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Impulsivity partially mediates the association between reduced working memory capacity and alcohol problems

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ABSTRACT

Although alcohol use disorders (AUDs) have been associated with impulsive personality traits and reduced working memory capacity (WMC), less is known about the nature of their interrelationships. This study was designed to test the hypothesis that low WMC is associated with both impulsive personality and alcohol problems, and that impulsive personality mediates the association between low WMC and alcohol problems. Measures of impulsive personality, WMC, and alcohol problems were assessed in a sample of young adults ($N = 474$), that varied widely in severity of alcohol problems, 57% of whom had alcohol dependence. Simple correlations revealed that WMC, impulsive personality traits, and alcohol problems were all significantly related. Structural equation models (SEMs) showed that impulsivity partially mediated the association between WMC and alcohol problems. Although directionality cannot be determined from these cross-sectional data, the results suggest that reduced WMC may promote impulsivity, which in turn, predisposes to alcohol problems.

Introduction

Poor self-regulation is a fundamental feature of alcohol use disorders (AUDs). AUDs are associated with undercontrolled, impulsive personality (Finn, Mazas, Justus, & Steinmetz, 2002; Finn, Sharkansky, Brandt, & Turcotte, 2000; Magid, MacClean, & Colder, 2007) and reduced working memory capacity (Aytaclar, Tarter, Kirisci, & Lu, 1999; Finn & Hall, 2004; Finn et al., 2002, 2009; Noël, Bechara, Dan, Hanak, & Verbanck, 2007), both of which contribute to, or reflect, problems with self-regulation. Although both impulsive personality and low working memory capacity are associated with poor self-regulation which contribute to a vulnerability for AUDs (Finn, 2002), less is known about their inter-relationship and whether they reflect similar or different vulnerability mechanisms for AUDs. The purpose of this study was to investigate evidence in support of the hypothesis that low working memory capacity promotes increased impulsivity, which, in turn, increases vulnerability to alcohol problems and excessive alcohol use.

Impulsive personality and AUDs

Numerous cross-sectional and prospective studies demonstrate that impulsive, undercontrolled, personality traits are associated with high levels of alcohol use and lifetime alcohol problems (Caspi, Moffitt, Newman, & Silva, 1996; Castellanos-Ryan, Rubia, & Conrod, 2011; Chassin, Flora, & King, 2004; Cloninger, Sigvardsson, & Bohman, 1988; De Wit, 2009; Finn et al., 2000, 2002; Magid et al., 2007; Smith et al., 2007; Verdejo-García, Lawrence, & Clark, 2008; Whiteside & Lynam, 2003; Wills, Vaccaro, & McNamara, 1994). Alcohol and other substance use disorders also are associated with elevated levels of impulsivity on different behavioral tasks as well (Bjork, Hommer, Grant, & Danube, 2004; Bobova, Finn, Rickert, & Lucas, 2009; Finn, 2002; Finn, Mazas, Justus, & Steinmetz, 2002; Kirby, Petry, & Bickel, 1999; Petry, 2001).

Although impulsivity is conceptualized in a number of different ways (Evenden, 1999; MacKillop, Mattson, Anderson MacKillop, Castelda, & Donovick, 2007), we conceptualize impulsivity narrowly as reflecting increased appetitive motivation in combination with difficulties inhibiting approach behavior, once it is primed or activated (De Wit, 2009; Finn, 2002). We consider impulsivity to be associated with fundamental problems in the self-regulation of approach behavior reflected in failures to inhibit those approach behaviors that lead to a greater likelihood of negative consequences (Finn, 2002; Luego, Carrillo de la Pena, & Ortero, 1991). Other conceptualizations of impulsivity include characteristics such as sensation seeking or risk taking (Evenden, 1999; Whiteside & Lynam, 2003), which we consider as separate, but correlated traits, associated with different mechanisms. A narrow definition has the advantage of focusing more on specific mechanisms rather than a broader range of mechanisms. Impulsivity is significantly associated with a number of indicators of poor

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self-regulation, such as alcohol problems, antisocial – externalizing behavior, and poor emotional regulation (Caspi et al., 1996; Chassin et al., 2004; Finn, 2002; Finn et al., 2002; Krueger, Caspi, Moffit, Silva, & McGee, 1996; Magid et al., 2007; Trasseger & Robinson, 2009).

Similar to other traits, (e.g., De Wit, 2009; Patton, Stanford, & Barratt, 1995; Swann, Bjork, Moeller, & Dougherty, 2002), impulsivity is considered to reflect a number of interactive mechanisms (Finn, 2002) that ultimately result in self-control deficits manifested as difficulties inhibiting impulses once approach behavior has been activated (Finn et al., 2002), decreased inhibitory motor control (Castellanos-Ryan et al., 2011; Logan, Schachar, & Tannok, 1997), and a lack of tolerance for delay, as in increased discounting of delayed rewards or difficulties delaying gratification (Bobova et al., 2009). The aim of the current study is to investigate the hypothesis that low working memory capacity and the personality trait of impulsivity reflect, in part, a common mechanism associated with poor self-regulation which contributes to alcohol problems.

