Novel Behavioral Economic Approaches for Measuring Substance Use Severity and Motivating Change

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America is experiencing unprecedented increases in “deaths of despair”
Behavioral Economic and Reinforcer Pathology Models of Alcohol and Drug Use

Focus on choice: behavior is allocated to an activity based on the cost/benefit ratio of that activity relative to other available activities.

Levels of drug use are sensitive to:

- Price
- Delay to Reward
- Alternatives

Addiction = drugs have greater reinforcing value than available alternatives.
Reinforcer Pathology: Why do people sometimes choose drug rewards even in the presence of alternatives?

Figure 2. Depiction of the accrual of reinforcing value of two commodities over time. The y axis represents relative subjective value, and the x axis represents time over a course of years. The red curve depicts the reinforcing value of choosing to engage with a drug reinforcer, such as alcohol, at different time points. The blue curve represents the reinforcing value of...
Behavioral Economic Measures of Substance Use Risk/Severity

- **Reinforcing Efficacy**: *individual differences* in the extent to which an individual *wants* or values a substance
  - Demand curves\(^2\text{-}^5\)
  - Relative substance-related activity participation and enjoyment (reinforcement-ratio)\(^2\text{-}^5\)

- **Ability to experience and access to substance-free reward**\(^9\)
  - Reward Probability Index (RPI)\(^6\), measures of anhedonia

- **Intertemporal choice or future orientation**:
  - Delay discounting, Consideration of future consequences, Relative discretionary monetary allocation\(^7\text{-}^8\)

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1 Murphy et al., 2005; 2 Murphy & MacKillop, 2006; 3 Dennhardt, Yurasek, & Murphy, 2015 4 Roma, Hursh, & Hudja, 2015; 5 Morris et al., 2017, 6 Carvalho et al., 2011, 7 MacKillop et al., 2011; 8 Tucker et al., 2019; 9 Acuff, Dennhardt, Correia, & Murphy, 2019.
Alcohol Reinforcing Efficacy: Hypothetical Alcohol Purchase Task (Demand Curve Measure)

"Imagine that you and your friends are at a bar from 9pm to 2am to see a band. The following questions ask how many drinks you would purchase at various prices. The available drinks are standard size beer (12oz), wine (5oz), shots of hard liquor (1.5oz), or mixed drinks with one shot of liquor. Assume that you did not drink alcohol before you went to the bar and will not go out after."

Demand Curve Measures of Reinforcing Efficacy

Consumption Curve

**Intensity:**
consumption at minimal price

**Elasticity:**
slope of the demand curve
- to what degree to participants respond to changes in price

**Breakpoint:**
Price when consumption is 0

Expenditure Curve

$O_{\text{max}}$: $P_{\text{max}}$:
Maximum expenditure   Maximum inelastic price

*Indices are reliable and correlated with actual drink purchases in lab (Amlung et al., 2012; Acuff & Murphy 2017)*
High/Inelastic Demand is Uniquely Associated with Alcohol and Drug Problem Severity

- Higher demand is associated with:
  - greater levels of alcohol/drug problems\(^1,7,8\)
  - craving\(^2\)
  - impulsivity\(^3\)
  - drinking to cope\(^4\)
  - cigarette smoking\(^5\)
  - comorbidity (depression and PTSD)\(^6\)

\(^1\)Murphy & MacKillop, 2006; \(^2\)MacKillop et al., 2010; \(^3\)Smith et al., 2010; \(^4,5\)Yurasek et al., 2011, 2013; \(^6\)Murphy et al., 2013; \(^7\)Skidmore & Murphy, 2014; \(^8\)Morris et al., 2017
Alcohol Demand and DSM-5 Alcohol Use Disorder (AUD) Symptoms in a Large Swiss Population Sample (N = 4790 men)

Bertholet, Murphy, Daeppen, Gmel, & Gaume (2015). Drug and Alcohol Dependence
Elevated Alcohol Demand Uniquely Predicts Drinking and Driving

- Teeter & Murphy (2015). ACER
- Teeters, Meshesha, Pickover, & Murphy (2014). ACER
Demand for Alcohol is Sensitive to Next-Day Contingencies

Family History is Related to Less Sensitivity of Demand to Next-Day Contingencies

