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ORIGINAL ARTICLE

A Longitudinal Behavioral Economic Analysis of Non-medical Prescription Opioid Use Among College Students

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Abstract Despite the growing opioid epidemic in the US, few studies have identified theoretically based risk factors for non-medical prescription opioid (NMPO) use among young adults. The goal of the current study was to evaluate the behavioral economic hypotheses that NMPO use would be associated with lower levels of reinforcement from substance-free activities and future time orientation. Participants were 71 undergraduate students (62% women, 52.1% Caucasian, 35.2% African American) who either reported past-year NMPO use or demographically similar control participants with no past-year drug use. Participants provided information on alcohol and drug use, completed three measures of substance-free reinforcement (time allocation to exercise and academic activities, hedonic response to substance-free pleasant images, and self-report anhedonia), and a measure of future orientation, at baseline, 6-month, and 12-month follow-up. Consistent with nationwide trends, most NMPO users also reported use of marijuana (94%) and alcohol (80%). Compared to no drug use, NMPO use was associated with lower time allocation to academic activities, lower hedonic response to pleasant images, greater self-reported anhedonia, and lower future orientation across the 12-month study period. Among NMPO users, greater positive hedonic response to substance-free pleasant images predicted less alcohol use at 12-month follow-up, and greater baseline future orientation predicted less marijuana and NMPO use at 12-month follow-up. These findings provide partial support for behavioral economic models that link substance misuse to diminished levels of substance-free reinforcement and lower consideration of the future.

Keywords Substance-free reward · Behavioral economics · Non-medical use of prescription opioids

College students report high levels of alcohol and drug use; 63.1% of US college students report past-month alcohol use, 34.4% report past-year marijuana use, 20.8% report past-year illicit drug use other than marijuana, and 13% report past-year non-medical use of prescription drugs (Johnston, O'Malley, Bachman, Schulenberg, & Miech, 2015; McCabe, West, Teter, & Boyd, 2014). Rates of non-medical prescription opioid (NMPO) use among young adults have increased over the past two decades, and use is associated with high rates of morbidity and mortality (Blanco et al., 2007; White House, 2011; Johnston et al., 2015). In 2014, young adults between ages 18 to 25 years had higher rates of NMPO use than any other age groups (Center for Disease Control and Prevention, 2016). NMPO use is a significant public health concern in part because the increase in NMPO use has coincided with significant growth in heroin use; among persons 18 to 25 years of age, rates of heroin use have increased 109% from 2002-2013 (Jones, Logan, Gladden, & Bohm, 2015). Most heroin users report starting with NMPO and then transition to heroin, which is often more available, inexpensive, and potent (Longo, Compton, Jones, & Baldwin, 2016).

Among college students, NMPO use most often co-occurs with the use of alcohol (77%), marijuana (80%), and/or other drugs (Brandt, Taverna, & Hallock, 2014). Thus, it is important to understand the risk of NMPO use among individuals who also use other drugs, and there is some evidence that use

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of two or more drugs is associated with higher levels of negative social and health consequences, including risk for overdose (Keith, Hart, McNeil, Silver, & Goodwin, 2015). College students who report past-year use of both marijuana and alcohol have lower grades, miss more classes, and report more legal and interpersonal problems when compared with alcohol only using peers (Shillington & Clapp, 2006). Unfortunately, very few studies have examined risk factors for NMPO use among college students using theoretical approaches. The goal of the current paper is to identify behavioral economic risk factors for NMPO use among college students.

Behavioral Economic Theories of Substance Misuse

Behavioral economic research attempts to describe the conditions under which substance consumption emerges as a preferred activity from an array of other activities (Bickel et al., 2007; Bickel, Johnson, Koffarnus, MacKillop, & Murphy, 2014; Rachlin, 1997). To study this phenomenon, researchers have developed a variety of self-report methods for quantifying the relative degree of substance-related versus substance-free (SF) reinforcement (Heinz, Lilje, Kassel, & de Wit, 2012), including measures of time or money allocation to drugs versus alternatives (Tucker, Vuchinich, & Rippens, 2002), measures of hedonic response (pleasure ratings; Lubman et al., 2009), and choice between substance-related and SF stimuli (Moeller et al., 2012).

Numerous empirical studies suggest that high rates of substance use are most likely in contexts devoid of SF sources of reinforcement, and experimental studies with both human and non-human animals show that substance use will generally decrease if access to alternative reinforcers is increased (Carroll, Anker, & Perry, 2009; Cosgrove, Hunter, & Carroll, 2002; Higgins, Heil, & Lussier, 2004). In non-addicted populations, an environment enriched with SF reinforcers may serve as a protective factor against substance use (Audrain-McGovern, Rodriguez, Rodgers, & Cuevas, 2011; Bardo, Klebaur, Valone, & Deaton, 2001). However, as addiction develops, natural reinforcers lose their ability to compete as feasible alternatives to drug use, thereby increasing the relative reinforcing value of a substance (Rachlin, 1997; Volkow et al., 2010), and leading to progressively greater time and other resources devoted to drug-related compared to drug-free reinforcers (Tucker et al., 2002; Tucker, Vuchinich, Black, & Rippens, 2006).

