trial failure (postfailure mean pumps [PFMP]) was also calculated and included in the model given the theoretical relevance of postpunishment responding in alcohol use disorders. Therefore, the indicator variables extracted include (i) AMP and (ii) PFMP.

Risk-Attitudes. The DOSPERT, a 30-item self-report measure of risk-attitudes, was included to complement the BART. This self-report measure assesses attitudes toward risk-taking in 5 content domains: financial decisions, health/safety, recreational, ethical, and social (Blais and Weber, 2006). Participants were instructed to rate the likelihood that they would engage in domain-specific risky activities using a 7-point rating scale ranging from 1 (extremely unlikely) to 7 (extremely likely), with subsequent total scores ranging from 30 to 210. Higher scores represent an increased likelihood of engaging in risky behaviors. The following indices were used: (i) total score on the financial subscale (FINANCE), (ii) total score on the health/safety subscale (HEALTH), (iii) total score on the recreational subscale (REC), (iv) total score on the social subscale (SOCIAL), and (v) total score on the ethical subscale (ETHICS).The standardized Cronbach alpha coefficients for the subscales in this sample were found to be 0.711, 0.602, 0.837, 0.709, and 0.837, respectively, which are similar to those found in the normative sample of the scale (0.83, 0.71, 0.86, 0.79, and 0.75, respectively). Additionally, the means and standard deviations were found to be similar to those from the normative sample (Blais and Weber, 2006).

Impulsive Decision Making. The DDT was administered as a measure of impulsive decision making. In this task, participants were asked to make a series of 27 hypothetical choices by pressing 1 of 2 keyboard buttons between small immediate rewards and larger delayed rewards. The stimuli came from a previously validated measure of discounting (Kirby et al., 1999), and participants were instructed to respond as if the rewards (i.e., money) were real. Choice patterns were analyzed to estimate hyperbolic discounting functions derived from the following equation: $V = A/(l + kD)$, where V is the present value of the delayed reward A at delay D, and k is a free parameter that determines the discount rate (Mazur, 1987). As k increases, the individual discounts the future reward more steeply; therefore, it can be thought of as an impulsiveness parameter, with higher values corresponding to higher levels of impulsive decision making. These k scores index the preference for smaller immediate rewards relative to larger delayed rewards, akin to the ability to delay gratification. Three k variables were extracted from this measure, each pertaining to different magnitudes of reward: Means = $25, $55, $85; SEM variables (i) K-SM, (ii) K-MED, and (iii) K-LG, respectively.

Response Inhibition. Response inhibition was assessed using the SST, which consists of 64 total trials. On each trial, a left- or right-pointing arrow was presented on the computer screen, with the participants instructed to quickly press the arrow key on the keyboard corresponding to the direction of the arrow presented on the screen (Go trial). For the stop trials (25% of trials), a tone sounded at varying delays after onset of the Go stimulus, which signaled participants to attempt to inhibit their response. The time interval between the go and the stop signals [or the stop signal delay (SSD)] started at 250 ms for ladder 1 and 350 ms for ladder 2, and varied from 1 stop trial to the next according to a staircase procedure: If the subject succeeded in withholding the response, the SSD increased by 50 ms; conversely, if they failed, the SSD decreased by 50 ms. From this procedure, an average SSD was computed for each ladder of trials that represents the time delay required for the participant to succeed in withholding a response in the stop trials half of the time (Logan, 1994). The Go process was characterized by median reaction time to respond in trials assuming 50% probability to inhibit (MGRT50). Three indicator variables were extracted for use in the model: (i) SSD for ladder 1 (SSD1), (ii) SSD for ladder 2 (SSD2), and (iii) MGRT assuming 50% probability to inhibit (MGRT50).

