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ORIGINAL ARTICLE

The phenotype of recovery VI: The association between life-history strategies, delay discounting, and maladaptive health and financial behaviors among individuals in recovery from alcohol use disorders

Liqa N. Athamneh[1,2] | Roberta Freitas-Lemos[1,2] | Julia C. Basso[1,2] | Diana R. Keith[1,2] | Michele J. King[1,2] | Warren K. Bickel[1,2]

[1]Addiction Recovery Research Center, Fralin Biomedical Research Institute at VTC, Roanoke, Virginia, USA

[2]Center for Transformative Research on Health Behaviors, Fralin Biomedical Research Institute at VTC, Roanoke, Virginia, USA

Correspondence
Warren K. Bickel, Fralin Biomedical Research Institute at VTC, Roanoke, VA 24016, USA.
Email: wkbickel@vtc.vt.edu

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Abstract

Background: The life-history theory is a well-established framework that predicts behaviors and explains how and why organisms allocate effort and resources to different life goals. Delay discounting (DD) is associated with risky behaviors and has been suggested as a candidate behavioral marker of addiction. Thus, we investigated the relationship between DD, life-history strategies, and engagement in risky behaviors among individuals in recovery from alcohol use disorder (AUD).

Methods: Data from 110 individuals in recovery from addiction from The International Quit & Recovery Registry, an ongoing online registry designed to understand recovery phenotype, were included in the analysis. The association between life-history strategies, DD, engagement in risky behaviors, and remission status were assessed.

Results: Life-history strategy scores were significantly associated with DD rates and finance, health, and personal development behaviors after controlling for age, sex, race, ethnicity, years of education, marital status, smoking status, and history of other substance use. Remission status was significantly associated with life-history strategy, DD, drug use, fitness, health, and safe driving after controlling for age, sex, race, years of education, marital status, and smoking status. In addition, a mediation analysis using Hayes' methods revealed that the discounting rates partially mediated the association between remission status and life-history strategy scores.

Conclusions: Life-history strategies and remission status are both significantly associated with DD and various health and finance behaviors among individuals in recovery from AUD. This finding supports the characterizations of DD as a candidate behavioral marker of addiction that could help differentiate subgroups needing special attention or specific interventions to improve the outcomes of their recovery. Future longitudinal studies are warranted to understand the relationships between changes in life-history strategies, DD, maladaptive health behaviors, and remission status over time.

KEYWORDS
delay discounting, health and finance behaviors, life-history theory, recovery from addiction, remission

INTRODUCTION

Alcohol use disorder (AUD) is a serious public health problem in the U.S., with more than 15 million adults meeting criteria (Substance Abuse & Mental Health Services Administration, 2018), and an estimated economic burden of $249 billion every year (Centers for Disease Control & Prevention, 2018). Recovery from addiction is possible, as millions of individuals who once had a problem with alcohol or drugs no longer do (Feliz, 2012; Substance Abuse and Mental Health Services Administration [US] & Office of the Surgeon General [US], 2016a). More than 50 million adults in the U.S. are in remission from AUD (White, 2012), many without formal treatment (U.S. Department of Health & Human Services, 2016). However, we have a limited understanding of recovery from alcohol use, its predictors, and the underlying decision-making processes that could inform treatment strategies.

The life-history theory is a well-established framework that predicts behaviors and the ways in which organisms, including humans, allocate energy and resources to different goals over their life course (Kaplan & Gangestad, 2015; Roff, 1993). Successful allocation of time, resources, and energy among different tasks necessary for survival and reproduction is a fundamental challenge for all organisms. The life-history theory explains the fitness trade-offs individuals make to overcome the challenges unique to their environment (e.g., efforts for mating versus parenting, reproduction now versus in the future, and offspring quantity versus quality). For example, those living in unpredictable environments, where the future is less certain (Black et al., 2017; Ellis et al., 2009), tend to have a "time preference" that prioritizes short-term goals over long-term investments (i.e., fast life-history strategy). As a result, this leads to earlier maturation, more aggression, and higher engagement in risky behaviors that may provide immediate rewards (Chisholm, 1999; Ellis et al., 2009; Frankenhuis et al., 2016). In contrast, individuals living in stable, predictable environments tend to make energy allocation decisions that prioritize long-term goals and delayed investments. This decision may entail greater interest in education, delayed sexual debut, greater parental investment, less aggression, and less engagement in risky behaviors (Figueredo et al., 2007; Griskevicius et al., 2011). Taken together, these behaviors represent functional adaptations to specific environments (Frankenhuis et al., 2016) in a continuum of fast to slow strategies (Ellis et al., 2009). Life-history theory and data from previous research suggest that humans, during development, are capable of facultatively adjusting their life-history strategies in response to environmental conditions (Belsky et al., 1991; Chisholm, 1999; Ellis, 2004). Even though life-history strategy manifests reasonable within-species heritable variation (Figueredo et al., 2004), individual differences are thought to stem from the effects of early-life experiences, via mechanisms enabling developmental flexibility (Frankenhuis & de Weerth, 2013; Nettle & Bateson, 2015; Nettle et al., 2013). A study by Brumbach et al. (2009) indicated that in adolescence, the environmental parameters of unpredictability have longitudinal effects into young adulthood and concurrent effects on life-history development. Moreover, the study suggested that adolescent life-history traits would predict young adult life-history strategy (Brumbach et al., 2009).

