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Favorable associations with alcohol and impaired self-regulation: A behavioral economic analysis

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ABSTRACT

Background: Recent research has demonstrated that both poor self-regulation and favorable implicit associations toward alcohol can play important roles in predicting drinking. Less well studied, however, is how the interplay between implicit associations and self-regulation may impact decisions about alcohol consumption. Behavioral economics is one important tool that may provide insight into the cognitive processes that impact demand for alcohol and drinking decisions.

Methods: Healthy young adult participants completed an Implicit Association Task (IAT) that measured the strength of associations between approach/avoid attributes and target alcohol/neutral images. Impaired self-regulation was assessed by a classic delay discounting task. Participants also completed an Alcohol Purchase Task (APT), which yields multiple behavioral economic indices, chief among which are intensity (the number of drinks a participant would consume if the drinks were free) and elasticity (the degree to which an increased per-drink price impacts the number of drinks consumed in a hypothetical drinking situation). Finally, participants completed a timeline follow-back assessment of past-90-day drinking.

Results: Findings indicated that implicit approach associations toward alcohol predicted increased demand for alcohol on the APT. Although delay discounting did not have a direct effect on demand for alcohol, there was a significant interaction between IAT and delay discounting, such that higher implicit alcohol approach associations predicted particularly high demand for alcohol among participants with poorer self-regulation. APT and IAT, in turn, predicted self-reported drinking behavior.

Conclusions: These results suggest that favorable attitudes toward alcohol, together with poor self-regulation, can significantly impact drinking decisions in healthy young adults.

1. Introduction

Contemporary dual-process theories of alcohol use and abuse propose that decisions about drinking are influenced by a continuous interplay between two separate cognitive systems in the brain: (1) an implicit, automatic system that unconsciously influences behavior via early cognitive processes, including attentional biases and implicit memory associations, and (2) an explicit, reflective system that is capable of tempering these faster processes with emotional control, reasoned analysis, and purposeful deliberation prior to action (Burton et al., 2012; Dickson et al., 2013; Field and Wiers, 2012; Houben and Wiers, 2009; Stacy and Wiers, 2010). Conflict between the two systems is theorized to be resolved by the strengths of the processes involved and the relative control afforded by each system, and may wax and wane over the course of an encounter with alcohol (Houben and Wiers, 2009; Stacy and Wiers, 2010).

Consistent with this dual process conceptualization, individual differences in the functioning of the automatic and reflective systems have been shown to influence drinking decisions (Houben and Wiers, 2009; Stacy and Wiers, 2010; Thush et al., 2008). Automatic

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processes have typically been assessed using indices of attentional bias, including visual probe tasks and measures of implicit associations. Implicit associations about alcohol are known risk factors for problematic drinking and can be used to predict alcohol consumption, cravings, and problematic drinking in a variety of participant populations (Burton et al., 2012; de Wit, 2009; Jajodia and Earleywine, 2003; Lindgren et al., 2013; Stacy and Wiers, 2010). Implicit associations about alcohol are often assessed via the Implicit Association Task (IAT), which exists in multiple versions (Greenwald et al., 1998; Ostafin and Palfai, 2006; Stacy and Wiers, 2010), and the associations themselves have been repeatedly validated as predictors of drinking outcomes, including consumption, binge drinking and cue reactivity (Jajodia and Earleywine, 2003; Ostafin and Palfai, 2006; Palfai and Ostafin, 2003; Roefs et al., 2011).

In addition to implicit associations, deficits in reflective processing and self-regulation have been increasingly recognized as important contributors to the development of substance abuse: for example, people who act impulsively are more likely to abuse alcohol and other drugs (de Wit, 2009; Houben and Wiers, 2009). Impulsivity is multi-dimensional component of executive functioning that includes behavioral inhibition and impaired decision-making, and as a construct, describes the extent to which individuals exhibit inappropriate or maladaptive behavior (de Wit, 2009; Lejuez et al., 2010; Weafer et al., 2013). Such maladaptive behavior may include rapid action without consideration of consequences, decreased ability to delay reward, difficulty with concentrating on present tasks, poor control of response inhibition, and reduced skill at ignoring or regulating urgent emotional impulses (Lejuez et al., 2010; Weafer et al., 2013). Numerous studies have provided evidence that impulsivity is predictive of early drinking, with more-impulsive individuals starting to drink earlier in their lives than less-impulsive individuals (Lejuez et al., 2010).