There is evidence that chronic substance misuse is associated with diminished dopamine response to naturally occurring SF rewards such as food or erotic stimuli (Koob, 2006; Volkow & Baler, 2014). This may result in the experience of anhedonia, or the inability to obtain pleasure from naturally reinforcing stimuli (Janiri et al., 2005; Sell et al., 1999; Zijlstra, Veltman, Booij, van den Brink, & Franken, 2009). Lubman et al. (2009) found that heroin-dependent patients rated pleasant pictures as less arousing and drug-related pictures as more pleasant and arousing. Thus, drug dependent individuals may experience diminished subjective response to SF stimuli, and this may in part explain the diminished engagement in SF activities that has been shown to characterize substance dependence. However, this phenomenon has not been studied in young adult non-treatment seeking populations.

Individuals who drink heavily and use drugs may also under-engage in constructive alternative behaviors in part because the rewards associated with these activities are generally delayed. A number of studies suggest that heavy substance use is associated with lower future orientation (greater discounting of future rewards; MacKillop et al., 2011; Reynolds, 2006). Individuals who have low future orientation may be less likely to engage in the prosocial and goal-directed behaviors that contribute to positive future health, academic, or career outcomes and may instead allocate their behavior towards immediately reinforcing activities such as using alcohol or drugs (Bickel et al., 2014). Meshesha, Dennhardt, and Murphy (2015) found that, among college students, level of drug use was associated with diminished enjoyment from SF activities, and spending less time exercising, studying, and participating in extracurricular activities above and beyond heavy drinking. Although previous studies have assessed cross-sectional associations between substance use, SF reward and activity engagement among young adults, no study has assessed SF reward and future orientation longitudinally among young adult NMPO users.

Present Study

Previous research with patients in treatment has shown that drug users demonstrate reduced hedonic responses to SF reinforcers compared to non-drug using controls and that this reduced responsiveness predicted future drug use (Lubman et al., 2009). To our knowledge, however, no studies have investigated the longitudinal relations between SF reward, future orientation, and drug use among non-treatment seeking young adult drug users. The present study tested the hypotheses that NMPO use among college students will be associated with (a) less time allocation to future oriented SF activities (academic or exercise), (b) diminished hedonic response to naturally rewarding stimuli, and (c) lower future time orientation, relative to a matched control group. We also expect that baseline measures of SF hedonic response and future orientation will predict substance use at 12-month follow-up.

Method

Participants

Participants were 71 undergraduate students who either reported past-year NMPO use ($n = 35$) or control participants ($n = 36$) with no past-year drug use. On average, participants were 20.01 ($SD = 1.6$) years old and the sample was 62% women, 52.1% Caucasian, 35.2% African American, 7% Asian, and 5.6% Multiethnic. Consistent with nationwide trends, the majority of NMPO users also reported past-month use of marijuana (94.4%) and alcohol (80%). Because very few MNPO users exclusively use NMPO without additional use of alcohol or other drugs, we did not attempt to identify NMPO users who did not use alcohol or other drugs due to concerns of low generalizability of such a sample. Control participants were recruited to match NMPO use participants on gender and age.

Exclusion criteria for all participants were: reported history of bipolar disorder, psychotic symptoms/psychotic disorder, significant head injury (e.g., that included loss of consciousness or a concussion diagnosis), medical use of prescription stimulants and opioids, and current use of psychiatric medication other than antidepressants. Exclusion criteria were selected as (a) these conditions on their own may influence levels of SF reward and ability to complete measures and (b) the larger study from which these data was obtained was investigating executive functioning among NMPO users. Control participants were excluded if they used illicit drugs or consumed alcohol on more than one day in a typical week in the past month.

Procedure

The university's institutional review board approved all study procedures. Participants were identified from the psychology subject pool and classroom screenings (that identified recent NMPO users and matched control participants). At baseline, eligible participants completed a computerized battery of self-report measures and a clinical interview with a trained graduate student in an individual 90-min appointment. Participants received a choice of either course credit or a $25 cash payment. Six- and 12-month follow-ups were 60-min individual appointments that consisted of completing a self-report computerized survey and a clinical interview, participants received $40 cash payments per follow-up.