Murphy, Yurasek, Dennhardt, Mesheha et al. (2014). *Journal of Studies on Alcohol and Drugs.*
High Opportunity Cost Demand as an Indicator of Weekday Drinking and Distinctly Severe Alcohol Problems: A Behavioral Economic Analysis

Keenan J. Joyner, Lidia Z. Mashesa, Ashley A. Demhardt, Brian Borsari, Matthew P. Mariner, and James G. Murphy
**Experimental manipulations of behavioral economic demand for addictive commodities: A meta-analysis**

- The strength of a substance reinforcer is affected by:
  - Cue exposure
  - Stress
  - Magnitude
  - Opportunity Cost
- Pharmacotherapies and behavioral treatment reduce demand

Acuff, Amlung, Dennhardt, MacKillop, & Murphy (2019). *Addiction*
Relative substance-related activity participation and enjoyment (reinforcement-ratio) Measures of Reinforcing Efficacy
## Modified Reinforcement Survey: Adolescent Reinforcement Survey Schedule

<table>
<thead>
<tr>
<th>Activities</th>
<th>Frequency with alcohol or drugs</th>
<th>Frequency without alcohol or drugs</th>
<th>Enjoyment with alcohol or drugs</th>
<th>Enjoyment without alcohol or drugs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Go places with siblings or family members</td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
<td><img src="image3.png" alt="Image" /></td>
<td><img src="image4.png" alt="Image" /></td>
</tr>
<tr>
<td>2. Talk with friends</td>
<td><img src="image5.png" alt="Image" /></td>
<td><img src="image6.png" alt="Image" /></td>
<td><img src="image7.png" alt="Image" /></td>
<td><img src="image8.png" alt="Image" /></td>
</tr>
<tr>
<td>3. Read a book</td>
<td><img src="image9.png" alt="Image" /></td>
<td><img src="image10.png" alt="Image" /></td>
<td><img src="image11.png" alt="Image" /></td>
<td><img src="image12.png" alt="Image" /></td>
</tr>
<tr>
<td>4. Go on a date</td>
<td><img src="image13.png" alt="Image" /></td>
<td><img src="image14.png" alt="Image" /></td>
<td><img src="image15.png" alt="Image" /></td>
<td><img src="image16.png" alt="Image" /></td>
</tr>
</tbody>
</table>

**Frequency**
- 0 = 0 times
- 1 = once a week or less
- 2 = 2-4 times per week
- 3 = about once a day
- 4 = more than once day

**Enjoyment**
- 0 = unpleasant or neutral
- 1 = mildly pleasant
- 2 = moderately pleasant
- 3 = very pleasant
- 4 = extremely pleasant

Frequency X Enjoyment = Obtained Reinforcement

Relative Behavioral Allocation and Enjoyment Related to Substance Use vs. Other Activities

Reinforcement Ratio:

<table>
<thead>
<tr>
<th>Substance-Related Reinforcement</th>
<th>(Substance-Related Reinforcement + Substance-Free Reinforcement)</th>
</tr>
</thead>
</table>

Person A
24 Drinks/Week
Reinforcement Ratio = .15

Person B
24 Drinks/Week
Reinforcement Ratio= .65

-reliable, and associated with alcohol use and problems
(Hallgren et al., 2016; Magidson et al., 2017; Morris et al., 2017; Skidmore et. al 2014)
Structural Equation Model of Reinforcer Pathology Variables Predicting Alcohol Use and Problems

- Alcohol demand and proportionate substance-related reinforcement independently associated with greater alcohol consumption and problems.

- Consideration of Future Consequences was associated with alcohol-related problems and proportionate substance-related reinforcement but was not significantly associated with alcohol consumption or alcohol demand.

- Small counter-intuitive association b/t delay discounting and alcohol problems.

Behavioral Treatment Reduces Reinforcement Ratio, Change in R-Ratio following intervention may be a marker of successful treatment

![Change in R-Ratio](image)

Brief motivational interventions reduce reinforcement-ratio relative to control at 1-month, and change in reinforcement-ratio mediates treatment outcomes over 16-months 1-4

- Similar results with natural recovery samples (relative alcohol-related discretionary expenditures 5)
- Similar results with weight loss intervention (relative food-free reinforcement)6

1Dennhardt et al. (2014); 2Murphy et al. (2005); 3Murphy et al. (2015); 4Murphy et al. (2019) 5Tucker et al 2009; 6Buscemi et al 2014
Pharmacological and Behavioral Treatment Reduces Alcohol Demand, Change in demand immediately following intervention may be a marker of successful treatment.

