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RESEARCH ARTICLE

ALCOHOL CLINICAL & EXPERIMENTAL RESEARCH

Rate-dependent effects of narrative interventions in a longitudinal study of individuals who use alcohol

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Abstract

Background: Delay discounting (DD), the decrease in reward valuation as a function of delay to receipt, is a key process undergirding alcohol use. Narrative interventions, including episodic future thinking (EFT), have decreased delay discounting and demand for alcohol. Rate dependence, the relationship between a baseline rate and change in that rate after an intervention, has been evidenced as a marker of efficacious substance use treatment, but whether narrative interventions have rate-dependent effects needs to be better understood. We investigated the effects of narrative interventions on delay discounting and hypothetical demand for alcohol in this longitudinal, online study.

Methods: Individuals ($n = 696$) reporting high- or low-risk alcohol use were recruited for a longitudinal 3-week survey via Amazon Mechanical Turk. Delay discounting and alcohol demand breakpoint were assessed at baseline. Individuals returned at weeks 2 and 3 and were randomized into the EFT or scarcity narrative interventions and again completed the delay discounting tasks and alcohol breakpoint task. Oldham's correlation was used to explore the rate-dependent effects of narrative interventions. Study attrition as a function of delay discounting was assessed.

Results: Episodic future thinking significantly decreased, while scarcity significantly increased delay discounting relative to baseline. No effects of EFT or scarcity on the alcohol demand breakpoint were observed. Significant rate-dependent effects were observed for both narrative intervention types. Higher delay discounting rates were associated with a greater likelihood of attrition from the study.

Conclusion: The evidence of a rate-dependent effect of EFT on delay discounting rates offers a more nuanced, mechanistic understanding of this novel therapeutic intervention and can allow more precise treatment targeting by demonstrating who is likely to receive the most benefit from it.

KEYWORDS
alcohol, delay discounting, episodic future thinking, longitudinal, rate dependence

All authors contributed in a significant way, and all authors have read and approved the final manuscript.

INTRODUCTION

Alcohol use disorder (AUD) continues to pose a significant challenge to health in the United States, with an estimated 15 million adults meeting the criteria (Substance Abuse and Mental Health Services Administration, 2018). Moreover, AUD imposes significant financial strains, with an estimated yearly $249 billion economic cost (CDC, 2018). While existing treatment options are efficacious and replicable, considerable room for improvement remains. For example, only one in nine individuals with AUD benefits from treatment with medication (Rösner, Hackl-Herrwerth, Leucht, Lehert, et al., 2010; Rösner, Hackl-Herrwerth, Leucht, Vecchi, et al., 2010). One contributing factor may be the considerable heterogeneity in AUD.

Current diagnostic approaches, including the Diagnostic and Statistical Manual Criteria, 5th edition (DSM-5) rely on aggregating a constellation of symptoms to establish a diagnosis. However, these criteria fail to provide specifics regarding an individual's disorder or precise targets for treatment. The National Institute of Mental Health proposal of the Research Domain Criteria (RDoC) (Insel et al., 2010) intended to remedy this by identifying biologically based transdiagnostic mechanisms to develop more targeted and effective treatments. One behavioral process included within the RDoC framework is delay discounting (Levitt et al., 2022) (DD), the devaluation of a reward as a function of the delay to receipt.

The DD rate is a measure of the temporal window, the time horizon through which an individual considers and integrates reinforcement. Individuals with a constricted temporal window (higher rate of DD) will be more likely to value brief, intense reinforcement, such as alcohol or other drugs (Kwako et al., 2018). In contrast, individuals with a broader temporal window will be more likely to value rewards that accrue over a longer duration, such as education and prosocial relationships. The DD rate reflects an individual's preference for immediate rewards at the expense of greater rewards in the future and quantifies the balance between neural executive and impulsive systems (McClure et al., 2004; McClure & Bickel, 2014). An excessive preference for immediate rewards has been identified in relation to many aspects of AUD, including differentiating dependent individuals from controls (Bobova et al., 2009; Mitchell et al., 2005; Petry, 2001), the severity of use (MacKillop et al., 2010; Vuchinich & Simpson, 1998), polysubstance use (Moallem & Ray, 2012; Moody et al., 2015), relapse risk (Turner et al., 2021), and psychiatric comorbidities (Dom et al., 2006). Concordant findings among other substance classes and across psychopathologies highlight DD as a key undergirding mechanism in substance use disorders (SUDs) and a trans-disease process (Bickel et al., 2012, 2019).

