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Using Demand Curves to Quantify the Reinforcing Value of Social and Solitary Drinking

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Abstract

Background: Young adults typically drink in social settings and report high levels of episodic heavy drinking despite a range of adverse consequences. Behavioral economics posits that this may reflect a reinforcer pathology in which alcohol is overvalued relative to other reinforcers. Theoretically, the value of alcohol is related to both the direct pharmacological effects of alcohol (euphoria, sedation) and to the associated social reinforcement, but to date no studies have differentiated the value of social vs. solitary drinking. The current study examines two modified hypothetical alcohol purchase tasks (APTs), one explicitly social and one explicitly solitary, in order to quantify the reward value of social vs. solitary drinking, and to determine if there are unique clinical correlates of solitary alcohol demand.

Methods: Participants were young adults ($N = 274$, $M_{age} = 25.15$, $SD = 4.10$) recruited from Mturk and from a university subject pool. Participants completed a solitary and social APT, in addition to measures of alcohol consumption and problems.

Results: Participants reported significantly greater demand in the social APT compared to the solitary APT across all demand indices. Elevated solitary and social demand were associated with elevated levels of alcohol use and problems. Using a residualized change approach, solitary demand amplitude (maximum consumption and expenditure) and persistence (price sensitivity) contributed additional variance above and beyond their social APT composite counterparts in predicting typical drinks per week and the self-care, academic/occupational, and physical dependence subscales of the YAACQ.

Conclusions: The presence of peers increases alcohol demand compared to a solitary scenario, and greater relative solitary drinking demand may be a risk factor for greater alcohol consumption and problems.

Keywords

Young adults; Alcohol; Alcohol demand; Solitary drinking; Social drinking

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Annually, approximately 82% of adults ages 19 to 30 consume any amount of alcohol, and roughly 68% report drinking in the past 30 days (Schulenberg et al., 2018). Further, heavy episodic drinking (defined as 4/5 or more drinks in a row for women/men) tends to peak between 18 and 25 years, while daily alcohol use continues to gradually increase through the second and third decades of life (Schulenberg et al., 2018). Patterns of frequent heavy episodic drinking can often lead to significant acute (e.g., hangovers, blackouts, DUI) and chronic (e.g., academic/occupational impairment, physical dependence, alcohol-related cirrhosis) health and social consequences (Jennison, 2004; Tapper & Parikh, 2018). Indeed, alcohol-related deaths have doubled over the past decade, with the greatest increases among females and adults aged 25–34 (White et al., 2020).

Behavioral economics integrates principles of microeconomics and operant psychology to explain choice behavior and provides a helpful framework for understanding choices to drink (Bickel et al., 2017; Bickel & Marsch, 2001; Hursh, 1984). From this perspective, choices to drink are made in a manner that maximizes benefits and minimizes costs. Despite the range of potential consequences, many young adults regularly engage in episodic heavy drinking. This may reflect an overvaluation of alcohol, a phenomenon central to the behavioral economic reinforcer pathology theory. Alcohol can become highly valued when there is a paucity of rewarding alternatives (e.g., limited social or leisure options, or satisfying relationships or vocational/academic pursuits) and/or when alternative rewards are delayed relative to the immediacy of alcohol-related reward (both the pharmacological effects of alcohol and the associated social reward), resulting in consistent preference for alcohol relative to alternatives. Because regular alcohol use can reduce the reward value of substance-free alternatives (e.g., negatively impact health, interpersonal, or vocational functioning), this further enhances the relative value of alcohol resulting in a vicious reinforcer pathology cycle of increasing preference for alcohol over available alternative rewards (Bickel et al., 2014; Rachlin, 1997).

Behavioral economic researchers operationalize alcohol reward value via hypothetical alcohol purchase tasks (APTs) that ask participants to estimate how many drinks they would purchase and consume across an escalating series of prices in a typical drinking scenario (Kaplan et al., 2018; Murphy & MacKillop, 2006; Petry & Bickel, 1998). These responses are used to plot alcohol demand curves, which generate indices representing different aspects of motivation to consume alcohol, such as intensity (consumption when drinks are free), breakpoint (the price at which consumption is fully suppressed), O_{max} (maximum expenditure across prices), P_{max} (the price at which maximum expenditure occurs), and elasticity (the rate of change in consumption as a function of price, or degree of sensitivity to price increases). Within-person consumption prototypically descends as price increases, but individual differences in the degree that this occurs, and in peak consumption and expenditures, have been useful indicators of problematic use (Kiselica et al., 2016).

Although standard APTs narrowly define price as monetary expenditures, individuals' decisions about whether and how much to drink are likely influenced by a variety of non-

financial costs as well, including health, personal, and social cost. As a result, APTs have been systematically modified to test the influence of various contextual factors, such as cue exposure (MacKillop et al., 2010) and opportunity costs (i.e., the loss of a potential benefit from an alternative activity), like having a next-day responsibility (Martinetti et al., 2019), and meta-analytic results have demonstrated consistent effects on alcohol demand in the hypothesized directions (Acuff et al., 2019). Some studies have also reported on the between-person predictive utility of differences in alcohol demand derived from two APTs (Joyner et al., 2019), which may reflect a broader modeling of elasticity of demand that accounts for variation in context aside from monetary price. For example, college students with a family history of problematic alcohol use have shown smaller reductions in demand derived from a standard APT compared to a modified APT in which the individual had a class the next morning (Murphy et al., 2014).

