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Direct and Indirect Effects of Alcohol Craving and Demand on Obsessive and Compulsive Drinking Characteristics: The Role of Impulsivity

James V. Turner IV
CUNY Hunter College

Direct and Indirect Effects of Alcohol Craving and Demand on Obsessive and Compulsive Drinking Characteristics: The Role of Impulsivity

by

James Turner IV

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December 1, 2021	Dr. Joel Erblich
Date	Thesis Sponsor
December 1, 2021	Dr. Jonathan Avery
Date	Second Reader

Abstract

Craving for alcohol when faced with alcohol-related cues in one's environment, or cue-induced craving, has been postulated as an important factor in the development and maintenance of problem drinking. Recent behavioral economic studies have suggested that cue-induced craving may operate by increasing alcohol demand, which in turn, has been shown to be predictive of problem drinking. Lacking, however, are studies that directly test the possibility that the relationship between cue-induced craving and problem drinking is mediated by increases in alcohol demand. Furthermore, the degree to which these effects might be potentiated among impulsive drinkers has not been well-explored. Social drinkers (n=107) aged 18 – 25, recruited from an urban university campus, completed: 1) a classic laboratory cue-induced craving task, in which participants were exposed to alcohol cues and reported their craving responses immediately before and after the exposure, 2) a behavioral economic measure of alcohol demand (the Alcohol Purchase Task--APT), 3) a measure of problem drinking characteristics (Obsessive-Compulsive Drinking Scale [OCDS]), and 4) behavioral (delay discounting) and self-report (UPPS-P, BIS) measures of impulsivity. Findings indicated that cue-induced craving was associated with higher levels of demand as well as higher scores on the OCDS. Demand was also related to higher OCDS. Estimation of bootstrapped 95% confidence intervals revealed a significant indirect effect of cue-induced craving on OCDS through increased demand. Interestingly, higher levels of self-reported impulsivity potentiated both the effect of demand and the indirect effect of cue-induced craving on OCDS. The results underscore the importance of behavioral economics as a mechanism underlying the effects of cue-induced craving on obsessive and compulsive drinking characteristics, especially among impulsive drinkers.

Introduction

In the United States, excessive drinking is a leading cause of preventable deaths, with 95,000 people dying from alcohol abuse every year (Esser et al., 2020). Data from a 2019 study showed that more than half of the US population had consumed alcohol in the past 30 days, 16% of people binge drank alcohol, and 7% reported drinking heavily. Data from the World Health Organization (WHO), Centers for Disease Control and Prevention (CDC), and the National Institute on Alcohol Abuse and Alcoholism (NIAAA) show that drinking is a major public health issue and that for many, it is not easy to stop drinking (World Health Organization, 2019). One hypothesized reason why people have difficulty quitting, stopping, or managing their alcohol consumption, is because of their strong cravings. One helpful tool that researchers now have is the ability to model cravings in the laboratory to be analyzed more carefully. This is accomplished by exposing people to alcohol-related stimuli and measuring their craving responses in controlled conditions, a phenomenon known as “cue-induced craving.” A large amount of literature has demonstrated that exposure to alcohol in a laboratory reliably elicited cravings and that, perhaps, more importantly, these cue-induced cravings are predictive of several important outcomes including an individual's frequency to drink, the potential for alcohol dependence, and potential for relapse (e.g., Drummond, 2000).

Recent studies have suggested that cue-induced cravings predict an individual’s cost-related decision making ('behavioral economics') of alcohol demand. Alcohol demand is a behavioral economic concept that is used to quantify characteristics of an individual’s motivation to drink. One common instrument to measure demand is the Alcohol Purchase Task (APT). The APT queries drinkers' desire to consume alcohol under a set of increasing price points, and yields several indices of alcohol demand, including: (a) demand intensity (alcohol consumption when

drinks are free), (b) breakpoint (the first price at which no alcohol is consumed), (c) elasticity (the degree of subject sensitivity to alcohol consumption when influenced by per-drink prices), (d) O_{max} (maximum alcohol expenditure), and (e) P_{max} (price at maximum alcohol expenditure).