In behavioral economics, "time preference" is a multidimensional construct that falls under the umbrella concept of "impulsivity" (Chisholm, 1999; Cross et al., 2011; Evenden, 1999). Delay discounting (DD) is an important facet in this construct (Frederick et al., 2002). DD is a behavioral economic index that reflects the process by which the value of a reinforcer decreases as a function of the delay to its receipt (Mazur, 1987) and functions as the psychological mechanism underpinning strategic decision-making (Bickel et al., 2012, 2014, 2019). DD is associated with factors related to life-history theory such as resource scarcity (Bickel et al., 2016; Griskevicius et al., 2011) and pubertal onset (Khurana et al., 2012). Also, DD is related to risky behaviors, including aggression and sexual risk-taking (Celio et al., 2016; Reimers et al., 2009). DD has been suggested as a candidate behavioral marker of addiction (Bickel et al., 2014) and a trans-disease process that predicts engagement in other, non-drug, maladaptive behaviors (Bickel et al., 2012; Bickel & Mueller, 2009). For example, individuals with substance use disorder have significantly higher discounting rates (i.e., demonstrating shorter time preferences and rapid devaluation of future rewards) than healthy controls (Amlung et al., 2017; MacKillop et al., 2011). This finding is robust in most misused drugs (Baker et al., 2003; Coffey et al., 2003; Madden et al., 1999), including alcohol (Mitchell et al., 2005). Also, excessive discounting is associated with a higher propensity to engage in unhealthy behaviors, including overeating, obesity, texting while driving, fewer dental visits, less flu shot usage, not wearing sunscreen, infrequent exercise, gambling, and non-compliance to medical prescriptions (Amlung et al., 2017; Bradford, 2010; Chesson et al., 2006; Daugherty & Brase, 2010; Garza et al., 2016; Hayashi et al., 2015; Snider et al., 2018).

A growing body of research supported the hypothesized association between having a lifespan-limiting disease early in life and the adoption of faster life-history strategies. For example, compared to healthy controls, those growing up with serious chronic health conditions (e.g., cancer, epilepsy, and diabetes) experience earlier pubertal onset (Park et al., 2012; Widen et al., 2012), earlier age at first reproduction (Waynforth, 2012), and engagement in more risky sexual activities (Suris et al., 2008; Valencia & Cromer, 2000). In addition, previous studies reported an association between life-history theory-related factors and valuation, frequency, and severity of substance use (Athamneh et al., 2019b; Durrant et al., 2009; Hampson et al., 2016; Richardson et al., 2014). However, to our knowledge, the relationship

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between life-history strategies, DD, and engagement in risky behaviors (e.g., alcohol use and poor health-related activities) among individuals in recovery from AUD has not been previously examined. The current study investigated the relationship between life-history strategies (fast to slow continuum), DD, and the engagement in poor health and financial behaviors among individuals in recovery from AUD.

Additionally, as an integral part of the recovery process, the remission from alcohol status and its association with life-history theory and DD were examined. Remission is defined as the absence of AUD criteria (measured using the DSM-5) in the last 3 months (Hasin et al., 2013). For this study, data were collected from the International Quit & Recovery Registry (IQRR), an ongoing online registry designed to understand recovery's phenotype (Athamneh et al., 2019a; see also Athamneh et al., 2017). As individuals with a slow life-history strategy would demonstrate greater general health, developmental steadiness, and stability in mental and physical functioning (Figueredo et al., 2007), we hypothesize that, among individuals in recovery from AUD, slower life-history strategies would be associated with lower rates of discounting and less engagement in maladaptive health behaviors. In addition, we hypothesize that individuals in remission from AUD will show slower life-history strategies and lower discounting rates compared to those not in remission. Moreover, given that those experiencing fast life-history strategy tend to have a "time preference" that prioritizes short-term goals over long-term investments (Black et al., 2017; Ellis et al., 2009), which may then lead to higher engagement in risky behaviors (Chisholm, 1999; Ellis et al., 2009; Frankenhuis et al., 2016), we hypothesize that the association between life-history strategies and remission status would be partially mediated by valuation of the future as measured by rates of discounting.

Establishing the association between life-history strategies, DD, engagement in various health and financial behaviors, and remission status might help identify subgroups at higher risk (Humphreys & Bickel, 2018; Kelly, 2017). These individuals may need tailored interventions to address their higher impulsivity and increase their likelihood to achieve better recovery outcomes.

MATERIALS AND METHODS

Participation in the study was voluntary. Participants completed an electronic consent where the consent information is provided at the beginning of the online survey and consent is reached by answering "yes" to the question, "Your consent to participate in this research is implied when you choose to continue with the assessment. Would you like to continue?". The Institutional Review Board at Virginia Polytechnic and State University approved the current study.

Participants

The data used in the current study was collected through the IQRR, an online registry for individuals recovering from substance misuse. The IQRR aims to understand the phenotype of recovery, the different factors that enable or hinder overcoming addiction, and the association between substance use and decision-making. Adults from all around the world who volunteer to register on the IQRR website (https://quitandrecovery.org) must self-report being in recovery and provide a valid email address. After registering, individuals can create profiles that enable them to connect with other IQRR registrants and participate in the IQRR assessments without any minimum commitment to stay in the registry. Links for assessments are emailed to all registrants through a monthly newsletter. Participation in the assessments is voluntary and open to all the registry members. Only those who completed the current survey were included in the study. For each assessment completed, participants receive a badge and 400 to 1000 points (depending on the assessment's length and complexity) that can be exchanged for money (100 points = $1.00). The IQRR also has many open-access recovery resources available for the general public at any time.