As such, context-adapted APTs might be particularly helpful in understanding young adult drinking. One important contextual element that has not yet been modeled is the social context of drinking. Young adult drinking often occurs in a social context (Murphy et al., 2006), and the reinforcing value of drinking likely reflects both the direct pharmacological reinforcing properties of alcohol and the social reward associated with drinking with peers. Social relationships increase evolutionary fitness (Alexander, 1974), and anything paired with social connection thus has the potential to become a salient reinforcer. This is particularly true during the developmental span from adolescence through young adulthood, an exigent period for establishing social status and potential mating partners (Ellis et al., 2012). Indeed, evidence does support that alcohol increases feelings of social connection. An experimental laboratory study conducted by Sayette and colleagues (2012) demonstrated that those participants who consumed alcohol (compared to a control beverage or placebo) scored higher on objective indicators of social interaction and connection and self-reported experiencing elevated bonding and enhanced behaviors associated with positive affect. Further, individuals tend to seek out acceptance in a group by emulating behaviors associated with that group, and it is no surprise that those who perceive higher alcohol consumption amongst their peers are also more likely to consume alcohol at higher levels (Neighbors et al., 2008). Thus, many young adults report that the negative consequences associated with heavy drinking are outweighed by the positive social effects of drinking (Miller et al., 2018; Nezlek et al., 1994). The results of these studies suggest highlight how social connection might increase the value of drinking are consistent with recent work demonstrating that greater heavy drinking in the social network is associated with greater alcohol demand, and that alcohol demand accounts for the variance in the relation between alcohol density in the social network and alcohol misuse (Acuff et al., 2020). Not surprisingly, the vast majority of heavy drinking episodes occur in social rather than solitary settings (Gonzalez et al., 2009).

When young adults do drink in isolation, then, it may be indicative of problem drinking. Estimates suggest that between 31 and 48% of individuals report drinking any alcohol while alone in the past month, and between 17 and 25% report a solitary heavy drinking episode (Demers & Bourgault, 1996; Gonzalez et al., 2009). Indeed, solitary drinking episodes are related to higher levels of alcohol problems than are social drinking episodes (Gonzalez et al., 2009), which may be in part due to the fact that solitary drinking seems driven by coping

motives, which are often associated with higher levels of alcohol problems than other motives for drinking (e.g., enhancement, conformity, celebration; Gonzalez et al., 2009; Mohr et al., 2013). In support of this explanation, those reporting solitary drinking are more likely to report depression, suicidal ideation, and anxiety (Gonzalez et al., 2009), and solitary drinking mediates the relation between both depression and alcohol problems among young adults (Keough et al., 2015). Solitary drinking may also be associated with a loss of control over drinking (Keough et al., 2018) and increased risk for alcohol use disorder (Creswell et al., 2014). It is important to note that, although solitary drinking is linked to coping motives, many may also drink while in social situations to alleviate anxiety (Keough et al., 2016).

Current Study

Previous findings suggest that endogenous and exogenous factors influence demand, that APTs are sensitive to these factors, and that insensitivity to these factors might reflect more problematic patterns of alcohol use. However, the effects of manipulations to the drinking context (i.e., social v. solitary) on alcohol demand have not previously been examined. The current study compares two modified APTs: one in which the participant is drinking with two friends, and one in which the participant is drinking alone. This study isolates the effects of peers on motivation to drink and explores the predictive utility of motivation to consume alcohol in a context void of social benefits. First, because most young adults drink socially and the standard APT asks for responding in a typical drinking situation, we hypothesized that demand in the social APT will be comparable to demand in the standard APT. Second, we hypothesized that demand in both APTs will be significantly greater compared to demand in the solitary APT. Third, we hypothesized that individuals with higher levels of alcohol problems would demonstrate higher levels of demand on both social and solitary APTs, and smaller reductions in demand from the social to the solitary condition, compared to those with low levels of alcohol problems. Fourth, we hypothesized that males would report higher alcohol demand than females across both APTs, and that those in college would report higher alcohol demand than their non-college attending peers, given the known relations between both sex and student status on alcohol demand and alcohol misuse. Finally, we hypothesized that solitary APT demand would explain unique variance in typical drinks per week and alcohol problems above and beyond social drinking APT demand.

Methods

Participants

Participants were recruited from a psychology subject pool at a large public university in the southern United States and through Amazon’s Mechanical Turk (Mturk). To be included in the study, participants had to be between 18 and 30 years old and report drinking any amount of alcohol in the past 6 months. Participants were also required to successfully answer at least three out of four attention check items for data to be used in analyses (Hauser & Schwarz, 2016). A total of 358 and 200 individuals completed the survey via Mturk and the subject pool, respectively. 202 (56.4%) individuals from Mturk and 72 (36%) from the subject pool both reported alcohol use in the past 6 months and satisfactorily completed the attention check. Data collection and screening methods largely reflect best practice

suggestions for using this subject pool (Mellis & Bickel, 2020). Demographic data for the full sample and for each data source are reported in Table 1. Participants from the SONA subject pool and from Mturk differed in sex, student status, age, typical drinks per week, and alcohol problems.

Measures

Alcohol Demand.—Three hypothetical alcohol purchase tasks (APTs) were used to assess alcohol demand across three scenarios/conditions: standard, social, and solitary. The first condition presented a standard alcohol purchase task (Murphy & MacKillop, 2006) in which participants were instructed to pretend to purchase and consume alcohol with the following vignette in mind:

> Imagine that you and your friends are at a party on a Thursday night from 9:00 PM until 1:00 AM to see a band. Imagine that you do not have any obligations the next day (i.e., no work or classes). The following questions ask how many drinks you would purchase at various prices. The available drinks are standard size domestic beers (12 oz.), wine (5 oz.), shots of hard liquor (1.5 oz.), or mixed drinks containing one shot of liquor. Assume that you did not drink alcohol or use drugs before you went to the party, and that you will not drink or use drugs after leaving the party. Also, assume that the alcohol you are about to purchase is for your consumption only during the party (you can't sell or bring the drinks home).

Participants were then instructed to report the number of standard drinks they would purchase and consume at each of the following price points: $0.00 (free), $0.50, $1.00, $1.50, $2.00, $2.50, $3.00, $4.00, $5.00, $6.00, $7.00, $8.00, $9.00, $10.00, $11.00, $12.00, $13.00, $14.00, $15.00, $16.00, $18.00, $20.00, $22.00. This standard hypothetical APT has demonstrated good reliability and evidence for validity (Amlung & MacKillop, 2015; MacKillop et al., 2007; Murphy & MacKillop, 2006), and has frequently been used in young adult populations (Acuff, Soltis, Dennhardt, et al., 2018; Martinetti et al., 2019).

