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TOWARD QUANTIFYING THE ABUSE LIABILITY OF ULTRAVIOLET TANNING: A BEHAVIORAL ECONOMIC APPROACH TO TANNING ADDICTION

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Many adults engage in ultraviolet indoor tanning despite evidence of its association with skin cancer. The constellation of behaviors associated with ultraviolet indoor tanning is analogous to that in other behavioral addictions. Despite a growing literature on ultraviolet indoor tanning as an addiction, there remains no consensus on how to identify ultraviolet indoor tanning addictive tendencies. The purpose of the present study was to translate a behavioral economic task more commonly used in substance abuse to quantify the "abuse liability" of ultraviolet indoor tanning, establish construct validity, and determine convergent validity with the most commonly used diagnostic tools for ultraviolet indoor tanning addiction (i.e., mCAGE and m*DSM-IV-TR*). We conducted a between-groups study using a novel hypothetical Tanning Purchase Task to quantify intensity and elasticity of ultraviolet indoor tanning demand and permit statistical comparisons with the mCAGE and m*DSM-IV-TR*. Results suggest that behavioral economic demand is related to ultraviolet indoor tanning addiction status and adequately discriminates between potential addicted individuals from nonaddicted individuals. Moreover, we provide evidence that the Tanning Purchase Task renders behavioral economic indicators that are relevant to public health research. The present findings are limited to two ultraviolet indoor tanning addiction tools and a relatively small sample of high-risk ultraviolet indoor tanning users; however, these pilot data demonstrate the potential for behavioral economic assessment tools as diagnostic and research aids in ultraviolet indoor tanning addiction studies.

Key words: behavioral addiction, behavioral economics, demand, hypothetical purchase task, tanning

The subdiscipline of behavioral economics in behavior analysis initially provided a theoretical account of operant responding in varying forms of reinforcer economies (Hursh, 1980, 1984; Hursh & Roma, 2016; Kagel & Winkler, 1972). Continued research has rendered behavioral economics a viable approach to understanding reinforcer value and consumption under constraining conditions such as closed economies, price increases, and effort manipulations (Kagel, Battalio, & Green, 1995). The analysis of reinforcer consumption under constraining conditions gave rise to a novel means of understanding drug self-administration, which researchers quickly translated to human models of addiction and dependence (Bickel, DeGrandpre, & Higgins, 1993; Bickel, DeGrandpre, Higgins, & Hughes, 1990; Bickel, DeGrandpre, Hughes, & Higgins, 1991; Bickel, Hughes, DeGrandpre, Higgins, & Rizzuto, 1992; Bickel, Madden, & Petry, 1998; DeGrandpre, Bickel, Hughes, & Higgins, 1992; Hursh, 1993). Contemporary behavioral economics is now widely adopted—both within and outside of behavior analysis—as a robust conceptual, methodological, and analytical framework for behavioral addictions and substance use disorders (Bickel, Jarmolowicz, Mueller, & Gatchalian, 2011; Bickel, Johnson, Koffarnus, MacKillop, & Murphy, 2014; Carter & Griffiths, 2009; Jarmolowicz, Reed, DiGennaro Reed, & Bickel, 2016; MacKillop, 2016) and behavioral health, in general (Bickel & Vuchinich, 2000).

Much of the contemporary success in behavioral economics is due to its scalability in informing public policy (Hursh & Roma, 2013) and utility in identifying potential abuse liability of particular commodities (Christensen, Silberberg, Hursh, Huntsberry, & Riley, 2008; Hursh & Winger, 1995). Toward this end, behavioral economists have begun to rely on hypothetical purchase tasks (see Roma, Hursh, & Hudja, 2016) to simulate consumption as a means of safely and quickly quantifying abuse liability (Jacobs & Bickel, 1999; Murphy & MacKillop, 2005; Murphy & MacKillop, 2006) and informing effective policies to

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reduce dependence (MacKillop et al., 2012). The hypothetical purchase task is used to quantify demand and demand elasticity for a commodity, most typically drugs of abuse (e.g., alcohol, tobacco, heroin), whereby individuals report how many units of a commodity they would purchase or the probability of a single purchase across a wide range of prices (Roma et al., 2016). Beyond being an efficient analog to drug administration, hypothetical purchase tasks feature sufficient psychometrics such as convergent/divergent validity (MacKillop et al., 2008; Murphy, MacKillop, Tidey, Brazil, & Colby, 2011) and temporal stability (Amlung & MacKillop, 2012; Few, Acker, Murphy, & MacKillop, 2011; 2012). Although these hypothetical purchase tasks demonstrate adequate psychometric properties for traditional drugs of abuse (see also: Amlung, Acker, Stojek, Murphy, & MacKillop, 2012; Kiselica, Webber, & Bornovalova, 2016; MacKillop, 2016; MacKillop & Murphy, 2007; Reed, Kaplan, & Becirevic, 2015), the degree to which hypothetical purchase tasks are translatable to under-researched behavioral addictions remains relatively unknown. The purpose of this translational study was to examine the degree to which a hypothetical purchase task for ultraviolet indoor tanning (UVIT) corresponds with known markers of UVIT dependence used in clinical dermatology.