A total of 112 participants completed the assessment. Inclusion criteria required that participants be 18 years or older and meet the DSM-5 criteria for lifetime abuse and dependence of alcohol (report at least 2 DSM-5 criteria of AUD during lifetime). Participants were excluded from the analysis if they failed the attention check question in which participants were asked to choose between receiving $500 now or $1000 now.

Study measures

DD

An adjusting-delay task (Koffarnus & Bickel, 2014) was used to assess discounting rates. The task determines the delay at which the larger reward loses half of its value when compared to the immediate reward. The task starts by asking participants to choose between $1000 in 3 weeks or $500 now. Based on the choice made, the delay in receiving the $1000 reward is lengthened or shortened for the next question (i.e., if the smaller but immediate reward is chosen, the next question shortens the delay for the $1000 reward to 1 day; if the larger but delayed reward is chosen, the next question lengthens the delay to 2 years). The delays continue to adjust for a total of five choice trials (Koffarnus & Bickel, 2014).

The estimated delay at which the value of the larger reward will be reduced by 50% (i.e., ED_{50}) was calculated using the indifference points (expressed in days) provided by the adjusting-delay task. Then, an estimate of the discounting rate (k) was calculated using the inverse of this ED_{50} ($1/ED_{50}$) based on Mazur's hyperbolic discounting equation (Koffarnus & Bickel, 2014; Yoon & Higgins, 2008). The natural log transformation of k was used in the current analyses as the observed k values were positively skewed. The 5-trial adjusting-delay task was utilized in the current study because of its flexibility, brevity, and accuracy in assessing the discounting rate (Koffarnus & Bickel, 2014). However, the task is relatively new and only determines a single indifference point, therefore increasing the possibility of measurement error.

Life-history battery

The K-SF-42 (Figueredo et al., 2017) is a short form of the 199-items Arizona Life-History Battery (ALHB; Figueredo et al., 2007). The K-SF-42 consists of 42 items that assess a set of cognitive and behavioral indicators of life-history strategy and correlates highly with the ALHB. Example items include "I can find something positive even in the worst situation" and "I contribute a great deal to the welfare and well-being of my friends these days". Answers ranged from "Disagree strongly (score = −3)" to "Agree strongly (score = +3)". Answers for other questions such as "How much have your friends offered to take you somewhere?" ranged from "Not at all (score = 0)" to "A lot (score = 3). Scores range from −72 to 198, where low aggregated scores (low-*K*) indicate fast strategy while high scores (high-*K*) indicate slow strategies on the "fast-slow" continuum. These distinctive strategies are supposed to be reflected by individual differences in, for example, tendencies to take risks, altruism and relations, and time preference (e.g., Figueredo et al., 2006).

Health behaviors questionnaire

The Health Behaviors Questionnaire includes 55 items asking about general health and financial behaviors (Snider et al., 2018). The behaviors were categorized into seven groups: drug use, finances, fitness, food, health, household savings, personal development, and safe driving. Participants were asked to rate the relative frequency with which they engage in these behaviors. For example, "How often do you use illegal drugs, give to charity, use sunscreen, pay for your own health insurance, take the stairs instead of the elevator?" with answers ranging from "never" to "almost always." Some questions asked participants to indicate the number of times they engaged in a specific health behavior (e.g., "how many hours of sleep do you get per night?"). The 55 questions were randomized, and categories of items were not asked together (Snider et al., 2018). Higher scores indicate a higher frequency of positive behaviors associated with those behavioral groups except for drug use (i.e., higher scores indicate higher incidence of negative drug use behaviors).

DSM-5 for AUD

The criteria of the DSM for AUD fifth edition (American Psychiatric Association, 2013; Hasin et al., 2013) assessed the lifetime, last year, and last 3 months AUD. Participants answered 11 symptom questions from the DSM-5 criteria for the diagnosis of AUD (American Psychiatric Association, 2013; Hasin et al., 2013; Sullivan et al., 2020). DSM-5 AUD lifetime diagnosis was defined as reporting two or more criteria in their lifetime. Sustained remission status was established if participants indicated not meeting any AUD criteria (other than craving) in the last 12 months. Early remission status was established if participants indicated not meeting any AUD criteria (other than craving) in ≥3 to <12 months. Psychometric studies examined the test-retest reliability and validity of DSM-5 AUD diagnosis and indicated fair to good test-retest reliability ($\kappa = 0.4$ to 0.6) and fair to excellent dimensional criteria scales (intraclass correlation coefficient [ICC] = 0.5 to 0.9, respectively; Grant, Goldstein, Saha, et al., 2015; Grant, Goldstein, Smith, et al., 2015; Hasin et al., 2015).

Demographics and substance use

Demographic data, including age, race, ethnicity, annual income, sex, marital status, and education level, were collected.

To determine history of use of other substances for each participant, we used the standard IQRR question, "Please select which of the following substances you have used in your lifetime, either to get high or to self-medicate a problem using substances that were not approved by your doctor. Please select all that apply." Answers include the following choices: (a) nicotine; (b) alcohol; (c) cannabis products; (d) opioids; (e) cocaine; (f) stimulants; (g) prescription pain relievers; (h) tranquilizers/depressants; (i) hallucinogens; (j) dissociative anesthetics; (k) inhalants; (l) other; or (m) none. Examples were provided for each addiction. History of other substance use was coded as Yes/No, with participants considered "Yes; with a history of other substance use" if they selected any substance(s) in addition to alcohol and nicotine.