Social Alcohol Demand.: The second condition presented a similarly structured alcohol purchase task in which participants were instructed to consider the following scenario, with italics included here denoting differences from the standard APT:

> *Imagine that you are traveling with two friends and you have the opportunity to purchase alcohol in your hotel room*. The available drinks are standard size domestic beers (12 oz.), wine (5 oz.), shots of hard liquor (1.5 oz.), or mixed drinks containing one shot of liquor. Assume that you could not obtain alcohol from any other source (i.e., you could not leave and go to a bar or liquor store). Also, assume that the alcohol you are about to purchase is for your consumption only during that evening. In other words, you can't sell the drinks or give them to anyone else or save the drinks you purchase for another day. *Everything you buy is, therefore, for your own personal consumption during one evening at the hotel. Also assume you're your friends will make the same drink purchases that you make*.

This vignette attempts to isolate the social aspect of alcohol demand, specifying that the individual is drinking with only two friends outside of a party or bar setting. Again,

participants were instructed to report the number of standard drinks they would purchase and consume at each of the same price points listed for the standard APT.

Solitary Alcohol Demand.: The third condition, a similarly structured task to the standard and social APTs, instructed participants to consider the following scenario, with italics included here denoting differences from the social APT:

> Imagine that you are *traveling alone* and you have the opportunity to purchase alcohol in your hotel room. The available drinks are standard size domestic beers (12 oz.), wine (5 oz.), shots of hard liquor (1.5 oz.), or mixed drinks containing one shot of liquor. Assume that you could not obtain alcohol from any other source (i.e., you could not leave and go to a bar or liquor store) and that you also can't save the drinks you purchase for another day. Everything you buy is, therefore, for your own personal consumption during one evening at the hotel.

This vignette attempts to isolate alcohol demand outside of any social context. Participants were instructed to report the number of standard drinks they would purchase and consume at each of the same price points as the standard and social APTs. The current study examined four observed indices from each APT condition: intensity (consumption with no constraint, or when drinks are free), breakpoint (price at which consumption reaches zero), O_{max} (maximum expenditure), P_{max} (price at which O_{max} occurs and when demand becomes inelastic). We also derived elasticity (the rate of change in consumption as a function of price) using the exponentiated equation (Koffarnus et al., 2015). In the current study, k (1.32) was calculated by subtracting the log10-transformed average consumption at the highest price from the log10-transformed average consumption at the lowest price using the raw data from all three APTs (Koffarnus et al., 2015). Data were screened for inconsistency using the Stein macro (Stein et al., 2015) based on the following criteria: (1) trend (detection limit for $\Delta Q < 0.025$); (2) bounce (detection limit for $B = 0.10$); (3) reversal from zero (detection limit number for reversals = 2 or more). For the standard APT, 6.7% did not pass due to reporting of a single number across prices (e.g., all 1s, or all 0s) and 14.1% did not pass due to inconsistencies. Similarly, for the social APT, 7.3% did not pass due to reporting of a single number across prices and 14.1% did not pass due to inconsistencies. Finally, for the solitary APT, 12.6% did not pass due to reporting of a single number across prices (all 1s, or all 0s) and 14.8% did not pass due to inconsistencies. Data was deleted pairwise, (i.e., observed indices for data that was valid but could not be used for calculating elasticity was still used for observed analyses). Elasticity data was calculated using the Demand Curve Analyzer software (Gilroy et al., 2018), which is freely available online at: https://github.com/miyamot0/DemandCalculatorQT. Factor analysis has revealed that demand indices fall into two distinct factors: amplitude (intensity and O_{max}), representing maximum consumption and expenditure, and persistence (breakpoint, O_{max}, P_{max}, and elasticity), representing price sensitivity. Responding on hypothetical purchase tasks are correlated with actual purchasing behavior (Amlung & MacKillop, 2015), and test-retest reliability for alcohol purchase tasks are robust (Acuff & Murphy, 2017).

Alcohol Consumption.—To determine the typical number of drinks consumed per week, we used the Daily Drinking Questionnaire (DDQ; Collins et al., 1985). Participants

estimated the number of drinks they consumed on each day in a typical week in the past month. The number reported for each day of the week was summed to produce a total estimate of drinks per week. The DDQ has been shown to correlate highly with other measures of alcohol consumption and has been frequently used in young adult samples (Geisner et al., 2015).

Alcohol Related Problems.—The Young Adult Alcohol Related Consequences Questionnaire (YAACQ; Read et al., 2006) was used to assess for alcohol-related problems experienced at least once in the past month. The YAACQ is a 48-item self-report measure that asks respondents to indicate whether or not (Yes/No) they experienced alcohol-related problems across any of the following domains: Social/Interpersonal, Impaired Control, Self-perception, Self-care, Risk Behaviors, Academic/Occupational, Physical Dependence, and Blackout Drinking. Internal consistency in the current sample was $\alpha = 0.97$ for the full measure.

Data Analysis

Outliers were identified as 3.29 standard deviations above the mean and winsorized to be one unit above the next highest non-outlying value (Tabachnick & Fidell, 2013). Typical drinks per week, in addition to intensity, O_{max}, and elasticity indices for all APT conditions, demonstrated skewness or kurtosis values outside of acceptable limits (−2 and 2) and were thus square root transformed. To test our first and second hypotheses, we used paired sample *t*-tests comparing indices from the solitary APT with those from the social and standard APTs. To test our third and fourth hypothesis, we used mixed between-within ANOVAs to examine the effects of sex (male v. female), student status (current student v. nonstudent), and alcohol problem severity level (low v. moderate/high alcohol problems) on demand across the solitary and social APT conditions. We determined alcohol problem group membership based on previously published results of a relative operating curve analysis split by sex (Read et al., 2015). Males/females scoring below 8/10 on the YAACQ, respectively, were categorized into the low group; all others were combined into a single moderate/high category due to small sample size for the moderate group. In order to reduce the number of ANOVA analyses and enhance reliability, we created composites of the demand factors amplitude (combining intensity and O_{max}) and persistence (combining breakpoint, P_{max}, O_{max}, and elasticity) by standardizing each demand index and averaging the variables for each factor together (MacKillop et al., 2009). To test our fifth and final hypothesis, we examined correlations between social and solitary demand indices with typical drinks per week and alcohol problems. We also used independent sample *t*-tests to examine differences in percent change in hypothetical consumption from the social and solitary condition on each price up to $5.00, as a sufficient number of participants reported consumption at this point.in the social purchase task.[1] Due to the multiple comparisons, we decided to use a more stringent *p*-value of .01 for the *t*-test analyses. Next, we examined the predictive utility of solitary demand over and above social demand, using the amplitude and persistence