One key measure of impulsivity that is highly relevant to the immediate reward associated with drug use is the Delay Discounting Task (DDT; Richards et al., 1999). Impulsive delay discounting refers to a preference for smaller, more immediate rewards over greater, more distant rewards (Richards et al., 1999), and studies have shown that alcohol-dependent individuals prefer more immediate rewards of lesser value rather than delayed rewards of greater value in delay-discounting tasks (Lejuez et al., 2010; Richards et al., 1999). As noted above, the ability to delay reward is only one phenotype of the larger construct of impulsivity, and as such delay discounting may not fully characterize impulsivity-related executive dysfunction. However, since delay discounting is conceptualized in terms of monetary reward, it may be especially relevant to research about economic decisions related to alcohol consumption, like the quantity of drinks purchased. Recent research by Hamilton and Potenza (2012) has linked delay discounting outcomes to poor financial decisions and dysfunctional behavioral economics in addictive behavior. This research suggests that delay discounting can provide a valuable lens through which to investigate the interplay and relative impact of automatic self-regulatory processes and slower, more reflective economic decision-making.

To better understand how these factors contribute to problem drinking, recent research has begun to focus on elucidating the process of decision making regarding alcohol consumption. Behavioral economics, which predicts consumption by comparing the desirability of a substance against the impact of restraints on its availability, provides a novel method of assessing decisions to drink in the laboratory via standardized, hypothetical purchase tasks (Amlung et al., 2012; Bertholet et al., 2015; Murphy and MacKillop, 2006). Past research has shown that price is a significant predictor of alcohol consumption (Bertholet et al., 2015; Skidmore and Murphy, 2011), and behavioral economic tasks allow researchers to calculate demand as a function of fluctuation in prices, allowing insight into the cognitive processes that underlie individual drinking decisions while controlling for dynamic contextual influences that might result in a deviation between actual recent drinking as reported on self-report and retrospective interview measures of alcohol consumption and underlying motivation for alcohol (Murphy and MacKillop, 2006). For example, while a retrospective estimate of consumption can be broken down into weekly averages and reveal clusters of binge drinking behavior, behavioral economic demand curve models can illuminate the cognitive tensions involved in making decisions about purchasing alcohol: for example, when does price transition from a mere feature of consumption to an obstacle that impacts drinking decisions? Or, put differently, at what price point does consumption begin to wane because cost constraints become more salient than the desire to drink (MacKillop and Murphy, 2007)? Similarly, demand curves can model a maximum desired level of consumption assuming a lack of contextual restraints. Using these behavioral economic data to characterize the consumption patterns of young adult social drinkers may help distinguish between adaptive and maladaptive attitudes toward alcohol that could lead some young drinkers to become problematic drinkers later in life.

In behavioral economic theories of addiction, the relative reinforcing efficacy (RRE) of alcohol describes the extent to which alcohol is capable of influencing individual drinking behavior. RRE can be defined as the quantity of action (lever presses, for example, in a rodent study) or behavior (the amount of money spent on a drink) that an individual will expend in order to obtain a substance (Murphy et al., 2009): higher RRE indicates a substance with greater potential for abuse compared to a substance with lower relative reinforcing efficacy (Murphy and MacKillop, 2006). RRE can be reliably measured via hypothetical purchase tasks [in this study, the Alcohol Purchase Task (APT; Murphy and MacKillop, 2006)] that ask participants to describe how many drinks they would purchase at different price points (Murphy et al., 2009). This procedure produces a demand curve that yields several different behavioral economic measures of RRE, including intensity (the number of drinks consumed when free), elasticity (the extent to which increasing prices reduce demand for alcohol), breakpoint (the price at which participants will cease to purchase drinks), P_{max} (a second index of elasticity), and O_{max} (the maximum amount of money that will be spent on alcohol) (Murphy and MacKillop, 2006). Individual differences in RRE have been shown to predict alcohol consumption and alcohol-related problems (Murphy et al., 2009; Murphy and MacKillop, 2006) as well as response to alcohol interventions (Dennhardt et al., 2015; Murphy et al., 2015). Understanding predictors of RRE, especially in non-alcohol-dependent young adult social drinkers, may be critical in guiding preventive efforts.