Working memory capacity, impulsivity, and alcohol problems

Executive functioning relies heavily on adequate levels of working memory capacity for effective self-direction (Finn, 2002; Kimberg & Farah, 1993). Working memory capacity plays a critical role in self-regulation and decision-making (Barkley, 1997, 2001; Bechara & Martin, 2004; Finn, 2002; Kimberg & Farah, 1993), providing the capacity and space for deliberation, self-reflection, and hypothetical reasoning processes that are essential in adaptive decision-making (Barkley, 2001; Finn, 2002; Oberauer, 2002). We and others theorize that a larger working memory processing capacity facilitates attention shifting during decision-making from more salient, temporally proximal (immediate) to less salient, distal (future) outcomes, while simultaneously allowing for the consideration of future consequences of decisions (Finn, 2002; Finn & Hall, 2004; Oberauer, 2002). A larger working memory capacity is associated with the capacity to keep in mind more items, even under distraction (Finn, 2002; Finn et al., 2002). Highly salient information is more easily retained in working memory because of it's primacy and because it attracts more attentional resources (Fine & Minnery, 2009; Finn, 2002; Shih, 2008). However, lower salient information is more difficult to retain in working memory, in part because of interference effects from higher salient information in working memory (Finn, 2002). In general, those with a high working memory capacity can more easily retain both high and lower salient information in mind, while those with low working memory capacity have greater difficulty retaining low salient information (Finn, 2002). Impulsivity reflects, in part, a tendency to behave in response to immediate contingencies (e.g., rewards) and not to regulate behavior in accordance with long term (less salient) outcomes. Thus, those with a high working memory capacity are able to utilize less salient information, which is often information about future outcomes, to guide their behavior and are therefore less impulsive. On the other hand, those with lower working memory capacity show poor impulse control (i.e., greater impulsivity), because they are less able to keep in mind and utilize less salient, distal information about behavioral outcomes, and are more likely to be driven by immediate, highly salient information (Barkley, 1997, 2001; Finn, 2002; Finn et al., 2002; Hinson, Jameson, & Whitney, 2003).

Indicative of its association with poor self-regulation, low working memory capacity is associated with alcohol problems (Finn, 2002; Finn & Hall, 2004; Finn et al., 2009; Verdejo-García et al., 2008) and externalizing problems such as childhood conduct problems, adult antisocial behavior, other substance abuse problems, and attention-deficit-hyperactivity disorder (Barkley, 1997; Finn et al., 2009). We propose that low working memory capacity contributes to higher levels of impulsivity, a trait indicative of poor self-regulation, which in turn predisposes to alcohol problems. Although some studies suggest an association between low working memory capacity and laboratory tasks of impulsive decision-making, such as the delay discounting task (Bobova et al., 2009; Hinson et al., 2003), an association between personality measures of impulsivity and low working memory capacity has yet to be demonstrated. The current study investigates this by testing the hypotheses that (i) low working memory capacity will be associated with more alcohol problems, (ii) impulsivity will be associated with more alcohol problems, and, (iii) impulsivity will account for a significant portion of the variance in alcohol problems associated with working memory capacity (i.e., impulsivity mediates the relationship between low working memory capacity and alcohol problems).

Materials and methods

Participants

Recruitment

Participants were recruited using a strategy designed to select a sample that varied widely in impulsive, externalizing behavior with approximately half of the sample meeting DSM-IV criteria (American Psychological Association, 1994) for alcohol dependence (Finn et al., 2009). The recruitment strategy, outlined below, used advertisements designed to recruit a sample of alcohol dependent subjects who varied considerably in their level of disinhibited, externalizing behaviors and problems. In fact, in Finn et al. (2009) we showed substantial heterogeneity within the alcohol dependent sample on measures of externalizing problems and cognitive capacity. This strategy involved using newspaper advertisements and flyers placed around a university campus and local town asking for responses from persons who varied in terms of alcohol consumption levels, alcohol problems, antisocial behavior, impulsivity, and social deviance (cf. Finn et al., 2009). The advertisements/flyers requested responses from a range of individuals using statements such as: *"Are you a heavy drinker?", "Did you get into a lot of trouble as a child?", "Are you a more reserved and introverted type of person?", "WANTED: Subjects interested in psychological research", "Are you impulsive?", "WANTED: Males/Females, 18–25 yrs old, who only drink modest amounts of alcohol and who do not take drugs.", "Do you think you have a drinking problem?", "Are you adventurous (daring, etc)?: Psychologist studying adventurous carefree people who have led exciting impulsive lives..."*.