Naltrexone
Bujarski, MacKillop, & Ray (2012) ECP.

Motivational Interviewing
Murphy, Dennhardt et al. (2015). JCPP.
Soltis, Acuff, Campbell, Mun, Dennhardt, Borsari, Martens, & Murphy (under review)
Reward Deprivation is a Risk Factor for Drug Self-Administration and Addiction

Alexander et al., 1978; 1981; Higgins et al., 2004; Miller et al. (2012). Drug and Alcohol Dependence; see also Ginsberg and Lamb (2018).
Factors Contributing to Reward Deprivation Among Humans

- Poverty, lack of access to quality education
  - Association b/t drug use and poverty is mediated by reward deprivation
    - Andrabi, Khoddam, & Leventhal, 2017

- Discrimination, systemic racism (racial trauma)

- Environments that lack access to social/leisure activities

- Mental health conditions (depression, social skill deficits)

- Medical conditions that cause pain or limit activities

- Transitions/life events
  - Unemployment, divorce, moving, diminished access to hobbies/sports

- Chronic alcohol and drug use erodes natural sources of reward
  - Impairs health, work, relationships; reduces neural sensitivity to drug-free reward

  — Addiction is both a “brain disease” & an “environmental disease”
COVID-19 Pandemic Reward Deprivation and Mental Health

Pandemic Causes Spike in Anxiety & Depression

% of U.S. adults showing symptoms of anxiety and/or depressive disorder*

- Symptoms of anxiety disorder: 8.2% (January-June 2019) vs. 28.2% (May 14-19, 2020)
- Symptoms of depressive disorder: 6.6% (January-June 2019) vs. 24.4% (May 14-19, 2020)
- Symptoms of anxiety or depressive disorder: 11.0% (January-June 2019) vs. 33.9% (May 14-19, 2020)

* Based on self-reported frequency of anxiety and depression symptoms. They are derived from responses to the first two questions of the eight-item Patient Health Questionnaire (PHQ-2) and the seven-item Generalized Anxiety Disorder (GAD-2) scale.

Sources: CDC, NCHS, U.S. Census Bureau
COVID-19 Pandemic and Alcohol and Drug Use

Acuff, Tucker, & Murphy (in press). *Experimental and Clinical Psychopharmacology*
Context/Reward Deprivation and The Overdose Epidemic

Fatal Drug Overdose Rates are Much Higher in Some Places than Others

Factors Contributing to Geographic Differences in Fatal Drug Overdose Rates, 2014-16

Percent Difference in Drug Mortality Rate for a One Standard Deviation Change in the Predictor Variable

-20  -10  0    10   20   30

Separated/divorced, %
Not working, %
Per capita opioid prescribing
Public assistance receipt, %
No 4-year college degree, %
Single parent families, %
Poverty, %
Jobs in mining, %
Vacant housing units, %
Jobs in retail, services, food, %
Income inequality
Jobs in business/professional, %
Jobs in FIRE, %
Jobs in manufacturing, %
Jobs in farming, fishing, forestry, %

White non-Hispanic midlife mortality from “deaths of despair” in the U.S. by education

Ages 50-54, deaths by drugs, alcohol, and suicide

Significant Cultural Shifts May be Increasing Reward Deprivation

Figure 5.4: Time spent on the internet, sleeping more than 7 hours a night most nights, frequency of in-person social interaction across 7 activities, and general happiness, standardized (Z) scores, 8th and 10th graders, Monitoring the Future, 2006-2017
Significant Cultural Shifts May be Increasing Reward Deprivation

Figure 5.5: Correlation between activities and general happiness, 8th and 10th graders, Monitoring the Future, 2013-2016 (controlled for race, gender, SES, and grade level)
To Understand the Role of Reward and Environmental Context in Addiction (risk and recovery), we need to Understand Our Evolutionary Context
Until the past few centuries survival required sustained effort in goal directed activities, outdoor physical activity, and social cooperation.
• Thus, we are biologically ill-equipped for social isolation, sedentary lifestyles

• We are prepared for “scarcity” & especially motivated to pursue short-term “low effort” rewards when they are available (next meal was uncertain)

  • We are ill-equipped for food abundance & easy access to drugs and other low effort yet potent reinforcers (electronics)
  • Social activity, physical activity, and activities that increase our social status may be especially potent rewards
And drug rewards are often associated with social reward, especially for young adults.