Over 10 million Americans are estimated to use UVIT annually (Guy, Berkowitz, Holman, & Hartman, 2015), with the highest prevalence among Caucasian college-aged females (aged 18–21; 31.6%) who report 27.6 UVIT events per year, on the average (Centers for Disease Control, 2012). These statistics suggest relatively intense consumer demand for UVIT in this population, which is troubling given clear and widely publicized reports that UVIT before the age of 25 increases one's risk of skin cancer by up to 102% (Wehner et al., 2012). Such substantial demand for UVIT likely results from a host of contributing factors. Curious potential UVIT users are subject to a multi-billion-dollar industry (Bizzozero, 2009) with advertising techniques that health professionals have likened to those used in the tobacco industry (Holman et al., 2013). After trying UVIT, some users may experience pleasurable consequences by way of physiological sensations, relaxation, social praise, perceptions of increased attractiveness, and other reinforcement mechanisms (Cafri et al., 2006; Feldman et al., 2004; Hillhouse & Turrisi, 2012; Kaur, Liguori, Fleischer, & Feldman, 2006; Schneider et al., 2013; Warthan, Uchida, & Wagner, 2005). Indeed, Feldman and colleagues (2004) documented a potential reinforcement effect of UVIT by demonstrating that regular UVIT users exposed to both a typical UV sunbed and an identical sunbed containing a UV filter will use the sunbed emitting UV, *ceteris paribus*, despite these users being blind to which sunbed contained the filter. Thus, UV radiation may be considered a consumable *substance*, considering that exposure to UV radiation in UVIT is associated with cutaneous opioid release (Kaur, Liguori, Fleischer et al., 2006; Kaur, Liguori, Lang et al., 2006).

The notion of UVIT dependence has been substantiated by studies drawing parallels between UVIT and substance-related disorders (Ashrafioun & Bonar, 2014; Mosher & Danoff-Burg, 2010). Academic dermatologists report many UVIT users exhibit substantial difficulty in abstaining from UVIT, as well as physiological withdrawal symptoms upon abstinence initiation, regardless of their initial motives to tan (Ashrafioun & Bonar, 2014; Harrington et al., 2011; Nolan, Taylor, Liguori, & Feldman, 2009). Reports of such dependence have led to a proliferation of discussions on UVIT as a commodity with abuse liability, akin to other substance-related disorders (Ashrafioun & Bonar, 2014; Harrington et al., 2011; Nolan et al., 2009). Moreover, the maladaptive choices (Bickel et al., 2011, Bickel, Jarmolowicz, MacKillop et al., 2012; Bickel, Jarmolowicz, Mueller et al., 2012; Bickel et al., 2014; Jarmolowicz et al., 2016) associated with UVIT dependence appear similar to other behavioral addictions (see discussion by Reed, 2014).

Despite developments in tanning-specific addiction assessment tools (Heckman et al., 2014; Hillhouse, Turrisi, Stapleton, & Robinson, 2010; Schneider et al., 2015), many UVIT addiction studies have relied upon tools initially developed for smoking/drinking problems or behavioral addictions; notably, the CAGE (Cut-down, Annoyed, Guilty, Eye-opener) and the substance-related disorder diagnostic criteria from the *Diagnostic and Statistical Manual of Mental Disorders (Fourth Edition, Text Revision; DSM-IV-TR;* American Psychiatric Association, 2000; Ashrafioun &

Bonar, 2014; Cartmel et al., 2013; Harrington et al., 2011; Heckman, Egleston, Wilson, & Ingersoll, 2008; Mosher & Danoff-Burg, 2010; Poorsattar & Hornung, 2007; Schneider et al., 2013; Warthan et al., 2005). For example, Ashrafioun and Bonar surveyed 533 university students and found that 31% of the sample met criteria for tanning dependence according to a tanning-specific modification of the CAGE (see below), as well as significant correlations between tanning dependence and obsessive-compulsive and body dysmorphic disorders. Mosher and Danoff-Burg found that 39% of 229 university students met tanning dependence criteria according to the CAGE, and 31% met dependence criteria according to tanning-specific modified *DSM-IV-TR* criteria (see below). Additionally, participants with tanning dependence profiles reported significantly greater prevalence of anxiety and consumption of other commodities with abuse liability (e.g., marijuana, alcohol), in line with Bickel and colleagues' (Bickel, Jarmolowicz, MacKillop et al., 2012; Bickel, Jarmolowicz, Mueller et al., 2012) view that risky health decisions favoring immediate reinforcers (e.g., UVIT for short-term gains despite long-term health impacts) may be a transdisease process underlying addiction and spanning a range of additional clinical disorders.

Initially designed for alcohol use problems, the CAGE is composed of four criteria (Aertgeerts, Buntinx, & Kester, 2004): whether individuals (1) report being told to Cut-down use of the commodity, (2) feel Annoyed when others comment about their consumption of the commodity, (3) have felt Guilty for consuming the commodity, and (4) use the commodity as an Eye-opener (i.e., use the commodity upon waking in the morning). Affirming at least two criteria is regarded as an indication of potential dependence. A modified CAGE (mCAGE) assessment has subsequently become one of the more commonly used screeners for UVIT dependence (Schneider et al., 2015). However, Schneider and colleagues exposed a number of limitations regarding its use in UVIT contexts: (a) the clinical utility of the mCAGE for UVIT has been untested, (b) potential sampling problems, and (c) lack of no-UVIT controls. These authors demonstrated a larger and more representative sample of UVIT users did not replicate findings from earlier studies employing the mCAGE; rather, the mCAGE over-predicted UVIT dependence.

