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Increased Behavioral Economic Demand and Craving for Alcohol following a Laboratory Alcohol Challenge

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Abstract

Background and aims—Although increases in subjective alcohol craving have been observed following moderate doses of alcohol (e.g., priming effects), the effects of alcohol consumption on behavioral economic demand for alcohol are largely unstudied. This study examined the effects of alcohol intoxication on alcohol demand and craving.

Design—A between-subjects design in which participants were randomly assigned to either an alcohol (n = 31), placebo (n = 29) or control (n = 25) condition.

Setting—A laboratory setting at the University of Missouri, USA.

Participants—Eighty-five young adult moderate drinkers were recruited from the University of Missouri and surrounding community.

Measurements—Change in demand for alcohol across time was measured using three single items: alcohol consumption at no cost (i.e., intensity), maximum price paid for a single drink (i.e., breakpoint), and total amount spent on alcohol (i.e., Omax). Alcohol demand at baseline was also assessed using an alcohol purchase task (APT). Craving was assessed using a single visual analog scale item.

Findings—In the alcohol group compared with the combined non-alcohol groups, intensity, breakpoint, and craving increased from baseline to the ascending limb and decreased thereafter (ps < 0.05; Omax $p = 0.06$). Change in craving following alcohol consumption was significantly associated with change in each of the demand indices (ps < 0.0001). Finally, the demand single items were associated with corresponding indices from the APT (ps < 0.01).

Conclusions—Alcohol demand increases following intoxication, in terms of both the maximum amount people are willing to pay for one drink and the number of drinks people would consume if drinks were free. Behavioral economic measures of alcohol value can complement subjective craving as measures of moment-to-moment fluctuations in drinking motivation following intoxication.

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Keywords

Alcohol; behavioral economics; demand; craving; priming effects

Introduction

Alcohol intoxication is widely known to increase the likelihood of a number of negative consequences, including excessive consumption. The notion that the consumption of alcohol can lead to a loss of control over continued use has a long history [1, 2], and difficulty controlling drinking once use is initiated is part of the diagnostic criteria for alcohol use disorder in the DSM-5 [3]. While the behavioral effects of alcohol—such as impaired inhibitory control [4]—are thought to contribute to continued drinking following intoxication, a growing body of research has also implicated cognitive and motivational factors [5]. Excessive drinking while intoxicated, therefore, may be partially explained by dynamic increases in motivation for alcohol.

One approach to measuring moment-to-moment fluctuations in alcohol motivation involves the assessment of subjective craving [6, 7]. Laboratory [8-11] and naturalistic studies [12] have demonstrated that moderate doses of alcohol can elicit greater craving and alcohol-seeking behaviors, often referred to alcohol priming [13]. However, not all studies have reported significant increases in alcohol motivation following consumption [14-16]. These inconsistencies have largely been attributed to methodological differences across studies, particularly in the timing and number of assessments and the variability in methods used to measure subjective craving [7] .

Another approach to assessing alcohol motivation that has been shown to be related to subjective craving is behavioral economic demand, which refers to the quantitative relationship between consumption of a commodity and its cost [17]. Behavioral economics posits that excessive drinking stems from overvaluation of alcohol relative to other rewards, as indicated by increased demand [17, 18]. In the laboratory, demand is typically measured via self-report alcohol purchase tasks (APTs) that assess alcohol consumption at a range of prices [19]. Price-level consumption data is typically consolidated into one or more demand indices prior to data analysis. Common demand indices include intensity (i.e., consumption when drinks are free), breakpoint (i.e., price at which consumption is suppressed to zero), O_{max} (i.e., maximum expenditure on alcohol), P_{max} (i.e., price associated with O_{max}), and elasticity (i.e., proportionate change in consumption with change in price, also referred to as price sensitivity) [19, 20]. These indices have been shown to be related to drinking quantity/frequency, severity of dependence, and poor treatment outcomes [19, 21, 22]. Laboratory research has found that behavioral economic indices of alcohol value are increased following exposure to alcohol-related cues [23, 24] and negative mood inductions [25, 26]. Both of these manipulations commonly elicit increases in craving [27, 28].