Given the centrality of DD to SUDs, interventions targeting DD are an active area of research. In addition to modulating discounting rates, interventions targeting DD have demonstrated concomitant changes in a variety of reinforcers. Episodic future thinking (EFT), a narrative intervention which shifts attention toward positive future outcomes, has been shown to decrease rates of DD (Craft et al., 2020; Daniel et al., 2013; Snider et al., 2016; Stein et al., 2016, 2018), as well as decrease demand for alcohol (Bulley & Gullo, 2017; Snider et al., 2016), tobacco (Stein et al., 2016), cocaine (Snider et al., 2021) and fast foods (Sze et al., 2017). EFT is proposed to work by shifting neural focus toward distal outcomes, thereby strengthening the engagement of executive regions of the brain involved in planning and long-term goal setting (Schacter et al., 2017). In contrast, narrative interventions involving sudden negative outcomes, such as abrupt economic losses due to loss of employment or experiencing a hurricane (i.e., economic scarcity) have been shown to increase DD rates (i.e., greater preference for immediate reinforcement) (Bickel, Wilson, et al., 2016; Craft et al., 2021) and increase demand for reinforcers such as cocaine (Snider et al., 2021) and fast foods (Snider et al., 2020). This duality is a demonstration of the theoretical validity of DD.

In the context of the literature highlighting the potential therapeutic efficacy of narrative interventions to improve behavioral health, an unresolved empirical issue remains: for whom are these interventions likely to be most effective? Who is less likely to receive a benefit from this type of intervention? One tool to investigate these questions is the phenomenon of rate dependence. Rate dependence refers to a systematic relationship between the response level observed in a system at baseline and the response level following an intervention. Rate dependence as a behavioral phenomenon has been well characterized in pharmacological investigations of reinforcement (Sanger & Blackman, 1976). A few studies have explored the potential rate-dependent effects on DD rates in addictive disorders. A re-analysis of DD rates among individuals receiving treatment for SUDs, including tobacco, opioids, and stimulants, reported that DD rates changed in a rate-dependent fashion among those receiving highly efficacious treatment or working memory training (Bickel et al., 2014). Rate-dependent effects on DD were not observed for less efficacious treatments or the working memory training control task. Additionally, an investigation of working memory training on the effects of EFT reported a rate-dependent effect of EFT on DD in the active trained group (Snider et al., 2018). This rate-dependent effect was not observed in the working memory sham control group.

To the best of our knowledge, rate-dependent effects have not been previously investigated in DD with EFT alone or with a scarcity narrative. In this study, we conducted a three-week longitudinal investigation of the effects of two narrative interventions (EFT and scarcity narratives) on DD and demand for alcohol in individuals at high- or low-risk for AUD. Consistent with prior studies, we hypothesized that narrative interventions would modulate DD and demand (i.e., EFT would decrease discounting and alcohol demand; scarcity would increase discounting and demand). Moreover, we hypothesized that these narrative interventions would demonstrate a rate-dependent effect on DD.

MATERIALS AND METHODS

Participants for this longitudinal online study were recruited from the Amazon Mechanical Turk (MTurk; www.mturk.com) website.

MTurk is a crowdsourcing platform that allows the hosting of human intelligence tasks (HITs), which participants can qualify for and complete for monetary compensation. Potential participants were eligible for this study if they: (1) lived in the United States; (2) had at least a 90% approval rating on prior completed HITs; (3) were willing to participate in two follow-up surveys; (4) indicated alcohol use in the last 12 months; and (5) reported high-risk or low-risk alcohol use. Alcohol use risk was determined by criteria previously published by Mellis et al. (2017). Alcohol use qualified as high-risk if a participant scored ≥ 10 on the Alcohol Use Disorders Identification Test (AUDIT; Saunders et al., 1993) and qualified as low-risk if a participant scored ≤ 7 on the AUDIT. Individuals with an AUDIT score of 8 or 9 were not eligible for this study. This was a 3-survey longitudinal study conducted over a 3-week span, with 1 survey per week. Participants were paid $2.50 for completing the first survey, $3.50 for completing the second, $4.50 for completing the third survey, and paid a $2.50 bonus for completing all three surveys. Data quality is a concern on online data collection platforms due to potential inattentive or random responding, as well as automated response methods (i.e., bots; Chmielewski & Kucker, 2020; Mellis & Bickel, 2020; Stokel-Walker, 2018), and investigations have demonstrated that excluding data from individuals who fail attention check questions or provide nonsystematic delay discounting can improve data quality (Craft et al., 2022; Yeh et al., 2022). Thus, participants were required to pass two attention check questions and meet the criteria for systematic DD (Johnson & Bickel, 2008) in the baseline survey to be eligible to participate in the week 2 and week 3 surveys. We expected that individuals reporting more severe alcohol use would be more likely to fail data quality checks and less likely to return in subsequent weeks. Thus, we over-recruited from the high-risk drinking group by a factor of 3:1. Figure 1 displays the consort diagram of participant drop-out. In total, 696 individuals completed the baseline survey, of which 360 were eligible to participate in the two follow-up surveys. In week 2, 218 individuals returned, for an attrition rate of 39.4%. In week 3, 165 individuals returned, for an attrition rate of 24.3% from week 2 to week 3 and an overall attrition rate of 54.3%.

Measures

Demographics

Demographic data including age, gender, race, ethnicity, annual household income, and level of education were collected.

Alcohol use

Participants completed the AUDIT (Saunders et al., 1993). Levels of risky alcohol use are assessed across 10 items with a score ranging from 0 to 40, with higher scores indicating a higher risk of harmful use.