Telephone screening interview

Each participant who responded to the advertisements and flyers was administered a telephone screening interview. The interview began with a short description about the nature of the study, followed by a series of questions regarding the predetermined inclusion/exclusion criteria. Criteria questions addressed demographic and medical information, symptoms of alcohol and drug abuse and dependence, childhood conduct disorder, antisocial personality disorder, and attention-deficit hyperactivity disorder. Those who met the criteria were then described additional necessary information about the study. Potential participants were told the study would take a total of nine hours, divided into three testing sessions; and would be compensated with hourly pay for their participation. Participants were informed they would be required to take a breath-alcohol test upon arrival at the laboratory. It was requested that they refrain from consuming alcoholic beverages or using recreational drugs within 12 h of arriving for the experiment. It was also requested that they

get at least 6 h of sleep the night before and eat within 3 h of the testing session.

Study exclusion criteria

Participants were excluded from the study if they (a) were not between the ages of 18 and 30, (b) could not read or speak English, (c) did not have at least a 6th grade education level, (d) had never consumed alcohol, (e) were currently taking prescription drugs that affect behavior, (f) had a history of severe psychological problems, (g) or a history of major cognitive impairments or head trauma. At the beginning of each session, participants were asked about their alcohol and drug use over the past 12 h and were given a breath alcohol test using an Alco Sensor IV (Intoximeters Inc., St. Louis, MO). If a participant reported using any drugs within the past 12 h, had a breath alcohol level above .0%, reported feeling hung over or sleepy, or were unable to answer test questions, they were excluded from participation at that session and rescheduled.

Sample characteristics

The entire sample consisted of 474 young adults, 222 males and 252 females. Table 1 presents information on the basic sample demographics and measures of alcohol consumption habits. Most participants were college students. Ethnicity breakdown of the sample consisted of 77% Caucasian, 12% African-American, 6% Asian, 3% Hispanic, and 1% accounted for other ethnic backgrounds. Fifty-seven percent of the sample ($n = 271$; 153 men; 118 women) met DSM-IV (American Psychiatric Association, 1994) diagnostic criteria for alcohol dependence. Our recruitment strategy also resulted in a relatively high prevalence of disinhibited characteristics in the non-alcohol dependent subjects evidenced by the fact that 35% of these subjects had a history of conduct disorder without alcohol dependence. DSM-IV diagnostic status was ascertained using the Semi-Structured Assessment for the Genetics of Alcoholism (SSAGA; Bucholz et al., 1994).

Measures

Alcohol problems were quantified as the total number of positive responses to questions in the alcohol abuse and dependence section of the SSAGA (Bucholz et al., 1994) (dichotomous "yes" vs "no" response scoring format; $\alpha = .97$). Problem counts included all questions in the alcohol abuse/dependence section of the SSAGA, some of which are not considered in establishing DSM-IV diagnoses, but are part of the interview for assessing diagnoses in other systems, such as RDC, Feighner, DSM-III-R, and ICD-10 systems.

Table 1
Sample characteristics.

Sex	222 Males/252 females
Age (years)	22.0 (SD = .50)
Years education	13.8 (SD = 2.0)
Alcohol frequency (occasions, per week) over past 6 months	3.02 (SD = 2.1)
Alcohol quantity (drinks), over past 6 months	5.40 (SD = 4.5)
Maximum number of drinks on a single occasion in past 6 months	7.31 (SD = 6.95)
Maximum number of drinks ever consumed on a single occasion	21.3 (SD = 16.3)
Lifetime alcohol problems	28.0 (SD = 21.7)
Lifetime marijuana problems	10.2 (SD = 11.9)
Lifetime problems with other drugs	15.2 (SD = 27.4)

Alcohol frequency measure is the number of occasions per week the subject reported consuming alcohol in a typical week for the past 6 months. Alcohol quantity is the average number of drinks consumed per drinking occasion. Lifetime alcohol problems, marijuana problems, and drug problems are the total of the positive responses to SSAGA (Semi-structured Assessment for the Genetics of Alcoholism) questions for alcohol abuse and dependence, marijuana abuse/dependence and other drug (excluding caffeine and tobacco) abuse/dependence.

Impulsive personality

Impulsivity was quantified as a latent variable (IMP) with the following three indicator variables. (i) The total score of the 19-item impulsivity scale (EIV-imp) (dichotomous "yes" vs "no" response scale; $\alpha = .84$) from the Eysenck Impulsivity I_6 Questionnaire (Eysenck, Pearson, Easting, & Allsop, 1985), (ii) the total score of the 24-item control scale (MPQcon) (mostly forced choice or true-false response scale; $\alpha = .88$) from the Multidimensional Personality Questionnaire (MPQ; Tellegen, 2000), and, (iii) the total score of the20-item Novelty-Seeking subscale (TCI_ns) (5 point response scale; [1-definitely false to 5 definitely true] $\alpha = .78$) from the 144 item version of Cloninger's Temperament and Character Inventory (TCI-144; Cloninger, 1995). The TCI-144 novelty seeking scale is a 20 item scale that is comprised of the items with the highest intra-item reliability (Cloninger, 1995). This version of Cloninger's novelty seeking scale does not have the four subscales included in the original, longer version of the TCI (Cloninger, Pryzbeck, Svrakic, & Wetzel, 1994). Novelty seeking was included as a measure of impulsivity because a key facet of Cloninger's novelty seeking construct is poor self control and it is highly correlated with other measures of impulsivity (Finn, 2002; Finn et al., 2002; also see Table 2.) The MPQcon (control) scale is essentially the same as an impulsivity scale except high scores reflect high self-control, while low scores reflect high impulsivity (low self-control; Tellegen, 2000). These measures of impulsivity have been associated with poor response inhibition in approach contexts (Finn et al., 2002), lower working memory capacity (Bobova et al., 2009), increased discounting of delayed rewards (Bobova et al., 2009), and increased alcohol problems (Bobova et al., 2009; Finn, 2002; Finn et al., 2002).