Similar to the translation of CAGE for UVIT purposes, researchers have adapted the language from the substance-related disorders diagnostic criteria in the *Diagnostic and Statistical Manual of Mental Disorders (Fourth Edition, Text Revision; DSM-IV-TR;* American Psychiatric Association, 2000). The initial translation of these substance-related disorders criteria for UVIT has become the standard language for use in identifying potential UVIT dependence (Warthan et al., 2005). As per standard *DSM-IV-TR* criteria, affirming at least three of the seven criteria is regarded as an indication of potential dependence.

Because "no gold standard for categorizing tanning dependence has yet been established" (Schneider et al., 2015), the purpose of this study was to compare the degree of dependence on the more commonly used clinical screeners for UVIT dependence (i.e., mCAGE and m*DSM-IV-TR*) to contemporary behavioral economic indicators of substance related disorders (behavioral economic demand via hypothetical purchase task) using recent, non-recent, and never UVIT users. Specifically, we explored the relation between mCAGE and m*DSM-IV-TR* ratings to behavioral economic demand (Bickel et al., 1998; Hursh, 1993) for UVIT. Behavioral economic demand is a quantitative marker of how consumers defend consumption of a given commodity as the price of the commodity increases. For example, a behavioral economist assesses the degree to which a consumer consumes a commodity under ideal market pressures (e.g., very low costs to the consumer). The behavioral economist also measures the elasticity of demand by quantifying change in consumption as a function of varying costs. Relatively inelastic demand—that is, stable consumption that is insensitive to price increases—indicates stronger demand for the commodity and stronger underlying reinforcing effectiveness. Demand elasticity also informs additional quantitative markers of demand, such as P_{max} (the price associated with unit elasticity where one-unit increase in price is met with one-unit decrease in consumption), O_{max} (consumption at P_{max}), and essential value (*EV*; a standardized metric based on an elasticity rate constant that succinctly summarizes an organism's consumption of the target commodity).

Behavioral economic demand for commodities of abuse serves as a major component in

the reinforcer pathologies model (Bickel, Jarmolowicz, MacKillop et al., 2012; Bickel, Jarmolowicz, Mueller et al., 2012; Bickel et al., 2014), which is a theoretical approach in the understanding and treatment of substance-related disorders grounded in behavior science. Specifically, stronger demand is considered a marker of potential substance-related disorder. The degree of demand inelasticity for a commodity is thereby associated with that commodity's abuse liability. Validating behavioral economic measures of abuse liability using common diagnostic tools for UVIT may provide insight on the validity of our translation of the hypothetical purchase task for this novel behavioral addiction. Demonstrating a conceptually systematic relation between demand and UVIT abuse will enable additional clinical research on the behavioral economic components of UVIT use and potentially inform novel treatment procedures.

Methods

Participants

A total of 102 undergraduate females enrolled in an introductory psychology course were recruited and received extra credit for participating. The final sample for analysis contained 93 female participants between the ages of 18 and 36 (mean age = 20.19 years [*SD* = 2.87]) after excluding participants based on response patterns on the behavioral economic task (see criteria below). More than simply a convenience sample, this demographic represents the population at the highest risk of UVIT-induced cancer (Karagas et al., 2002; Wehner et al., 2012). All data were collected two weeks prior to the university's scheduled spring break, which is a temporal event associated with increased tanning rates on college campuses (Heckman et al., 2008). An information statement consent process entailed a written cover letter explaining the broad goals of the study, along with the risks (i.e., boredom), benefits (i.e., increased understanding of consumer choices), and participant rights (i.e., voluntary participation, anonymity of results) associated with participation. The information statement explained that subsequent completion of the paper-based task (see below) was an indication of written consent. This consent process permits further anonymity and confidentiality as no participant names are directly linked to their responses. All procedures, including the information statement consent process, were approved by the Human Subjects Committee of the University of Kansas Lawrence Campus (#20635).

Procedures

Participants completed the mCAGE and m*DSM-IV-TR* to determine potential dependence to UVIT. For the mCAGE (Mosher & Danoff-Burg, 2010; Warthan et al., 2005), affirmative responses to at least two of the following four statements resulted in a positive classification, whereas affirmative responses to less than two of the following four questions resulted in a negative classification:

1. Do you try to cut down on the time you spend in tanning beds or booths?
2. Do you ever get annoyed when people tell you not to use tanning beds or booths?
3. Do you ever feel guilty that you are using tanning beds or booths too much?
4. When you wake up in the morning, do you want to use a tanning bed or booth?

The following seven diagnostic criteria comprising the m*DSM-IV-TR* (American Psychiatric Association, 2000; Mosher & Danoff-Burg, 2010; Warthan et al., 2005) were scored identically to past studies (Ashrafioun & Bonar, 2014; Mosher & Danoff-Burg, 2010; Warthan et al., 2005):

1. (a) Do you think you need to spend more and more time in tanning beds or booths to maintain your perfect tan?
   (b) Do you think your tan will fade if you spend the same amount of time in a tanning bed or booth each time?
2. Do you continue to use tanning beds or booths so your tan will not fade?
3. When you go to tanning salons, do you usually spend more time in the tanning bed or booth than you had planned?
4. Do you try other non-tanning-related activities, but find you really still like spending time in tanning beds or booths best of all?
5. (a) How many days a week do you spend in tanning beds or booths?

(b) How many days a week do you spend tanning in the sun?
(c) Do you tan year round?
(d) Have you ever missed work, a social engagement, or school because of a burn from tanning bed or booth use?