A number of studies have suggested that cue-induced craving is related to increases in alcohol demand. In one example, MacKillop et al.'s (2010) study examined 61 participants, 38 with alcohol use disorder (AUD), and evaluated how they performed on the APT. The participants ranged from 21-65 years old, and all were heavy drinkers according to the NIAAA criteria. For men, the criteria are defined as consuming more than four drinks on any day or more than 14 drinks per week. For women, the criteria is defined as consuming more than three drinks on any day or more than seven drinks per week (NIAAA, 2017). Results showed that participants with AUD symptoms exhibited heightened levels of cue-induced craving, as well as increased alcohol demand, suggesting an important link between the two.

Cravings can give rise to significant obsessive and compulsive rumination about drinking alcohol. The Obsessive-Compulsive Drinking Scale (OCDS) was developed to assess such thoughts (Anton, 2000). A study done at the Medical University of South Carolina evaluated past research focusing on the cognitive characteristics of craving, the relationship between the brain mechanisms of obsessive-compulsive thoughts about drinking (OCTD) and addiction. Findings of this study indicated that alcohol cravings were associated with significant increases in OCTD. Further consistent with the importance of OCTD, a study conducted by Schmidt et al. (2011) examined the validity of OCDS as it relates to craving and whether it is a predictor of negative outcomes among alcohol-dependent inpatients, regardless of whether they maintain abstinence. The study consisted of 198 alcohol-dependent subjects who were in an inpatient clinic. The OCDS was administered during the stay, and again at discharge from the treatment

facility, at 6-month, 12-month, and 24-month follow-ups. Findings of the study indicate that for alcohol-dependent inpatients that are being treated under standardized conditions, OCDS scores 6 months after discharge were predictive of their 12-month OCDS scores. Additionally, the same is true of their 12-month scores being predictive of the 24-month outcome. Perhaps most importantly, findings also indicated that OCDS scores were strongly correlated with later alcohol relapse. Lacking however, are studies that evaluated the potential interplay between cue-induced cravings, demand, and OCTD as proposed here.

Another major predictor of alcohol use is impulsivity. Impulsivity is a complex trait that has been measured in a number of ways in relation to alcohol use. These include self-report measures of impulsivity (e.g., BIS, UPPS-P, see Methods), as well as behavioral measures of delay discounting, as described next.

Delay discounting refers to an individual's decision to either choose a small reward sooner or wait longer for a larger reward later. Previous research has shown that people with AUDs have greater delay discounting, which is considered to be a personality trait that plays a significant role in negative decision-making throughout many maladaptive behaviors (Mobini et al., 2007). Research suggests that it can help identify current substance use severity as well as identify future use and how one will respond to treatment (Stanger et al., 2012). MacKillop et al. (2010) found that delay discounting was related to key alcohol-related outcomes, including increased demand and drinking behavior. In another study (Phung et al., 2019), the goal was to expand on how effort discounting compares to delay discounting behavior among individuals who drink. Additionally, they looked at how these preferences change between monetary and alcohol rewards. The first experiment was conducted on 100 participants whom all confirmed that they drank alcohol. They completed a series of tasks such as: delay discounting for

monetary reward, effort discounting for monetary reward, delay discounting for alcohol reward, and effort discounting for alcohol reward. The results showed that people with more severe AUD showed greater delay discounting for monetary rewards, which is consistent with past research. This suggests that those individuals who abuse alcohol will have greater impulsivity and lack of control. The study also found that the more severe one's alcohol use, the greater their delay discounting was when alcohol was offered to them as a reward. This is extremely relevant as it shows that such behavior persists regardless of the reward. The second experiment consisted of 411 participants all of whom were brought through the same protocol and procedures of the first experiment but with the addition of the alcohol purchase task. The results were similar to experiment one and clearly showed that individuals who met more DSM-5 criteria for alcohol use severity had a higher demand for alcohol. Participants meeting more DSM-5 criteria were willing to put more effort in for alcohol, rather than monetary rewards.