Data Analytic Plan—SEM

The a priori multidimensional model of impulsivity was tested using a SEM framework. The hypothesized model examined the relationships between the 4 impulsivity latent constructs (risky decision making, risk-attitudes, impulsive decision making, and response inhibition) and latent constructs representing alcohol use and alcohol problems. Consistent with the literature, it was hypothesized that the 4 latent dimensions of impulsivity would be associated and as such interfactor correlations were specified between them. The latent constructs included indicator variables as defined in the measures section. A 2-step approach was used to identify and select appropriate indicators to include in the model. The first step was to identify the variables of each task that were consistent with what is conventionally used in the literature to model each individual task. The second step involved assessing the loadings of these indicator variables onto their respective constructs within the model, resulting in the removal of 1 indicator variable as described later. The variances of the 4 impulsivity constructs were constrained to equal 1 to standardize the metrics of the constructs. Modeling analyses were conducted using the EQS version 6.1 for Windows SEM program (Bentler, 1995). Owing to the skewed distribution of alcohol use and problems in this sample of problem drinkers, robust statistics that correct for nonnormality will be reported for all estimates of model fit. Statistical model fit was assessed with the Satorra–Bentler scaled chi-squared fit index (Satorra and Bentler, 2001). However, the use of the chi-square likelihood ratio test to assess model fit has been deemed unsatisfactory for numerous reasons (see Tanaka, 1993), so a relative estimate (ratio of chi-square to degrees of freedom) was also calculated. Values <2 on the relative chi-square indicate adequate model fit (Byrne, 1989). Descriptive model fit was assessed with the robust versions of the comparative fit index (CFI; Bentler, 1990) and the root mean square error of approximation (RMSEA; Browne and Cudeck, 1993). Both the CFI and the RMSEA are sensitive to model misspecification and are minimally affected by sample size (Hu and Bentler, 1995). The CFI ranges from 0 to 1, with values above 0.90 indicating acceptable fit (Bentler, 1990). The RMSEA ranges from 0 to 8, where fit values <0.05 indicate close fit and values <0.10 indicate reasonable fit (Steiger, 1990).

RESULTS

Descriptive Statistics

Six subjects were removed from the analyses as a result of positive assessments for either bipolar disorder or psychosis, as determined by the SCID, and 10 others were excluded because of missing data on 1 or more of the neurocognitive measures, leaving a total of 139 subjects (42 women, 97 men) in the analyses reported herein. Of those, 71.9% met DSM-IV criteria for alcohol dependence, 15.2% met criteria for alcohol abuse only, 8.6% were diagnostic orphans (i.e., endorsed 1 or 2 dependence symptoms but did not meet diagnostic criteria for either alcohol abuse or dependence), and 4.3% did not endorse any symptoms of either alcohol abuse or dependence. Means and standard deviations on all study measures are presented in Table 2.

SEM Model Results

The model was found to fit well statistically (S-B scaled χ^2 [120, n = 139] = 194.30; relative χ^2 = 1.619) and descriptively (CFI = 0.935, RMSEA = 0.067). As the sample is

Table 2. Means and Standard Deviation (SD) for All Observed Model Parameters

Construct	Variable	Mean	SD
Alcohol use	DRINKS	7.00	4.57
	BINGE	0.69	0.28
Alcohol problems	ADS	15.69	7.02
	DRINC	44.25	22.12
	COUNT	5.41	2.95
Risky decision making (BART)	AMP	18.81	4.02
	PFMP	17.88	3.83
Risk-attitudes (DOSPERT)	FINANCE	18.53	6.98
	HEALTH	22.32	6.62
	REC	23.37	9.27
	SOCIAL	29.74	7.16
	ETHICS[a]	16.94	6.44
Impulsive decision making (DDT)	K-SM	0.07	0.07
	K-MED	0.06	0.08
	K-LG	0.05	0.07
Response inhibition (SST)	SSD1	275.25	100.05
	SSD2	299.89	97.74
	MGRT50	500.50	100.46
	MGRT[a]	499.17	86.49
	SSRT[a]	214.78	63.59

[a]Parameter excluded from final model.

BART, Balloon Analogue Risk Task; DOSPERT, domain-specific risk-attitude scale; DDT, delay discounting task; SST, stop signal task; DRINKS, average drinks per drinking day; BINGE, percent binge drinking days; ADS, severity of alcohol dependence; DRINC, negative drinking consequences; COUNT, DSM-IV alcohol abuse/dependence symptoms; AMP, adjusted mean pumps; PFMP, postfailure mean pumps; FINANCE, financial subscale; HEALTH, health/safety subscale; REC, recreational subscale; SOCIAL, social subscale; ETHICS, ethical subscale; K-SM, *k* value for small magnitude rewards; K-MED, *k* value for medium magnitude rewards; K-LG, *k* value for large magnitude rewards; SSD1, stop signal delay for ladder 1; SSD2, stop signal delay for ladder 2; MGRT50, median go reaction time assuming 50% probability to inhibit; MGRT, mean go reaction time; SSRT, stop signal reaction time.

comprised of problem drinkers and not individuals with alcohol use disorders per se, a model excluding diagnostic orphans and individuals who did not endorse any alcohol use disorder symptoms (assessed using the SCID) was also tested; however, the results were found to be virtually identical (S-B scaled χ^2 [120, n = 122] = 182.51; relative χ^2 = 1.52, CFI = 0.935, and RMSEA = 0.066), and therefore, the entire sample was retained for subsequent analyses. Inspection of the indicator loadings for all factors identified 1 variable that accounted for very little variance, the ethical subscale from the DOSPERT (ETHICS; β = 0.424, R^2 = 0.18), so it was dropped from the model. The model was reanalyzed without this indicator variable and the resulting fit indices were as follows: S-B scaled χ^2 [104, n = 139] = 155.89, relative χ^2 = 1.50, CFI = 0.952, and RMSEA = 0.060. The final estimated model, with standardized path coefficients, is presented in Fig. 1. This model accounted for 38% of the variance in alcohol problems. The following results are based on this final model, with the standard statistical significance threshold of $p < 0.05$ employed.