The objective of this study was to extend previous research examining the effects of implicit associations and deficits in self-regulation on alcohol use (Burton et al., 2012; Houben and Wiers, 2009). We hypothesized that higher levels of impulsivity, as well as stronger implicit approach associations with alcohol, would predict greater alcohol demand on the APT, which in turn, would be related to higher levels of past consumption. In addition, we hypothesized that social drinkers with higher levels of both impulsivity and implicit alcohol approach associations would exhibit particularly high alcohol demand on the APT, as well as higher levels of past drinking behavior.

2. Methods

2.1. Participants

Participants were healthy young adult social drinkers (n = 36) recruited from a New York City university who consumed an average of at least three drinks per week. Participants received monetary compensation for their time. Sixty-one percent of participants (n = 22) were women and 39% (n = 14) were men. The mean age of the sample was 19.6 years (SD = 1.9). Forty-two percent of participants reported being Caucasian, 23% reported being African American, 17% reported being Hispanic, and 17% reported being Asian. Participants reported beginning to drink regularly at age 19.2 (SD = 2.2), consuming an average of 3.7 (SD = 1.9) drinks per drinking episode, and 2.8 (SD = 1.2) drinking episodes per week. The mean Obsessive Compulsive Drinking Scale (OCDS) (Anton et al., 1995) score in this non-alcohol-dependent sample of social drinkers was 10.8 (SD = 4.8), well below the mean scores typically reported in clinical samples (e.g. 22.5, reported in Anton et al., 1995).

Potential participants were excluded on the basis of drinking an average of fewer than three drinks/week), current or past psychotic disorder, current or past substance abuse disorder (with the exception of nicotine dependence), a score greater than 8 on the Alcohol Use Disorders Identification Test (AUDIT; Saunders et al., 1993), a history of cardiovascular disease, or current pregnancy. Additionally, participants who failed a urine toxicology screen were excluded from the study.

2.2. Materials and procedure

The research procedures described herein were approved by the University Integrated Institutional Review Board of Hunter College, the City University of New York. Participants provided informed consent, a urine sample for toxicology screening, and a breath sample [using an Alco-Sensor IV portable breath alcohol analyzer (Intoximeters, Inc., St. Louis, MO)] to confirm sobriety. Participants completed the Obsessive Compulsive Drinking Scale (Anton et al., 1995), a 90 day drinking TLFB interview, and completed measures of implicit association, delay discounting, and alcohol purchase tasks, as described below.

2.2.1. Implicit association test. Participants completed a variant of the Implicit Association Task (IAT; Greenwald et al., 1998) that was developed by Ostafin and Palfai (2006) and measured the strength of individuals' associations between approach/avoid attribute words ("approach": approach, closer, advance, forward, toward; "avoid": avoid, away, leave, withdraw, escape) and target images of alcohol and water. Participants were instructed to sort alcohol and water images with approach words and avoid words in different blocks of trials. In one block of trials, participants were instructed to classify alcohol-related images with approach words and water-related images with avoid words. In a separate block of trials, the pairings were reversed, and participants matched alcohol-related images to avoid words and water-related images to approach words. Differences in categorization latencies between the two sets of blocks were used to assess individual tendencies to associate alcohol with approach or avoid words. Block presentations were randomized. Consistent with Greenwald et al. (2003), trials with latencies greater than 10,000 ms were eliminated and participants for whom more than 10% of trials had latencies less than 300 ms were excluded from analyses. Latencies on error trials were replaced with the mean latency for the block plus an additional 600 ms error penalty. The IAT was scored using the *d*-score algorithm of Greenwald et al. (1998, 2003), with higher *d*-scores indicating stronger associations between alcohol and "approach" and lower scores indicating stronger associations between alcohol and "avoid."