[1]It is impossible to plot percent change from social to solitary conditions among participants with 0 demand at a given price in the social condition. As sample size diminished across increasing prices, it becomes less representative of the full sample and more influenced by outliers, resulting in large standard errors and unstable means and *t*-test results. We used a conservative approach and examined mean differences only for prices with adequate data.

composites, on typical drinks per week and alcohol problems using hierarchical linear regressions. In each model, sex and student status were included in the first step. We then separately examined social demand (either persistence or amplitude) and solitary demand in the second step. Finally, we examined a model including both social and solitary demand composites to determine if residualized change predicts alcohol use and total problems. In *post hoc* exploratory analyses, we also used the residualized change approach to examine the effect of solitary demand composites on YAACQ subscales (given that some of the YAACQ problem domains are social in nature, i.e., interpersonal conflict).

Results

Mean Differences in Demand Indices across Purchase Task Conditions

Means and standard deviations for demand indices in each purchase task condition are reported in Table 2. Demand and expenditure curves for the social and solitary conditions are reported in Figure 1. The exponentiated equation provided a good fit for participant level data across the standard (mean R^2 = .87; median R^2 = .88), social (mean R^2 = .86; median R^2 = .88), and solitary (mean R^2 = .82; median R^2 = .84) APT conditions and an excellent fit for aggregated data (R^2 = .99 for all three conditions). Solitary APT demand intensity, breakpoint, O_{max}, and P_{max} were significantly lower, and elasticity significantly higher, than the same indices in the social and standard conditions, suggesting overall lower demand for alcohol in the solitary condition. Mean demand index values were similar across social and standard APT conditions, with the exception of intensity, which was higher in the social condition.

Next, we examined the effects of alcohol problem severity level, sex at birth, and student status on differences in demand composites across social and solitary APTs using mixed model ANOVAs (see Table 3 for individual demand index descriptive statistics by sex, student status, and alcohol problem severity). There was a main effect of alcohol problem severity on demand amplitude (F[1,225] = 21.81, p < .001, η_p^2 = .09) and persistence (F[1,178] = 9.11, p = .003, η_p^2 = .05) in both the social and solitary APTs. There were no significant interactions between alcohol problem severity group and the alcohol purchase task condition (i.e., social vs. solitary), suggesting that changes in demand from the social to the solitary condition were similar in both alcohol problem groups. There was not a main effect of student status on either amplitude or persistence. However, there was a significant student status by APT condition interaction for amplitude (Wilks' Lambda = .98, F[1,226] = 5.35, p = .02, η_p^2 = .02), suggesting that, compared to non-college attending participants, college students reported greater *reductions* in demand from the social to the solitary APT condition. There was a main effect of sex on amplitude (F[1,225] = 21.13, p < .001, η_p^2 = .09) and persistence (F[1,178] = 5.76, p = .02, η_p^2 = .03). There was also a significant sex by APT condition interaction for amplitude (Wilks' Lambda = .98, F[1,225] = 4.71, p = .03, η_p^2 = .02), suggesting that, compared to male participants, female participants reported greater *reductions* in demand from the social to the solitary APT condition. No other main effects or interaction effects were significant.

Relations between Social and Solitary Demand and Alcohol Severity

All demand indices for both social and solitary APTs were associated with both typical drinks per week and alcohol problems, except for elasticity, which was not associated with alcohol problems in either condition (Table 4; Standard APT correlations also reported). Based on Fisher's *r*-to-*z* transformations, there were no significant differences between the strength of correlations for indices in the social versus solitary APTs. Figure 2 represents percent change in price-level alcohol demand from the social to the solitary APT condition, split by level of alcohol problem severity. In general, those in the moderate/high alcohol problem group reduced hypothetical consumption by an average of 17% across prices from the social to the solitary condition, while those in the low alcohol problem severity group reduced hypothetical consumption by an average of 41% across prices. Effect sizes differences were small for prices up to $5.00 (Cohen's *d* range = .16 - .32). None of the differences between groups for these prices were significant ($p > .01$).

Hierarchical regression analysis results are reported in Table 5. Controlling for sex and student status, both social and solitary persistence were separately associated with typical drinks per week and alcohol problems. When included in the same model, solitary persistence predicted typical drinks per week above and beyond social persistence ($p = .009$, $\Delta R^2 = .04$), but not alcohol problems ($p = .72$, $\Delta R^2 = .001$). Controlling for sex and student status, both social and solitary amplitude were separately associated with typical drinks per week and alcohol problems. When included in the same model, solitary amplitude predicted typical drinks per week ($p = .04$, $\Delta R^2 = .02$), and demonstrated a small nonsignificant trend level effect on alcohol problems ($p = .069$, $\Delta R^2 = .01$), above and beyond social amplitude. When examining separate YAACQ subscales in *post hoc* exploratory analyses, solitary amplitude significantly predicted self-care problems ($\beta = .24$; $p = .027$; $\Delta R^2 = .02$), academic/occupational problems ($\beta = .24$; $p = .025$; $\Delta R^2 = .02$), and physical dependence ($\beta = .27$; $p = .01$; $\Delta R^2 = .03$). No other regressions were significant.