As 16.6% of this sample identified themselves as current regular smokers (smoking more than 10 cigarettes per day), the effects of current smoking status on the impulsivity constructs were analyzed. To do so, multivariate analyses of variance were estimated for each impulsivity construct separately, including current smoking status as the only grouping factor. The effect of current smoking status was not found to be significant for any of the impulsivity constructs, even when the criteria for regular smoker was lowered to smoking 1 or more cigarettes per day (ps < 0.05), and thus current smoking status was not considered in subsequent analyses. Within each latent construct, all standardized factor loadings were generally large and statistically significant (absolute values ranged from 0.621 to 0.971, with the exception of the financial subscale of the DOSPERT loading at 0.415). The interfactor correlation between the risky decision making and risk-attitude constructs was moderate and statistically significant (r = 0.379), suggesting that the BART and DOSPERT measure separate, but related, aspects of risk-taking. The interfactor correlations between risky decision making and impulsive decision making (r = −0.343), and risk-attitudes and impulsive decision making (−0.434) were found to be significant as well, suggesting that steeper delayed discounting rates are associated with more conservative risk-taking. Response inhibition failed to correlate with the other impulsivity constructs (ps > 0.05). The variation in degree and direction of the interfactor correlations provides further support for the argument to assess risk-taking and response inhibition as distinct subtypes of impulsivity.

As expected, the path from alcohol use to alcohol problems was found to be statistically significant (β = 0.357). The impulsive decision making construct loaded highly and significantly onto both alcohol outcomes (β = 0.233 for alcohol use and β = 0.370 for alcohol problems). The effect decomposition of the impulsive decision-making factor on alcohol problems (including the direct and indirect paths) was found to be 0.453, suggesting higher k values are associated with a greater occurrence of alcohol problems. Self-reported risk-attitudes failed to reach significance for either path to the alcohol outcome constructs (β = 0.042 for alcohol use and β = 0.201 for alcohol problems), whereas the behavioral risky decision-making construct loaded significantly and negatively onto alcohol problems (β = −0.219), but not alcohol use (β = −0.049). The differential loadings from the constructs of risk-taking suggest behavioral measures of risk-taking are better able to capture the variance in alcohol problems as compared to self-report measures; however, the (unexpected) negative relationship warrants further investigation. Lastly, response inhibition failed to significantly load onto either alcohol outcome construct (β = −0.069 for alcohol use and β = 0.041 for alcohol problems). Together, these results support the multidimensional nature of impulsivity as well as the differential contribution of the subtypes of this construct to alcohol use and alcohol problems independently in this sample of problem alcohol drinkers.

DISCUSSION

This study sought to extend the current literature on impulsivity and alcohol use by simultaneously examining an a