6. Have you ever missed any scheduled event (social, occupational, or recreational activities) because you decided to use tanning beds or booths?
7. (a) Do you believe you can get skin cancer from the sun?
(b) Do you believe you can get skin cancer from tanning beds?
(c) Does this keep you from spending time in the sun or using tanning beds or booths?

Specifically, each "yes" response is scored as one affirmative indicator, with the following exceptions for items 1, 5, and 7: (1) question 1 is scored as affirmative for "yes" responses to both 1a and 1b; (2) question 5 is scored as affirmative for positive responses on at least 2 subparts (responses other than 0 are scored positive for 5a); and (3) question 7 is scored as affirmative for a "yes" response to 7a and/or 7b and a "no" response to 7c. At least three affirmative responses across the seven items resulted in a classification of potential dependence (i.e., positive classification); less than three affirmative responses resulted in a classification of no potential dependence (i.e., negative classification).

We created a composite diagnostic based on classifications on the mCAGE and m*DSM-IV-TR*. Participants who scored positive for potential dependence on at least one of the two screening scales (mCAGE and m*DSM-IV-TR*) were classified as "At Risk" ($n = 42$) and those who scored negative across both scales were classified as "No Risk" ($n = 51$).

In addition to completion of the screening scales, participants reported the time they last used a UVIT device (Table 1) and were classified according to the following criteria: Recent users ($N = 37$) were classified as using UVIT within the past month, Non-Recent users ($N = 28$) were classified as using UVIT within the past 5 years but not within the past month, and Never users ($N = 28$) were classified as never using UVIT. No participants reported their last UVIT use more than 5 years ago.

Table 1

Demographic Characteristics of Study Participants

Characteristic	No. (%) of 93 Participants	
Age, years		
18-19	42	(45)
20-21	41	(44)
22-23	5	(5)
24-25	2	(2)
>25	3	(2)
Skin type		
Burns, never tans	4	(4)
Burns easily, then develops light tan	17	(18
Burns moderately, then develops light tan	18	(19)
Burns minimally, then develops moderate tan	32	(34)
Does not burn, develops dark skin	20	(22)
Does not burn, shows no change in noticeable appearance	1	(1)
N/A	1	(1)
UVIT Use Frequency		
Never	28	(30)
Non-Recent (within past 5 years, not within past month)	28	(30)
Recent (within past month)	37	(40)

Note, the total number of participants who were classified as either "At Risk" or "No Risk" or as Recent, Non-Recent, or Never users is less than the original sample size due to exclusionary criteria described in the data analysis section below.

Finally, to measure behavioral economic demand for UVIT, participants completed a tanning purchase task (TPT) developed based on previous studies using hypothetical purchase tasks (Murphy & MacKillop, 2006; Reed et al., 2015; Roma et al., 2016). The TPT was administered via paper and pencil with the following instructions:

> "*What is the likelihood that you sign up for a month of the most basic unlimited tanning? Use a value of 0 if you would NEVER consider signing up at the given price. Use a value between 0–100 to indicate the extent that you are likely to sign up at the given price. Use a value of 100 if you would not hesitate in signing up at the given price.*"

where the given price of tanning was defined as a base price of $30.00 (approximately 50-75% the price of local salon packages to ensure relative inelasticity of demand at low

prices in the demand curve) *plus* a tax ranging from $0.00 (no tax) to $60.00. The progression of total price included the following taxes: $0.00 (no tax), 0.30, 0.60, 1.50, 3.00, 4.50, 6.00, 7.50, 9.00, 12.00, 15.00, 18.00, 22.50, 30.00, and 60.00. Given past research suggesting that most tanning facilities offer unlimited tanning packages (e.g., Kwon et al., 2002), we instructed participants to report the likelihood of purchasing the month of unlimited tanning by handwriting their numeric response (in % likelihood) on a blank line to the right of each total price (i.e., base price plus tax). While frequency of consumption is typically—but not exclusively—used in hypothetical purchase tasks (for other examples of demand curves using likelihood responses, see Henley, DiGennaro Reed, Kaplan, & Reed, 2016; Roma et al., 2016), participants were unlikely to have experience purchasing *single* tanning sessions which may have compromised the integrity of their responses. The use of progressively increasing tax prices modeled the effects of potential excise tax increases on indoor tanning (comparable to the 10% excise tax on indoor tanning services levied by the Patient Protection and Affordable Care Act 2010).

Data Analysis

Responses on the TPT were converted to a proportion (out of 1) and subsequently analyzed according to the exponential model of demand (Hursh & Silberberg, 2008) using a freely available GraphPad Prism® template provided by the Institutes for Behavior Resources (http://www.ibrinc.org/index.php?id=181; note that this GraphPad Prism® solution uses standard nonlinear regression to minimize the sum of squares via the Marquardt method; Marquardt, 1963):

$$\log Q = \log Q_0 + k \cdot \left(e^{-\alpha \cdot (Q_0 \cdot C)} - 1 \right) \qquad (1)$$

where Q is the likelihood of purchase at each tax price (i.e., C), Q_0 (i.e., *Demand Intensity*) is the maximum likelihood of purchase associated with no tax (converted to $.01 for curve-fitting purposes), k is the range of consumption in logarithmic units (in this case $k = 2$ due to the absolute range of responses, ranging from .01-1), and α is the rate of change in elasticity across the demand curve.