Measures

Drug and Alcohol Use

In a clinical interview, participants reported past-year (number of days) use of illicit drugs and nonmedical use of prescription drugs (see Table 1). The Structured Clinical Interview for *DSM* Disorders (SCID; adapted for *DSM*-5 criteria) was administered to assess for past-year opioid, alcohol, and cannabis use disorder symptoms (First, Gibbon, Spitzer, & Williams, 1996). The Daily Drinking Questionnaire (Collins, Parks, & Marlatt, 1985) assessed past month typical weekly drinks consumed.

Substance-Free Reinforcement

Weekly Time Allocation Behavioral economic approaches view time as a valuable commodity and relative time allocation as an index of the reinforcing value of an activity (Heinz et al., 2012). Given that academic activity is a central focus during college, we examined time allocated to academic activity as an index of the relative value of this important substance-free reinforcement domain. Similarly, exercise is another central substance-free reinforcement category that has shown inverse relations with substance use (Meshesha et al., 2015; Stoutenberg, Rethorst, Lawson, & Read, 2016). Participants were asked to report the number of hours they spent engaged in various activity categories in a typical week in the past month, including studying or completing homework assignments, attending classes, extracurricular activities, employment, exercise, alcohol and drug use, family, religious, community, fraternity or sorority, and web browsing (Meshesha et al., 2015). These activity categories are not mutually exclusive, and it is possible that participants reported engaging in two categories simultaneously (e.g., spending time exercising and with family), but were categorized as separate activities. The percent of time allocated to the categories of academic engagement (completing homework, attending classes, and participating in extracurricular activities) and percent of time allocated to exercise were divided over all reported time allocation categories and multiplied by 100 [e.g., (academic/sum of all activities) X 100]. Greater relative time allocation towards these activity categories reflects greater reward value associated with academics or physical exercise.

Hedonic Response to Pleasant Images A series of validated objectively pleasant images ($n = 10$) selected from the International Affective Pictures System (Lang, Bradley, & Cuthbert, 2008) were presented to participants. The pictures presented included images of nature (e.g., beach, flowers), money, and fireworks. Participants viewed each image (presented in random order) for 2000 ms and then rated image pleasantness on an 11-point (0-10) Visual Analog Scale (Wewers & Lowe, 1990). Rating of each image was summed to assess subjective pleasantness ratings. Higher scores reflect greater hedonic response to substance-free reward.

Self-Report Anhedonia Participants completed the Snaith-Hamilton Pleasure Scale (SHAPS; Snaith et al., 1995), a 14-item self-report measure that assesses the level of

Table 1 Descriptive data on weekly drinking, cigarette use, and past-year drug use days among NMPO users and controls

	Baseline			6-month follow-up			12-month follow-up		
	*n** (%)	*M*	*SD*	*n** (%)	*M*	*SD*	*n** (%)	*M*	*SD*
Typical drinks per week									
NMPO use	28 (80.0)	11.38	12.92	23 (65.7)	6.77	5.88	25 (71.4)	6.93	6.52
Control	8 (22.2)	0.50	1.25	4 (44.1)	0.28	0.77	7 (19.4)	0.58	1.29
Past month days smoked cigarettes									
NMPO use	27 (77.1)	9.41	12.49	21 (60)	8.43	12.41	23 (65.7)	5.52	10.37
Control	–	–	–	–	–	–	–	–	–
Illicit drug use									
Marijuana									
NMPO use	33 (94.4)	154.37	125.43	25 (71.4)	143.69	135.31	29 (82.9)	144.75	120.22
Control	–	–	–	2 (5.6)	3.60	20.88	3 (8.3)	3.03	17.14
Opioids									
NMPO use	35 (100)	20.60	28.95	18 (51.4)	13.05	13.05	15 (42.9)	6.26	11.84
Control	–	–	–	–	–	–	–	–	–
Stimulants									
NMPO use	12 (34.4)	10.60	27.90	7 (20.0)	0.72	1.60	8 (22.9)	3.68	10.30
Control	–	–	–	–	–	–	–	–	–
Sedative									
NMPO use	20 (57.1)	5.3	9.40	11 (31.4)	3.27	5.61	17 (48.6)	4.32	8.09
Control	–	–	–	–	–	–	–	–	–
Hallucinogens									
NMPO use	11 (31.4)	1.27	2.70	8 (22.9)	0.52	1.02	7 (20.0)	0.75	1.81
Control	–	–	–	–	–	–	–	–	–
Cocaine									
NMPO use	6 (17.1)	0.83	2.50	4 (11.4)	0.72	1.92	6 (17.1)	4.25	14.85
Control	–	–	–	–	–	–	–	–	–
Methamphetamine									
NMPO use	1 (2.9)	0.81	4.90	–	–	–	–	–	–
Control	–	–	–	–	–	–	–	–	–
Designer drugs									
NMPO use	8 (22.9)	0.73	1.70	3 (8.6)	0.14	0.44	3 (8.6)	0.18	0.64
Control	–	–	–	–	–	–	–	–	–
Sleeping									
NMPO use	4 (11.4)	0.41	1.20	1 (2.9)	0.03	0.18	2 (5.7)	0.06	0.35
Control	–	–	–	–	–	–	–	–	–
Synthetic drugs									
NMPO use	1 (2.9)	0.27	1.60	–	–	–	–	–	–
Control	–	–	–	–	–	–	–	–	–
Heroin									
NMPO use	2 (5.7)	0.08	0.40	1 (2.9)	0.03	0.180	–	–	–
Control	–	–	–	–	–	–	–	–	–