Despite its potential as a measure of dynamic changes in alcohol motivation, the effects of alcohol consumption on behavioral economic demand have been largely unstudied. To our knowledge, only one prior study has reported acute alcohol effects on demand [29]. Following an intravenous alcohol administration (target BrAC = 0.06 g%), participants reported greater breakpoint and P_{max} price on an APT, but intensity and O_{max} were not affected by alcohol. This study was designed to examine the combined effects of naltrexone and polymorphisms of the μ-opioid receptor gene in Asian Americans and was not optimally designed to isolate acute alcohol effects. Nevertheless, this study provided preliminary evidence that demand may be dynamically altered following alcohol administration.

The absence of studies in this area may be due to the lack of assessments that are well-suited for examining dynamic changes in demand following alcohol consumption. With a few exceptions [23, 25, 30], APT assessments are typically framed in the context of a hypothetical drinking situation instead of the present moment. In addition, purchase tasks often assess consumption at twenty or more prices which may not be optimal in an alcohol administration context. One way to simplify these measures is to forgo price-level assessment and assess demand indices directly. For intensity, this involves essentially the same question as the free price item on an APT (e.g., the number of drinks consumed if they were free). Breakpoint and O_{max} are not explicitly assessed on APTs but are instead typically calculated based on responses across several prices. Nonetheless, these indices can be assessed by asking participants the highest price they would pay for a single drink (breakpoint) or the maximum total amount they would spend on alcohol (O_{max}). Calculating measures of price sensitivity (e.g., P_{max} and elasticity) typically requires consumption values at multiple prices and, as such, these indices are not well-suited for a single item format. In sum, using a single item format has the potential to be a more efficient and less burdensome method of assessing certain aspects of alcohol demand.

The aims of the present study were twofold. First, we aimed to test whether behavioral economic demand, assessed using single items for intensity, breakpoint, and O_{max}, would display a priming effect similar to that of subjective craving following alcohol consumption. We assessed demand and craving at multiple time points following consumption of an alcohol, placebo, or control beverage in order to assess their change across the breath alcohol concentration (BrAC) curve. We hypothesized that demand and craving would increase following alcohol consumption and changes in alcohol demand and craving would be correlated over time. Second, we evaluated the strength of the relation between the demand single items and demand indices obtained from a full APT assessment. We predicted that higher demand on the single items would be significantly correlated with higher demand on the APT.

Method

Participants

Participants were recruited from the University of Missouri and the surrounding community. E-mail advertisements were sent via university listservs and fliers were posted on campus and at local businesses. Potential participants were screened via a telephone interview. Participants were required to be at least 21 years old and report consuming five or more drinks on one occasion in the preceding six months. Participants were excluded if they were pregnant/nursing, had a body mass index (BMI) greater than 30, were taking medication with which alcohol use is contraindicated, or reported a psychiatric, medical or substance use disorder. Ninety-two participants enrolled in the study. Seven participants were later excluded: 2 participants became ill following alcohol administration, a participant in the placebo group failed the manipulation check, and 4 participants either failed to comply with pre-session instructions or misreported their eligibility at screening (e.g., BMI >30). The final sample (n = 85) was 52% female and 82% Caucasian, with a mean age of 22.94 years (SD = 3.41) (Table 1). Participants typically drank alcohol twice a week and consumed 3-4 drinks per drinking day.

Measures

Demographics—Demographic information such as age, sex, race, and income was collected with a self-report questionnaire.

Alcohol use—Past-month quantity and frequency of alcohol use was assessed using the items from NIAAA Task Force on Recommended Alcohol Questions [31]. The Young Adult Alcohol Consequences Questionnaire (YAACQ) assessed consequences associated with alcohol use [32].