Current smoking status was assessed using the following question: "What is your current smoking status?" with the following multiple choices: current cigarette smoker, former cigarette smoker, or never smoked cigarettes.

Statistical analysis

Descriptive statistics were used to determine the means and distribution of sample characteristics. To assess the statistical predictive utility of K-SF-42 of discounting rates and health and finance behaviors, bivariate linear regression analyses of the K-SF-42 score were carried out with DD and each of the Health and Finance Behaviors subscales, and results were presented as unadjusted coefficients with 95% confidence intervals (CI). In addition, to assess the ability of K-SF-42 to predict discounting rates, health behaviors, and/or remission status statistically, multivariable linear regression analysis (using the Sidak pairwise correction) was run with each of the measures as dependent variables and K-SF-42 and demographics (i.e., age, sex, race, ethnicity, years of education, marital status, smoking status, history of other-substance use) as independent variables.

One-way ANOVA analyses and chi-square tests were run to compare the means and distribution of sample characteristics between remission groups (e.g., not in remission, in early remission, in sustained remission). When appropriate, post hoc comparisons were conducted using the Sidak pairwise correction. No significant

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difference in any of the demographics or outcome measures was found between those who were identified as in early remission ($n = 37$) or sustained remission ($n = 29$; data not shown). To ease the analysis and interpretation of the results and given the small sample size for those in sustained remission, the two remission groups were reclassified into one group (i.e., in remission).

To assess the association between the remission status and life-history strategies, DD, or health behaviors, we first ran *T*-test and chi-square tests to compare the means and distribution of sample characteristics between the "in remission" and "not in remission" groups. Second, separate multivariable logistic regressions were performed between the remission status and life-history strategies, DD, or finance and health behaviors, while controlling for demographic variables that were significantly different between the two remission groups in the first step. Next, a mediation analysis was generated with a logistic regression for the binary outcome: remission status (Hayes, 2019). The mediation analysis was conducted using Hayes' (Hayes, 2017) methods to explore whether discounting rates partially account for the association between life-history strategies and remission status. A bootstrapping technique (with 10,000 bootstrap samples) to estimate 95% CI was used. A 95% CI for the product of indirect path coefficient that does not include zero provides evidence of a significant indirect effect (Preacher et al., 2007). Analyses were conducted using IBM SPSS Statistics Version 26 (IBM Analytics; George & Mallery, 2019) and macro-program PROCESS 3.4 (Hayes, 2009, 2017) at a significance level of 0.05.

RESULTS

A total of 112 participants completed the study and 110 were included in the analysis (two subjects failed the attention check test, choosing $500 now instead of $1000 now). Of the included participants, 60% were females, 91% were white, 95% were non-Hispanic, 35% were married, 30% were current smokers, and 67% reported a history of using substances other than nicotine. In addition, participants reported a mean age of 48.65 (SD 15.32), and a mean year of education of 14.08 (SD 4.71). The current study sample is comparable in demographics such as age, sex, race, ethnicity, and education to that of the larger registry sample (data not shown).

Assessing the statistical predictive utility of K-SF-42 of discounting rates and different health and finance behaviors, the multivariable linear regression results indicated that K-SF-42 scores are significant statistical predictors of discounting rates and finance, health, and personal development subscales even after controlling for demographics (i.e., age, sex, race, ethnicity, years of education, marital status, smoking status, and history of other-substance use; Table 1).

To assess the association between the remission status and life-history strategies, DD, or health behaviors, first, *t*-test and Pearson chi-square test of the continuous and categorical demographic variables, respectively, were used to assess demographic differences between the remission groups and indicated a significant difference in age ($p < 0.001$), race ($p = 0.016$), years of education ($p = 0.004$), marital status ($p < 0.001$), and smoking status ($p = 0.001$) between the two groups (Table 2). Those in remission were older, had higher education levels, and were mainly white, married, and non-smokers. In the current sample, higher K-SF-42 scores (slower life-history strategies) were reported among those in remission ($M = 70.32$, SD = 26.30) compared to those not in remission ($M = 55.93$, SD = 24.19, $p = 0.005$) and lower rates of discounting were found among those in remission ($M = -6.21$, SD = 1.77) compared to those not in remission ($M = -4.01$, SD = 3.37, $p < 0.001$; Figure 1). Means and frequencies of the main variables cross-classified by sex and remission status are shown in Table 3. Second, we controlled for all the significantly different demographic variables (in the first step) in the final multivariable logistic regression analysis. In this study sample, even though sex was not significantly different between the two remission groups, it was at a certain trend toward significance ($p = 0.08$). Hence, we controlled for

TABLE 1 Linear regression results for the K-SF-42 predicting DD rates, and the maladaptive health behaviors

Variable	Unadjusted coef. (95% CI)	*p* value	Adjusted coef. (95% CI)[a]	*p* value[b]
Lnk	−0.022 (−0.041 −0.003)	0.023	−0.023 (−0.042 −0.004)	0.017
Health behaviors				
Drug use	−0.009 (−0.018 0.001)	0.041	−0.007 (−0.015 0.001)	0.096
Finance	0.009 (0.005 0.013)	<0.001	0.007 (0.002 0.011)	0.003
Fitness	0.007 (0.001 0.012)	0.021	0.003 (−0.002 0.011)	0.171
Food	0.005 (0.002 0.008)	0.005	0.003 (−0.001 0.007)	0.075
Health	0.006 (0.003 0.009)	<0.001	0.005 (0.002 0.009)	0.004
Household savings	0.005 (0.000 0.009)	0.040	0.004 (−0.001 0.009)	0.159
Personal development	0.015 (0.010 0.020)	<0.001	0.013 (0.007 0.019)	<0.001
Safe driving	0.002 (0.003 0.007)	0.432	0.001 (−0.005 0.006)	0.866

Note: CI, confidence interval; DD, delay discounting.