*Number of participants per group who reported one or more drinks in a typical week in the past month, one or more days of cigarette use in the past month, or one or more days of drug use in the past year

enjoyment obtained from various events or stimuli. Higher scores on the SHAPS indicate greater levels of anhedonia. The SHAPS has good psychometric properties, the measure has high internal consistency and test-retest reliability (Franken, Rassin, & Muris, 2007; Leventhal, Chasson, Tapia, Miller, & Pettit, 2006). Internal consistency of the SHAPS in this sample was good at both baseline and follow-up ($\alpha = .89$-$.93$).

Future Time Orientation

Future time orientation was assessed using the Consideration of Future Consequence – Short Version (CFC-S), an 8-item measure used to examine the extent to which individuals are influenced by the immediate versus distant consequences of their behavior (Petrocelli, 2003; Strathman, Gleicher, Boninger, & Edwards, 1994). Items on the CFC-S are summed to form a single scale that has demonstrated good internal consistency and test-retest reliability (Strathman et al., 1994) as well as convergent and construct validity (Adams & Nettle, 2009). Internal consistency of the CFC-S in this sample was good at both baseline and follow-up ($\alpha = .78$-$.84$).

Depression

Depressive symptoms were included as a covariate and measured using the depression scale from the Depression, Anxiety and Stress Scale-21 (Lovibond & Lovibond, 1995). The DASS-21 is a reliable and valid measure of depression in college students (Mahmoud, Hall, & Staten, 2010). Internal consistency of this measure was good at both baseline and follow-up ($\alpha = .84$-$.88$).

Data Analysis

The depressive symptoms variable was Winsorized using the recommendations of Tabachnick and Fidell (2012) and square root transformed to obtain normal distribution. SPSS Statistics 20.0 (SPSS, 2011) was used to conduct a series of repeated measures analysis of covariance (ANCOVAs) to examine group differences on the SF reinforcement variables and future orientation, while controlling for gender, ethnicity, age, and baseline depression. To assess the relations between all substance-free variables and depression at baseline, Pearson correlations were computed using all 71 participants' data.

Within the NMPO use group, alcohol and marijuana use at 12-month follow-up were overdispersed (without zero inflation), where the variance exceeds the mean (Atkins, Baldwin, Zheng, Gallop, & Neighbors, 2013). NMPO use at 12-month follow-up was overdispersed due to zero inflation. To test the predictive value of baseline measures of hedonic response to pleasant images, self-report anhedonia, and future orientation on alcohol, marijuana, and NMPO use at follow-up, we conducted separate negative binomial regression models for alcohol and marijuana use (Atkins et al., 2013) and negative binomial hurdle regression model for NMPO use (Bandyopadhyay, DeSantis, Korte, & Brady, 2011). In a negative binomial hurdle model, two models are simultaneously estimated for drug use: a logistic "hurdle" model for zeroes assessing the likelihood of using opioids and a negative binomial model for counts assessing the number of days used, if used (Atkins et al., 2013). Baseline predictors were regressed on follow-up drug use (alcohol, marijuana, or opioid) while controlling for age, gender, ethnicity, depression, and baseline drug use. All regression models were conducted using Mplus version 7.3 (Muthén & Muthén, 1998-2012).