Alcohol purchase task—Participants completed a hypothetical APT [19] that asked participants how many standard-sized drinks of their preferred alcoholic beverage they would consume at 21 prices, ranging from free to $30 / drink. Participants were given standard instructions based on previous studies using APTs (e.g., assume a typical drinking situation, no opportunity for drinking elsewhere, no stockpiling drinks for later consumption) [19, 22]. The following observed indices of alcohol demand were generated: APT-intensity (consumption when drinks were free); APT-breakpoint (the first price at which consumption was suppressed to zero); and APT-O_{max} (maximum alcohol expenditure) [see 19, 24].

Alcohol demand single items—Real-time level of alcohol demand was assessed using three single items. These items correspond to the observed demand indices generated from a standard APT. Intensity was assessed by asking, “If drinks were free, how many drinks would you have right now?” with a response range of 0-14 drinks. Breakpoint was assessed by asking, “What is the maximum amount that you would pay for a single drink right now?” with a response range of $0-20. O_{max} was assessed by asking, “What is the maximum total amount that you would spend on drinking right now?” with a response range of $0-40. Response ranges on these items were based on values reported in prior studies using APTs in similar samples [e.g., 19, 24, 33].

Alcohol craving—Subjective craving for alcohol was assessed using a single 100-point visual analog scale (VAS) item, asking “How much do you want a drink right now?”

Breath alcohol concentration—Breath alcohol concentration was assessed using a FSTAlco-Sensor breathalyzer device (Intoximeters, Inc.; St. Louis, MO). Readings were collected at five minute intervals following beverage administration.

Procedure

This study employed a double-blind, between-subjects design in which participants were randomly assigned to the alcohol (*n* = 31), placebo (*n* = 29) or control (*n* = 25) condition. Participants were asked to abstain from alcohol and drug use for 24 hours prior to their appointment and to refrain from eating for 60 minutes prior to the start of their session. Participants arrived at the lab at 10:00 AM, with beverage administration occurring at approximately 12:00 PM. Sessions were administered by two staff members. One staff member was blind to condition and interacted with the participant. A second staff member handled random assignment at the beginning of the session, prepared the beverages, and collected BrAC readings. Participants first provided informed consent and sobriety was verified (i.e., BrAC = 0.00 g%). Female participants were given a urine pregnancy test; no participants tested positive. Participants then completed computerized questionnaires, including the demographics and APT assessments. To control for gastric content, participants consumed a small meal (15% of recommended daily caloric intake based on sex and body size) 90 minutes prior to beverage administration.

Alcohol dose was calculated on an individual basis to produce a peak BrAC of 0.10 g% at approximately 60 minutes post-consumption [34]. Specific doses were approximately 0.85 g/kg for males and 0.73 g/kg for females [34, 35]. The alcohol group expected to receive alcohol and consumed 190-proof pure grain alcohol mixed with orange juice in a 1:3 ratio. The placebo group expected to receive alcohol but consumed orange juice with 6 mL of 190-proof alcohol floated on top. The control group did not expect to receive alcohol and consumed only orange juice. Volume of the placebo and control beverages was equivalent to the volume had the participant been assigned to the alcohol group. Beverages were divided equally into two glasses and participants consumed each glass in one minute, with a five minute break between glasses [36, 37]. The alcohol demand single items and alcohol craving were administered five times: baseline, immediately post-consumption, ascending BrAC (~0.06 g%), peak BrAC (~0.10 g%), and descending BrAC (~0.06 g%) [37]. Timing of assessments for the placebo and control groups was based on estimated rate of change in BrAC [e.g., 38]. Ascending, peak, and descending assessments were administered approximately 35 min (*SD* = 11), 77 min (*SD* = 14), and 193 min (*SD* = 41) after drinking began.

The placebo manipulation was verified by asking participants whether they believed they received alcohol and how many standard drinks they received. Participants were debriefed and informed of beverage group status. Participants in the alcohol group remained in the laboratory until their BrAC was below 0.04 g% [39]. Placebo and control participants were permitted to leave following the conclusion of the study. Participants were compensated $12/hour and were transported home via a prepaid taxi or friend. All procedures were approved by the University of Missouri Institutional Review Board.