Internal consistency was high for all trial blocks, with Cronbach's α ranging from 0.87 to 0.91.

2.2.2. Delay discounting task. Deficits in self-regulation (i.e., impulsivity) were assessed by a computerized Delay Discounting Task (DDT; Richards et al., 1999) in which participants indicated their preference for receiving an immediate amount of money at the end of the testing session against a larger amount of money after a waiting period of 0, 2, 30, 180, or 365 days. A typical trial might ask a participant, "would you rather have $10 in 30 days or $2 at the end of the session?" Each participant was asked a series of questions with varying amounts and time delays in order to determine "indifference points" for each of the hypothetical delays and discounts used in the task. Indifference points were defined as the present value that the participant selected as equivalent to $10 after each time period. Participant indifference points can be plotted as curves (see Richards et al., 1999) with a general formula of $V = A/(1 + kD)$, where V is the present acceptable value of an amount A after a given delay or discount of D. The k parameter varies between participants and is a measure of the steepness of individual delay and discounting curves. Larger values for k indicate a greater preference for immediate over delayed (or discounted) rewards and thus indicate more impulsivity (Reed et al., 2012; Richards et al., 1999). To increase task motivation, participants were told that one of their answer choices would be selected at random at the end of the session, and that they would receive that amount of money, either immediately if they had selected an immediate reward or after the delay period they had chosen. The DDT has been used extensively in the addiction literature as a behavioral measure of impulsivity in which a preference for an immediate but lesser reward is associated with greater impulsivity than a preference for a greater but more temporally-remote reward (de Wit, 2009; Weafer et al., 2013)

2.2.3. Alcohol purchase task. The Alcohol Purchase Task (APT; Murphy and MacKillop, 2006) was used to assess participant demand for alcohol via behavioral economic analysis. The APT, which asks participants to estimate how many drinks they would purchase at different price points, yields multiple behavioral measures, including intensity, elasticity, breakpoint, P_{max}, and O_{max}, as described above (Murphy et al., 2009; Murphy and MacKillop, 2006). Elasticity is calculated by modeling responses and fitting a curve that best describes the relationship between price and hypothetical consumption. Using this model, a derived measure of intensity (the intercept of the model, where consumption levels are predicted for $0 expenditure) is also calculated, yielding (1) observed indices of demand: observed intensity, breakpoint, P_{max}, and O_{max}, and (2) derived measures of demand: derived intensity and elasticity. The derived indices have the advantage of using all of the participants' responses, whereas the observed indices have the advantage of face-validity. The APT has been tested extensively in US college student populations (Murphy et al., 2009; Murphy and MacKillop, 2006) and more recently in non-US student populations (Amlung et al., 2012; Bertholet et al., 2015) and found to be a valid and reliable measure of alcohol demand in both groups.

2.2.4. Timeline follow-back interview. The timeline follow-back (TLFB; Sobell and Sobell, 1992) is an interview method assessment that reconstructs past drinking behavior with high reliability and validity (Searles et al., 2002; Vinson et al., 2003). Participants reported past 90-day alcohol consumption during the TLFB interview from which measures of total drinks, drinking days, and drinks per drinking day, were obtained.

Table 1
Study variables.

Variable	M (*SD*)
Implicit Association Test[a]	−0.32 (0.35)
Delay Discounting coefficient “k”	0.54 (2.0)
Alcohol Purchase Task	
Observed Indices	
Intensity	6.63 (4.17)
Breakpoint	13.10 (4.67)
O_{max}	17.12 (8.25)
P_{max}	7.40 (5.08)
Derived Indices	
Elasticity	0.0092 (0.003)
Intensity	7.77 (5.59)
Timeline Follow-Back	
Total drinks past 90 days	65.4 (44.7)
Drinking days	25.2 (14.9)
Drinks per drinking day	2.8 (1.5)

[a] *d*-score was used to calculate the degree of ‘approach’ vs. ‘avoid’ associations.