Discussion

Previous research suggests that young adult drinking typically occurs in a social context, that solitary drinking is an indicator of problem drinking, and that individual differences in behavioral economic indices of motivation to purchase and consume alcohol (alcohol demand) are associated with alcohol problem severity (Gonzalez et al., 2009; Mohr et al., 2013; Morris et al., 2017). The present study extends this work by explicitly modeling demand in social and solitary contexts and isolating the impact of presence of friends on alcohol demand. Overall, mean consumption and expenditures were approximately 33–40% lower in solitary APTs compared to the standard or social APTs. Thus, one important implication of these results is that a significant amount of the variance in alcohol motivation captured by standard APTs is due to the opportunity to drink in a social setting (i.e., the pharmacological effects of alcohol reward *plus* associated social reward). Consistent with previous research (Borsari & Carey, 2001; Murphy et al., 2006), these results point to the importance of the social context as a critical determinant of drinking in young adult populations and extend that work by precisely quantifying the degree to which the presence of peers increases alcohol reward value. It is also noteworthy, however, that most of the

sample reported motivation to drink even in solitary conditions; mean consumption levels approached binge level when solitary drinks were free (demand intensity) and mean maximum expenditure (O_{max}) was just under $15, suggesting that alcohol reward value is high even when it is separated from social reward.

Consistent with previous research (Kiselica et al., 2016), individual participant differences in alcohol demand were significantly related to alcohol use and problems, with intensity and O_{max} (amplitude) showing the largest associations. Individuals with elevated alcohol problems reported significantly greater demand across both social and solitary demand conditions. Notably, individuals with elevated alcohol problems reported consuming over 6 standard drinks when drinks are free in a solitary situation, suggesting a desire for binge level intoxication even when alone. Strength of association between demand in the solitary and social APTs and alcohol use/problems was almost identical.

Consistent with previous literature that have found relations between alcohol problems and solitary drinking (Gonzalez et al., 2009), regression analyses indicated that solitary demand amplitude predicted recent drinking, and several subscales of the YAACQ, above and beyond the corresponding social APT index. The effect of solitary demand on alcohol consumption, above and beyond social demand, was relatively large. Although many alcohol problems occur in social contexts (Merrill et al., 2018), and “social drinking” is not necessarily benign, decisions about whether or how much to drink when one is alone may more directly reflect elevated valuation for the pharmacological effects of alcohol, which may be a critical predictor of chronic alcohol use and (ultimately) related health problems. Indeed, when total problems were disaggregated into individual subscales, solitary drinking uniquely predicted self-care, academic/occupational, and physical dependence. Further, our findings corroborated evidence suggesting higher correlations between solitary drinking and these three specific alcohol problem domains compared to other domains (Keough et al., 2018). Solitary drinking has been previously connected with coping motives and internalizing spectrum psychiatric states, such as anxiety and depression (Gonzalez et al., 2009; Keough et al., 2015, 2016), which are also uniquely connected with alcohol problems (Acuff, Soltis, Luciano, et al., 2018). Future research might investigate this phenomena in the context of elevated stress or depressive symptoms and coping-related drinking motives (Dennhardt et al., 2016; Luciano et al., 2019). Related, personality traits, such as introversion/extroversion, may play a role in the association between alcohol demand and the drinking context and should also be a subject of future research.

Demand in the social APT (drinking with two friends in a hotel room) was generally similar to demand in the standard APT (drinking with friends at a party), other than the fact that intensity was slightly higher in the social APT. It is possible that the opportunity to receive free drinks in a hotel scenario was especially appealing, possibly due to the novelty of this particular drinking situation. Drinking in a hotel with only two friends may also have been viewed as a safer environment for heavy drinking than a party due to reduced concerns about having to drive/walk home. In this age group, hotels may also be associated with vacation, rather than work or business travel, which may have additional implications related to drinking level. Future research should explicitly manipulate elements of the social context

(number of peers, presence of romantic partner, setting and purpose of hotel stay) in order to further evaluate how these social-contextual factors influence demand.

Overall, both males and females were highly sensitive to drinking price and the presence of peers, with consumption levels well over the binge threshold when drinks were cheap or free and peers were present. Consistent with previous research (Murphy & MacKillop, 2006), males reported greater alcohol demand than females across both social and solitary conditions. When given the opportunity to drink for free, men reported a desire to drink to the binge level (*M* intensity = 4.96), whereas women, on average, reported a desire to drink just under 3 drinks. Interestingly, reductions in amplitude from the social to the solitary conditions were greater for females than for males, suggesting that, compared to young women, young men's desire to drink may be more tied to the direct pharmacological effects of alcohol, and less social-context dependent. This may contribute to the greater long-term risk for AUD among men compared to women (Schulenberg et al., 2018).

Similarly, although students and non-students reported similar demand in both the social and the solitary APTs, maximum consumption and expenditures (amplitude), a key predictor of risk for acute alcohol-related harm (MacKillop et al., 2009), showed smaller reductions from the social to solitary condition for young adults who were not in college. In our sample, college status and age were highly correlated, which may in part explain the smaller reductions in amplitude from the social to solitary condition and may also reflect the fact that college drinking is more centrally driven by social motives. Additionally, non-students and individuals in their later 20s may have greater familiarity with solitary drinking contexts in real life and reduced stigma around drinking alone. However, for some young adults, this may also reflect an increasing age-related progression of AUD, including elevated tolerance and decreasing contextual control over drinking.

Strengths, Limitations, and Future Directions

This research contributes to a growing body of literature examining manipulations of behavioral economic demand and suggests that APTs are useful for isolating different components of motivation to drink (Acuff et al., 2019). Although young adult drinking is largely a social phenomenon, variability in the relative valuation of social and solitary drinking may be a clinically relevant risk marker. This is the first study to systematically evaluate the influence of peers on alcohol demand as well as the unique predictive validity of solitary alcohol demand as a predictor of alcohol use and problems. Our results provide support for the validity of a modified APT that differentiates social versus solitary alcohol demand.