Data Analysis

Multilevel growth models with responses to demand and craving items (level 1) nested within participants (level 2) were estimated in SAS 9.4 (SAS Institute Inc., Cary, NC) using PROC MIXED. The rationale for this approach was threefold: (1) multilevel models account for the nesting of responses within participants; (2) multilevel models are robust to missing values in the data; and (3) multilevel models have been increasingly applied to alcohol administration data from complex within-subjects designs [e.g., 40]. Separate quadratic growth models, using unstructured working correlation matrices, were specified for each of the demand single items as well as craving. Time was dummy coded from baseline = 0 to descending limb = 4. As such, the intercept of each model is interpreted as demand and craving prior to consumption. Drinking quantity and YAACQ total score were entered into the models to control for drinking patterns and alcohol problems, respectively.

To examine the acute effects of alcohol on changes in alcohol demand, we entered both fixed main effects and cross-level interaction terms for condition (placebo = reference) with the time variable. There were no significant differences between the placebo and control beverage groups for the demand single items or craving (see Figure S1 and Table S1). Therefore, these groups were combined into a single no-alcohol group for all analyses. We then examined whether level of demand on the single items was associated with demand on the full APT. To do this, we included the different APT indices as time-invariant covariates in the model of their respective single item measure. Finally, we included craving as an additional time-varying covariate in the models to determine whether change in craving was associated with the change in each of the demand items.

Results

Descriptive Statistics

Computer error resulted in a small percentage of missing values for the alcohol demand single items (2.9% of all data points) and a larger percentage of missing values for alcohol craving (15.8% of all data points)[1]. For the alcohol group, the mean BrAC levels were 0.065 g% (*SD* = 0.005), 0.093 g% (*SD* = 0.013), and 0.073 g% (*SD* = 0.011) for the ascending limb, peak, and descending limb assessments, respectively. Alcohol demand on the APT was prototypical, with consumption decreasing as drink prices increased and expenditure conforming to an inverted U-shape (Figure 1). Compared to the no-alcohol group, alcohol participants reported significantly higher APT-O_{max} ($p < .05$), but there were no group differences in APT-intensity or APT-breakpoint (Table 1).

Acute Alcohol Effects on Alcohol Demand

There were no statistically-significant differences between groups at baseline for any of the three demand items. Change in demand is depicted in Figure 1 and results of the multi-level models are presented in Table 2. For change in Intensity and Breakpoint over time, both the alcohol × linear slope and alcohol × quadratic slope terms were significant For O_{max}, only alcohol × quadratic slope was statistically significant. For the alcohol group, but not the no-alcohol group, demand increased from post-consumption to ascending limb and then decreased from ascending limb to the descending limb.

[1]The high rate of missing values for craving resulted from a computer error, where a response at the minimum value was incorrectly coded as missing for some individuals. To examine the potential influence of this error, we ran all study analyses replacing missing craving values with the minimal response (i.e., 0). The pattern of results was unchanged.

For all three indices, higher demand on the APT was associated with higher demand on the corresponding single items (*p*s < .01; Table 2). Each of the single items was also positively correlated with its corresponding APT index at each time point, with amount of shared variance differing considerably across indices (R^2 = .04-.42) (Table S2). Finally, there were significant positive correlations among the single items at each of the five time points. The highest correlations were between O_{max} and breakpoint (*r*s .82-.86, *p*s < .001), followed by O_{max} and intensity (*r*s .52-.65, *p*s < .001), and comparatively smaller magnitude correlations between intensity and breakpoint (*r*s .36-.45, *p*s < .001).