Executive working memory capacity

Executive working memory capacity was quantified as a latent variable comprised of two complex span dual-tasks as indicators: the Operation-Word Span test (OWS; Conway & Engle, 1994) and a modified version of the Auditory Consonant Trigram test (ACT; Brown, 1958). Previous research has shown that that these complex span tasks are valid measures of executive working memory capacity, as well as reflective of the capacity for resistance to distraction, mental manipulation, attentional control, and maintenance of memory traces over time (Engle, Kane, & Tuholski, 1999; Kane, Poole, Tuholski, & Engle, 2006; Unsworth & Engle, 2007, 2008). The OWS task involves a dual-task context, and competition for attentional resources and maintenance of activation of mental

Table 2
Bivariate correlations among measures of impulsivity, working memory capacity, and alcohol problems.

Variable	Impulsivity			WMC		AlcProbs	Mean (SD)
	1	2	3	4	5	6	
1. Imp	–	−.74**	.70**	−.26**	−.21**	.51**	10.4 (4.6)
2. Cont		–	.75**	.19*	.14**	−.45**	11.4 (6.0)
3. Nov			–	−.16**	−.13**	.50**	67.5 (10.9)
4. ACT				–	.64**	−.24**	28.4 (11.3)
5. OWS					–	−.21**	41.3 (11.8)
6. AlcProb						–	28.0 (21.7)

Note. Imp = Eysenck and Eysenck's (1978) Impulsivity scale.
Cont = Multidimensional Personality Questionnaire (MPQ) control scale.
Nov = Tridimensional Character Inventory, Novelty Seeking scale.
ACT = Auditory consonant test; OWS = Operation-Word Span test; AlcProbs = Alcohol Problems.
**$p < .01$, *$p < .05$.

representations. The task involves the ability to remember a word after reading aloud a mathematical operation (6/4 + 1 = 25? fish). The participant is required to read aloud the mathematical operation and respond "yes" or "no" indicating if the operation is correct, and then to read aloud the word. After a series of these combinations (which vary from two to six), the participant is then asked to recall the words in the same order they were presented. An individual's performance on this task is measured in the number of correct words recalled in the correct order.

The ACT test involves recalling three-consonant nonsense letter strings after counting backwards by threes for varying lengths of time. This task involves dividing attention as well as strength of the maintenance/decay of the contents of working memory over time (Brown, 1958; Stuss, Seethem, & Poirier, 1987). This test was slightly modified for this study to add four and five letter nonsense consonant strings in order to increase working memory load. It has been observed that this manipulation allows for a greater range of group differences (Finn et al., 2009). To administer this task, the experimenter reads the consonant string at the rate of one letter per second, followed by a three-digit number. The participant counts back by threes from that number for either 18 or 36 s, and then must recall the letters in the exact order they were read by the experimenter. It is assumed that counting backwards interferes with the rehearsal of the consonants. Performance on this task was measured by the number of correct letters recalled across all string lengths and time delays.

Data analysis

About two percent of subjects had missing data on some of the impulsive personality measures (not more than 2 measures). For these cases, missing data were handled by imputation using all available measures for the imputation process. The primary data analysis was a structural equation model (SEM) with maximum likelihood estimation to test hypotheses about the association between WMC, impulsivity, and alcohol problems. Impulsivity and working memory capacity were assessed using latent variables as illustrated in Fig. 1. A mediational model (Fig. 1) was constructed to examine whether our data are consistent with the hypothesis that impulsivity mediates the relationship between WMC and alcohol problems. In order to estimate mediation effects, bootstrapped ($k = 20{,}000$) and bias-corrected 95% confidence intervals (CIs) were estimated for the indirect effects (Preacher, Rucker, & Hayes, 2007). Mediation is tested by examining the direct, indirect, and total effects for paths from WMC to alcohol problems and use. Significant mediation effects are apparent when indirect effects are significant and total effects are reduced in the presence of the mediator. Pearson product moment correlations also are reported to illustrate the strength and direction of the associations among the different indicator variables. SEM was conducted using AMOS 18.0 (Arbuckle, 2009). Finally, an alternate mediation model was examined as an exploratory approach to examine evidence that WMC may mediate the association between impulsivity and alcohol problems.