[a]Adjusted to age, sex, race, ethnicity, years of education, marital status, smoking status, and history of other-substance use.

[b]For the adjusted values.

TABLE 2 Chi-square and *t*-test results for the demographics variables by remission status

Characteristics	Frequency (% column)/mean (SD)		
	Not in remission $n = 44$	In remission $n = 66$	p value[a]
Female	22 (50%)	44 (66.7)	0.080
Marital status			<0.001
Single	23 (52.3)	13 (19.7)	
Married	7 (15.9)	31 (47.0)	
Divorced	4 (9.1)	15 (22.7)	
Other	10 (22.7)	7 (10.6)	
Income			0.195
Less than $9999	21 (47.7)	10 (15.2)	
$10,000 to $29,999	11 (25.0)	25 (37.9)	
$30,000 to $49,999	6 (13.6)	9 (13.6)	
$50,000 to $69,999	3 (6.8)	10 (15.2)	
$70,000+	3 (6.8)	5 (18.2)	
Race			0.016
White	36 (81.8)	64 (97.0)	
Black/African American	6 (13.6)	0 (0.0)	
Other	2 (4.5)	2 (3.0)	
Non-Hispanic	42 (95.5)	62 (93.9)	0.544
Use of other substances	26 (59.1)	48 (72.7)	0.135
Smoking status			
Current cigarette smoker	22 (50.0)	11 (16.7)	0.001
Age	39.11 (14.82)	55.20 (11.91)	<0.001
Years of education	12.72 (5.92)	15.50 (4.05)	0.004
Discounting rates (lnk)	−4.15 (3.28)	−6.20 (1.78)	<0.001
The K-SF-42	55.93 (24.19)	70.32 (26.30)	0.005

[a]Between the two remission groups.

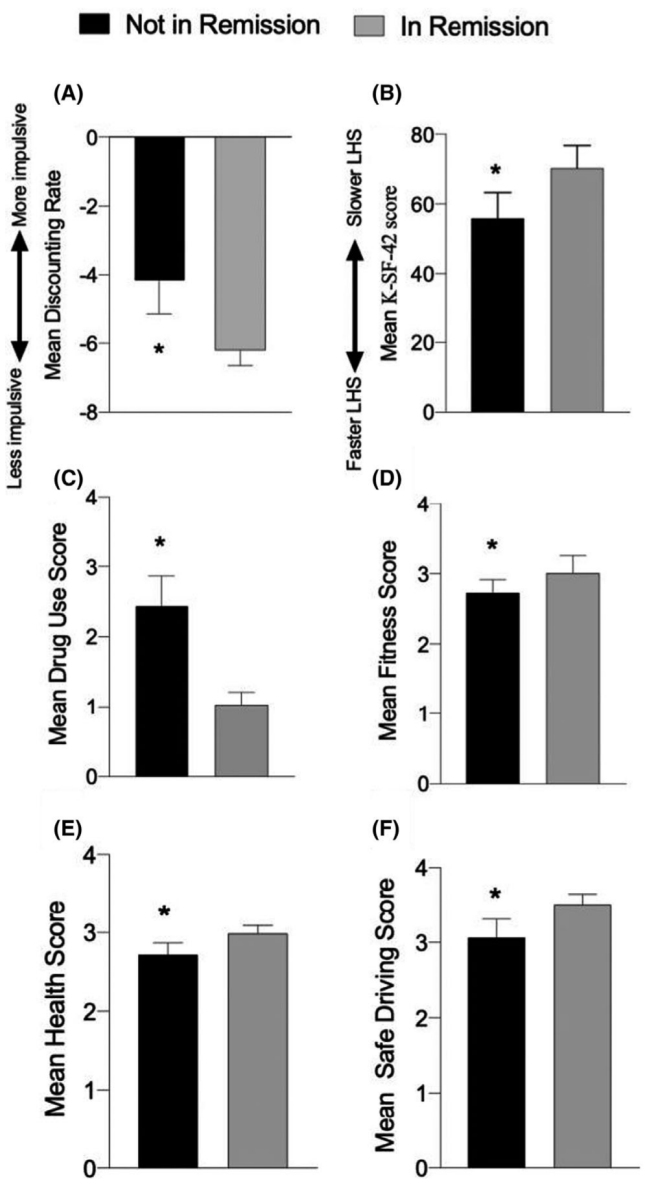

FIGURE 1 A comparison of (A) discounting rates (ln[k]); (B) life-history strategies (LHS); (C) drug use score; (D) fitness scores; (E) health scores; and (F) safe driving scores between individuals in remission and not in remission from AUDs. Error bars represent 95% CI. $p < 0.05$