Association between Alcohol Demand and Subjective Craving

Similar to the pattern observed for alcohol demand, craving in the alcohol group increased from post-consumption to the ascending limb and decreased thereafter (Figure 1D and Table 2). When we included alcohol craving as a time-varying covariate in the models, change in craving was significantly associated with change in each demand index (Intensity: B = 0.03, SE = 0.01; β = .24; t = 6.44, p < .0001; Breakpoint: B = 0.03, SE = 0.01; β = .20; t = 5.76, p < .0001; O_{max}: B = 0.10, SE = 0.01; β = .27; t = 8.30, p < .0001). The single items were also positively correlated with craving at each time point, albeit at differing magnitudes (Table S2). The highest amount of shared variance was between intensity and craving (R^2 = .06-.23), followed by Omax and craving (R^2 = .06-.15), with smaller shared variance for breakpoint and craving (R^2 = .03-.07)

Discussion

Moderate doses of alcohol can elicit increases in subjective craving [8-13], but it is unclear whether these priming effects extend to other measures of alcohol motivation, such as alcohol demand. Consistent with Bujarski et al [29], alcohol increased the maximum amount that participants were willing to pay for a single drink (i.e., breakpoint). Alcohol also increased the number of drinks participants would consume if drinks were free (i.e., intensity). Thus, intoxication produced an upward shift in the amplitude of the alcohol demand curve at low prices and shifted the curve such that individuals would continue to drink at higher prices. Finally, level of demand on the three single items was significantly associated with demand on the full APT, and change in demand followed a similar time course as craving.

An advantage of behavioral economics is that it quantifies a construct such as alcohol motivation into externally-relevant metrics such as number of drinks and money spent [17]. By demonstrating that these demand indices are sensitive to alcohol priming effects, our results may allow for testing mechanisms by which alcohol-induced increases in subjective craving can influence drinking. For example, alcohol demand could represent an intermediate step between craving and consumption, such that dynamic increases in craving produce a corresponding increase in the relative value of alcohol that, in turn, influences drinking decisions. Further research is needed to clarify the relationship between fluctuations in craving, demand, and subsequent drinking behavior.

From a methodological standpoint, these results support the utility of using single items as valid measures of alcohol demand. In terms of external validity, we found that changes in demand tracked changes in craving, which is consistent with studies using APTs [23-25]. Higher demand on the single items was also associated with greater demand on the APT, supporting the internal validity of the single items. Prior studies using APTs have found particularly high correlations between breakpoint and O_{max} [19, 22, 23, 25], which were similarly highly correlated in the present study. Given the high correlation between the O_{max} and breakpoint, it is possible that these items are measuring a common underlying aspect of alcohol value. A priority moving forward is to determine the extent to which the O_{max} and breakpoint items provide unique information about dynamic influences on demand. Another priority is to develop methods for estimating price sensitivity (e.g., elasticity and P_{max}) using a small number of items, particularly since price sensitivity has been shown to be affected by alcohol [29].

This study provides some of the first data on alcohol effects on demand. These results require replication in samples with varying levels of alcohol use and misuse. Nonetheless, this study suggests a number of promising directions for future research. Considering the inconsistent relationship between priming effects and alcohol consumption [8-10], an important next step is to determine whether increases in demand predict actual drinking. Future studies utilizing alcohol self-administration paradigms may help clarify this relationship. Another important future direction is to adapt the single items to assess demand for other addictive substances, including tobacco [41, 42] and illicit drugs [42-44].

There are several limitations to the current study. The demand measures assessed self-reported alcohol consumption. Although prior research has found close correspondence between hypothetical and actual-reward APTs [24], whether this relationship holds for the single items is unknown. While typical instructions were provided for the APT, only limited instructions were provided for the single items in order to keep the assessment as brief as possible. Participants were also not explicitly told to assume their current income when making choices. Future studies should examine the impact of different task instructions on the single items. The sample was drawn from one geographic location, and the majority of participants were young adults and Caucasian, which may limit generalizability. Participants were tested in a laboratory setting, rather than natural drinking environments. The brevity of the demand single items makes them particularly amenable to studies using an ecological momentary assessment framework, which would allow for the examination of fluctuations in alcohol motivation outside the laboratory [45-47]. Finally, the alcohol administration protocol included a relatively strong beverage, a short consumption period, and an unusual time of day for alcohol consumption. This protocol may not be representative of typical drinking patterns for social drinkers.