- Lab studies demonstrate alcohol (at low doses) is an effective social lubricant.
- Naturalistic studies indicate that greater drinking quantity is associated with more “enjoyment.”
- Reductions in drinking are associated with reductions in social reward.

Sayette et al. 2012; Murphy et al. 2005, 2006
Drinking as a Function of Age

Cannabis Use among Young Adults

In the past five years, daily¹ marijuana use has continued to rise for non-college young adults, reaching its highest level in 2017 at 13.2%.

Daily¹ use is almost three times higher in the non-college group.

¹Daily use is defined as use on 20 or more occasions in the past 30 days.

(NIDA, 2018)
Integrating Behavioral Economic and Social Network Influences in Understanding Alcohol Misuse in a Diverse Sample of Emerging Adults

Acuff, MacKillop, & Murphy (2020), ACER
Using Demand Curves to Quantify the Reinforcing Value of Social and Solitary Drinking

Acuff, Soltis, & Murphy (2020), ACER
Measuring Substance-Free Reward and Reward Deprivation

Understudied relative to other behavioral economic variables (demand and delay discounting)

Challenging to identify and quantify the reinforcing value of all activities in an individual’s environment compared to measuring the reinforcing value of alcohol/drugs, or delay discounting

Young Adult Prescription Opiate Users Show Blunted Response to Drug-Free Stimuli

- Participants – prescription opioid users vs. matched controls
- Covariates – age, gender, depression, ethnicity
- Baseline value predicts 12 month change in alcohol use

Meshesa, Pickover, Teeters, Murphy (2017). The Psychological Record. See similar studies with fMRI (Meuller) and EEG (Bartholow)
Reward Probability Index (Carvalho et al., 2011)

May measure more historical and persistent reward deprivation

• Environmental Suppressors (reward availability)
  – My behaviors often have negative consequences.
  – I have few financial resources, which limits what I can do.
  – Changes have happened in my life that have made it hard to find enjoyment.

• Reward Probability (ability to experience reward)
  – I feel a strong sense of achievement.
  – There are many activities that I find satisfying.
  – I have many interests that bring me pleasure.
Are AUD Symptoms Associated with Chronic Deficits in Reward Among Emerging Adults?
Are AUD Symptoms Associated with Chronic Deficits in Reward Among Heavy Drinking Emerging Adults?

- **Baseline analyses:**
  RPI Total and environmental suppressors are associated with AUD symptoms beyond drinking level, depression, and demographics

Moderate/Severe AUD Symptoms are Associated with Persistent Deficits in Reward Availability over a 16-month Timeframe

Linear growth curve models (controlling for drinking & demographics) demonstrated moderate/severe AUD group (n = 130) showed gradual increase in reward over time but remained lower than group of heavy drinkers with none or mild AUD (n = 261)
Behavioral Economic Research Provides Support for Treatments that Increase Substance-free Reward

- Intensive treatments for treatment seeking populations: contingency management, community reinforcement, behavioral activation, Mindfulness Oriented Recovery Enhancement (MORE); 12-Step Interventions
- Also necessary to develop brief approaches to increase reward for non-treatment seeking populations or as an adjunct to standard treatment

Substance-Free Activity Session (SFAS)

- Single session behavioral economic supplement to brief motivational alcohol intervention
  - Goals are to increase:
    - positive and enjoyable substance-free activity and commitment to college/life goals (studying, internships, exercise, etc.)
    - the salience of delayed rewards
    - the extent to which behavior (e.g., attending class, internship, studying) is viewed as part of a pattern leading to delayed rewards
    - Understanding of the costs of drinking/drug use on other important goals/rewards

How does this fit with your values and long term goals?

What is the current and future value of each of these activities?