sex in the multivariable logistic regression analysis as well (Table 4). The multivariable logistic regression analysis indicated that the K-SF-42 scores; $B = (0.020)$, SE = .010, Wald = 3.948 $p = 0.047$) and discounting rate; $B = (-0.222)$, SE = 0.111, Wald = 4.002 $p = 0.045$) are statistically significant predictors of remission status even after controlling for age, sex, education, race, marital status, and smoking status. In addition, the remission status was significantly associated with drug use: $B = (-1.512)$, SE = 0.360, Wald = 17.65 $p < 0.001$; fitness: $B = (.752)$, SE = 0.325, Wald = 5.349, $p = 0.021$; health: $B = (1.171)$, SE = 0.544, Wald = 4.642 $p = 0.031$; and safe driving: $B = (0.791)$, SE = 0.352, Wald = 5.061 $p = 0.024$ scores even after adjusting for covariates (Table 4).

The mediation analysis results (Figure 2) suggested a significant indirect association between K-SF-42 scores and remission status, through DD (point estimate = 0.006, 95% CI = 0.0005 0.0161). Overall, the discounting rates (lnk) represented 34% of the total effect between K-SF-42 and remission status.

DISCUSSION

The present study examined the association between the assessments of life-history strategies and discounting of delayed monetary rewards, maladaptive health behaviors, and remission status in

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TABLE 3 Means (SD) for the main variables cross-classified by sex and remission status

Characteristics	Mean (SD)			
	Not in remission $n = 44$		In remission $n = 66$	
Sex	Male $n = 22$	Female $n = 22$	Male $n = 22$	Female $n = 44$
Discounting rates (lnk)	−3.60 (3.30)	−4.70 (3.24)	−6.08 (2.05)	−6.27 (1.65)
The K-SF-42	60.72 (23.60)	51 (24.34)	75.27 (22.64)	67.84 (27.87)
Health behaviors				
Drug use	2.37 (1.54)	2.5 (1.29)	0.90 (0.51)	1.09 (.81)
Finance	3.12 (0.52)	2.96 (0.60)	3.30 (0.46)	3.38 (0.62)
Fitness	2.92 (0.76)	3.09 (0.88)	2.84 (0.70)	2.67 (0.78)
Food	2.92 (0.38)	2.90 (0.48)	3.08 (0.48)	3.16 (0.47)
Health	2.81 (0.55)	2.62 (0.40)	2.88 (0.42)	3.03 (0.42)
Household savings	3.07 (0.53)	3.10 (0.72)	2.89 (0.83)	3.34 (0.49)
Personal development	3.10 (1.04)	3.10 (0.91)	3.51 (0.71)	3.37 (0.66)
Safe driving	3.08 (0.89)	3.04 (0.71)	3.53 (0.56)	3.5 (0.57)

TABLE 4 Summary of multivariable logistic regression analysis of life-history strategies, discounting, and maladaptive health behaviors predicting remission status

Characteristics	*B*	*SE*	Wald	*p* value	Exp (B)	95% CI for Exp (B)
The K-SF−42	0.020	0.010	3.948	0.047	1.020	0.1000 1.040
DD rates	−0.222	0.111	4.002	0.045	0.801	0.645 0.996
Health behaviors						
Drug use	−1.512	0.360	17.65	<0.001	0.220	0.109 0.446
Finance	0.623	0.424	2.158	0.142	1.864	0.812 4.279
Fitness	0.752	0.325	5.349	0.021	0.472	0.249 0.892
Food	0.517	0.527	0.960	0.327	1.676	0.597 4.711
Health	1.171	0.544	4.642	0.031	3.226	1.112 9.361
Household savings	−0.067	0.370	0.033	0.856	0.935	0.453 1.931
Personal development	0.324	0.306	1.124	0.289	1.383	0.759 2.519
Safe driving	0.791	0.352	5.061	0.024	2.207	1.107 4.397

Abbreviations: CI, confidence interval; DD, delay discounting; SE, standard error.

[a]Variables entered in all models are age, sex, race, years of education, marital status, and smoking status.

a sample of individuals in recovery from AUD from the International Quit and Recovery Registry. The results indicate significant associations between life-history strategies and discounting rates and many health and finance behaviors (i.e., finance, health, and personal development subscales). Slower life-history strategies (higher scores) were observed among those with lower discounting rates and those scoring higher in finance, health, and personal development subscales (indicating positive behaviors). In addition, being in remission was significantly associated with slower life-history strategies (higher scores), lower discounting rates, less drug use, and higher scores in fitness, health, and safe driving. Below, we discuss those findings in more detail.

As previously noted, life-history strategies vary along a continuum from fast to slow, evidencing different resource allocation patterns toward competing for biological goals, such as growth and health maintenance (Del Giudice, 2014). Slower life-history strategies reveal long-term planning, secure relationships with parents, partners, family and friends, greater altruism, and religiosity. Conversely, faster life-history strategies reveal short-term planning, less altruism and religiosity, and insecure relationships with parents, partners, family, and friends (Figueredo et al., 2017).