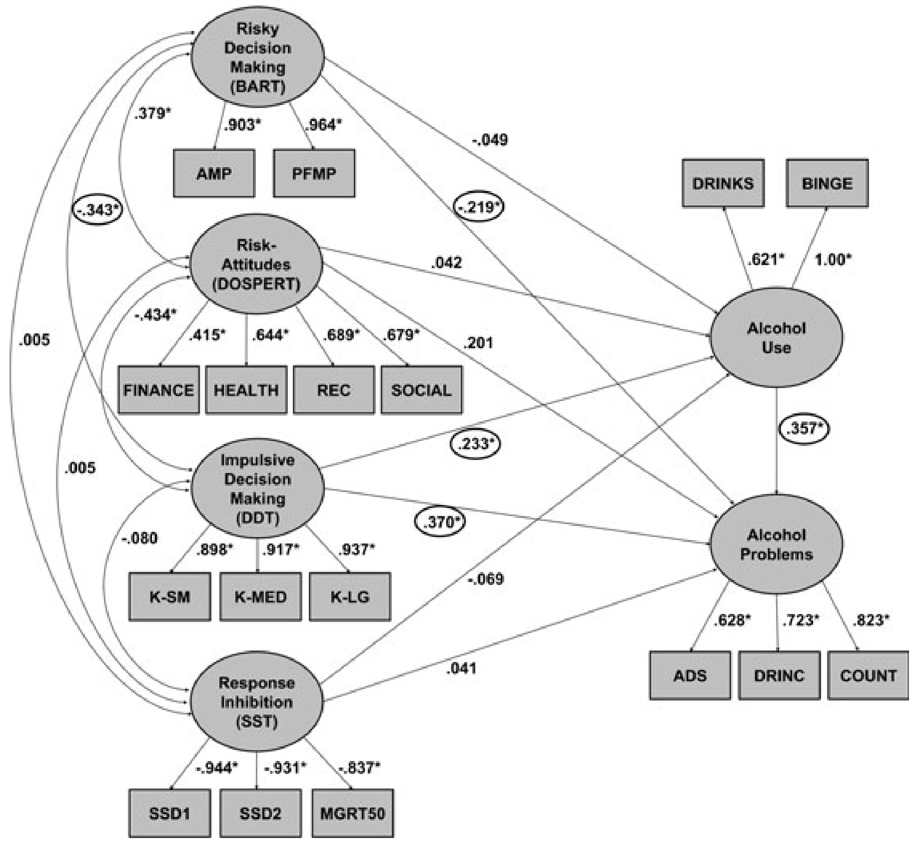

Fig. 1. Model of alcohol use and problems among problem drinkers including measures of 3 dimensions of impulsivity (risky decision making, impulsive decision making, and response inhibition). Coefficients are standardized path coefficients. *$p < 0.05$. Alcohol use variables: DRINKS, average drinks per drinking day; BINGE, percent binge drinking days. Alcohol problem variables: COUNT, DSM-IV alcohol abuse/dependence symptoms; ADS, severity of alcohol dependence score; DRINC, negative drinking consequences score. Balloon Analogue Risk Task (BART) variables: AMP, adjusted mean pumps; PFMP, post failure mean pumps. Domain-specific risk-attitude scale (DOSPERT) variables: FINANCE, financial subscale score; HEALTH, health/safety subscale score; REC, recreational subscale score; SOCIAL, social subscale score. Delay discounting task (DDT) variables: K-SM, *k* value for small magnitude rewards (~\$25); K-MED, *k* value for medium magnitude rewards (~\$55); and K-LG, *k* value for large magnitude rewards (~\$85). Stop signal task (SST) variables: SSD1, stop signal delay for ladder 1; SSD2, stop signal delay for ladder 2; MGRT50, median go reaction time assuming 50% probability to inhibit.

priori model with multiple dimensions of impulsivity and to determine how each dimension relates to alcohol consumption and problems in a large community sample of problem drinkers. Three subtypes of impulsivity were included in the model (impulsive decision making, response inhibition, and risky decision making, along with a self-report measure of risk-attitudes), with direct and indirect paths from each subtype to alcohol use and alcohol problems simultaneously estimated. The interrelations between the impulsivity subtypes were found to support the emerging view that such dimensions assess related but distinct aspects of the global impulsivity construct. Notably, the current model suggests that response inhibition (i.e., the ability to inhibit a prepotent response) indexes a qualitatively disparate facet of global impulsivity not related to risk-taking or impulsive decision making, as observed in the nonsignificant interfactor correlations, in the present sample of problem drinkers.

The impulsive decision-making construct, indicated by k parameters from the DDT, was identified as the strongest predictor of both use and problems, implying higher levels of delayed discounting are associated with greater alcohol consumption and the experience of more alcohol-related problems. This construct was found to load higher onto alcohol problems than alcohol use, suggesting it may best capture the impulsivity variance predictive of the negative consequences associated with alcohol use over and above the effects of alcohol consumption per se. These findings converge with a number of previous studies revealing a significant association between discounting and alcohol misuse (MacKillop et al., 2010; Mitchell et al., 2005; Petry, 2001).

In contrast, however, previous studies assessing samples of social drinkers did not find a significant association between impulsive decision making and alcohol misuse (Fernie et al., 2010; MacKillop et al., 2007), suggesting that this form of impulsivity is more specific to higher levels of drinking pathology. Importantly, impulsive decision making has also be found to be associated with poor treatment response for both alcohol (Tucker et al., 2002, 2006) and tobacco (Krishnan-Sarin et al., 2007; MacKillop and Kahler, 2009), suggesting it is relevant to both alcohol use disorder severity and clinical outcomes. There is also an increasing understanding of the neurobiology of discounting, from animal models (Cardinal et al., 2001), genetic association studies (Eisenberg et al., 2007), and human neuroimaging studies (Bickel et al., 2009; McClure et al., 2004). In the same spirit that the current study used SEM to concurrently contextualize the multiple indices of impulsivity, it will be important for future studies to concurrently clarify the neurobiological, behavioral, and clinical dimensions of discounting.