Results

Demographic Differences, Drug Use, and Associations Among Variables

Follow-up rates were 87% at 6 months and 92% at 12 months and did not differ between groups. NMPO group and controls did not significantly differ on gender [χ^2 (1, $N = 71$) = 0.01, p = NS], ethnicity [χ^2 (3, $N = 71$) = 1.61, p = NS], age [t (68) = 0.29, p = NS], taking antidepressants [χ^2 (1, $N = 71$) = 0.18, p = NS], or the presence of a serious medical condition [χ^2 (1, $N = 71$) = 1.73, p = NS]. The NMPO group reported higher depression, [t (69) = 3.99, $p < .001$], and typical drinks per week [t (65) = 6.45, $p < .001$] compared to the control group. At baseline, all NMPO participants reported opioid use, and the next most frequently used substances were marijuana and alcohol (see Table 1). On average, the NMPO group reported 3.54 ($SD = 3.02$) *DSM-5* cannabis use disorder symptoms, 1.77 ($SD = 2.41$) *DSM-5* opioid use disorder symptoms, and 2.57 ($SD = 2.57$) *DSM-5* alcohol use disorder symptoms. On average, NMPO participants reported initiating alcohol use 4.29 ($SD = 2.34$) years ago, opioids 2.39 ($SD = 1.61$) years ago, and any drugs 3.85 ($SD = 2.41$) years ago; approximately 83% reported marijuana and 11% reported opioids as the first illicit drug used.

Pearson correlations among the substance-free variables indicated two significant associations: pleasant image ratings were negatively correlated with self-reported anhedonia ($r = -.51$) and future orientation was positively correlated with time spent on academic activities ($r = .28$). Depression was not correlated with any of the outcome variables.

Change in Drug Use over Time

Paired sample t-tests indicated that NMPO use was lower at 12-month follow-up compared to baseline [t (30) = 2.17, $p = .038$]. However, no significant changes were observed for days of marijuana use [t (31) = .24, p = NS] or typical weekly drinks [t (27) = 1.71, p = NS] from baseline to 12-month follow-up.

Substance-Free Reinforcement

A series of repeated-measures ANCOVAs revealed: (a) significant main effect of group on percent of time allocated to academic engagement [F (1, 49) = 10.72, $p = .002$,

$\eta_p^2 = .18$], with the NMPO group allocating *less time* to academic related activities compared to controls (Fig. 1); however, there were no group differences in time spent on exercise $F(1, 50) = .66$, $p = .41$, $\eta_p^2 = .01$; (b) significant main effect of group on valence ratings of pleasant images, [$F(1, 50) = 4.84$, $p = .03$, $\eta_p^2 = .08$], with the NMPO group rating the pleasant images as *less pleasant* compared to controls (Fig. 2); (c) significant main effect of group on self-reported anhedonia [$F(1, 49) = 4.78$, $p = .03$, $\eta_p^2 = .09$], with the NMPO group reporting *greater* levels of anhedonia compared to controls (Fig. 3).

Future Time Orientation

A repeated measures ANCOVA revealed a significant main effect of group of future time orientation, [$F(1, 51) = 8.89$, $p = .004$, $\eta_p^2 = .148$]. The NMPO group reported lower future time orientation compared to the control group (Fig. 4).

Predictors of Substance Use at 12-Month Follow-Up

All regression results are presented in Table 2. In a negative binomial regression model, pleasant image rating at baseline predicted less drinks per week at 12-month follow-up ($B = -.22$, $p = .041$). Similarly, future orientation at baseline predicted less marijuana use at 12-month follow-up ($B = -.29$, $p = .025$). Further, there was a non-significant trend level association between academic time allocation at baseline and drinks per week at 12-month follow-up ($B = -.39$, $p = .065$). In a negative binomial regression model, future orientation at baseline predicted fewer count opioid use days at 12-month follow-up ($B = -.11$, $p = .002$); however, there were no significant effects for the hurdle model (use vs. abstinence) for opioid use at 12-month follow-up. Baseline self-report anhedonia was not associated with follow-up substance use.

Discussion

The present study investigated the hypotheses that NMPO use among non-treatment seeking young adults is associated with deficits in SF reinforcement and future orientation across time. Consistent with our hypotheses, the NMPO group, compared to controls, reported lower time allocation to academic activities, lower hedonic response to pleasant images, greater self-reported anhedonia, and lower future orientation across the three study time points. These differences were relatively stable across the 12-month follow-up period, with the exception of academic disengagement among NMPO users, which increased from baseline to follow-up. Further, our results suggest that NMPO use reduced during the 12-month follow-up period while marijuana and alcohol use were relatively stable.

The finding that NMPO use is associated with lower hedonic response to SF rewarding stimuli extends prior findings that treatment seeking drug-dependent individuals rated pleasant pictures as less arousing relative to drug-related pictures (Lubman et al., 2009). Our results are also consistent with studies indicating that regular marijuana users show impairments in responses to dopamine stimulation (Volkow & Baler, 2014) and reward anticipation of activity compared to non-users (van Hell et al., 2010). It is important to note, however, that although NMPO use was associated with greater self-reported anhedonia and lower valence ratings for objectively pleasant images, the effect sizes were small to moderate (explaining 8-9% of the variance). Nevertheless, the current study is the first to suggest that relatively high functioning,