Delay discounting

DD rates for hypothetical $100 and $1000 rewards were measured using an adjusting amount task (Du et al., 2002). At the start

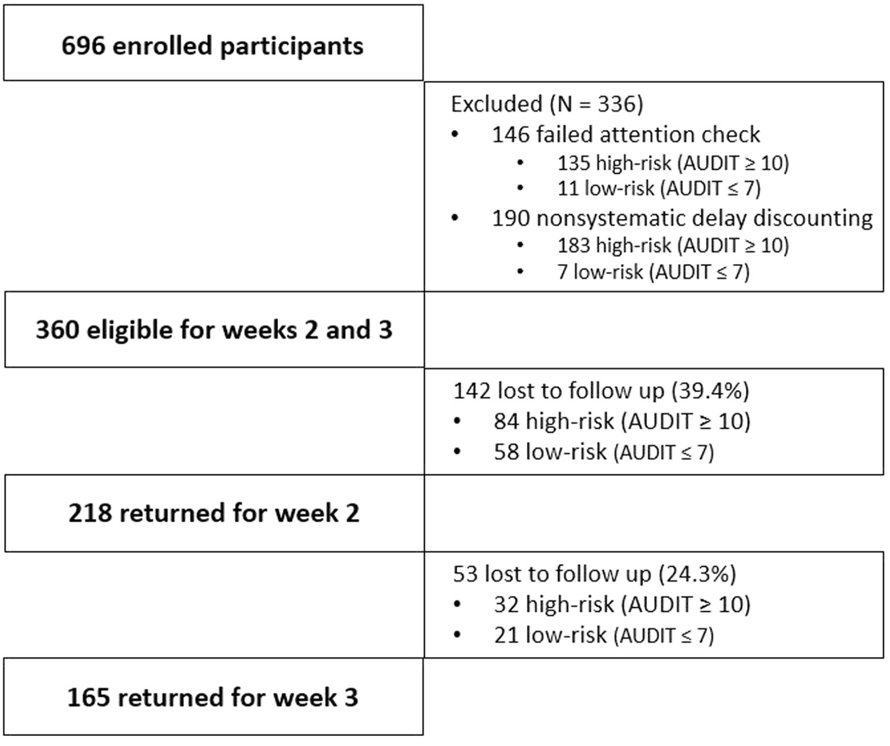

FIGURE 1 Consort diagram of participant flow.

of the task, participants chose between a smaller, immediately available reward ($50 or $500) or a larger reward available after a delay ($100 or $1000). The smaller amount was then titrated up or down, based on prior choices, across successive trials until reaching an indifference amount. The indifference amount represents the point at which the value of the immediate and delayed rewards are subjectively equal. Indifference amounts were determined for 7 delays (1 day, 1 week, 1 month, 3 months, 1 year, 5 years, 25 years) and fit to a hyperbolic model to calculate an individual's *k* value, or discount rate (Mazur, 1987). All discount rates were natural log transformed to stabilize the variance and reduce positive skew. Normality was assessed via visual interpretation of the data.

Alcohol breakpoint demand task

Hypothetical demand for alcohol was measured using a single-item task to assess the alcohol demand breakpoint (i.e., the maximum price paid for a single alcoholic beverage) (Athamneh et al., 2019). Specifically, a standard-sized alcoholic beverage was defined to participants as "12 fl oz of regular beer/8-9 fl oz of malt liquor/5 fl oz of wine /1.5 fl oz of distilled spirits" and participants were then asked "What is the maximum price you would be willing to pay for one standard-sized alcoholic beverage received now?"

Narrative interventions

Episodic future thinking (EFT)

Participants created episodic cues using previously reported methods (Snider et al., 2016). Briefly, participants generated cues by describing detailed, positive events that could occur at distinct time points in the future. Cues were generated for 7 time points: 1 day, 1 week, 1 month, 3 months, 1 year, 5 years, and 25 years. Episodic future cues were presented during the delay discounting task (1 cue per trial, matched to delay) and alcohol breakpoint demand task (1 randomly selected cue). Participants were instructed to read and think about their future events as if they were experiencing them while making their task responses.

Scarcity hurricane narrative

Participants were presented with an experimenter-generated narrative of experiencing the effects of a hurricane. The narrative used is as previously described (Craft et al., 2021; Snider et al., 2020). The hurricane narrative was presented at the start of the delay discounting tasks and alcohol breakpoint demand task, and participants were instructed to read it and make their responses as if they were currently experiencing this event.

Procedures

Baseline

Participants completed the delay discounting tasks for $100 and $1000 (order randomized), the alcohol breakpoint demand task, and a demographic questionnaire.

Week 2

Participants were randomly assigned to one of two narrative intervention groups, EFT or scarcity. Participants in the EFT group generated cues and then completed delay discounting tasks for $100 and $1000 (order randomized) and the alcohol breakpoint demand task with their cues presented during the tasks. Participants in the scarcity group read the hurricane narrative and then completed delay discounting tasks for $100 and $1000 (order randomized) and the alcohol breakpoint demand task.