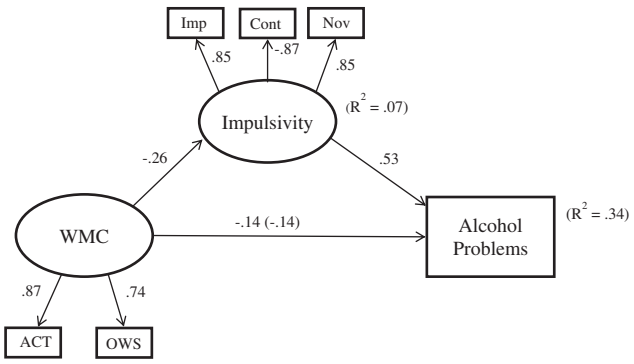

Fig. 1. Mediational structural equation model of the association between working memory capacity, impulsivity, and alcohol problems. Single directional arrows represent standard regression weights. All paths are statistically significant at $p < .001$, except the reduced direct effect from impulsivity to alcohol problems ($p = .004$). The indirect effect of working memory capacity on alcohol problems is presented in parentheses. Directional regression paths do not infer causal direction.

To assess the degree to which the structural models fit the sample variance–covariance data, two criteria of model fit were relied upon: the Normed Fit Index (NFI: Bentler & Bonett, 1980), the Comparative Fit Index (CFI: Bentler, 1990), and the Root-mean-square error of residual approximation (RMSEA: Browne & Cudek, 1993). Although guidelines for good fit vary, typically NFI and CFI values above .90 or .95 indicate very good fit (Browne & Cudek, 1993; Hu & Bentler, 1999). An NFI value of .90 indicates that 90% of the saturated model is reproduced by a tested model. Generally speaking, RMSEA values at or below .08 reflect a reasonable fit to the data (Bentler & Bonett, 1980; Browne & Cudek, 1993); however, RMSEA values less than .05 are the rule of thumb criteria for a good fit to the data (Browne & Cudek, 1993).

Results

Pearson correlations among all indicator variables

Table 2 presents the correlations among all of the variables used in the SEMs. There were high intercorrelations among the three measures of impulsivity and between the two WMC measures. As expected there were significant correlations among measures of WMC, alcohol problems, and IMP.

Testing a mediational model of working memory capacity, impulsivity, and alcohol problems

Our theory holds that low WMC predisposes to greater impulsivity, which, in turn, leads to more alcohol problems, rather than IMP leading to low WMC. The ideal test of this theory involves using a longitudinal design. Since we only have cross-sectional data, we examined whether our data are consistent with the hypothesis that impulsivity mediates the association between low WMC and alcohol problems, rather than providing a direct test of mediation. The correlational analyses indicated that WMC was significantly negatively correlated with both impulsivity and alcohol problems. Second, the mediational model (Fig. 1) fit the data well, χ^2 (7) = 20.39, $p < .005$, CFI = .989, NFI = .984, RMSEA = .064. BIC = 106.65. The model revealed significant total effects ($\beta = -.28$, $p < .0001$), direct effects ($\beta = -.14$, $p < .004$), and indirect effects ($\beta = -.14$, $p < .004$, 95% CI [−.20, −.08]) of WMC on alcohol problems providing clear evidence for partial mediation. Fig. 1 displays the indirect effect of WMC on alcohol problems in parentheses. Significant partial mediation is illustrated by the significant indirect effect of WMC on alcohol problems ($\beta = -.14$, $p < .004$, 95% CI [−.20, −.08]) via impulsivity, and the significant reduction in total effects of WMC on alcohol problems (from ($\beta = -.28$, $p < .0001$) to ($\beta = -.14$, $p < .004$)). The significant direct effect of WMC on alcohol problems ($\beta = -.14$, $p = .004$) reflects the part of the association between WMC and alcohol problems that is not mediated by impulsivity. As can be seen in Fig. 1, there were significant direct effects of WMC on impulsivity ($\beta = -.26$, $p < .0001$; $R^2 = .07$) and impulsivity on alcohol problems ($\beta = -.53$, $p < .00001$).

The alternative mediation model, where the positions of WMC and impulsivity are switched in the model such that the mediation role of WMC for the association between impulsivity and alcohol

problems did not provide any evidence of mediation. The indirect effect of impulsivity on alcohol problems (via WMC) was not significant ($\beta = .037$). The direct effect of impulsivity on alcohol problems was significant ($\beta = .53$, $p < .0001$). In fact, in this model the direct effect of WMC on alcohol problems was ($\beta = -.14$, $p = .004$), which is lower than the total effects observed in the hypothesized mediational model SEM ($\beta = -.28$, $p = .0001$). This is due to the fact that part of the variance in alcohol problems is accounted for by impulsivity regardless of the position in the model because each SEM models the same variance − covariance matrix.

Thus our analyses are consistent with the hypothesis that impulsivity partially mediates the association between (low) WMC and alcohol problems, and not the other way around.

Discussion

The overarching goal of this study was to investigate the associations between working memory capacity, impulsive personality, and alcohol problems and test the hypothesis that impulsivity partially mediates the association between low working memory capacity and alcohol problems. The results show that low working memory capacity is significantly associated with impulsive personality traits. Furthermore, the results indicate that a part of the variance in alcohol problems associated with low working memory capacity is accounted for by impulsivity. This result is consistent with our theory that impulsive personality and low working memory capacity share a common mechanism of vulnerability to alcohol problems, and that low working memory capacity may predispose to greater impulsivity, which, in turn, may lead to more alcohol problems.