In summary, the present study extends the literature on alcohol priming effects by demonstrating that alcohol demand also increases following intoxication. These findings provide initial support for using a small number of self-report items to assess indices of alcohol demand when full APT assessments may not be feasible. More generally, this study contributes to the literature suggesting that behavioral economic measures of alcohol value can complement subjective craving as measures of moment-to-moment fluctuations in drinking motivation.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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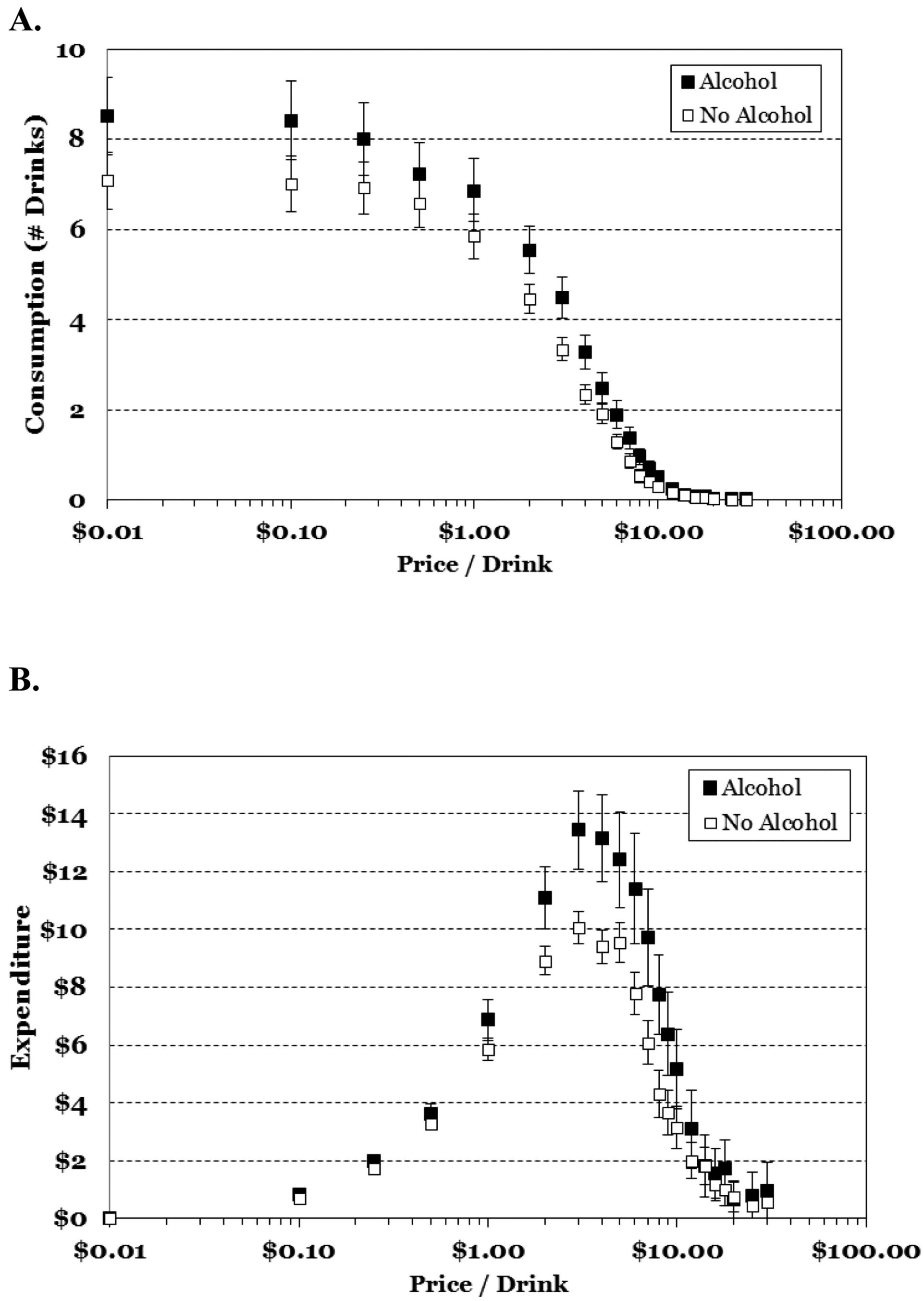

Figure 1.