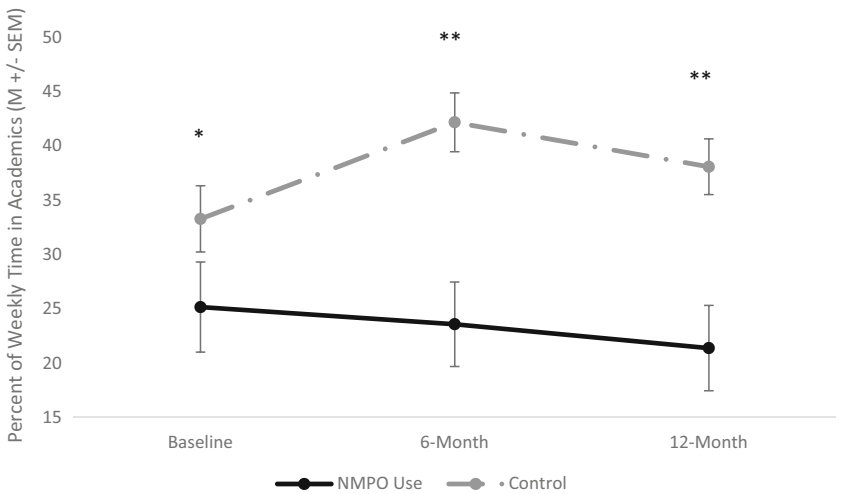

Fig. 1 Percent of time allocated to academic engagement (i.e., studying, attending classes, and extracurricular activities) in a typical week in the past month. Data are presented for NMPO and control groups at baseline, 6-month, and 12-month follow-up. Results show a main effect for group on academic activities; NMPO group spent less time engaged in academic related activities in a typical week. Asterisks indicate group differences at the specified time point. Error bars reflect +/- one standard error of the mean (SEM). *$p < .05$, **$p < .01$

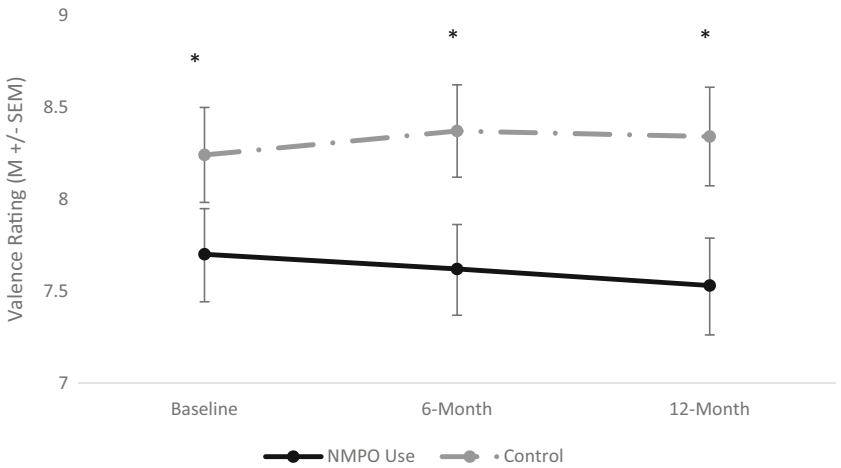

Fig. 2 Pleasant image valence ratings at baseline, 6-month, and 12-month follow-up among NMPO and control groups. Higher values indicate greater levels of anhedonia. Results show a main effect for group on pleasant image ratings; NMPO users rated pleasant images as less pleasant. Asterisks indicate group differences at the specified time point. Error bars reflect +/- one standard error of the mean (SEM). * $p < .05$

non-treatment seeking college students who use drugs may experience some degree of blunted hedonic response to SF reward, that degree of response to SF reward predicts alcohol use at 12-month follow-up, and that these effects are independent of depressive symptoms. These results are consistent with previous findings (Lubman et al., 2009) that heroin dependent patients' arousal ratings of pleasant images significantly predicted heroin use at follow-up. Moeller et al. (2012) also found choice to view cocaine related images compared to pleasant images predicted drug use at follow-up among individuals in treatment. Although these findings have been investigated in treatment seeking populations, non-treatment seeking young adults are an important population to study in order to begin to evaluate the possible etiological significance of diminished response to drug-free reward.