How would this need to change to be more aligned with your future goals?
Other Substance-Free Activity Session (SFAS) Elements

- Personalized feedback on specific career requirements, how they can pursue local internships etc.
- Personalized feedback on coping with stress/depression
- Personalized feedback on substance-free leisure activities  *e.g.*, *You mentioned you enjoy photography, here is information on a campus photography club....*
- Goal setting, info on mobile apps to facilitate goal progress
- Phone/text booster contact incorporated in current trials
RCT of Two-Session (plus booster) Brief Interventions for Heavy Drinking College Students

- Despite small effect sizes, there has been very little research aimed at enhancing brief intervention efficacy by adding novel theoretically grounded intervention elements

- Participants (N = 393) recruited from 2 public universities (all reported recent heavy drinking):
  - Were randomized to:
    - 1) Standard alcohol-focused BMI session + Behavioral Economic Substance-Free Activity Session (SFAS; N = 130)
    - 2) Standard alcohol-focused BMI + Individual Relaxation Training (active control) (N = 125)
    - 3) Assessment-only (N=138)
  - Phone booster sessions (beginning of spring semester) for SFAS & Relaxation participants

- Follow-ups assessments:
  - 1-month follow-up rate = 93%
  - 6-month follow-up rate = 88%
  - 12-month follow-up rate = 87%
  - 16-month follow-up rate = 79%

Two Session BMI + Substance-Free Activity Session (SFAS) or Relaxation Training is Associated with Enduring Reductions in Drinking and Problems (larger effects compared to most single-session interventions)

-Results mediated by increased protective behaviors and substance reinforcement
-Both conditions also improved anxiety, depressive symptoms, & self-regulation

Murphy et al. (2019). *Journal of Consulting and Clinical Psychology*. 
Impact of Treatment on Reward Availability Trajectory Groups (Growth Mixture Models)

For students in the LR trajectory, BMI + SFAS led to greater increases in reward availability and reduced rates of Moderate/Severe AUD at 1, 6, and 12 months compared to BMI + RT and AO conditions, and also at 16 months compared to AO.

Murphy, Campbell, Joyner, Dennhardt, Martens, & Borsari (under review).
SFAS as a Booster with Adult Alcohol Treatment Outpatients

Pilot trial investigating a brief behavioral economic intervention as an adjunctive treatment for alcohol use disorder*

Lidia Z. Mesheha, Kathryn E. Soltis, Edward A. Wise, Damaris J. Rohsenow, Katie Witkiewitz, James G. Murphy

*Center for Alcohol and Addiction Studies, Brown University School of Public Health, Providence, RI 02912, United States of America

Department of Psychology, The University of Memphis, Memphis, TN, United States of America

Division of Admissions and Advising, University of New Mexico, Albuquerque, NM, United States of America
Summary and Implications

- Results provide support for:
  - behavioral economic “reinforcer pathology” models of young adult AUD\(^1\)
  - research examining the role of reward deprivation as a factor in the development and course of AUD, including response to brief intervention\(^2\)
  - measurement advances that allow for precise quantification of substance-free reward\(^9\)
  - treatments that directly target substance-free reward\(^3, 8\)
    - Behavioral Activation\(^4\), Community Reinforcement/Contingency Management\(^5\), Mindfulness Oriented Recovery Enhancement (MORE)\(^6\); Substance-free Activity Session SFAS\(^6\)
  - Public policies aimed at increasing substance-free activities for youth (e.g., Iceland model\(^7\))

\(^1\)Acuff et al., 2018; \(^2\)Tucker et al 2009; \(^3\)McKay, 2016; \(^4\)Daughters et al. 2008; \(^4\)Meyers et al., 1999; \(^5\)Garland et al., 2014; \(^6\)Murphy et al., 2012, 2019; \(^7\)Kristjansson et al., 2010, 2016; \(^8\)Fazzino et al., 2019; \(^9\)Acuff et al., 2019
Title of Program: VCBH Monthly Lecture Series FY2021

Title of Talk: Novel Behavioral Economic Approaches for Measuring Substance Use Severity and Motivating Change

Speaker/Moderator: James G. Murphy, PhD

Planning Committee Members: Stephen H. Higgins, PhD, Philip Ades, MD, Diann Gaalema, PhD

Date: September 16, 2020

Workshop #: 21-265-01

Learning Objectives

1.

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