Demand and expenditure curves from the alcohol purchase task. Self-reported alcohol consumption (Panel A) and expenditure (Panel B) as a function of drink price for alcohol group (filled squares) and no alcohol group (unfilled squares). X-axis presented in logarithmic coordinates for proportionality. Data points reflect mean (+/− SE).

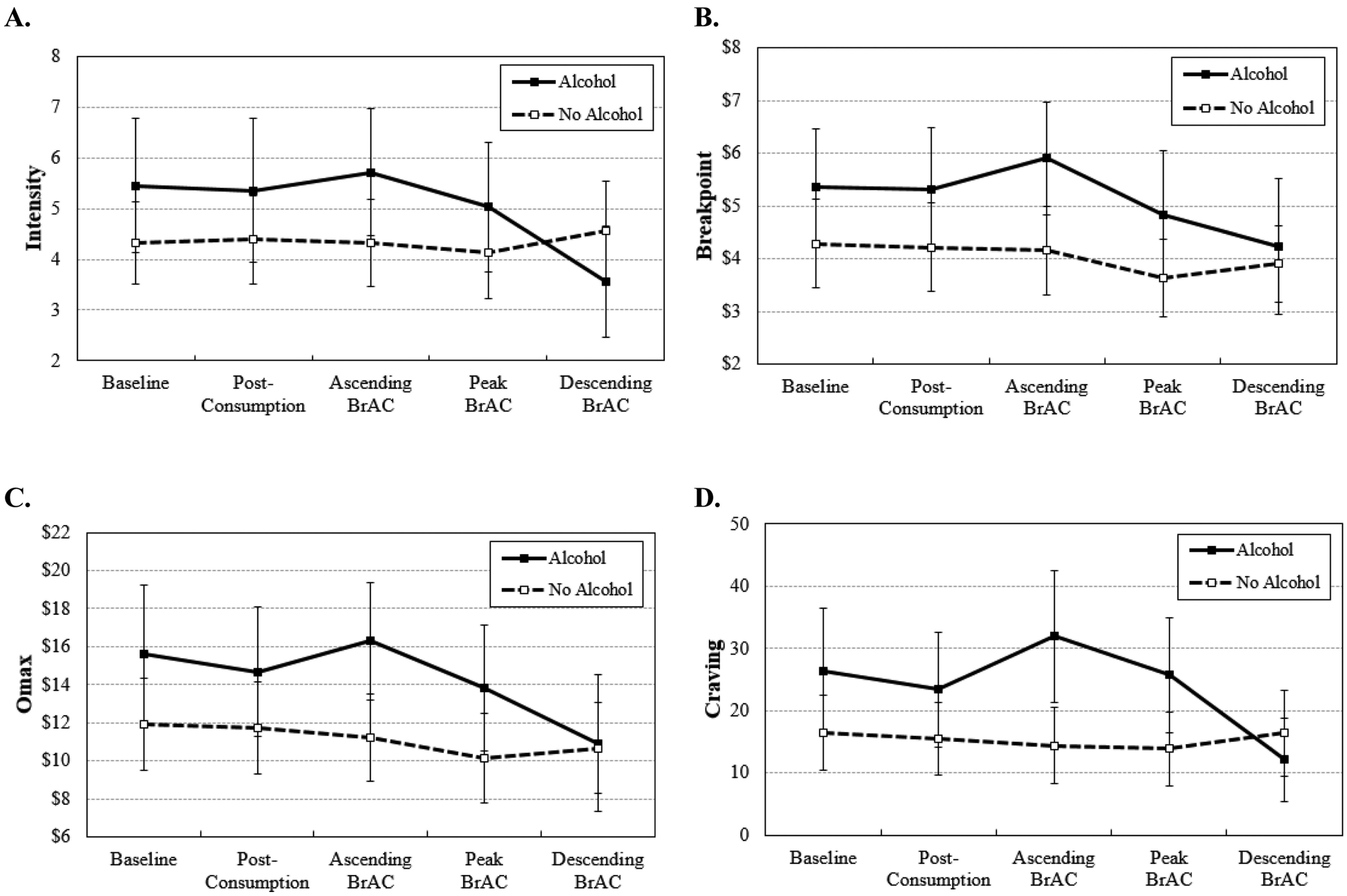

Figure 2.