Several other behavioral economic metrics were calculated using freely available software (Kaplan & Reed, 2014) and equations theorized by Hursh (2014). P_{max} is the price at which likelihood of purchase disproportionately decreases with increases in price (i.e., slope = −1, unit elasticity), calculated as:

$$P_{max} = \frac{(.083 \cdot k + 0.65)}{(Q_0 \cdot \alpha \cdot k^{1.5})} \qquad (2)$$

O_{max} represents maximum expenditure, but for the purposes of the current study represents the expected tax revenue at P_{max}, and is calculated by multiplying P_{max} by Q at P_{max}. Finally, essential value (*EV*) reflects the normalized (i.e., relatively k- and Q_0-independent) reinforcing value of the commodity, with larger *EV*s signifying relatively higher demand. Essential value was calculated as:

$$EV = \frac{1}{(100 \cdot \alpha \cdot k^{1.5})} \qquad (3)$$

All demand indices were derived except *Intensity* and k (i.e., constrained in Equation 1). A "0" value was inputted for P_{max}, O_{max}, and *EV* for participants who indicated no level of consumption at any price. Participants' data were excluded if their responses derived negative demand indices ($n = 1$) or if responses on the TPT contained multiple instances of consumption value increases across increasing prices ($n = 2$). These exclusionary criteria follow the logic of Stein and colleagues' (Stein, Koffarnus, Snider, Quisenberry, & Bickel, 2015) algorithm for identifying nonsystematic data while also permitting examination of zero demand datasets (e.g., zero consumption across all prices). Six additional participants were excluded due to unusable P_{max} values (range = $412,142.20 to $1.8x10^{14}$). All unusable P_{max} values were artifacts of consumption patterns containing a series of exclusively nondecreasing, nonzero consumption values (extreme inelasticity) before reporting complete suppression in consumption throughout the remainder of the TPT; such patterns return near-zero α values (due to extreme inelasticity), which returns nonsensical P_{max} values when inputted to Equation 2. Thus, the final sample size after exclusions was 93. Chi-square analyses were

conducted using IBM® SPSS® Statistics Version 22.0.0.0 (64-bit; Windows) and all other statistical tests were conducted using GraphPad Prism® 7.00 for Windows.

Results

A Pearson χ^2 analysis was used to examine the relation between mCAGE and m*DSM-IV-TR* and between frequency and diagnostic status. Results indicate a significant relation between mCAGE and m*DSM-IV-TR*, χ^2 (1, N = 93) = 7.353, p = .007; d = .281, replicating previous findings (Mosher & Danoff-Burg, 2010; Warthan et al., 2005). Among the 30 participants who scored positive on only one of the two diagnostic tools, 24 scored positive on the mCAGE and only six scored positive on the m*DSM-IV-TR*. The relation between usage status and diagnostic status (Table 2) was also significant, χ^2 (2, N = 93) = 34.101, p < .0001; d = .606.

The left panels in Figures 1 and 2 show Equation 1 provided an excellent fit to the group data (R^2 = 0.96-1.0; RMSE = .033-.096), regardless of categorization or status. For individual comparisons, participants' behavioral economic indices were graphed and descriptive statistics were obtained to determine distribution shape. Kruskal-Wallis and Dunn's multiple comparisons tests were performed to compare demand indices across the three frequency categorizations (right panel of Fig. 1). Each significance level (alpha) was adjusted to account for multiple comparisons. Multiple comparisons yielded significant differences for all of the following measures at p < .02. For *EV*, results showed significant differences between the three groups, H (2, N = 93) = 38.67, p < .0001. Comparisons for *Intensity* also showed significant differences, H (2, N = 93) = 34.11, p < .0001. Finally, significant differences were observed for P_{max} (H [2, N = 93] = 38.08, p < .0001) and O_{max} (H [2, N = 93] = 38.67, p < .0001). These results suggest groups of participants with more recent UVIT use exhibit significantly greater UVIT demand than groups with less recent or no lifetime use.

Table 2

Association Between Frequency and Diagnostic Findings

	Composite Diagnostic Status		
Frequency	**No Risk**	**At Risk**	**Total, No. (%)**
Never	28 (30)	0 (0)	28 (30)
Non-Recent	12 (13)	16 (17)	28 (30)
Recent	11 (12)	26 (28)	37 (40)
Total, No. (%)	51 (55)	42 (45)	93 (100)

Note. Composite Diagnostic Status (Participants were classified as No Risk if they scored negative on both mDSM-IV-TR and mCAGE screening tools; Participants were classified as At Risk if they scored positive on at least one of the screening tools); Frequency (Participants were classified as Never tanners if they had never used UVIT; Non-Recent tanners if they had used UVIT within the past 5 years but not within the past month; Recent tanners if they had used UVIT within the past month)

Because data did not approximate a normal distribution and we hypothesized At-Risk individuals would display stronger demand for UVIT, nonparametric one-tailed Mann–Whitney U tests were performed to compare diagnostic status across indices of demand (right panel of Fig. 2). For *EV*, At-Risk individuals (M_{rank} = 60.36) displayed significantly higher median values than No-Risk individuals (M_{rank} = 36), U = 510, p < .0001. At-Risk individuals (M_{rank} = 61.30) reported significantly higher *Intensity* than No-Risk individuals (M_{rank} = 35.23), U = 470.5, p < .0001. For P_{max} and O_{max}, At-Risk individuals (M_{rank} = 60.49; 60.36) showed significantly higher values than No-Risk individuals (M_{rank} = 35.89; 36), U = 504.5, p < .0001 and U = 510, p < .0001, respectively. Taken together, results indicate higher demand for the At-Risk group compared to the No-Risk group.