One major limitation is that the purchase task conditions were not counterbalanced, and therefore the effect may be at least partially attributable to order effects. Another limitation is that we did not include measures of mood, coping, or social drinking motives, or actual recent solitary drinking episodes. Further, our hotel drinking scenario may feel unrealistic or may be unfamiliar for those participants who do not travel frequently and may also have led to inflated drinking estimates. However, hotels are a location where drinks are typically available for purchase and this scenario allowed us to hold the overall drinking setting constant while explicitly manipulating the presence of two peers who presumably make

similar drinking decisions as the participant. Related to the hotel condition, the solitary condition technically does not preclude the individual from going downstairs and socializing at the hotel bar after consuming the drinks. Another limitation is the cross-sectional design; future research should determine if the solitary drinking APT has incremental predictive validity for clinical outcomes beyond the standard APT (Murphy et al., 2015; Toomey et al., 2007). It is also important to note that although effect sizes in our regression analyses predicting alcohol use and problems from solitary demand were small, this is balanced by the fact that the models included a number of covariates (including sex and social demand).

Implications for Alcohol Prevention and Treatment

Young adult drinking is often inextricably tied to socializing, and even those young adults who drink frequently may be as much or more motivated by the opportunity to socialize than by the direct effects of alcohol. However, our results suggest that, although demand is significantly lower when drinking is solitary, individuals with high levels of alcohol problems, men, and young adults who are not students report hypothetical consumption exceeding a binge drinking threshold when given the opportunity to drink for free even when alone. Solitary alcohol demand may be helpful for predicting future solitary drinking and specific problems among college students who may currently drink exclusively in social settings, which are common in college settings (Gonzalez et al., 2009).

Although existing measures of drinking motives can identify the strength of social versus other drinking motives, the modified solitary APT measures strength of motivation for solitary drinking based on drinking quantity choices and may help to identify individuals who are at highest risk for future problematic use. These individuals may require more intensive interventions that target negative affect, craving, and the reinforcing properties of alcohol (e.g., cognitive behavioral therapy, pharmacotherapy; Pedrelli et al., 2019). Conversely, individuals with low solitary but high social demand may be well suited for intervention approaches that attempt to develop alternative ways of socializing without alcohol (Murphy et al., 2012, 2019; Toomey et al., 2007). Indeed, there is evidence that the presence of peers in a drinking scenario is a more robust predictor of enjoyment associated with a given drinking episode than the number of drinks consumed (Murphy et al., 2006), and that young adults experience better mood the day after socializing without drinking, and lower mood the day after drinking (Cronce et al., 2020).

Conclusions

Young adults often engage in heavy episodic drinking despite consequences, in part due to the associated social benefits. The current study isolated the social effects of alcohol with two novel APTs that specify whether the individual is drinking with friends or alone. The results suggest that sociality is a potent paired reinforcer for alcohol use and results in significant increases in alcohol demand; and that men, noncollege young adults, and individuals with high levels of alcohol problem demonstrate insensitivity to changes in the social contexts presented in the APTs. Individual differences in sensitivity to these contextual changes reflect an opportunity for personalized intervention, targeting either craving or social drinking dependent upon scores on these tasks. This work also highlights

the importance of isolating other distinct reinforcing components of alcohol and other drugs, which could elucidate novel and personalized intervention targets.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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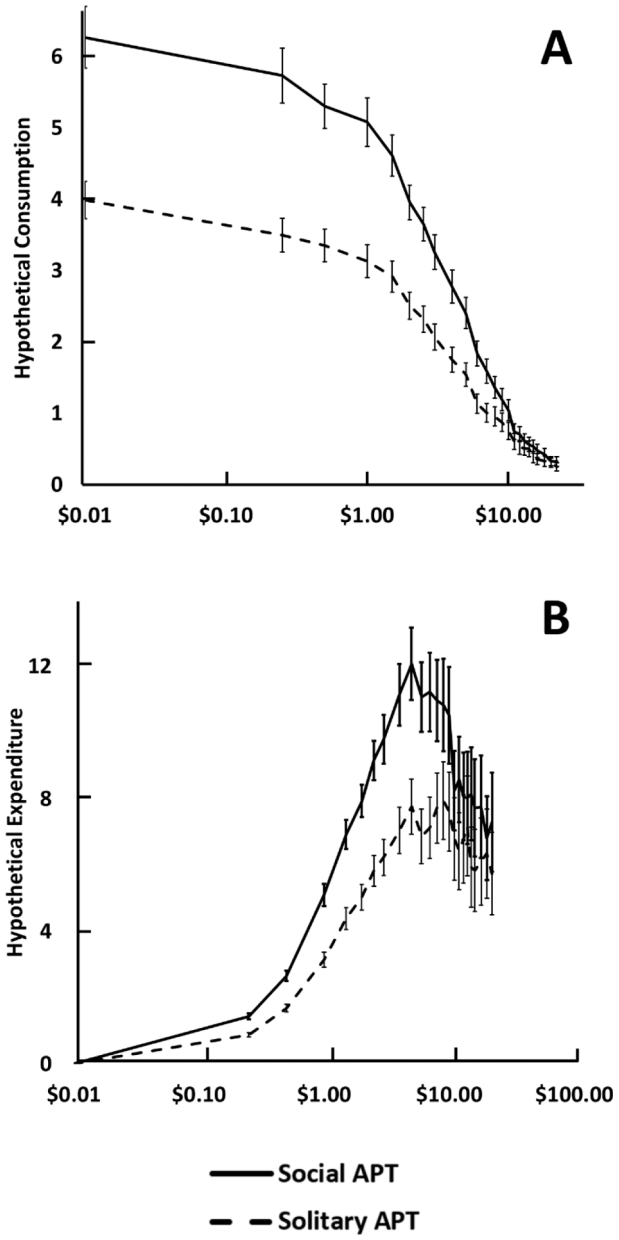

Figure 1.

Demand curves for average consumption (Panel A) and expenditure (Panel B) for the Social and Solitary APT conditions. The x-axis is log-transformed. Each data point represents average hypothetical consumption across participants on a particular price of the APT, with error bars reflecting standard error for each price. Consumption and expenditure values were lower in the solitary condition compared to the social condition.