As hypothesized, the NMPO group also reported lower future orientation than controls, and among drug users, higher levels of baseline future orientation predicted less frequent marijuana and opioid use at 12-month follow-up. This provides support for behavioral economic models that stress the role of time horizon as an important predictor of patterns of choices between drug-rewards and activities that are generally associated with delayed rewards, such as academic or career success and good physical health (Bickel et al., 2014; Tucker et al., 2006). Previous research in this area has primarily used hypothetical money choice (delay discounting) tasks to demonstrate that lower future orientation is a risk factor for substance abuse. The present study uses a distinct measure of future orientation to demonstrate stable differences in future orientation between NMPO users and controls over a 12-month period and suggests that NMPO users with lower future

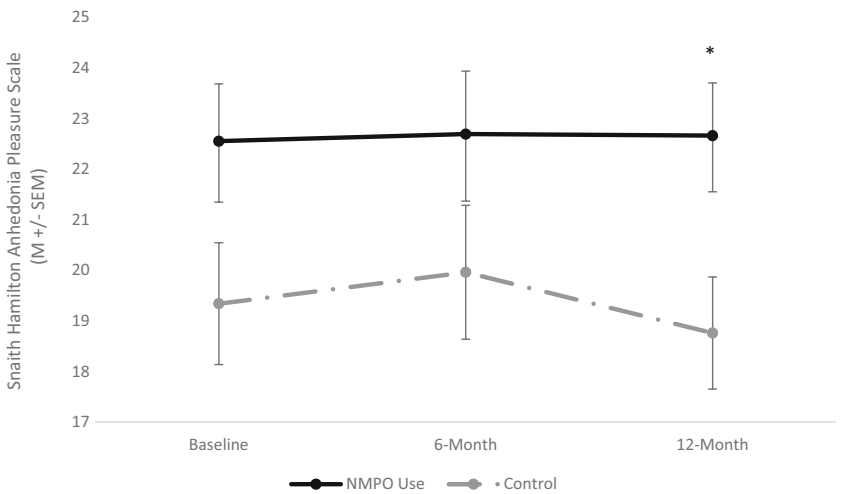

Fig. 3 Estimated self-reported anhedonia levels at baseline, 6-month, and 12-month follow-up among NMPO and control groups. Higher values, based on the Snaith-Hamilton Anhedonia Pleasure Scale, indicate greater levels of anhedonia. Results show a main effect for group on self-report anhedonia; NMPO users reported greater anhedonia. Asterisks indicate group differences at the specified time point. Error bars reflect +/- one standard error of the mean (SEM). * $p < .05$

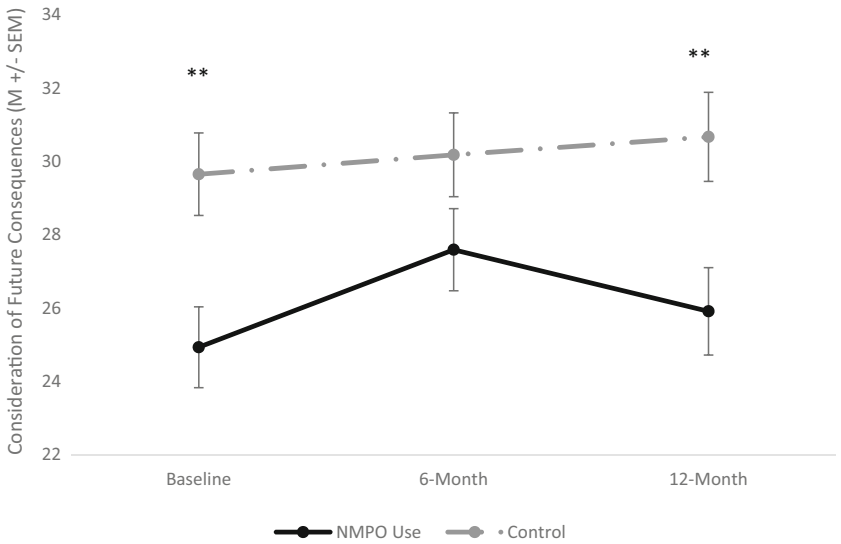

Fig. 4 Levels of future orientation at baseline, 6-month, and 12-month follow-up among NMPO users and controls. Higher values, as measured by the Consideration of Future Consequences scale, indicate greater levels of future orientation. Results show a main effect for group on future orientation; NMPO users reported lower future orientation. Asterisks indicate group differences at the specified time point. Error bars reflect +/- one standard error of the mean (SEM). ** $p < .01$

orientation at baseline are more likely to increase drug use over time. This extends previous research suggesting lower future time orientation predicts greater follow-up drinking in a brief alcohol intervention trial (Murphy et al., 2012). The present results also indicate that future time orientation is associated with academic engagement, which provides further support for the relevance of this construct to young adult decision making more generally.