Finally, we compared correlations between behavioral economic markers of demand for the aggregate pool of participants (i.e., regardless of UVIT use frequency or dependence risk status). We used Spearman ρ correlations given significant deviations from normality for all four demand metrics (Q_0, P_{max}, O_{max}, *EV*) based on the D'Agostino & Pearson omnibus normality test in GraphPad Prism®. Table 3 shows that all correlations were positive and strong (ρ range .79 to 1.00) and significant (p values range 5.55 x 10^{-21} to 0) with a .05 alpha level. This finding is to be expected given the parameter dependencies and mathematical similarities in calculating these behavioral economic markers of demand.

Discussion

In the current study, we employed a use-inspired, translational framework to examine

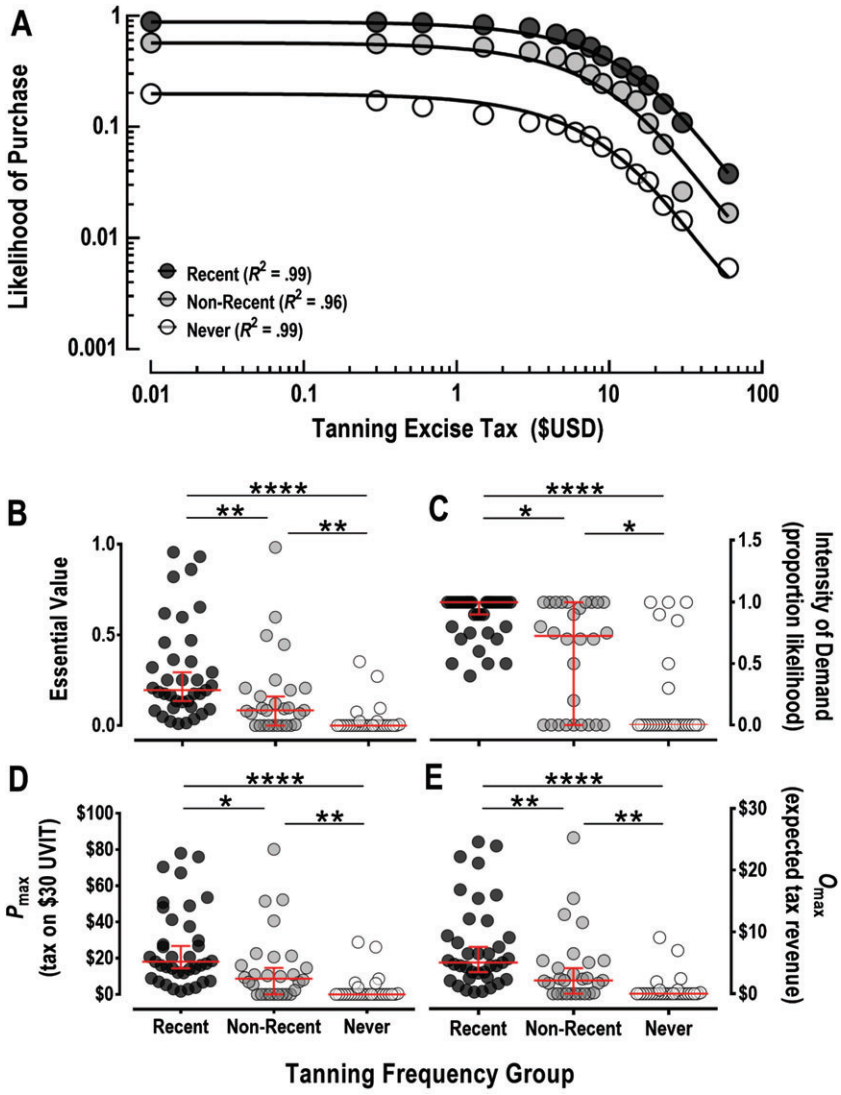

Fig. 1. Demand indices categorized by frequency of UVIT use. Participants were classified as Never tanners if they had never used UVIT; Non-Recent tanners if they had used UVIT within the past 5 years but not within the past month; Recent tanners if they had used UVIT within the past month. Panel A displays Equation 1 fitted to the mean data. Panels B-E show comparisons between participants' individual behavioral economic indices with error bars indicating median and 95% confidence interval. Significance levels between comparisons denoted by asterisks.
*$p < .05$. **$p < .01$. ****$p < .0001$

behavioral economic measures of abuse liability of UVIT to validate these measures against common diagnostic tools used to assess UVIT dependence (mCAGE and m*DSM-IV-TR*). Our discussion highlights the potential benefits and drawbacks of using the novel TPT in academic and clinical settings. Additionally, through the strategic use of an increasing progression of taxes layered onto a base-price for a month of unlimited UVIT, findings from the current study allow for the translation of the aforementioned behavioral economic measures to public policy implications (discussed below).