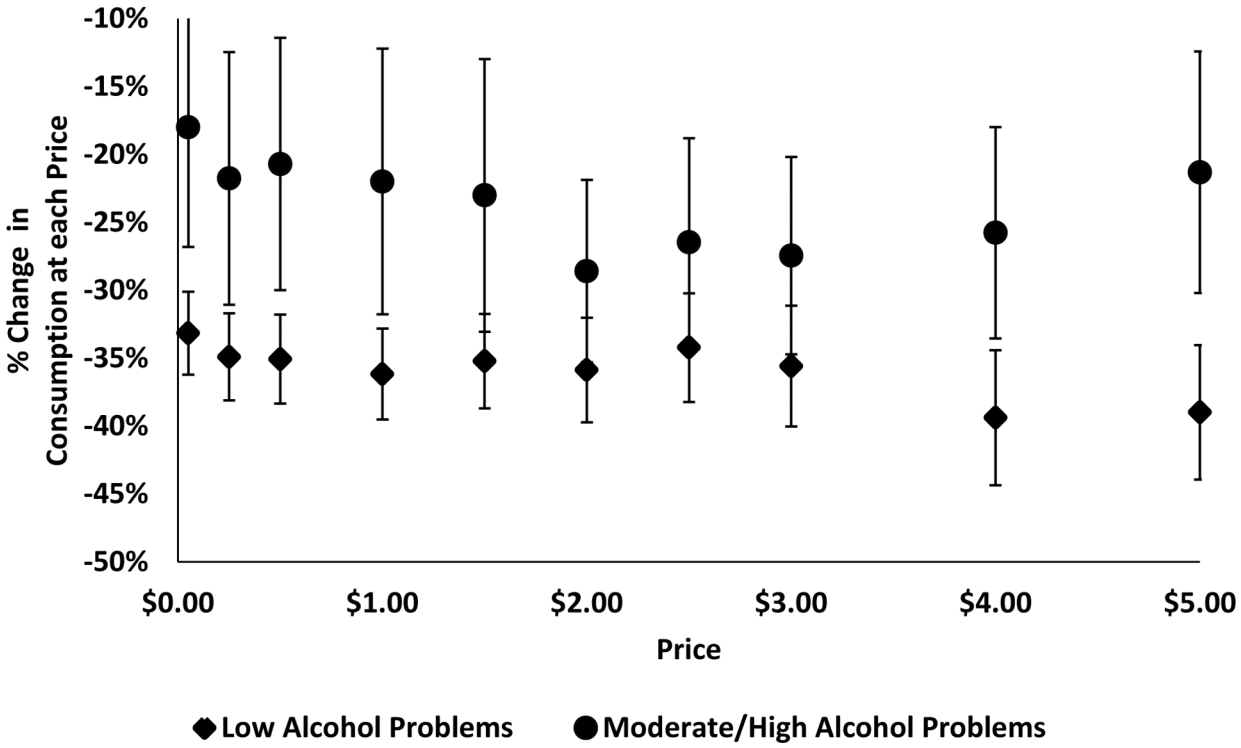

Figure 2.

Percent change in alcohol demand from the social to the solitary hypothetical purchase task, split by participants with low (n = 168; M = 2.27, SD = 2.55) and moderate/high (n = 103, M = 24.10, SD 9.14) alcohol problems. Results were only provided for prices retaining at least 2/3 of the sample for each group (from $0 to $5.00 price point). Between-subject alcohol problems groups were determined using empirical cutoffs resulting from a relative operating curve analysis (Read et al., 2015). Males/females scoring below 8/10 on the YAACQ, respectively, were categorized into the low group; all others were combined into a single moderate/high category. Independent sample t-tests suggested a significant difference at zero price (p = .04); trend-level effects were evident for prices up to $1.00 and for $5.00. All other prices were not significant.

Table 1.

Demographic Characteristics and Differences between Samples.

Variables	Full Sample (*N* = 274) *M* (*SD*), %	SONA Sample (*n* = 72) *M* (*SD*), %	Mturk Sample (*n* = 202) *M* (*SD*), %	*t*-value / χ^2 (df), *p*-value
Gender (Male)	57.1%	16.9%	71.3%	63.45 (1), < .001
Race				
White	72.6%	69.4%	73.8%	.50 (1), .48
Black	13.5%	19.4%	11.4%	
Asian	5.8%	2.8%	6.9%	
Other	1.5%	1.4%	1.5%	
Hispanic/Latino/a/x	5.8%	6.9%	5.4%	
Student Status (Yes)	40.9%	100%	19.8%	141.26 (1), < .001
Age	25.15 (4.10)	19.78 (2.30)	27.06 (2.63)	20.82 (272), < .001
Drinks per Week	7.86 (8.28)	5.22 (5.74)	8.79 (8.82)	3.88 (188.98), < .001
Alcohol Problems	10.63 (12.20)	6.92 (9.15)	11.94 (12.88)	3.55 (172.72), < .001

Table 2.

Differences in Demand Indices by Alcohol Purchase Task (APT) Condition

Demand Index	Standard APT *M* (*SD*)	Social APT *M* (*SD*)	Solitary APT *M* (*SD*)	Standard APT v. Social APT *t* (df), *p*-value	Standard APT v. Solitary APT *t* (df), *p*-value	Social APT v. Solitary APT *t* (df), *p*-value
Elasticity	.0311 (.0389)	.0287 (.0327)	.0518 (.0730)	−74 (204), .46	−5.94 (173), < .001	−6.00 (180), < .001
Intensity	5.71 (5.14)	6.30 (6.58)	4.00 (3.97)	−1.99 (225), .05	10.04 (223), < .001	10.26 (227), < .001
Breakpoint	8.96 (6.84)	8.86 (6.99)	6.91 (7.19)	.71 (226), .48	7.31 (223), < .001	6.99 (228), < .001
O_{max}	17.61 (27.75)	19.42 (26.13)	14.55 (23.84)	−2.26 (226), .03	7.22 (223), < .001	8.49 (228), < .001
P_{max}	6.46 (5.25)	6.22 (5.43)	5.16 (5.49)	.94 (226), .35	4.58 (223), < .001	4.01 (228), < .001

Note. *t*-values calculated with square root transformed variables for intensity, O_{max}, and elasticity. *M* = mean; *SD* = standard deviation

Table 3.