Change in alcohol demand (Panels A-C) and subjective alcohol craving (Panel D) over time. Solid lines correspond to the alcohol group and dashed lines correspond to the combined no alcohol (placebo + control) group. Data points reflect mean and 95% confidence intervals. *Note:* BrAC = breath alcohol concentration.

Table 1

Participant Characteristics by Beverage Group

	Alcohol Group (n = 31)	**No-Alcohol Group (n = 54)**
Age, *M* (*SD*)	22.90 (3.41)	22.65 (2.69)
Females	52%	52%
Caucasian	87%	80%
Income, *Med.*	<$25,000	<$25,000
Drinking frequency, *Med.*	1× / week	2× / week
Drinking quantity, *Med.*	3-4 drinks	3-4 drinks
YAACQ Total, *M (SD)*	14.45 (7.30)*	10.74 (7.64)
APT-Intensity, *M* (*SD*)	8.52 (4.79)	7.09 (3.31)
APT-Breakpoint, *M* (*SD*)	$10.19 (3.90)	$9.67 (4.47)
APT-O_{max}, *M* (*SD*)	$17.23 (10.53)*	$12.76 (5.50)

Note. APT = alcohol purchase task; YAACQ = Young Adult Alcohol Consequences Questionnaire; M = mean; Med. = median; SD = standard deviation.

*Group difference significant at $p < .05$.

Table 2

Results of Multilevel Growth Curve Models for Alcohol Demand and Craving

Variable	*B*	*SE B*	β	*t*	*p*
Intensity					
Linear slope	−0.03	0.18	−.01	−0.16	.87
Quadratic slope	0.00	0.05	.00	−0.01	.99
Alcohol (vs. no-alcohol)	0.14	0.61	.04	0.23	.82
Alcohol × Linear slope	0.66	0.30	.19	2.17	.03
Alcohol × Quadratic slope	−0.26	0.09	−.08	−3.00	.003
APT-Intensity	0.38	0.09	.45	4.42	<.001
Breakpoint					
Linear slope	−0.17	0.14	−.05	−1.14	.26
Quadratic slope	0.00	0.04	.00	−0.02	.98
Alcohol (vs. no-alcohol)	0.83	0.69	.26	1.20	.23
Alcohol × Linear slope	0.63	0.24	.20	2.64	.01
Alcohol × Quadratic slope	−0.19	0.06	−.06	−3.15	.002
APT -Breakpoint	0.24	0.07	.33	3.55	<.001
O_{max}					
Linear slope	−0.48	0.50	−.05	−0.97	.34
Quadratic slope	−0.01	0.11	.00	−0.08	.94
Alcohol (vs. no-alcohol)	1.38	2.23	.15	0.62	.54
Alcohol × Linear slope	1.58	0.82	.17	1.93	.06
Alcohol × Quadratic slope	−0.52	0.19	−.06	−2.74	.007
APT -O_{max}	0.26	0.12	.22	2.16	.03
Craving					
Linear slope	−2.16	2.69	−.09	−0.80	.43
Quadratic slope	0.52	0.62	.02	0.83	.41
Alcohol (vs. no-alcohol)	5.42	5.77	.32	0.94	.35
Alcohol × Linear slope	9.57	4.32	.39	2.22	.03
Alcohol × Quadratic slope	−3.02	1.00	−.12	−3.03	.003

Note: APT = alcohol purchase task; No alcohol (placebo + control) group served as reference group for comparison with the alcohol group in all analyses. Models controlled for alcohol problems (YAACQ total score) and drinking quantity.