Week 3

Participants were assigned to the opposite narrative intervention group as the prior week and completed the same procedures described in week 2.

Statistical analysis

Demographic characteristics were compared between the high- and low-risk drinking groups using *t*-test and Chi-square test as appropriate. An unpaired *t*-test was used to compare DD rates and a Mann–Whitney nonparametric test was used to compare alcohol demand between the high- and low-risk groups. A Mann–Whitney test was used for alcohol demand because these data were not normally distributed and included extreme outliers, even after the application of square-root and logarithmic transformations. A within-subject repeated measures (mixed model) one-way analysis of variance (ANOVA) approach was used to compare the effects of narrative interventions on DD and alcohol demand. Post hoc comparisons were made using Tukey's method and reported as mean difference and 95% confidence intervals (CI). All analyses were performed separately for individuals in the high- and low-risk groups. Counterbalanced data was collapsed within groups for all analyses.

A binary logistic regression model was used to understand the relationship between baseline DD rate and likelihood of attrition from baseline session to week 2 of the study. Attrition status (attriting or returning) was the dependent variable, and DD rate was the independent variable. The DD rate where a participant has equal odds of attriting or returning was determined as −1 * the intercept, that is, the value of DD when the regression model equals 0. This value of DD can be converted to the effective delay 50% (ED50), representing the delay at which a reinforcer loses 50% subjective value. This conversion is ED50 = 1/*k*.

Oldham's correlation (Oldham, 1962) was used to probe for the presence of a rate-dependent effect of narrative intervention on DD rates. Oldham's correlation is

$$\mathrm{Corr}\left((x-y),\frac{(x+y)}{2}\right)=\frac{S^2x-S^2y}{\sqrt{\left(S^2x+S^2y\right)^2-4r^2xyS^2xS^2y}}$$

where *x* represents the baseline measure, *y* is the post-intervention measure, s^2_x and s^2_y are the variances of *x* and *y*, respectively, and r_{xy} is the Pearson's correlation of *x* and *y*. Simply, Oldham's correlation is the correlation between the change of *x* and the average of *x* and *y*. Based on prior findings, Oldham's correlations of >0.3 or <−0.3 demonstrate a moderate effect size and indicate the presence of a rate-dependent effect (Bickel, Quisenberry, & Snider, 2016; Browne et al., 2010). Data for this study were analyzed and graphed in Graphpad Prism Version 9.4.1 (Graphpad Software) and R version 4.0.4 (R Core Team, 2021).

RESULTS

Demographic characteristics for the total sample and high- and low-risk drinking groups are presented in Table 1. The full sample reported an average age of 36.27 (±10.55) years, 40% female, 78.2% White, and 90.3% Non-Hispanic. Statistically significant differences in several demographic characteristics were observed upon stratifying the sample by the drinking-risk group. Relative to the low-risk group, the high-risk group was significantly older (p = 0.033), reported a lower proportion of female gender (p = 0.005), and higher level of education (p = 0.022). Statistically significant differences were not observed between the groups for race, ethnicity, or annual household income.

Delay discounting

Figure 2 compares DD rates between the high-risk and low-risk groups for the \$100 and \$1000 tasks. DD rates were not significantly different between the groups for the \$100 task ($t(163) = 1.27$; $p = 0.207$; Cohen's $d = 0.20$) but were significantly different for the \$1000 task ($t(163) = 2.62$; $p = 0.009$; $d = 0.42$), suggesting evidence of the second type of magnitude effect (Mellis et al., 2017).

Repeated measures one-way ANOVA was used to compare discounting rates within-groups among the narrative conditions (EFT and scarcity; Figure 2). Significant intervention effects were identified for the \$1000 task in the high-risk group, $F(2,184) = 18.58$; $p < 0.001$; Cohen's $f = 0.43$, with EFT (−1.243; 95%CI: −2.256, −0.230) significantly reduced, while scarcity (1.337; 95%CI: 0.351, 2.323) significantly increased DD relative to baseline. Significant intervention effects were identified for the \$1000 task in the low-risk group, $F(2, 118) = 43.59$; $p < 0.001$; $f = 0.77$, with EFT (−0.931; 95%CI: −1.522, −0.3388) significantly reduced, while scarcity significantly increased DD relative to baseline (1.861; 95% 1.163, 2.558). Similar effects were observed for the \$100 task in both the high- and low-risk groups (see Data S1 and Table S1).

Alcohol demand

A Mann–Whitney *U* test was used to compare baseline alcohol demand between the groups. At baseline, the high-risk group had a statistically significant higher breakpoint price than the low-risk group (Mann–Whitney $U = 2626$, $n_1 = 72$, $n_2 = 93$, $p = 0.017$ two-tailed) (see Figure S1).