Our finding that the NMPO group spend less time on academic activities and that low baseline academic engagement was associated with greater alcohol use at 12-month follow-up is consistent with other research suggesting that drug use among college students is associated with lower grades, and increased likelihood of dropping out of college or delaying graduation (Arria, O'Grady, Caldeira, Vincent, & Wish, 2008; Suerken et al., 2016). The difference between the NMPO group and control participants' time allocation to academic activities was greater at 6- and 12-month follow-ups compared to baseline (Fig. 2), suggesting a significant and increasing negative effect of drug use on academic engagement in this population. This finding is also consistent with behavioral economic and matching-law based theories suggesting that the reinforcing value of an activity is best captured by measures of relative behavioral allocation (Herrnstein, 1970; Vuchinich & Tucker, 1988) and that engagement in substance-free and substance-related activities will generally be inversely related (Correia, Simons, Carey, & Borsari, 1998, 2005, Correia, Benson, & Carey, 2005). Thus, a decrease in substance-free reinforcement (e.g., academic engagement), is likely to result in greater time allocation to drug use. Beyond the potential direct deleterious effects of drug use on academic performance (e.g., cognitive impairment, fatigue), students who spend less time engaged in academic activities are more likely to perform poorly in college (Kuh, Cruce, Shoup, Kinzie, & Gonyea, 2008). Although academic time allocation was correlated with future orientation, it was not correlated with self-reported anhedonia or pleasant image ratings. This finding may be due to the different constructs that each

Table 2 Negative binomial and negative binomial hurdle regression analyses examining substance-free reinforcement and future orientation, predicting substance use at 12-month follow-up among NMPO users

	Parameter estimate		Robust SE		*p*-value	
	Binomial	Hurdle	Binomial	Hurdle	Binomial	Hurdle
Academic time allocation						
Opioids	-.279	-.095	.203	.169	.168	.574
Marijuana	.156		.108		.149	
Alcohol†	-.393		.213		***.065***	
Pleasant image ratings						
Opioids	.169	.327	.140	.397	.228	.410
Marijuana	.229		.147		.119	
Alcohol*	-.215		.105		**.041**	
Self-reported anhedonia						
Opioids	.060	-.011	.051	.086	.245	.899
Marijuana	.003		.030		.926	
Alcohol	.041		.032		.203	
Future orientation						
Opioid**	-.109	-.051	.036	.070	**.002**	.460
Marijuana*	-.289		.129		**.025**	
Alcohol	-.026		.038		.498	

* $p < .05$, ** $p < .01$, † $p < .10$

measure evaluates. The time allocation measure assesses day-to-day behavioral allocations, which might be more influenced by valuation of the future and relatively less influenced by anhedonia.

The null finding for exercise time allocation is contrary to behavioral economic theory as exercise is expected to serve as a substance-free alternative to drug use (Smith & Lynch, 2012). Indeed, the literature with adult substance users is consistent with the theory, in that exercise operates as a viable alternative to substance use (Lynch, Peterson, Sanchez, Abel, & Smith, 2013, Smith & Lynch, 2012). However, studies with young adults have demonstrated mixed results including positive, negative, and null associations between exercise and alcohol and drug use (Meshesha et al., 2015; Dunn & Wang, 2003; Moore & Werch, 2008; Musselman & Rutledge, 2010). This may in part be because both exercise and substance use are social behaviors among college students, and the generally flexible college student schedule may allow for ample time for both exercise and drugs/alcohol use, mitigating the expected protective effects of exercise.

Several limitations of this study should be noted. The study relied on self-reports of drug use, and although the assessment context was designed to enhance the validity of self-report (Tucker, Murphy, & Kertesz, 2010), future research should include biochemical verification of drug use. The small sample size of this study may have prevented the detection of significant associations, particularly in light of the relatively small effect sizes observed. The observational nature of the study and lack of random assignment or experimental design may limit the conclusion that can be drawn from these findings. Further, because most NMPO users also used alcohol and marijuana, our design could not isolate the role of NMPO use. However, because the overwhelming majority of NMPO users also use alcohol and marijuana (Catalano, White, Fleming, & Haggerty, 2011), recruiting individuals who exclusively use opioids would be difficult and have limited generalizability to the larger population of NMPO users who typically report use of other substances.

Despite these limitations, this is the first study to investigate longitudinally behavioral economic risk factors for NMPO use among young adults. These results suggest that NMPO use is associated with lower time allocation to academic engagement, greater anhedonia, lower responsiveness to pleasant stimuli, and lower future orientation. These deficits were present at baseline and persisted across the 12-month follow-up period. Further, lower responsiveness to substance-free pleasant stimuli and future orientation at baseline predict greater substance use at 12-month follow-up. These results provide some support for behavioral economic models that emphasize the role of substance-free reward and future time orientation as important contributors to substance misuse, and for treatments that attempt to increase future orientation and participation in substance-free activities (Correia et al., 2005; Murphy et al., 2012; Snider, LaConte, & Bickel, 2016).

Compliance with Ethical Standards

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Conflict of Interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the study.

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