Working memory, impulsivity, and alcohol problems

Consistent with previous research, the analyses showed that low working memory was associated with more alcohol problems (Finn, 2002; Finn & Hall, 2004; Finn et al., 2009; Verdejo-García et al., 2008). Working memory capacity was also inversely associated with impulsive personality. While some studies indicate an association between impulsive decision making (Bobova et al., 2009; Kirby et al., 1999), there are no reports in the literature of an association between impulsive personality and low working memory capacity. The mediational analyses indicated that impulsivity partially accounted for the association between low working memory and alcohol problems. This is consistent with the hypothesis that low working memory predisposes toward more impulsive behavior, which in turn leads to more alcohol problems. While studies clearly indicate that reduced cognitive capacity predates the onset of alcohol problems and is associated with increased risk for alcohol problems (Peterson, Finn, & Pihl, 1992), there is likely to be some bidirectionality in these associations, where alcohol problems may compromise working memory capacity and increase impulsivity as well. Nevertheless, the results are consistent with the idea that both low working memory capacity and impulsive personality are indicative of a common mechanism of poor self-regulation that may contribute to impaired self control and decision making (Barkley, 1997, 2001; Bechara & Martin, 2004; Finn, 2002; Kimberg & Farah, 1993). Our theory (Finn, 2002) holds that individuals who have lower working memory have difficulty keeping less salient information in mind and are more likely to be influenced immediate reward (highly salient information), when making decisions, and less likely to be influenced by long term outcomes (less salient information). This type of bias leads to greater impulsivity. In addition, a key feature of abusive, problematic drinking behavior is the relevant neglect of future negative consequences when making decisions to drink alcohol.

Limitations and conclusions

There are a few limitations should be considered when interpreting the results of this study. First, our data are cross-sectional in nature and cannot provide a true test of the theory that low WMC contributes to increased impulsivity. In addition, although the SEM path analyses include unidirectional regression paths, there is likely to be some bidirectionality in the effects. In other words, alcohol problems and excessive use may lead to more impulsive behavior or lower WMC (De Wit, 2009). Thus, one cannot make conclusions about causality from our results. Second, it should be noted that our sample is not randomly selected from the population. Rather, individuals in the study are biased toward those willing to participate in a research study conducted in a laboratory. The sample also is not representative of individuals in treatment for alcohol dependence. Some of our sample had sought and received treatment, but many of those with alcohol problems had not sought any sort of treatment for their problems. Another limitation of our sample is it's comprised mostly of young white adults, many of whom are college students. This again, is unrepresentative of the sample of alcohol dependent individuals in general. It should considered that our sample likely to be more representative of mostly white young adult males predominantly of a college student sample from the Midwest, rather than a general alcohol dependent sample. Finally, our sample is comprised of young adults in an emerging adulthood developmental phase. Different patterns of association between WMC, impulsivity, and alcohol problems may be present in late childhood, earlier adolescence, or middle age.

Despite these limitations, this research provides an interesting account of a potential common underlying mechanism and possible mediational relationship between reduced working memory capacity, impulsivity, and alcohol problems.

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References

American Psychiatric Association. (1994). *Diagnostic and statistical manual of mental disorders* (4th ed.). Washington, DC: Author.

Arbuckle, J. L. (2009). *AMOS (version 18. 0) [computer software]*. Chicago: Small Waters Corporation.

Aytaclar, A., Tarter, R. E., Kirisci, L., & Lu, S. (1999). Association between hyperactivity and executive cognitive function functioning in childhood and substance use in early adolescence. *Journal of the American Academy of Child & Adolescent Psychiatry, 38*, 172–178.

Barkley, R. A. (1997). Behavioral inhibition, sustained attention, and executive functions: constructing a unifying theory of ADHD. *Psychological Bulletin, 121*, 65–94.

Barkley, R. A. (2001). The executive functions and self-regulation: an evolutionary neuropsychological perspective. *Neuropsychology Review, 11*, 1–29.

Bechara, A., & Martin, E. M. (2004). Impaired decision making related to working memory deficits in individuals with substance addictions. *Neuropsychology, 18*, 152–162.

Bentler, P. M. (1990). Comparative fit indexes in structural models. *Psychological Bulletin, 107*, 238–246.

Bentler, P. M., & Bonett, D. G. (1980). Significance tests and goodness of fit in the analysis of covariance structures. *Psychological Bulletin, 88*, 588–606.

Bjork, J. M., Hommer, D. W., Grant, S. J., & Danube, C. (2004). Impulsivity in abstinent alcohol-dependent patients: relation to control subjects and type 1/type 2-like traits. *Alcohol, 34*, 133–150.