2.3. Data analysis

To address the study hypotheses, we conducted a series of multivariate analyses of variance (MANOVA). To assess effects of the IAT and DDT on APT, as per our hypotheses that (1) impulsivity and implicit associations would predict APT outcomes, and (2) impulsivity would moderate IAT scores to influence performance on the APT, we conducted two separate MANOVAs, one that included the observed APT indices (observed intensity, breakpoint, O_{max}, and P_{max}) as outcomes, and one which included the derived indices (elasticity and derived intensity) as APT outcomes. Univariate follow-ups of significant MANOVAs were then conducted to identify the specific outcome measure(s) that were predicted. We considered conducting a single, omnibus MANOVA, including all the observed and derived measures of the APT, but decided against this because of the similarity in construct and overlap between the observed and derived measures. Finally, we conducted a MANOVA to evaluate the effects of the IAT, delay discounting, and the APT on drinking behavior from the TLFB assessment. The outcomes included: (1) total number of drinks, (2) drinks per drinking day, and (3) drinks per week. As above, significant effects were investigated by univariate ANOVAs to determine the specific drinking outcome measure(s) that were predicted.

3. Results

3.1. IAT and demand for alcohol

Multivariate analyses of IAT scores are shown in Table 2 and were significantly predictive of the derived indices on the APT (elasticity and intensity): $F(2,28) = 3.8$, $p = 0.041$, $\eta^2 = 0.20$. Univariate analyses revealed that stronger alcohol approach associations significantly predicted reduced elasticity: $b = -0.004$, $SE = 0.001$, $p = 0.018$, $\eta^2 = 0.18$; and marginally predicted increased intensity: $b = 7.85$, $SE = 3.8$, $p = 0.05$, $\eta^2 = 0.12$. Interestingly, IAT was not predictive of observed measures of demand for alcohol (observed intensity, breakpoint, O_{max} and P_{max}): $F(3,21) = 1.5$, $p < 0.218$.

3.2. Delay discounting and demand for alcohol

The mean delay discounting coefficient was 0.55 (±2.0), reflecting considerable variability in discounting within the sample (Table 1). In contrast to our hypothesis, delay discounting was related to neither the observed [$F(3,19) = 0.45$; $p = 0.770$] nor the derived [$F(2,20) = 1.5$; $p = 0.254$] indices of the APT (Table 2). Interestingly, however, and as shown in Table 2, we did find that the interaction between delay discounting and IAT scores significantly predicted the derived indices of the APT; $F(2,20) = 3.94$; $p = 0.037$, $\eta^2 = 0.29$. Univariate analysis revealed that this effect was apparent for elasticity [$F(1,20) = 8.09$; $p = 0.010$, $\eta^2 = 0.28$], but not for intensity [$F(1,20) = 0.48$; $p = 0.497$]. The interaction between delay discounting and implicit associations did not predict observed indices of the APT; $F(3,19) = 0.07$; $p = 0.974$.

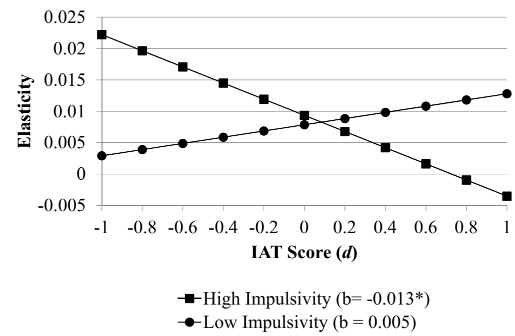

Fig. 1. Regression lines depicting relationships between alcohol approach IAT scores and price elasticity among social drinkers who were high (+1 SD) and low (−1 SD) on delay discounting.