Repeated measures one-way ANOVA was used to compare breakpoint alcohol demand within group among the narrative conditions. In the high-risk group, significant effects on demand were not observed, $F(2, 155) = 0.036$; $p = 0.94$; $f = 0$, with alcohol demand not significantly different in the EFT condition (−0.538; 95%CI: −19.90, 18.83) or scarcity condition (1.289; 95%CI: −15.53, 18.11) relative to baseline. Similarly, in the low-risk group, significant effects on demand were not observed, $F(1, 74) = 0.177$; $p = 0.73$; $f = 0$, alcohol demand was not significantly different in the EFT condition (0.842; 95%CI: −2.718, 4.401) or scarcity condition (0.611; 95%CI −3.897, 5.118) relative to baseline (See Figure S1).

Rate-dependent effects of narrative interventions

Oldham's correlation of $|r_{Oldham}| \geq 0.3$ was used to determine the presence of a rate-dependent effect of narrative interventions on DD rates. In the high-risk group, rate-dependent effects of EFT ($|r_{Oldham}| = 0.44$; $p < 0.001$) and scarcity ($|r_{Oldham}| = 0.37$; $p < 0.001$) were observed for the \$1000 task. In the low-risk drinking group, the rate-dependent effect of EFT ($|r_{Oldham}| = 0.55$; $p < 0.001$) and scarcity ($|r_{Oldham}| = 0.45$; $p < 0.001$) were observed for the \$1000 task. Similar effects were observed for the \$100 task (see Table S2). Figure 3 shows the proportion of change in discounting after EFT or scarcity narrative intervention as a function of the baseline DD rate.

Delay discounting and attrition status

Binary logistic regression was used to understand the relationship between baseline DD rate and the likelihood of attrition from baseline to week 2 of the study. Attrition status (attriting or returning) was the dependent variable, and DD rate and drinking risk were the independent variables. No statistically significant differences in demographics were observed based upon attrition status (see Table S3).

TABLE 1 Sample characteristics ($N = 165$).

Characteristics	Total $N = 165$	High-risk $N = 93$	Low-risk $N = 72$	p Value[a]
Age—years[b]	36.27 (10.55)	34.73 (9.13)	38.26 (11.92)	0.033
Gender[c]				
Female	66 (40.0)	28 (30.1)	38 (52.8)	0.005
Male	99 (60.0)	65 (69.9)	34 (47.2)	
Race[c]				
American Indian/Alaskan Native	4 (2.4)	3 (3.2)	1 (1.4)	0.544
Asian	18 (10.9)	12 (12.9)	6 (8.3)	
Black or African American	12 (7.3)	7 (7.5)	5 (6.9)	
White	129 (78.2)	71 (76.3)	58 (80.6)	
Other	1 (0.6)	0 (0.0)	1 (1.4)	
Refuse to answer	1 (0.6)	0 (0.0)	1 (1.4)	
Ethnicity[c]				
Hispanic	15 (9.1)	9 (9.7)	6 (8.3)	0.504
Non-Hispanic	149 (90.3)	84 (90.3)	65 (90.3)	
Refuse to answer	1 (0.6)	0 (0.0)	1 (1.4)	
Education level[c]				
High school diploma or GED	31 (18.8)	14 (15.1)	17 (23.6)	0.022
Associate degree	21 (12.7)	12 (12.9)	9 (12.5)	
Bachelor's degree	83 (50.3)	42 (45.2)	41 (56.9)	
Master's degree	26 (15.8)	22 (23.6)	4 (5.6)	
Professional degree (PhD, MD, JD, DDS)	3 (1.8)	3 (3.2)	0 (0.0)	
Refuse to answer	1 (0.6)	0 (0.0)	1 (1.4)	
Annual Income[c]				
<$30,000	29 (17.5)	16 (17.2)	13 (18.1)	0.871
$30,000 to $49,999	43 (26.1)	24 (25.8)	19 (26.4)	
$50,000 to $69,999	25 (15.2)	16 (17.2)	9 (12.5)	
$70,000 to $89,999	26 (15.8)	13 (14.0)	13 (18.1)	
$90,000 or greater	40 (24.3)	24 (25.8)	16 (22.2)	
Refuse to answer	2 (1.2)	0 (0.0)	2 (2.8)	
AUDIT score	12.62 (9.68)	19.72 (6.88)	3.44 (1.91)	<0.001
ln(k)[d] $100	−5.28 (2.10)	−5.10 (2.33)	−5.52 (1.75)	0.239
ln(k)[d] $1000	−6.15 (2.29)	−5.74 (2.62)	−6.67 (1.65)	0.014
Alcohol breakpoint[b]	15.85 (56.55)	23.25 (74.43)	6.31 (6.77)	0.0169

Abbreviation: AUDIT, Alcohol Use Disorder Identification Test.

[a]p-Value represents comparison between high- and low-risk alcohol groups.

[b]Mean.

[c]Frequency.

[d]Delay discounting rate (k).

A significant effect of DD rate was observed (OR: 0.89; 95%CI: 0.81, 0.99; $p = 0.011$), while drinking group was not significant (OR: 0.86; 95% CI: 0.22, 3.36; $p = 0.82$). A significant interaction between the drinking group and the discounting rate was not observed (OR: 0.87; 95% CI: 0.79, 1.22; $p = 0.86$), suggesting that individuals with higher DD were less likely to return to the second week of the study, regardless of drinking group status. Further, a participant with an ln(k) of −1.94 (ED50 of 6.96 days) or greater had at least a 50% probability of attriting.