One of these studies, conducted by Yarmush et al. (2016), researched the relationship between impulsivity and cue-induced craving in young healthy individuals, as well as identified any possible gender differences. They hypothesized that impulsivity would predict subjects reporting higher craving while exposed to alcohol-cues and that these effects would be particularly strong in women. Participants ranged from 18-25 years old and had reported consuming at least three alcoholic drinks per week. All 36 subjects were exposed to two imaginal cues, which were personalized for each of them. Craving was measured before and after each cue exposure using a 5-item, 0-100 alcohol craving questionnaire. The study found that exposure to alcohol-cues increased craving and that the effects were not significantly different across genders. They did find that impulsivity did predict significantly higher cue-induced craving in women, but not in men. Their hypothesis was upheld and was consistent with

previous research. Possible reasons for such data could be phase dependent (elevations in circulating estradiol), or that women are more sensitive to the neurological effects produced by alcohol. Most fascinatingly, this study touches on the possibility that impulsivity may exacerbate reactions to external stimuli that have been shown to trigger a craving to drink.

Another study in the Netherlands aimed to look at the effects of response inhibition (a dimension of impulsivity) on cue-induced craving for social drinkers. Participants were randomly assigned to the alcohol or water cues. They were exposed to water and then alcohol and their responses were measured for craving and response inhibition. As one would suspect, they hypothesized that 1) cue-induced craving would be higher for the alcohol exposure vs. water exposure, 2) that subjects with poor response inhibition, conscious choice to ignore irrelevant stimuli, will react less to alcohol cues, and 3) that social drinkers with impaired response inhibition will feel the effects of alcohol stimuli more intensely. The study consisted of 75 participants with a mean age of 23 years old. Results showed that there was a significant effect of response inhibition on levels of craving for alcohol. Interestingly, this was true regardless of whether the cue was water or alcohol. They also found that when subjects had both impaired response inhibition and perceived alcohol to be available, they experienced significantly higher cravings specifically to the alcohol cue. These findings suggest that impulsivity is associated with elevated cue-induced cravings and particularly so when subjects perceived that alcohol was available for consumption.

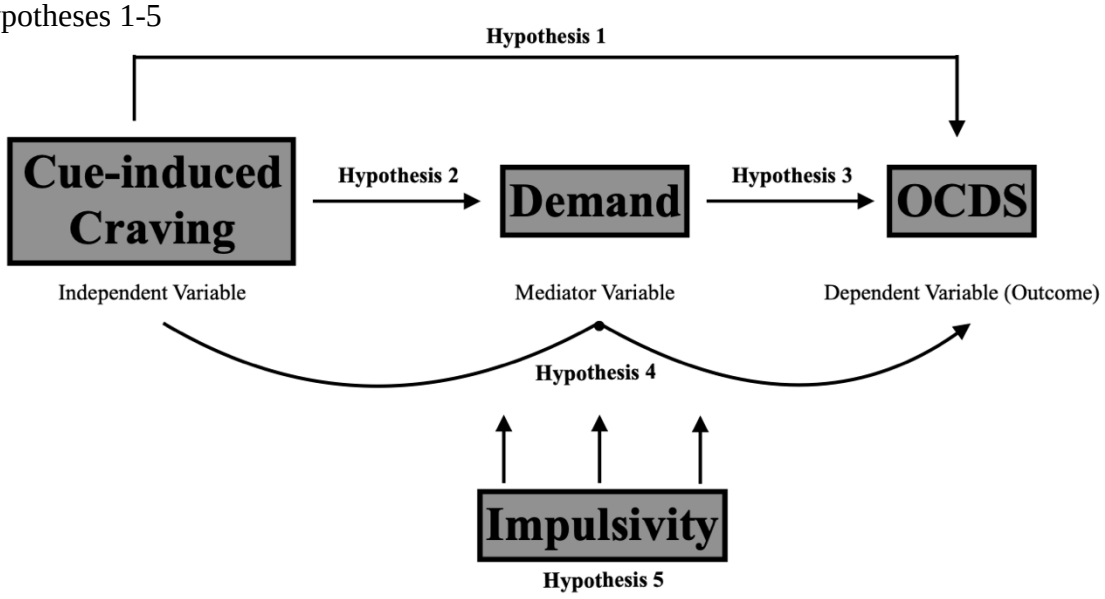
Gray and MacKillop (2014) researched 720 participants who were all adult smokers and reported drinking within the past year. The study aimed to explore the relationship between alcohol demand and alcohol misuse, examine sex differences in alcohol demand, and examine the relationship between alcohol demand and impulsive personality traits. Results were similar