To better characterize the significant interaction, we conducted a simple slopes analysis (Fig. 1) following the recommendations of Aiken and West (1991). Findings indicated that among participants exhibiting high levels of delay discounting (+1 SD), stronger alcohol approach associations were significantly predictive of decreased price elasticity ($b = -0.013$, $SE = 0.004$, $p = 0.004$). On the other hand, for participants who exhibited lower levels of delay discounting (−1 SD), alcohol approach associations were not predictive of price elasticity ($b = 0.005$, $SE = 0.003$, $p = 0.100$). This finding was consistent with our expectation that more-impulsive individuals would be less likely to slow consumption in the face of per-drink price increases than less-impulsive individuals.

3.3. Predictors of alcohol consumption

Finally, we conducted analyses to predict alcohol consumption from participants’ 90-day TLFB data. Higher IAT scores were related to increased alcohol consumption in a multivariate model (Table 3); $F(3,19) = 3.8$; $p = 0.032$, $\eta^2 = 0.41$. Follow-up univariate analyses revealed that this effect was driven by increases in the number of drinking days among participants with higher IAT scores ($b = 14.6$, $p = 0.049$), $\eta^2 = 0.21$. Interestingly, in this sample, neither delay discounting nor its interaction with IAT scores were related to alcohol consumption in multivariate models (Table 3). Although univariate analyses revealed a significant IAT x delay discounting interaction predicting drinking days, the direction of this effect was in the opposite direction than expected ($b = -23.2$): those participants who scored higher on impulsivity but lower on the IAT reported increased drinking days. Other univariate effects were not significant.

In addition, to relate the APT to actual drinking behavior, we analyzed relations between alcohol demand indices and past 90-day alcohol consumption. As indicated in Table 3, both derived and observed measures of intensity were strongly related to increased drinking in multivariate models [F’s = 11.4 and 11.2, respectively, p’s < 0.0001, $\eta^2 = 0.47$–0.68]. Follow-up univariate analyses revealed that these effects were driven by increases in both total drinks (b’s = 6.6 and 6.8, respectively, for derived and observed), as well as drinks per drinking day (b’s = 0.13 and 0.17, respectively, for derived and observed). Other demand indices (elasticity, breakpoint, O_{max}, P_{max}) were not related to alcohol consumption in the multivariate analyses, although O_{max} was pre-

Table 2
MANOVA of IAT and DD predicting APT.

	Multivariate			Elasticity			Intensity		
Task	F	p	η^2	F	p	η^2	F	p	η^2
IAT	3.8	**0.041**	0.20	6.6	**0.018**	0.18	4.3	**0.050**	0.12
DDT	1.5	0.254	0.08	1.8	0.197	0.08	0.3	0.599	0.01
IAT × DDT	3.9	**0.037**	0.29	8.1	**0.010**	0.28	0.5	0.497	0.02

P-values of less than 0.05 are in boldface.

Table 3
MANOVA of APT, IAT, and DDT scores predicting past 90-day drinking (TLFB).

	Multivariate			Total Drinks			Drinking Days			Drinks/Drinking Day		
Task	F	p	η^2	F	p	η^2	F	p	η^2	F	p	η^2
APT												
Elasticity	0.9	0.439	0.15	0.7	0.420	0.04	2.8	0.110	0.14	0.3	0.595	0.02
Intensity-Derived	11.4	**0.0001**	0.68	22.5	**0.0001**	0.56	1.3	0.271	0.07	9.9	**0.006**	0.36
Intensity-Observed	11.2	**0.0001**	0.47	21.1	**0.0001**	0.40	0.1	0.712	0.00	9.4	**0.005**	0.23
Breakpoint	0.5	0.654	0.05	1.4	0.245	0.04	0.3	0.611	0.01	0.8	0.390	0.02
O_{max}	2.1	0.118	0.19	0.7	0.394	0.02	0.6	0.437	0.02	6.7	0.015	0.19
P_{max}	1.2	0.326	0.12	0.4	0.528	0.01	0.1	0.752	0.00	3.3	0.077	0.10
IAT	3.8	**0.032**	0.41	0.1	0.769	0.01	4.5	**0.049**	0.21	3.2	0.092	0.15
DDT	0.6	0.637	0.10	1.7	0.214	0.08	1.1	0.297	0.06	0.003	0.859	0.01
IATxDDT	2.8	0.074	0.24	3.0	0.100	0.14	7.7	**0.013**	0.20	0.03	0.958	0.00

P-values of less than 0.05 are in boldface.

dictive of increased drinks per drinking day in a univariate analysis (see Table 3).