DISCUSSION

In this study, we examined the effects of two narrative interventions (EFT and scarcity) on DD and alcohol demand in a sample of individuals reporting high- and low-risk alcohol consumption behaviors. Consistent with our hypotheses and prior findings, the EFT intervention reduced DD while the scarcity intervention increased DD. A novel finding of this study was the observation of a rate-dependent effect on discounting rates of both EFT and scarcity interventions.

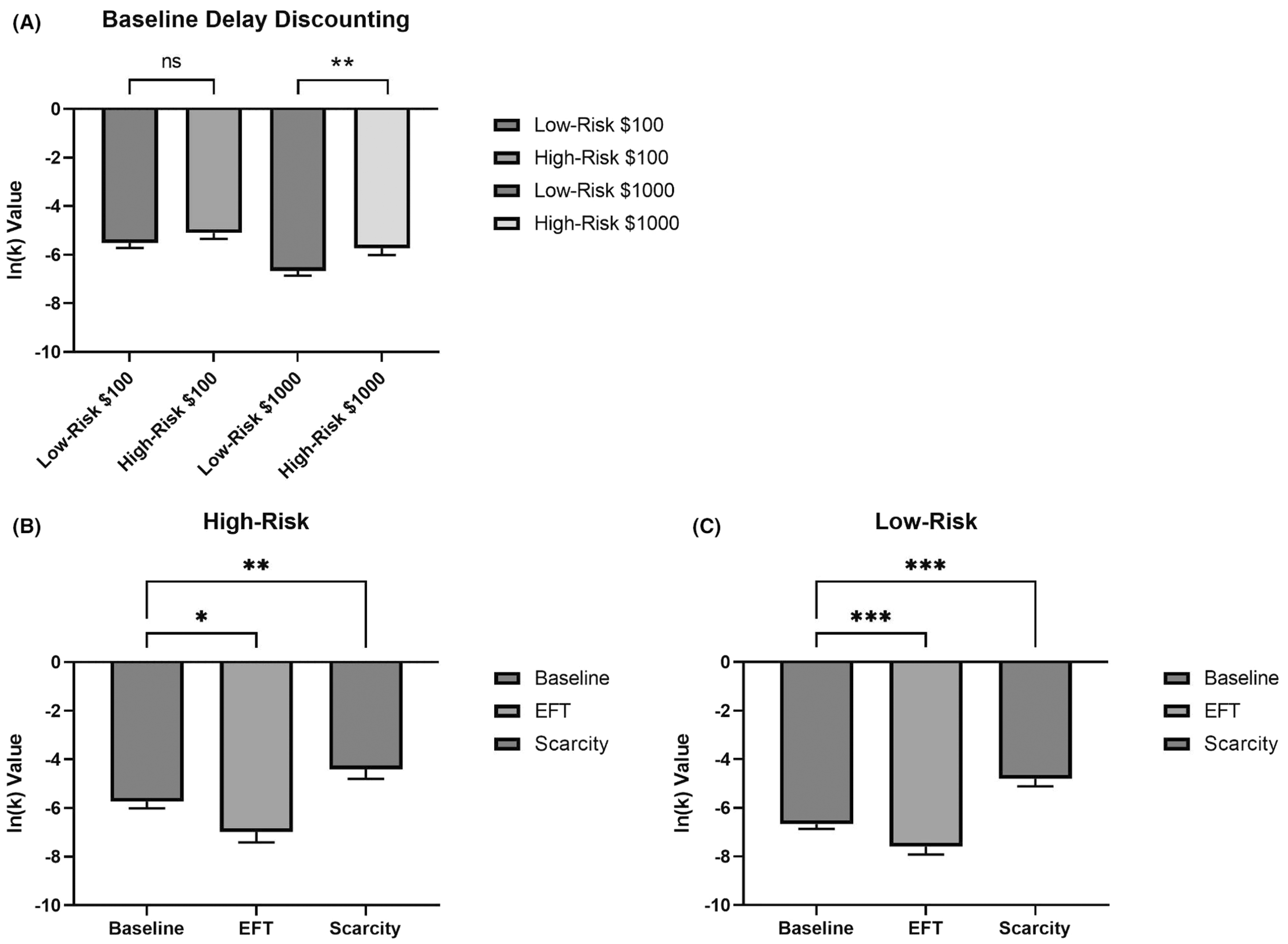

FIGURE 2 Comparison of delay discounting rates; (A) Mean (±SEM) $100 and $1000 discounting rates for high- and low-risk alcohol use groups. Differences in $1000 delay discounting relative to baseline after episodic future thinking (EFT) and scarcity narrative interventions for (B) High-risk and (C) low-risk alcohol use groups. ns, nonsignificant relationship; SEM, standard error of the mean. * indicates *p* value <0.03, ** indicates *p* value <0.002, *** indicates *p* value <0.001.