to previous research showing a significant association between the demand indices and alcohol misuse. The results also extended previous findings by explaining that the association was largely due to demand indices, intensity, and O_{max}. Additionally, males were found to have higher O_{max} and intensity, and lower elasticity than females, but these differences were not significant when adjusting for drinks per week and other covariates. Lastly, trait levels of sensation-seeking, urgency, and an individual's lack of premeditation were significantly associated with intensity and urgency, which were associated with O_{max}. These findings highlight the possible links between alcohol demand and alcohol misuse as well as between demand and impulsivity.

The purpose of the present study is to test a novel model of OCTD as depicted in Figure 1. The key hypothesis is that cue-induced craving is predictive of OCTD. A second hypothesis is that cue-induced craving will predict an increase in demand. A third hypothesis is that demand in turn will be predictive of increased OCTD. A fourth hypothesis is that demand mediates the effects of cue-induced craving on OCTD. Finally, a fifth hypothesis is that the relationships stated in hypotheses one through four will be particularly pronounced amongst individuals with high levels of impulsivity.

Figure 1.

Hypotheses 1-5



Methods

Overview

The research activities described in this paper were approved by the Hunter College Institutional Review Board of the City University of New York. Participants gave informed consent prior to engaging in this study, received compensation of $60 in cash for the protocol described in this report, and were fully debriefed upon completion. Participants attended two study sessions on different days. During the first session, participants provided urine and breath samples to confirm eligibility and completed background questionnaires, including self-report measures of impulsivity and a computerized delay discounting task (see below). During the second session, participants completed a classic cue-induced craving task, followed by the alcohol purchase task.

Participants

Participants were healthy young adult social drinkers (n=107), recruited from an urban university campus. Of the participants, 56.5% were female and 43.5% male. Their age ranged from 18-25 and had a mean age of 21.6. Potential participants were excluded if they reported consuming fewer than 3 drinks per week, endorsed a past or present psychiatric disorder, reported the current consumption of illegal substances, had a history of cardiovascular disease or current pregnancy, or failed either a urine toxicology screening for illicit drugs or an alcohol breath test (using an Alco-Sensor IV portable breath alcohol analyzer; Intoximeters, Inc., St. Louis, MO)

Background Questionnaires

The AUDIT (Saunders et al., 1993) is a 10-item questionnaire that collects information about alcohol consumption, dependence, and consequences. Possible scores range between 0 and 40, with scores over 8 suggesting the presence of harmful drinking (Bohn et al., 1995).

The OCDS (Anton et al., 1995) is a 14-item questionnaire in which participants respond on a Likert-like scale from 0 to 4. The scale consists of 2 subscales, obsessions, and compulsions, with a possible range of 0 to 28 for each, with higher scores indicating more obsessions and/or compulsions. For this study, the total OCDS score was used.

The Timeline Follow-Back Questionnaire (TLFB) (Sobell & Sobell, 1992) is an assessment designed to aid participants in accurately recalling their past alcohol consumption. For the purposes of this study, the TLFB assessed drinking over the 90 days prior to the participants' first laboratory session and collected data on the number of total drinks, drinking days, and drinks per day during that period.

Study Tasks

Alcohol Purchase Task

The APT requires subjects to self-report how many drinks they would consume at different prices ($0-$20) in a hypothetical drinking situation. The APT yields several indices of alcohol demand, including: (a) demand intensity (alcohol consumption when drinks are free), (b) breakpoint (the first price at which no alcohol is consumed), (c) elasticity (the degree of subject sensitivity to alcohol consumption when influenced by per-drink prices), (d) O_{max} (maximum alcohol expenditure), and (e) P_{max} (price at maximum alcohol expenditure).