Consistent with our first hypothesis, life-history strategies are significantly associated with discounting rates among individuals in recovery from AUD. Specifically, faster life and slower life strategies are associated with higher and lower rates of discounting, respectively. The current findings are consistent with previous studies demonstrating an association between discounting rates and components of the life-history theory, such as individual-specific

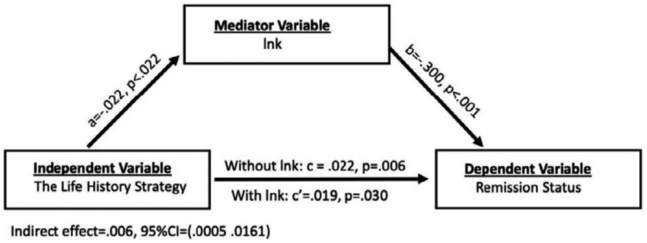

FIGURE 2 Mediation analyses using life-history strategies (The K-SF-42 scores). Given that the indirect effect is statistically significant, they support partial mediation

mortality risk (Lee et al., 2018; Pepper & Nettle, 2013), short-term mating orientation (Athamneh et al., 2019b), and early reproduction (Pepper & Nettle, 2013). This finding corroborates the idea that from a temporal standpoint, slower life-history strategies expand one's future perspective (lower discounting rates), while faster life-history strategies narrow one's future perspective (greater discounting rates; Del Giudice, 2014). In line with the framework of life-history theory (Del Giudice, 2014; Figueredo et al., 2006), this study also found an association between life-history strategy and engagement in finance, health behaviors, and personal development, with slower life-history strategies predicting higher frequency of engagement in these behaviors in individuals in recovery from AUD.

Together, these findings are particularly relevant to inform recovery strategies for individuals in recovery from substance use disorder, such as AUD. When applying this framework to SUD individuals, the literature suggests that the position along the life-history strategies continuum is directly related to substance use frequency and severity (Del Giudice, 2014; Richardson et al., 2019). The central hypothesis is that unpredictable environments require psychological adaptation, from which substance use can be a consequence. In this sense, individuals who adopt faster life-history strategies and have SUD may face more challenges in initiating and maintaining a recovery trajectory (Richardson et al., 2019). Effective interventions to modify life-history strategies might also extend one's temporal window and impact long-term health, leveraging recovery outcomes.

Additionally, in line with our second hypothesis, remission status was significantly associated with lower discounting rates. DD is a behavioral marker of future valuation, with an individual's DD rate indicating the regulatory balance between impulsive, immediate-focused behaviors and executive, future-driven behaviors (Bickel & Johnson, 2003; Odum, 2011). Those with lower discounting rates, indicating higher valuation for the future, were more likely to be in remission, having not experienced any symptoms of AUD (except craving) in the last 3 months. This finding is in line with our previous findings showing that as time in recovery progresses, the rate of DD decreases (Athamneh et al., 2019a). Additionally, clinical studies have found that substance abuse treatment significantly decreases DD rates (Landes et al., 2012). The finding that DD is associated with or can predict remission status is critical as AUD is a relapsing-remitting disorder. Return to alcohol use is common, with an estimated 40% to 60% of individuals with AUDs relapsing or returning to alcohol after an attempted stop (McLellan et al., 2000). Because AUD and other substance use disorders are chronic conditions, relapse can be a natural part of the recovery process and does not mean that recovery has failed. Our results indicate that DD may be an indicator of an individual's likelihood of relapsing and suggests that DD could be utilized as a target for interventions to improve treatment outcomes. For example, effective interventions that can modify the time perspective (e.g., from present to future) by decreasing DD (e.g., Episodic Future Thinking [EFT] or working memory training) may favor the transition from non-remission to remission status. Episodic future thinking, based on the science of prospection, is a process whereby individuals generate and engage in vivid, positive thinking about their future (Atance and O'Neill, 2001). This transition could subsequently induce positive health behavior changes. A previous study has shown that the inclusion of health goals into EFT may promote healthy decisions (Athamneh et al., 2020b). This suggests that EFT can be individually tailored to target long-term health and leverage recovery outcomes.

Further, remission status was associated with a slower life-history strategy, marking one of the first times this association has been demonstrated in the scientific literature. This finding indicates that successful states of recovery are linked to life-history strategies characterized by future-oriented thinking and behaviors; such strategies may include participation in a healthy lifestyle, engagement in educational opportunities, having stable relationships, and having few well-cared for offspring (Csathó & Birkás, 2018). Slow life-history strategies are associated with predictable or secure environments and ample resources (Brumbach et al., 2009; Chang & Lu, 2018; Ellis et al., 2009), which are more likely during periods of remission versus active addiction. Additionally, longitudinal data from the National Epidemiologic Survey on Alcohol and Related Conditions found that those in remission 1 and 3 years after the baseline assessment experienced fewer stressful life events (McCabe et al., 2016), again an indication of a predictable environment that supports a slow life-history strategy.

Further, remission status was associated with a lower frequency of drug use and a higher incidence of positive fitness, health, and safe-driving behaviors in individuals in recovery from AUD. These ideas corroborate the above findings. That is, a lower frequency of drug use and a higher frequency of health behaviors such as exercise and safe-driving indicate that individuals in recovery are engaged in behaviors that are indicative of a slow life-history strategy and geared towards a successful future. Surprisingly little has been done to directly study health behaviors in individuals in remission (perhaps due to the difficulty of capturing such longitudinal data); however, it is well accepted that recovery goes well beyond abstinence to engagement in a variety of healthy behaviors such as eating well, exercising, and establishing successful social relationships (Substance Abuse and Mental Health Services Administration [US] & Office of the Surgeon General [US], 2016b). Success in recovery is a multidimensional construct, measured by improvements in the quality of many aspects of life, including physical health (e.g., activities

of daily living, energy, pain, and work capacity), psychological functioning (e.g., appearance, feelings, self-esteem, perceived cognition), social relationships (e.g., social support, personal relationships, and sexual activity), and environment (e.g., financial resources, freedom, health and social care, and the home environment; Garner et al., 2014; Kaskutas et al., 2014). Of relevance, we recently reported that the association between remission status and quality of life in the domains of physical, psychological, and environmental health were partially mediated by DD, another metric of future valuation (Athamneh et al., 2020a). Future research is warranted to investigate whether interventions focused on improving health behaviors (e.g., episodic future thinking) may drive longitudinal success in recovery.