Contrary to our hypotheses, the narrative interventions did not modulate hypothetical demand for alcohol, as measured by a single-item breakpoint task. Lastly, DD rates significantly predict attrition in this longitudinal study. We expand on these findings and discuss their relevance below.

This study demonstrated a rate-dependent effect of EFT and scarcity narrative on DD rates in individuals reporting both high- and low-risk alcohol consumption. Our findings are consistent with prior reports of rate-dependent effects in nonclinical and clinical populations (Bickel et al., 2014; Bickel, Quisenberry, & Snider, 2016; Robbins & Sahakian, 1979). For example, Robbins and Sahakian (1979) found the rate-dependent effects of amphetamines in healthy adults, children, and children with hyperactivity. Furthermore, our results are consistent with studies of pharmacological and nonpharmacological interventions for individuals with SUD. Specifically, a rate-dependent effect on neural activity was shown following transcranial magnetic stimulation in individuals with AUD (Herremans et al., 2016). Effects consistent with rate dependence were seen with EFT among individuals with chronic pain, such that higher pain at baseline showed the largest reduction post-intervention (Craft et al., 2020). Notably, a re-analysis of substance use intervention studies showed rate-dependent changes in DD. Further, this re-analysis demonstrated that the interventions (i.e., working memory training, buprenorphine combined with counseling, and buprenorphine combined with contingency management) producing the largest gains in abstinence also had the largest reductions in discounting rates (Bickel et al., 2014). Importantly, this suggests that rate-dependent changes in DD may be a quantitative signature of treatment efficacy (Bickel et al., 2014). Taken together, our present finding of a rate-dependent effect of EFT suggests at least two relevant factors for treatment: (1) The evidence of the quantitative signature provides support for EFT as an intervention to improve health behaviors and (2) the presence of rate dependence can inform the development of targeted, personalized medicine approaches. For example, a provider of SUD treatment could include an assessment of discounting rate during intake to identify individuals who would benefit most from EFT. Individuals with lower discounting