Cue Exposure Task

The cue exposure task measured craving for alcohol immediately before and after a 90-second imaginal exposure to alcohol. The exposure was personalized by asking participants to describe a scenario that typically induces craving, and key features of their description were integrated into the exposure text. The participant was asked to close their eyes, and an experimenter read the script to the participant. Craving was measured using a face-valid 5-item (e.g., craving, urge, desire) self-report measure (0 to 100) used in previous work (Erblich et al., 2009; Yarmush et al., 2016).

Measures of Impulsivity

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, Kaplan, & Brewer, 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). The DDT was administered using Inquisit software.

Urgency, Premeditation (lack of), Perseverance (lack of), Sensation Seeking, Positive Urgency, Impulsive Behavior Scale (UPPS-P)

The UPPS-P scale was initially developed by Whiteside and Lynam and is composed of a 59-item questionnaire. In the current study, the short version of the UPPS-P consists of 20 items to measure impulsive predispositions and the five first-order impulsive factors: negative urgency, lack of premeditation, lack of perseverance, sensation seeking, and positive urgency. Whiteside and Lynam created this instrument to methodically illustrate which traits are measured across different existing measures and that impulsivity is a multi-dimensional and multi-faceted construct (Whiteside & Lynam, 2001).

Barratt Impulsiveness Scale (BIS)

The BIS was designed to measure the behavioral or personality trait of impulsivity. The tool consists of a 30-item questionnaire, in which each subject was requested to answer each item on a 4-point scale: 1 (rarely/never), 2 (occasionally), 3 (often), and 4 (almost always/always). Once the 30-item questionnaire is scored, it yields six primary factors of the scale: attention, motor impulsiveness, self-control, cognitive complexity, perseverance, and cognitive instability.

Additionally, there are also three secondary factors: attentional impulsiveness, motor impulsiveness, and non-planning impulsiveness. It is currently the most widely used instrument for the measure of impulsivity (Stanford et al., 2009).

Data Analysis

To address the study hypotheses, we conducted a series of linear regression analyses. However, prior to these analyses, we conducted a t-test to confirm that exposure to cues induced cravings. Next, we calculated a cue-induced craving score by subtracting pre-stimulus craving from post-stimulus craving. To test the study hypotheses, we employed the path analytic approaches described by Hayes (2013), using the SPSS PROCESS macro. To that end, we evaluated the pathway from cue-induced craving to OCTD, both as a direct effect, as well as an indirect effect, through each of the demand indices. We calculated bootstrapped confidence intervals for indirect effects to evaluate their significance. Finally, we added impulsivity as a second-stage moderator (i.e., to moderate the effects of demand on OCDS) to assess for moderated mediation, using PROCESS Model 14.

Results

Drinking Variables

Participants consumed an average of 3.2 drinks per episode (SD = 1.6) during an average of 9.0 drinks per week (SD = 9.5) over the past 90 days. The participants reported an average of 5.9 (SD = 7.4) binge-drinking episodes in the three months prior to enrollment in the study and had an average score of 10.2 (SD = 4.5) on the Alcohol Use Disorders Identification Test, indicating that some participants had engaged in risky drinking behavior. That said, the mean score on the Obsessive-Compulsive Drinking Scale (OCDS; Anton et al., 1995) was 9.7 (SD = 5.5), well below the average score of 22.5 typically observed in clinical samples (Anton et al., 1995) (see Tables 1 and 2). None of the participants were seeking treatment for their alcohol use nor expressed a desire to change their drinking habits.

Table 1.