In the final sample of 93 females, 65 (70%) reported use of UVIT in the past 5 years, with 37 of these 65 (57%) reporting use within the last month. Chi-squared analyses suggested a

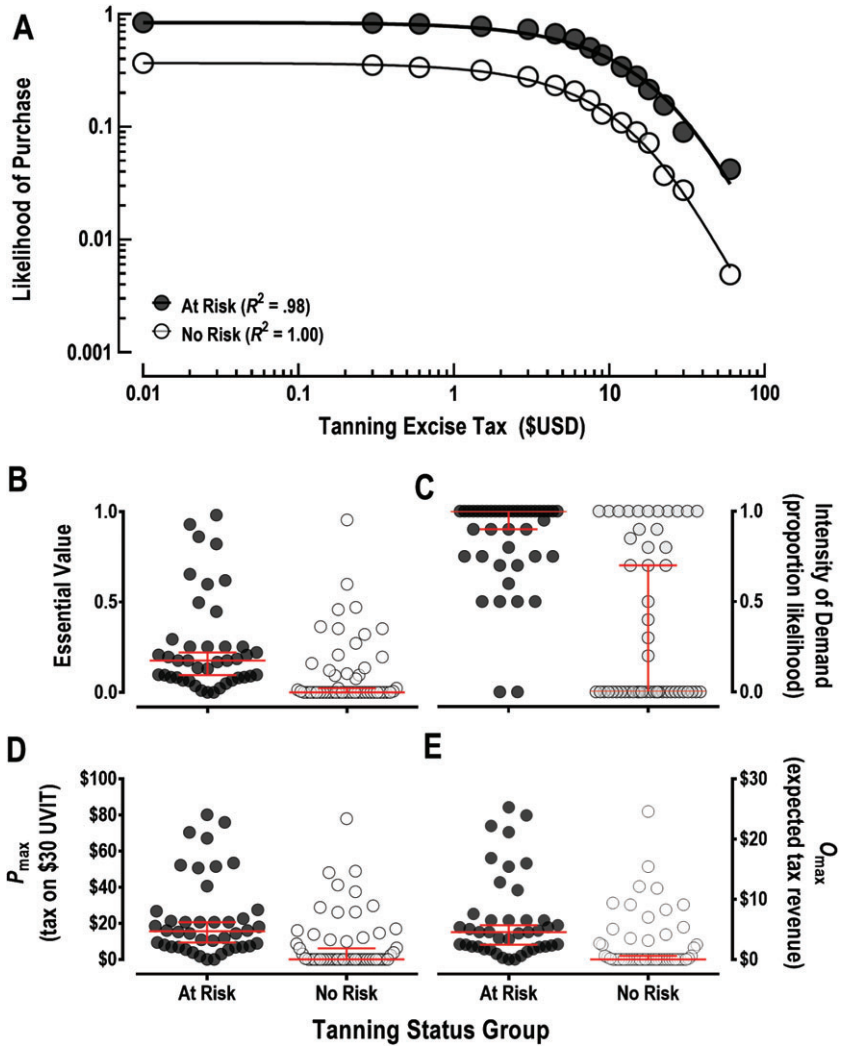

Fig. 2. Demand indices categorized by composite diagnostic status. Composite diagnostic status based on positive or negative classifications on the m*DSM-IV-TR* and mCAGE. Participants were classified as No Risk if they scored negative on both screening tools. Participants were classified as At Risk if they scored positive on at least one of the screening tools. Panel A displays Equation 1 fitted to the mean data. Panels B-E show comparisons between participants' individual behavioral economic indices, with error bars indicating median and 95% confidence interval. For all comparisons, $p < .0001$.

relation between frequency and diagnostic status on the mCAGE and m*DSM-IV-TR*. Behavioral economic measures of the reinforcing effectiveness of UVIT were significantly greater for the At-Risk participants, suggesting some convergent validity in these novel metrics for UVIT addiction. Moreover, of the 28 participants in the Never-use group, none met criteria for an At- Risk status.

In examining the 42 At-Risk participants, only 12 (29%) scored positive for potential UVIT dependence on both m*DSM-IV-TR* and mCAGE. These 12 participants may constitute a subsample of UVIT-dependent users, but the low proportion prohibits meaningful inferential statistical analyses. Of the remaining 30 participants scoring positive on only one of the diagnostic tools, 24 (80%) were due to mCAGE scores. This disproportionate number of participants corroborates Schneider and colleagues' (2015) critique of the mCAGE's tendency to over-predict dependence status in

Table 3

Correlation Matrix (Spearman's ρ) of Behavioral Economic Demand Measures

Measure	Measure			
	Q_0	P_{max}	O_{max}	EV
Q_0				
P_{max}	.79			
O_{max}	.84	.99		
EV	.84	.99	1.00	

Note. All correlations were significant at the .05 alpha level. See text for additional details.

UVIT users. Despite the majority of At-Risk participants being identified via the mCAGE's potentially oversensitive scoring, this group featured significantly greater behavioral economic demand for UVIT than No-Risk participants.

Demand indices have become contemporary behavioral economic markers (Carter & Griffiths, 2009; MacKillop, 2016) for (a) identifying the abuse liability of substances (Bickel, Jarmolowicz, MacKillop et al., 2012; Bickel, Jarmolowicz, Mueller et al., 2012; Bickel, Jarmolowicz, Mueller, & Gatchalian, 2011; Bickel et al., 2014; Bickel et al., 1998; Hursh, 1991; Hursh & Roma, 2016) and (b) predicting success of treatment for substance-related disorders (MacKillop & Murphy, 2007; Madden & Kalman, 2010; McClure, Vandrey, Johnson, & Stitzer, 2013). We posit that another potential benefit of hypothetical purchase tasks is that they are not readily identifiable diagnostic tools. That is, we speculate that respondents cannot discern what the task assesses and may thereby reduce reactivity in the form of "faking good." Both the mCAGE and m*DSM-IV-TR* use language that indicates the tools' goals; the Tanning Purchase Task (TPT) is absent of such language and may thereby yield more honest responding. Additional empirical work is obviously necessary to confirm our assumption. Nevertheless, the purchase task designed for this study may be useful to both researchers and clinicians interested in examining UVIT users' potential abuse risk.