4. Discussion

This study was the first to combine behavioral economic measures of drinking decisions with computerized measures of behavioral impulsivity and implicit associations toward alcohol. The results, which build upon previous research (Burton et al., 2012; Houben and Wiers, 2009), are partially consistent with poor executive control as a moderating factor between implicit alcohol associations and the decisions that young adult social drinkers make about their patterns of alcohol consumption. In many ways, this relationship can be understood as one example of the hypothesized interaction between the brain's automatic and reflective systems that was described earlier: implicit alcohol associations orient the social drinker toward or away from alcohol, and his or her level of executive control helps to determine whether to approach or avoid it.

As noted earlier, impulsivity has been conceptualized in the research literature as a multi-dimensional construct. Our use of the delay discounting task to account for individual variations in impulsivity, while useful in the present study because of the established relationship between delay discounting, financial decision-making, and behavioral economics (Hamilton and Potenza, 2012), is therefore only one potential phenotype of impulsivity, and our results should be considered with the view that more broadly defined phenotypes of impulsivity in future research may help characterize the generalizability and specificity of the effects observed in this study. Nevertheless, our findings suggest that impulsivity can be considered along with other components of executive functioning that have been shown to exhibit moderating relationships with drinking behavior. Deficits in working memory, for instance, have been found to predict drinking behavior in students with more positive implicit associations about alcohol, whereas in students with greater availability of working memory resources, alcohol use was influenced by explicit expectations—i.e., the type of thinking that is thought to come from the reflective system (Thush et al., 2008). In another study (Houben and Wiers, 2009), the strength of implicit associations about alcohol predicted drinking behavior and drinking problems when response inhibition was low (i.e., indicating deficits in executive functioning), but not when response inhibition was high. Taken together with the present results, variations in executive functioning seem to moderate the effect of implicit associations toward alcohol and their effects on decisions to drink.

As hypothesized, alcohol approach associations (i.e., IAT scores) predicted elasticity and intensity, which is generally consistent with previous research finding the IAT to be predictive of actual drinking behavior (Lindgren et al., 2013; Reich et al., 2010; Roefs et al., 2011; Rooke et al., 2008). Stronger alcohol approach associations predicted more inelastic consumption behavior on the APT, indicating decreased sensitivity to increases in the price of alcohol. Interestingly, IAT scores did not predict the APT's observed measures of alcohol demand. Although mixed findings with respect to the APT have been reported (Ramirez et al., 2015 submitted for publication), with many studies suggesting the observed indices of intensity and O_{max} show the most robust relations with clinical outcomes (Murphy et al., 2015), the present results suggest that the derived indices, which model the sum total of participants' responses across the entire task, may be most closely related to automatic alcohol approach tendencies.

Contrary to our expectations, and despite evidence that links delay discounting and impulsivity to actual alcohol use (Field et al., 2007; Papachristou et al., 2012) and alcohol demand (MacKillop et al., 2010) we did not find delay discounting scores to be predictive of any APT indices. One potential explanation for this result is that impulsivity may not operate in the laboratory in the same way that it does at the bar—an impulsive participant, for example, might react with greater impulsivity in "real-life" situations than when presented with hypothetical purchase questions. Previous research with the APT, however, has shown it to be a reliable proxy for actual alcohol consumption decisions (Amlung et al., 2012; Bertholet et al., 2015).

Follow-up analyses of the significant multivariate interaction between IAT scores and delay discounting coefficients suggested that effects were on elasticity rather than intensity. The fact that IAT scores predicted elasticity but not intensity in individuals with greater impulsivity is perhaps not surprising: delay discounting measures the extent to which long-term gain is valued against short-term reward, and reductions in elasticity result in spending more money on alcohol in the short-term rather than saving that money for alternate use in the long-term. Intensity, on the other hand, which represents the maximum number of drinks that would be consumed if alcohol were free, may reflect a different self-regulatory capacity (i.e., the capacity to regulate drinking in the absence of external [price] constraints).