Background and Drinking Variables

		Mean	*Std. Deviation*
Age:		21.64	2.06
		N	*%*
Gender:	Male	46	43.0%
	Female	61	57.0%
Race:	Black	14	13.1%
	White	30	28.0%
	Hispanic	25	23.4%
	Asian	31	29.0%
	Other	7	6.5%
Average Income:	≤39,999.99	51	47.7%
	≥40,000.00	56	52.3%
		Mean	*Std. Deviation*
Drinking Variables:	Total number of drinks past three months	71.33	61.30
	Average number of drinks per episode	3.16	1.61
	Number of drinks on per week	9.01	9.51
	Binge episodes over past three months	5.90	7.38
	Alcohol Use Disorders Identification Test (AUDIT) - Total Score	10.16	4.50

Cue-Induced Craving

A paired-samples t-test was conducted to compare craving in pre-stimulus and post-stimulus conditions. There was a significant difference in the scores for pre-stimulus (M=11.15, SD=17.72) and post-stimulus (M=21.34, SD=24.63) conditions; $t(106)= 6.07$, $p < 0.0001$. These results suggest that exposure to alcohol cues induced significant elevations in craving as depicted in Table 3.

Table 2.

Study Variables

		Mean	Std. Deviation
Alcohol Purchase Task (APT)	Intensity	10.01	7.56
	Elasticity	.008	.003
	Breakpoint	14.19	4.23
	P_{max}	7.93	5.43
	O_{max}	22.05	10.95
Cue-induced Craving		10.19	17.38
Obsessive Compulsive Drinking Scale (OCDS)		9.73	5.53
Measures of Impulsivity	Delay Discounting (AUC)	.08	.01
	UPPS-P Impulsive Behavior Scale (Total Score)	135.77	21.09
	Barratt Impulsivity Scale (Total Score)	61.79	12.80

Table 3.

Craving before and after exposure to alcohol cues

	Mean	N	Std. Deviation	Std. Error Mean
Pre-stimulus	11.15	107.00	17.72	1.71
Post-stimulus	21.34	107.00	24.63	2.38

Hypothesis Testing

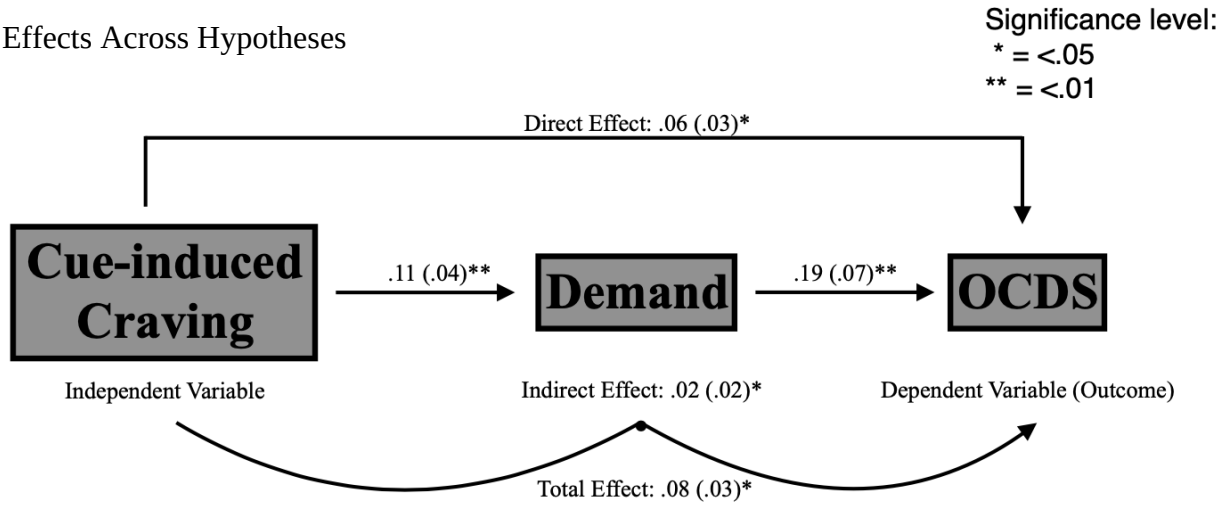
Our first hypothesis was that cue-induced craving would be predictive of OCTD. Consistent with our hypothesis, we found that individuals with higher levels of craving had higher OCDS scores ($b=.08$, $p<.05$). Our second hypothesis was that cue-induced craving would predict an increase in demand. Results partially supported our hypothesis; people with higher levels of craving had higher levels of demand, as measured by APT intensity ($b=.11$, $p<.01$), but not as measured by the other APT indices (p's >0.05). Our third hypothesis was that demand in

turn will be predictive of an increase in OCTD. We found that an increase in APT intensity was indeed predictive of higher scores on the OCDS (b=.19, p<.01) (see Figure 2).