Bobova, L., Finn, P. R., Rickert, M. E., & Lucas, J. (2009). Disinhibitory psychopathology and delay discounting in alcohol dependence: personality and

cognitive correlates. *Experimental and Clinical Psychopharmacology, 17*, 51–61.
Brown, J. (1958). Some tests of the decay theory of immediate memory. *Quarterly Journal of Experimental Psychology, 10*, 12–21.
Browne, M. W., & Cudek, R. (1993). Alternative ways of assessing model fit. In K. A. Bollen, & J. S. Long (Eds.), *Testing structural equation models* (pp. 136–162). Newbury Park, CA: Sage.
Bucholz, K., Cadoret, R., Cloninger, C. R., Dinwiddie, S., Hasselbrock, V., Nurnberger, J., et al. (1994). A new semistructured psychiatric interview for use in genetic linkage studies: a report of the reliability of the SSAGA. *Journal of Studies on Alcohol, 55*, 149–158.
Caspi, A., Moffitt, T. E., Newman, D. L., & Silva, P. A. (1996). Behavioral observations at age 3 years predict adult psychiatric disorders. *Archives of General Psychiatry, 53*, 1033–1039.
Castellanos-Ryan, N., Rubia, K., & Conrod, P. J. (2011). Response inhibition and reward response bias mediate the predictive relationships between impulsivity and sensation seeking and the common and unique variance in conduct disorder and substance misuse. *Alcoholism, Clinical and Experimental Research, 35*, 140–155.
Chassin, L., Flora, D. B., & King, K. M. (2004). Trajectories of alcohol and drug use from adolescence to adulthood. The effects of familial alcoholism and personality. *Journal of Abnormal Psychology, 113*, 483–498.
Cloninger, C. R. (1995). *TCI-144*. St. Louis: Washington University: Department of Psychiatry Mo.
Cloninger, C. R., Pryzbeck, T. R., Svrakic, D. M., & Wetzel, R. D. (1994). *The Temperament and Character Inventory (TCI): A guide to its development and use*. St. Louis, MO: Washington University, Center for the Psychobiology of Personality.
Cloninger, C. R., Sigvardsson, S., & Bohman, M. (1988). Childhood personality predicts alcohol abuse in young adults. *Alcoholism, Clinical and Experimental Research, 12*, 494–505.
Conway, A. R. A., & Engle, R. W. (1994). Working memory and retrieval: a resource dependent inhibition model. *Journal of Experimental Psychology: General, 123*, 354–373.
De Wit, H. (2009). Impulsivity as a determinant and consequence of drug use: a review of underlying processes. *Addiction Biology, 14*, 22–31.
Engle, R. W., Kane, M. J., & Tuholski, S. W. (1999). Individual differences in working memory capacity and what they tell us about controlled attention, general fluid intelligence and functions of the prefrontal cortex. In A. Miyake, & P. Shah (Eds.), *Models of working memory: Mechanisms of active maintenance and executive control* (pp. 102–134). New York: Cambridge University Press.
Evenden, J. L. (1999). Varieties of impulsivity. *Psychopharmacology, 146*, 348–361.
Eysenck, S. B. G., Pearson, P. R., Easting, G., & Allsop, J. F. (1985). Age norms for impulsiveness, venturesomeness, and empathy in adults. *Personality and Individual Differences, 6*, 613–619.
Fine, M. S., & Minnery, B. S. (2009). Visual salience affects performance in a working memory task. *Journal of Neuroscience, 29*, 8016–8021.
Finn, P. R. (2002). Motivation, working memory, and decision making: a cognitive-motivational theory of personality vulnerability to alcoholism. *Behavioral and Cognitive Neuroscience Reviews, 1*, 183–205.
Finn, P. R., & Hall, J. (2004). Cognitive ability and risk for alcoholism: short-term memory capacity and intelligence moderate personality-risk for alcohol abuse. *Journal of Abnormal Psychology, 113*, 569–581.
Finn, P. R., Mazas, C. A., Justus, A. N., & Steinmetz, J. (2002). Early-onset alcoholism with conduct disorder: go/no go learning deficits, working memory capacity, and personality. *Alcoholism, Clinical and Experimental Research, 26*, 186–206.
Finn, P. R., Rickert, M. E., Miller, M. A., Lucas, J., Bogg, T., Bobova, L., et al. (2009). Reduced cognitive ability in alcohol dependence: examining the role of covarying externalizing psychopathology. *Journal of Abnormal Psychology, 118*, 100–116.
Finn, P. R., Sharkansky, E. J., Brandt, K. M., & Turcotte, N. (2000). The effects of familial risk, personality, and expectancies on alcohol use and abuse. *Journal of Abnormal Psychology, 109*, 122–133.
Hinson, J. M., Jameson, T. L., & Whitney, P. (2003). Impulsive decision making and working memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 29*, 298–306.
Hu, L. T., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives. *Structural Equation Modeling, 6*, 1–55.
Kane, M. J., Poole, B. J., Tuholski, S. W., & Engle, R. W. (2006). Working memory capacity and the top-down control of the visual search: exploring the boundaries of "executive attention". *Journal of Experimental Psychology: Learning, Memory, and Cognition, 32*, 749–777.