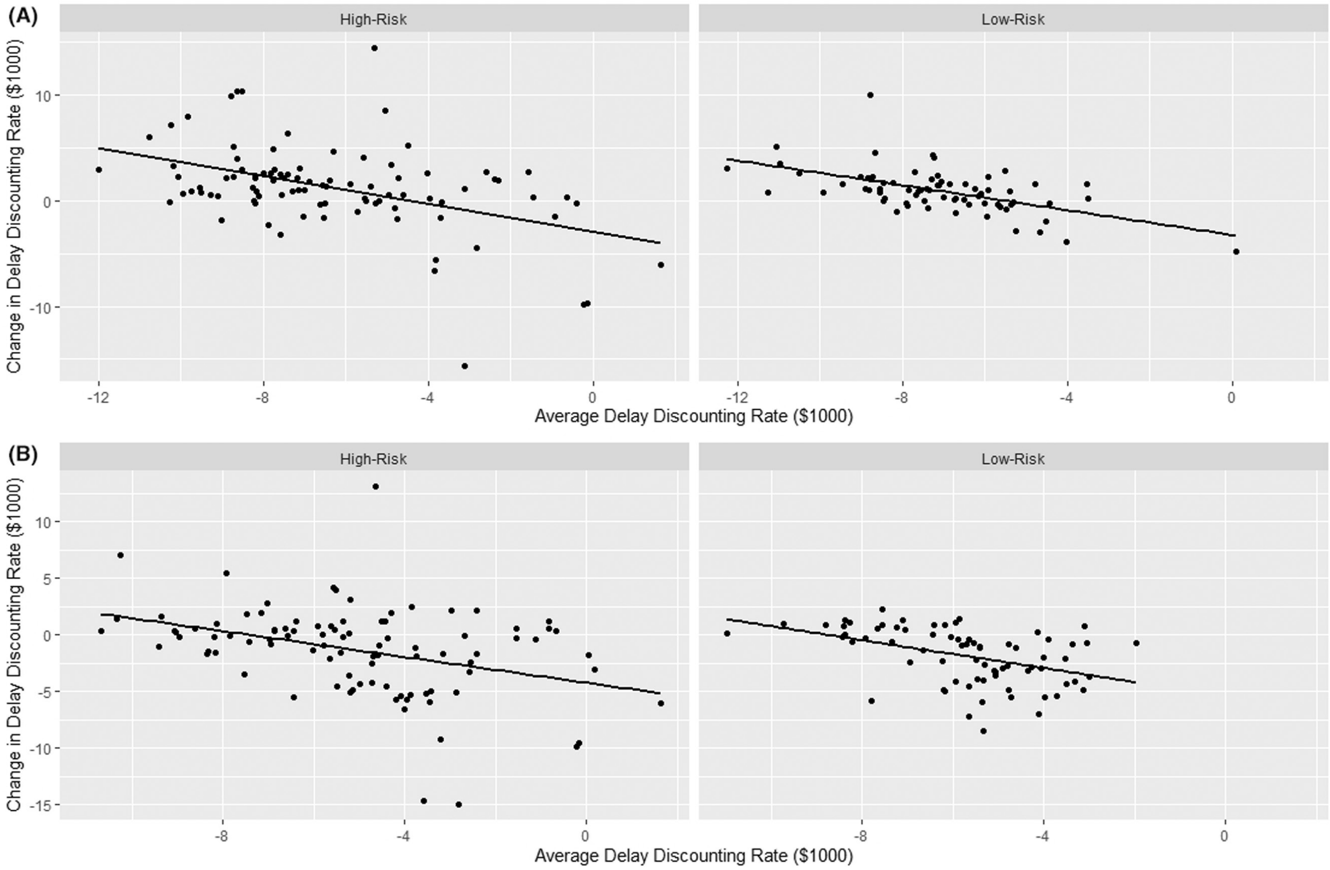

FIGURE 3 Rate-dependent effects of narrative interventions on delay discounting for $1000. Change in delay discounting rate (pre-post) as a function of average discounting rate after (A) episodic future thinking (EFT) for the high-risk and low-risk groups and (B) scarcity for the high-risk and low-risk groups.

rates may be already amenable to treatment approaches requiring more future focus and planning. In comparison, individuals with higher discounting rates could benefit from engaging with EFT to shift focus toward future outcomes.

In this study, the EFT and scarcity narrative interventions significantly changed DD rates in both the high- and low-risk alcohol use groups. These results are consistent with a body of literature that reports changes in DD following narrative interventions. That is, decreases in DD rates following EFT (Bromberg et al., 2017; Craft et al., 2020; Daniel et al., 2015; Mellis et al., 2019; Peters & Büchel, 2010; Snider et al., 2016, 2021; Stein et al., 2016, 2017, 2018; Sze et al., 2017) and increases in DD rates following an economic scarcity narrative (Craft et al., 2021; Mellis, Snider, & Bickel, 2018; Snider et al., 2020; Stein et al., 2021). The present study did not see an effect of the narrative interventions on demand, as assessed by a single-item breakpoint question. These results are inconsistent with reports of changes in demand or consumption produced by both interventions, EFT (Athamneh et al., 2021; Snider et al., 2021; Stein et al., 2016, 2018; Sze et al., 2017; Voss et al., 2021) and economic scarcity (Mellis, Athamneh, et al., 2018; Snider et al., 2020). The lack of an observed effect on demand could be explained by the finding of a systematic review, which demonstrated that demand indices (e.g., intensity of demand) other than the one used in this study were more sensitive (Zvorsky et al., 2019).

Another interesting finding from the present study is that individuals with higher discounting rates, independent of alcohol risk group, were less likely to return to the next study session. Here, the ED50 value where individuals had at least a 50% probability of attrition was 6.96 days, suggesting that individuals who are thinking ahead less than a week in time were less likely to return for the second session a week later. This finding highlights the potential utility of integrating DD into experimental design and sampling of longitudinal studies. Two such examples may be identifying individuals who are more likely to (1) be retained in the study thereby allowing more efficient study resource management and (2) drop out and providing them additional engagement and support to facilitate study participation. In the context of an EFT intervention, these additional engagement activities could increase the number of individuals who would be most likely to receive the greatest benefit from these treatments. Although the present study is not evaluating a treatment's efficacy, the results are consistent with recent reports of individuals with higher discounting rates having poorer retention in treatment studies (Barreno et al., 2019; Peters et al., 2013; Stevens et al., 2015).

We acknowledge several potential limitations in this study. First, given our findings regarding DD rate and attrition status, our results may represent a specific subset of individuals reporting risky alcohol use (i.e., those with low discounting rates). Second, we acknowledge the large proportion (~50%) excluded from participating in the two follow-up surveys due to failing attention checks or for nonsystematic delay discounting. However, previous work has demonstrated that failing attention checks or nonsystematic criteria is associated with random or inattentive responding on MTurk, meriting data for exclusion (Craft et al., 2022; Yeh et al., 2022). Third, rate dependence may be modified by demographic variables; however, these were not included in the analysis since due to the within-subject design and the paucity in literature that suggests demographic variables may modify the rate dependence. Lastly, the single-item task used to assess alcohol demand precludes analysis of alcohol demand indices other than breakpoint (e.g, intensity or elasticity of demand) and limits the interpretability of the findings we reported.

CONCLUSION

Rate-dependent effects of EFT and scarcity narratives on DD rates were demonstrated in this longitudinal study of individuals reporting high- or low-risk alcohol use. This finding sheds light on the mechanistic underpinnings of narrative interventions and can help inform implementation practices; that is, individuals with higher DD rates are more likely to receive greater benefits from this type of intervention.

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CONFLICT OF INTEREST

Although the following activities/relationships do not create a conflict of interest pertaining to this 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 Ria Health, is a consultant for Alkermes, Inc., and works on a project supported by Indivior, Inc. William H. Craft, Candice L. Dwyer, Devin C. Tomlinson, Yu-Hua Yeh, and Allison N. Tegge have no disclosures to report.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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