Similar to our findings on the relationships between IAT scores and the derived indices of elasticity and intensity, we found that stronger alcohol approach associations predicted increased self-reported alcohol consumption in a multivariate analysis of the TLFB data. These findings further support previous research (Burton et al., 2012; Jajodia and Earleywine, 2003; Ostafin and Palfai, 2006) on the importance of implicit alcohol associations. In addition to the relationship between IAT and consumption, we also found that both the derived and observed measures of APT intensity were strongly related to increased drinking in multivariate models, an effect that was driven by both increases in the total number of drinks in the TLFB period and the number of drinks per drinking day. Since intensity is a measure of the number of drinks that a person would drink if the drinks were free, participants with greater intensity would thus be expected to have consumed alcohol in greater quantities and more frequently than other participants. At the same time, however, our finding that other indices of demand on the APT did not predict alcohol consumption is more difficult to align with the expectations of this study. Based on previous research (Murphy et al., 2009; Murphy and MacKillop, 2006), we would have expected that participants with more inelastic demand for alcohol would consume more alcohol on a day-to-day basis, but this expectation was not supported by the TLFB data. Future studies with larger samples and more variability in drinking patterns may be warranted to more definitively address these relationships. Additionally, data on binge drinking patterns may be useful in future research projects to help characterize relationships that may exist between IAT, delay discounting scores and this important form of hazardous drinking.

Our findings that neither delay discounting nor the interaction between delay discounting and IAT were related to TLFB alcohol consumption were somewhat unexpected within the larger analysis. Although some inconsistent findings were observed in the univariate analyses, caution is warranted in interpreting these results, given the lack of an overall effect. One possible explanation is that our sample size was small and that TLFB reports of drinking, though a standard technique in alcohol research (Searles et al., 2002), do not always produce data free from errors: consumption recall, for example, becomes less accurate as the time in question becomes more temporally distant (Hoeppner et al., 2010) and differences in interview techniques can alter results (Fishburne and Brown, 2006). In a small sample of non-dependent drinkers, TLFB data may not have sufficient variability to allow statistically meaningful relationships to emerge with respect to delay discounting and/or IAT scores. The limited power of our small sample is likely not sufficient to fully model the pathways between IAT scores, delay discounting coefficients, APT results, and retrospective reports of drinking behaviors. The small sample size also made it inappropriate to test and interpret possible mediation effects between the various measures investigated in this study. Additional research with larger sample sizes will allow further investigation of these pathways and permit the analysis of mediation effects, which will hopefully allow us to clarify the preliminary results that we have obtained here. That said, findings provide a preliminary framework for better understanding drinking motivation in young adult social drinkers, and may be useful in ultimately developing approaches to forestall the onset of problem drinking.

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Contributors

P. Luehring-Jones contributed to data analysis and wrote the bulk of the manuscript. T.A. Dennis-Tiwary contributed to the drafting of the manuscript. J. Murphy and A. Dennhardt provided assistance with the experimental design of the study and data analysis. K. Lindgren provided assistance with the experimental design of the study and contributed to the editing of the manuscript. D. Yarmush conducted the bulk of the data collection and contributed to data analysis. J. Erblich designed the study, completed the analysis of the data, and contributed to the writing of the manuscript. All authors have reviewed and approved the present form of the manuscript.

Conflict of interest

None.

Author disclosures

P. Luehring-Jones contributed to data analysis and wrote the bulk of the manuscript. T.A. Dennis-Tiwary contributed to the drafting of the manuscript. J. Murphy and A. Dennhardt provided assistance with the experimental design of the study and data analysis. K. Lindgren provided assistance with the experimental design of the study and contributed to the editing of the manuscript. D. Yarmush conducted the bulk of the data collection and contributed to data analysis. J. Erblich designed the study, completed the analysis of the data, and contributed to the writing of the manuscript. All authors have reviewed and approved the present form of the manuscript.

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