Means and standard deviations of demand indices for the social and solitary Alcohol Purchase Task (APT) conditions split by student status, sex, and alcohol problem level.

Demand Index	Student *M* (*SD*)	Non-student *M* (*SD*)	Male *M* (*SD*)	Female *M* (*SD*)	Low Alcohol Problems *M* (*SD*)	Moderate/High Alcohol Problems *M* (*SD*)
Social APT						
Elasticity	.0285 (.0320)	.0288 (.0334)	.0245 (.0277)	.0342 (.0376)	.0308 (.0344)	.0234 (.0274)
Intensity	6.20 (6.26)	6.38 (6.82)	7.64 (8.17)	4.67 (3.20)	4.96 (3.31)	9.74 (10.53)
Breakpoint	7.96 (6.29)	9.47 (7.41)	9.76 (7.51)	7.60 (6.03)	7.95 (6.05)	10.96 (8.54)
O_{max}	15.51 (19.67)	22.14 (29.56)	24.29 (31.94)	13.32 (14.43)	15.14 (16.32)	30.27 (40.13)
P_{max}	5.48 (5.04)	6.74 (5.65)	6.93 (6.04)	5.35 (4.46)	5.58 (4.45)	7.88 (7.18)
Solitary APT						
Elasticity	.0557 (.0740)	.0494 (.0727)	.0430 (.0660)	.0647 (.0811)	.0551 (.0739)	.0436 (.0714)
Intensity	3.66 (3.97)	4.23 (3.97)	5.04 (4.52)	2.73 (2.73)	3.20 (2.88)	6.10 (5.48)
Breakpoint	5.50 (6.15)	7.90 (7.71)	8.60 (7.92)	4.79 (5.55)	5.78 (5.92)	9.79 (9.24)
O_{max}	10.30 (18.03)	17.57 (26.85)	19.35 (27.75)	8.75 (16.41)	10.53 (16.15)	25.23 (35.29)
P_{max}	4.44 (5.32)	5.67 (5.56)	6.10 (5.97)	3.94 (4.57)	4.47 (4.64)	6.87 (6.99)

Note. *M* = mean; *SD* = standard deviation.

Table 4.

Correlations between demand indices from the Social and Solitary APTs and both typical drinks per week and alcohol problems.

Demand Index	Typical Drinks per Week	Alcohol Problems
	Standard APT	
Elasticity	−25***	−01
Intensity	.49***	.34***
Breakpoint	.25***	.22**
O_{max}	.37***	.25***
P_{max}	.11	.17**
	Social APT	
Elasticity	−23**	−09
Intensity	.43***	.35***
Breakpoint	.26***	.20**
O_{max}	.37***	.23***
P_{max}	.16*	.20**
	Solitary APT	
Elasticity	−28***	−08
Intensity	.42***	.34***
Breakpoint	.30***	.24***
O_{max}	.39***	.24***
P_{max}	.20**	.21**

Note.

*** $p < .001$,

** $p < .01$,

* $p < .05$.

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Table 5.

Hierarchical regression analyses examining the predictive utility of social and solitary demand composites on typical drinks per week and alcohol problems.

Typical Drinks per Week					Alcohol Problems				
Variable	**Beta (*S.E.*)**	**β**	***t***	**ΔR^2**	**Variable**	**Beta (*S.E.*)**	**β**	***t***	**ΔR^2**
Persistence Composite									
Step 1				.06	Step 1				.01
Sex	−22 (.20)	−09	−1.13		Sex	−1.15 (1.61)	−06	−72	
Student	.48 (.20)	.19	2.38*		Student	1.03 (1.64)	.05	.63	
Step 2 (separate)					Step 2 (separate)				
Social Persistence	.32 (.10)	.22	3.26**	.05	Social Persistence	2.49 (.85)	.20	2.93**	.04
Solitary Persistence	.39 (.11)	.27	3.71***	.07	Solitary Persistence	2.24 (.88)	.19	2.55*	.04
Step 2 (Omnibus)				.07	Step 2 (Omnibus)				.04
Social Persistence	−17 (.20)	−11	−82		Social Persistence	1.94 (1.68)	.16	1.16	
Solitary Persistence	.52 (.20)	.35	2.65**		Solitary Persistence	.59 (1.63)	.05	.36	
Amplitude Composite									
Step 1				.05	Step 1				.01
Sex	−33 (.17)	−14	−1.95		Sex	−2.60 (1.48)	−13	−1.75	
Student	.28 (.17)	.12	1.63		Student	−1.25 (1.50)	−06	−83	
Step 2 (separate)					Step 2 (separate)				
Social Amplitude	.56 (.08)	.42	6.98***	.17	Social Amplitude	3.66 (.77)	.31	4.75***	.09
Solitary Amplitude	.56 (.08)	.43	6.85***	.17	Solitary Amplitude	3.60 (.74)	.32	4.84***	.09
Step 2 (Omnibus)				.18	Step 2 (Omnibus)				.09
Social Amplitude	.35 (.14)	.26	2.61*		Social Amplitude	1.67 (1.25)	.14	1.34	
Solitary Amplitude	.28 (.13)	.21	2.10*		Solitary Amplitude	2.23 (1.22)	.20	1.83	

Note. Sex and student status were included in the first step of each regression; in separate regression analyses, each demand composite was included in the second step, demarcated “second step (separate)” in the table. Finally, omnibus models assessed the residualized change in alcohol demand from the social to the solitary condition, demarcated by “second step (omnibus)” in the table.

*** $p < .001$,

** $p < .01$,

* $p < .05$.