Kimberg, D. Y., & Farah, M. J. (1993). A unified account of cognitive impairments following frontal lobe damage: the role of working memory in complex, organized behavior. *Journal of Experimental Psychology: General, 122*, 411–428.
Kirby, K. N., Petry, N. M., & Bickel, W. K. (1999). Heroin addicts have higher discount rates for delayed rewards than non-drug using controls. *Journal of Experimental Psychology: General, 128*, 78–87.
Krueger, R. F., Caspi, A., Moffit, T. E., Silva, P. A., & McGee, R. (1996). Personality traits are differentially linked to mental disorders: a multitrait-multidiagnosis study of an adolescent birth cohort. *Journal of Abnormal Psychology, 105*, 299–312.
Logan, G. D., Schachar, R. J., & Tannok, R. (1997). Impulsivity and inhibitory control. *Psychological Science, 8*, 60–64.
Luego, M. A., Carrillo de la Pena, M. T., & Ortero, J. M. (1991). The components of impulsiveness: a comparison of the I-7 Impulsiveness questionnaire and the Barratt Impulsivity Scale. *Personality and Individual Differences, 12*, 657–667.
MacKillop, J., Mattson, R. E., Anderson MacKillop, E. J., Castelda, B. A., & Donovick, P. J. (2007). Multidimensional assessment of impulsivity in hazardous drinkers and controls. *Journal of Studies on Alcohol and Drugs, 68*, 785–788.
Magid, V., MacClean, M. G., & Colder, C. (2007). Differentiating between sensation seeking and impulsivity through their mediated relations with alcohol use and problems. *Addictive Behaviors, 32*, 2046–2061.
Noël, X., Bechara, A., Dan, B., Hanak, C., & Verbanck, P. (2007). Response inhibition deficit is involved in poor decision making under risk in nonamnesic individuals with alcoholism. *Neuropsychology, 21*, 778–786.
Oberauer, K. (2002). Access to information in working memory: exploring the focus of attention. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 28*, 411–421.
Patton, J. H., Stanford, M. S., & Barratt, E. S. (1995). Factor structure of the Barratt Impulsiveness Scale. *Journal of Clinical Psychology, 51*, 768–774.
Peterson, J. B., Finn, P. R., & Pihl, R. O. (1992). Cognitive dysfunction and the inherited predisposition to alcoholism. *Journal of Studies on Alcohol, 53*, 154–160.
Petry, N. M. (2001). Delay discounting of money and alcohol in actively using alcoholics, currently abstaining alcoholics, and controls. *Psychopharmacology, 154*, 243–250.
Preacher, K. J., Rucker, D. D., & Hayes, A. F. (2007). Addressing moderated mediation hypotheses: theory, methods, and prescriptions. *Multivariate Behavioral Research, 442*, 185–227.
Shih, S.-I. (2008). The attention cascade model and attentional blink. *Cognitive Psychology, 56*, 210–236.
Smith, G. T., Fischer, S., Cyders, M. A., Annus, A. M., Spillane, N. S., & McCarthy, D. M. (2007). On the validity and utility of discriminating among impulsivity-like traits. *Assessment, 14*, 155–170.
Stuss, D. T., Seethem, L. L., & Poirier, C. A. (1987). Comparison of three tests of attention and rapid information processing across six age groups. *Clinical Neuropsychology, 1*, 139–152.
Swann, A. C., Bjork, J. M., Moeller, J. G., & Dougherty, D. M. (2002). Two models of impulsivity: relationship to personality and psychopathology. *Biological Psychiatry, 51*, 988–994.
Tellegen, A. (2000). *Manual of the Multi-Dimensional Personality Questionnaire*. Minneapolis: University of Minnesota Press.
Trasseger, S. L., & Robinson, J. (2009). The role of affective instability and UPPS impulsivity in borderline personality disorder features. *Journal of Personality Disorders, 23*, 370–383.
Unsworth, N., & Engle, R. W. (2007). The nature of individual differences in working memory capacity: active maintenance in primary memory and controlled search from secondary memory. *Psychological Review, 114*, 104–132.
Unsworth, N., & Engle, R. W. (2008). Speed and accuracy of accessing information in working memory: an individual differences investigation of focus switching. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 34*, 616–630.
Verdejo-García, A., Lawrence, A. J., & Clark, L. (2008). Impulsivity as a vulnerability marker for substance-use disorders: review of findings from high-risk research, problem gamblers and genetic association studies. *Neuroscience & Biobehavioral Reviews, 32*, 777–810.
Whiteside, S. P., & Lynam, D. R. (2003). Understanding the role of impulsivity and externalizing psychopathology in alcohol abuse: application of the UPPS impulsive behavior scale. *Experimental and Clinical Psychopharmacology, 11*, 210–217.
Wills, T. A., Vaccaro, D., & McNamara, G. (1994). Novelty seeking, risk taking, and related constructs as predictors of adolescent substance use: an application of Cloninger's theory. *Journal of Substance Abuse, 6*, 1–20.