Because the TPT returns systematic data in line with behavioral economic theory, this task may be useful in identifying young adults with substantial UVIT demand. Because demand markers generated via similar alcohol purchase tasks are "theorized to be an important recursive etiological marker" for later substance abuse in young adults (see review in MacKillop, 2016, p. 677), the TPT may be similarly helpful in identifying potential clinical UVIT dependence in this young adult population. Identifying excessive demand as an etiological marker for dependence may be particularly important for UVIT given the long-term disease trajectory associated with cumulative use, especially in young adults (Zhang et al., 2012). Finally, researchers have demonstrated that hypothetical purchase tasks may be regularly evaluated in single-subject design to monitor treatment success (Bujarski, MacKillop, & Ray, 2012; Madden & Kalman, 2010; McClure et al., 2013) and provide early indicators of treatment failures (MacKillop & Murphy, 2007) over treatment course periods. If the TPT exhibits these clinical advantages in dermatological study and use, health professionals may be able to use the TPT as a unique behavioral screener to identify potential UVIT abuse and monitor the emergence of dependence. While these advantages to hypothetical purchase tasks are dependent on evidenced test–retest reliability—which is well-documented in cigarette and alcohol purchase tasks (e.g., Few et al., 2011; MacKillop et al., 2008; Murphy, MacKillop, Skidmore, & Pederson, 2009)—we did not collect such measures; as such, additional research on the TPT temporal stability is needed.

The construct validity documented in this study suggests that this TPT warrants further investigation as both a research tool and diagnostic aid, preferably validated against more objectively documented UVIT use. Two clinical tools have recently been developed that appear to be substantially more conservative in assessing UVIT addiction: the Structured Interview for Tanning Abuse and Dependence (Heckman, Egleston, Wilson, & Ingersoll, 2008; Hillhouse et al., 2012) and the Tanning Pathology Scale (Heckman et al., 2014; Hillhouse et al., 2010). We suggest future comparisons of TPT demand to scores on these two scales, as well.

A final broader contribution of this study lies in its public policy implications, specifically in the P_{max} variable to derive the tax price associated with unit elasticity in participants' demand curves. In doing so, P_{max} provides an empirical basis for determining excise taxes

aimed at reducing problematic consumption of unhealthy commodities, and likewise predicts potential revenues from said taxes via computation of the O_{max} variable (Hursh & Roma, 2013; Roma et al., 2016). Behavioral economists have used cigarette purchase tasks to examine the potential policy implications of tobacco (MacKillop et al., 2012), fuel (Reed, Kaplan, Roma, & Hursh, 2014; Reed, Partington, Kaplan, Roma, & Hursh, 2013), or high-caloric food (Epstein, Dearing, Roba, & Finkelstein, 2010) taxation.

To date, we are unaware of any studies examining the effects of the tanning tax levied by the Patient Protection and Affordable Care Act on UVIT demand. Examination of $P_{\max}$ in Panel D of Figure 2 suggests Recent tanners would tolerate a tax of approximately $25 on a $30 package; this constitutes an 83% tax that far exceeds the current 10% tax levied by the Patient Protection and Affordable Care Act. Analysis of Non-Recent tanners suggests tolerance of an approximately $15 (50%) tax on $30 tanning services. Interestingly, Never tanners' point of tolerance with taxation approximates the 10% tax currently levied. These data collectively indicate that the 10% tanning tax falls in the inelastic portion of the demand curve for consumers of tanning services, suggesting that present policies are (1) likely to be ineffective in reducing demand for those individuals who currently engage in UVIT and (2) limiting potential revenue that could be used toward education and other abuse-reduction initiatives. This 10% tax may, however, effectively discourage young adults from *initiating* UVIT use. These behavioral economic markers of taxation tolerance, coupled with data indicating a relative lack of UVIT salons' compliance with the UVIT tax policy (Jain, Rademaker, & Robinson, 2012), warrant further investigation.

In summary, this study explored whether behavioral economic measures of ultraviolet indoor tanning (UVIT) demand via a novel hypothetical tanning purchase task (TPT) are associated with diagnostic criteria from established measures of UVIT addiction (mCAGE and m*DSM-IV-TR*) and self-reported frequency of UVIT use. Although our findings suggest the TPT has promise for assessing potential abuse liability of UVIT for current UVIT users, more psychometric work is necessary. Specifically, because this study utilized diagnostic tools translated from addiction sciences (i.e., behavioral economic demand), future studies should compare the results of the TPT with other emerging clinical tools explicitly designed for UVIT addiction; particularly, the Structured Interview for Tanning Abuse and Dependence (Heckman et al., 2008; Hillhouse et al., 2012) and the Tanning Pathology Scale (Heckman et al., 2014; Hillhouse et al., 2010). Further demonstration of the construct validity of the TPT may render it a beneficial tool for academic, clinical, and public health policy applications. In doing so, behavioral economic markers of dependence may demonstrate further translation to other behavioral addictions not yet researched using demand measures by applied behavioral economists.

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