In contrast to the Fernie and colleagues (2010) results, the risky decision-making construct was found to load significantly and negatively onto alcohol problems, suggesting that increased risky decision making is related to fewer alcohol-related problems and not related to alcohol use. This finding may be dependent on the current sample, as the Fernie and colleagues (2010) study sampled from a population of social drinkers in contrast to the problem drinkers recruited in the present study. However, a similar negative trend was observed between BART performance and risky behaviors in a sample of young adult cigarette smokers, where greater pumping was found to relate to positive traits (e.g., nonsmoking, employment, years of education, and higher IQ; Dean et al., 2011). The negative relationship observed in the current model, as well as the findings by Dean and colleagues (2011), could potentially be a byproduct of the task, as the range of balloon pumps in the current sample was restricted, resulting in the higher pump values being associated with better outcomes on the task.

Alternatively, it has been proposed that risk-taking need not only be considered as a predictor of negative outcomes and may at times be advantageous (Gullo and Dawe, 2008). Higher levels of risk-taking have been reported in successful entrepreneurs versus managers (Stewart and Roth, 2001). It is possible that nonimpulsive decision makers could benefit from taking greater risks in decision making, whereby having the propensity to engage in both impulsive and risky decision making could result in negative outcomes overall. Additionally, other positive consequences associated with risk-taking, such as peer approval and the pleasurable effects of substance use, may subjectively outweigh long-term negative consequences (Fernie et al., 2010). However, if this were the case, the same relationship to alcohol problems would be expected for the risk-attitudes construct as well, which was not found to exist in the current model. It is possible that the problem drinkers in this sample preferred the immediate reward of cashing in early on the BART trials (consistent with the impulsive decision-making findings) rather than continuing to pump the balloon, which would increase their chance of earning or losing greater sums of money; however, further investigation as to the nature of this negative relationship is warranted.

Surprisingly, the response inhibition construct failed to reach significance onto either alcohol outcome construct. This is not the first report of null findings on a response inhibition measure in a sample of problem drinkers (Mitchell et al., 2005), or tobacco users (Galván et al., 2011), and suggests that response inhibition may not be relevant to alcohol misuse as a trait variable; however, it is possible that response inhibition could differentiate between groups of problem drinkers and nonproblem drinkers. In fact, there is extensive evidence that it is highly sensitive to alcohol's effects (de Wit et al., 2000; Easdon et al., 2005; Fillmore and Rush, 2001; Fillmore and Vogel-Sprott, 1999; Marczinski and Fillmore, 2003; Mulvihill et al., 1997; Ramaekers and Kuypers, 2006). Importantly, these deficits are often observed at BACs below the U.S. limit of 0.08%, indicating that inhibitory control is sensitive to the effects of alcohol even at doses that are considered to be below the threshold of intoxication (Fillmore, 2003). Interestingly, interindividual variation in Go/No-Go performance following a single dose of alcohol has recently been shown to predict subsequent ad libitum alcohol consumption (Weafer and Fillmore, 2008). Thus, it may be that motor impulsivity is primarily related to alcohol misuse as a mechanism of alcohol's intoxicating effects.

This study must be interpreted in light of its strengths and weaknesses. This was a cross-sectional examination of problem drinkers, thereby precluding causal inferences. Additionally, although considered large for the nature of the sample, the sample size is not sufficient for further inquiry into sample characteristics such as the influence of age or gender within the specified SEM model. Future studies might address these limitations by recruiting larger samples within a longitudinal framework. Future research employing an SEM framework, such as the one proposed herein, is well suited for capturing the neural and genetic bases of impulsivity and its association with alcohol use outcomes. Such integrative models would allow us to more fully capture the complexity of impulsivity and its behavioral correlates.

On balance, this study extends the literature by utilizing a SEM analysis approach to simultaneously examine multiple measures of impulsivity and alcohol use/problems in a sample of problem drinkers. Although the model fits the data well, accounting for 38% of the variance in alcohol problems, the analysis identified only 2 impulsivity dimensions that significantly loaded onto the alcohol outcome constructs: (i) impulsive decision making, indexed by the DDT; and (ii) risky decision making, measured by the BART. The results highlight the importance of considering the distinct facets of impulsivity to elucidate their singular and combined effects on alcohol use initiation, escalation, dependence, and maintenance.

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