Indeed, consistent with our third hypothesis, DD accounted for 34% of the total effect observed in the association between remission status and life-history strategy. The theoretical framework of life-history theory permits the integration of behavioral economics and evolutionary psychology to explain optimal decision-making strategies (e.g., resource and time allocation to growth vs. survival vs. reproduction) employed in different contexts (e.g., high vs. low resource environment, illness vs. health). Thus, the mediation of DD likely captures and accounts for decision-making strategies employed in the life-history theory framework. In contrast, the independent effect of life-history strategies on remission reflects contextual factors. Interestingly, considerable debate has developed about the malleability of DD. Recent evidence suggests that it has both trait- and state-like characteristics (Odum & Baumann, 2010). Thus, an individual may be predisposed to making decisions within a certain temporal window but the environmental context may also influence decision-making.

One significant quality of the current study was using data from the IQRR. The IQRR is a unique online registry that enables the scientific study of the multi-dimensional domains of recovery, depicts different phenotypes of recovery, and provides an insight into the association between DD rates, life-history strategies, and remission status in this special population. The current study suggests various areas for future research. Further research examining the predictive utility of DD of life-history strategies for individuals in recovery from other addictions (e.g., gambling, food, video games, sex, other substances) may be useful. In addition, longitudinal studies that aim to characterize the long-term trajectory of the recovery process by understanding the relationships between changes in DD over time and their related changes in one's life-history strategies are needed.

Our study has several limitations worth noting. First, the online-based assessments limited our sample to only include individuals in recovery who use technology and have an email address, and consisted of self-report measures. However, many studies have validated the use of online data collection and reported results similar to laboratory-based data collection (Birnbaum, 2000; Suri & Watts, 2011). For example, online studies have replicated many phenomena related to discounting that were observed in laboratory studies such as cross-sectional differences in DD associated with cigarette smoking and AUD (Jarmolowicz et al., 2012; VanderBroek et al., 2016).

Second, the cross-sectional study design in the current investigation limited our ability to infer longitudinal mediation and/or predict the temporal precedence between life-histories and discounting (Maxwell et al., 2011). Changes in life-history strategies may predict DD or remission status. However, changes in discounting and or remission status could alter life-history strategies as well. In addition, many other factors that may be associated with life-history strategies and remission status such as growth pattern or recovery capital were not assessed in the current study. Therefore, the question of whether discounting is acting as a proxy for another untested mediator is still open. Future research comparing the effect of discounting to other key factors in the recovery process is warranted to better understand those associations.

In addition, although we encourage all registrants to join the registry, sampling bias for those who volunteered to participate in the study might be present. Moreover, as we mentioned in the methods section, even though the 5-trial adjusting-delay task used in the current study is flexible, brief, and can accurately assess the discounting rate (Koffarnus & Bickel, 2014), the task only assesses one indifference point, increasing the likelihood of measurement error. Finally, Figueredo et al. (2007) conceptualization of life-history strategy is too broad. For the past several years, various critiques have appeared in journals oriented to evolutionary psychology. The journal Human Evolution and Behavior published a special issue in November 2020 devoted to this topic (Frankenhuis & Nettle, 2020). Specifically, while Figueredo et al. (2006, 2007) asserted that aspects of personality and cognition could be subsumed under life-history strategy in a single dimension, recent critiques are cautioning about this broad extension of life-history theory (see Sear, 2020). For example, recent studies have not found a single dimension of life-history strategy, but rather two dimensions (Copping et al., 2017; Richardson et al., 2020). Hence, the findings of the current study should be interpreted with caution and future research replicating the current research using multiple dimensions of the life-history strategy is warranted to better assess the utility of this measure and understand those associations.

CONCLUSION

The current study extends previous studies among individuals in recovery to assess the association between life-history strategies, substance use, rates of discounting, and various health and finance behaviors among this population. The study findings indicate that life-history strategies are significantly associated with discounting rates and various health and finance behaviors among individuals in recovery from AUD. In addition, life-history strategies and discounting rates are significantly associated with the remission status. This finding could help distinguish subgroups of individuals in recovery that may need special attention or specific interventions to improve the outcomes of their recovery. Future longitudinal studies that aim to understand the relationships between

changes in life-history strategies, substance use, and DD over time are warranted.

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CONFLICT OF INTEREST

Although the following activities/relationships do not create a conflict of interest pertaining to this (poster/manuscript), in the interest of full disclosure, Dr. Bickel would like to report the following: W. K. Bickel is a principal of HealthSim, LLC; BEAM Diagnostics, Inc.; and Red 5 Group, LLC. In addition, he serves on the scientific advisory board for Sober Grid, Inc. and is a consultant for Alkermes, Inc. None of the other authors have any conflict of interest.

ORCID

Warren K. Bickel https://orcid.org/0000-0002-1048-7372

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