Our fourth hypothesis was that demand indirectly mediates the effects of cue-induced craving on OCTD. Consistent with this hypothesis, we found that cue-induced craving predicts demand, which in turn predicts high OCDS scores. The indirect effect was significant, as determined by bootstrapped 95% confidence intervals (b=.02, p<.05).

Figure 2.

Effects Across Hypotheses



To test our final hypothesis (Hypothesis 5), we included our three measures of impulsivity as moderators in a series of moderated mediation analyses using PROCESS, as described above. As shown in Table 4 and consistent with the hypothesis, the indirect effect of cue-induced craving on OCDS got stronger as impulsivity got higher. Interestingly, this was true for both the UPPS-P and BIS (Indices of Moderated Mediation = .0025 and .0701) p's<.05 but notably not for the DDT (Index of Moderated Mediation = -2.1941, p>.05).

Table 4.

Effects of Craving on OCTD Across Levels of Impulsivity

	Impulsivity	Indirect Effect	Standard Error	Lower-Level Confidence Interval	Upper-Level Confidence Interval
UPPS-P	Low	-.005	.01	-.026	.018
	Medium	.021	.014	.001	.055
	High	.045	.024	.004	.098
BIS	Low	-.009	.01	-.031	.013
	Medium	.018	.013	.001	.05
	High	.053	.026	.007	.109
DDT	Low	.06	.033	.005	.134
	Medium	.037	.021	.004	.087
	High	.016	.015	.001	.06

Discussion

The results of this study replicate previous work that has demonstrated that alcohol related cue-induced craving predicts OCTD (Kranzler et al., 1999) and extend findings by showing that an individual's economic demand drives the relationship which has been less studied. Findings indicated that cue-induced craving was associated with higher levels of demand, which was measured by APT intensity. APT intensity was in turn related to higher OCTD. Confidence intervals showed a significant indirect effect of cue-induced craving on OCTD through increased demand. This effect was further increased when subjects had higher levels of self-reported impulsivity. In particularly, the delay discounting task as a measure of impulsivity did not impact the indirect effects observed in this study. It is possible that the monetary delay discounting task we employed was not a sensitive indicator of alcohol-related impulsive behavior.

The results underscore the importance of behavioral economics as a mechanism underlying the effects of cue-induced craving on obsessive-compulsive drinking characteristics, especially among impulsive drinkers. Until now, it was only hypothesized how craving impacted drinking. This significant gap in knowledge has been narrowed by these findings which show that craving seems to not only change people's decision process but actually change the perceived economic value of alcohol in a given moment. Behavioral economics, as measured in this study by APT intensity, give us a concrete way to think about what is changing in terms of an individual's decision process to drink alcohol.

As found in past research (Yarmush et al., 2016), it is known that cue-reactivity is related to drinking but there is not a lot of information about cue-induced craving and OCTD. These findings build off an existing body of literature and provide a further understanding of how cue-

reactivity can help identify problem drinking. Studies (Fox et al., 2007) have discussed how exposure to alcohol cues produces increases in alcohol craving and negative emotions as well as a decrease in positive emotions. Unfortunately, until now, research has not shown that this, in turn, puts people at a greater risk to obsessively-compulsively drink.

In our study, we found the relationship between cue-induced craving and OCTD. This is consistent with Anton (2000) who also found that there was a relationship. Consistent with previous studies, our results (Hypothesis 2) found that cue-induced craving was related to demand. As indicated above, previous studies have looked at this and our findings are largely consistent. For example, MacKillop et al. (2010) found that craving was significantly associated with subjects who experiences AUD symptoms and intense alcohol demand. This study is broadly consistent with the effects that impulsivity has on drinking behavior (Coskunpinar, 2013) and we have demonstrated specifically how that might work; namely by the mediating process of demand (Hypothesis 4). As mentioned above, impulsivity has been shown to be an important factor in cue-induced craving and OCTD, but our study took the next step and identified how impulsivity can potentiate both the direct and indirect effects of craving on OCTD.

Furthermore, our data, compared to some previous literature, showed that cue-induced craving predicted demand but different elements of demand. MacKillop et al. (2010) found that among subjects with AUD, craving was significantly associated with AUD symptoms as well as higher alcohol demand. In our study, cue-induced craving was associated with higher levels of demand as measured by APT intensity.

Based on our findings, we now have a better understanding of how cue-induced craving affects an individual's decision to drink as well as their OCTD. Understanding the complexity of

OCTD and how our novel findings regarding what meditates cue-induced craving and OCTD, can be clinically significant while trying to help a patient drink less or achieve abstinence. As stated above, one major factor involved in decisions to consume alcohol is the presence of cues, or "triggers," that induce an individual's craving. Previous research has demonstrated that exposure to certain cues can induce significant craving reactions (Carter & Tiffany, 1999). Research has linked cue-induced craving to drinking outcomes, with some studies demonstrating that cue-induced cravings are associated with increased drinking and OCTD (Papachristou et al., 2014). Focusing on the mediating variable, demand provides a new conceptual model to understand part of what is rudimentary about the phenomena of alcohol use disorders.

The clinical significance of these findings lies in understanding a patient's valuation of alcohol and the discounting of delayed rewards. Past research has also suggested that these factors are predictive of treatment results and can help guide treatment (Stanger et al., 2012). A potential intervention utilizing these behavioral economic variables could be during talk-therapy sessions where clinicians emphasize the role of explicit incentives to demonstrate the effort or the cost of one's continual alcohol use. Furthermore, pre-screening students at college-counseling centers, especially those who are coming in for alcohol related incidents, can include self-report measures and assessments to gauge their demand for alcohol, impulsivity, and cue-induced craving (Bickel et al., 2014; Hogarth, 2020).

These findings can have further clinical implications by directing contingency management (CM), which provides an opportunity for subjects to win monetary prizes as reinforcers. Consistent with this possibility, a study by Petry et al. (2000) gave 42 alcohol-dependent individuals the opportunity to earn up to $200 if they provide negative breathalyzer results and complete steps toward treatment goals. Sixty-nine percent of subjects receiving CM

were still abstinent by the end of the eight-week treatment period. These results support the theory that an individual's demand can be managed to help maintain abstinence. Whether such an approach is useful for prevention remains to be seen.

This study provides some of the first data on the relationship between cue-induced craving and OCTD and how this relationship is mediated by an increase in alcohol demand. It provides novel data on how this relationship is potentiated among impulsive drinkers. We were also able to clearly model the pathway from cue-induced craving to demand to OCTD. These results will require replication in differing samples to further strengthen the data. Nonetheless, it provides several hopeful directions for future research such as adapting this model to assess demand and decision making for other addictive substances.

There are several limitations to this study such as the demand measures being self-reported. Furthermore, although previous research has found equivalence between hypothetical and actual monetary reward APT, replicating this study using monetary rewards would eliminate these limitations and further strengthen previous research. The sample that was used could also prevent generalizability since it was taken from one geographic location and only consisted of young adults ranging from 18-25 years old. Another limitation could be that all subjects were tested in a laboratory environment rather than their normal drinking environment. Unfortunately, we did not conduct this study longitudinally and cannot infer what impact it would have on actual drinking outcomes. Therefore, this is another direction for future research.

In summary, the present study extends the literature on the relationship between cue-induced craving and problem drinking, which is mediated by an increase in alcohol demand. Furthermore, it sheds light on the degree to which these effects might be potentiated among impulsive drinkers. These findings provide preliminary support for focusing on alcohol demand

characteristics in young adults as a potential indicator for their risk of OCTD. More generally, this study contributes to the literature suggesting that there is a clear pathway between cue-induced craving and OCTD and that this relationship is particularly strong among impulsive individuals.

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