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Delay discounting and substance use treatment outcomes: A systematic review focused on treatment outcomes and discounting methodology

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ABSTRACT

Introduction: Delay discounting—the tendency to choose small, immediate rewards over larger, delayed rewards—is robustly associated with substance use. Delay discounting may present challenges in treatment for substance use disorders, as individuals with elevated discounting may struggle to wait for the long-term rewards that come from abstinence, which may yield poorer treatment outcomes. However, evidence on the role of discounting in treatment outcomes has been inconsistent. The study conducted a systematic review of the literature to characterize the prospective effects of delay discounting measured pre-treatment on substance use treatment outcomes, with a focus on characterizing findings across: 1) type of treatment outcome and 2) methodology used to assess and characterize discounting.

Method: A systematic literature search identified $N = 17$ studies that examined the association between delay discounting at treatment entry (pre-treatment) and substance use treatment outcomes. Findings were reported across the following substance use treatment outcomes: abstinence, relapse, use frequency and related problems, and treatment adherence. Findings regarding discounting methodology were reported by type of discounting measure (adjusting choice task, fixed choice task, or experiential task) and parameter used to characterize discounting (k, log transformed k (lnk), and area under the curve).

Results: Delay discounting at treatment entry was not consistently associated with substance use treatment outcomes when examined across all studies overall (47 %) or by treatment outcome (0–40 % for most outcomes). The majority of studies (64 %) that used an adjusting choice, computer-based task reported a significant association between discounting and treatment outcomes, whereas few studies that used a fixed choice or experiential task reported significant associations with treatment outcomes (0–25 %). Most studies (71 %) that used the lnk parameter to characterize discounting reported significant associations between discounting and a range of treatment outcomes. In contrast, few studies that used k or AUC (25–33 %) reported significant associations between discounting and treatment outcomes.

Conclusion: When examined overall and by treatment outcome, evidence did not consistently indicate that delay discounting was prospectively associated with substance use treatment outcomes. However, delay discounting at treatment entry was more commonly associated with a variety of poorer treatment outcomes when researchers used more fine-grained methods to characterize discounting.

1. Introduction

Research has identified delay discounting as a robust predictor of substance use behavior (Critchfield & Kollins, 2001; Kollins, 2003; Odum et al., 2000). Delay discounting characterizes the degree to which individuals choose smaller, more immediate rewards over larger distal rewards (Bickel & Vuchinich, 2000; Mazur, 1987). Applied to substance use, individuals with elevated delay discounting may choose the smaller, immediate reward of using a substance over delayed future rewards, such as overall health, academic/work performance, or social relationships (MacKillop et al., 2011). An extensive body of evidence has emerged over the last 20 years identifying elevated delay discounting as a robust predictor of risky substance use behavior. For example, in both observational and experimental studies, elevated delay discounting has

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been consistently found to be associated with use of a variety of substances, including alcohol (Petry, 2012), cocaine (Bickel et al., 2011), opioids (Karakula et al., 2016), cannabis (Johnson & Bruner, 2012), and nicotine (Bickel et al., 1999). Furthermore, a recent meta-analysis revealed that steep discounting was associated with continuous measures of substance use (e.g., quantity and frequency of use) with a small effect size ($r = 0.11$), and that effects were relatively consistent across substances/addictive behaviors (Amlung et al., 2017). Research has also indicated that delay discounting may be positively associated with severity of substance use–related problems ($r = 0.17$) (Amlung et al., 2017) and greater likelihood of developing a substance use disorder (MacKillop et al., 2011). Thus, evidence from observational studies has consistently identified elevated delay discounting as an important risk factor for substance use and for the development of substance use disorder.

Given the degree to which delay discounting is a risk factor for substance use and related problems, elevated delay discounting may also present challenges in the treatment for substance use disorders. Individuals with elevated delay discounting may have greater difficulty in choosing the delayed rewards that may emerge from longer-term abstinence, such as improved physical, social, and economic circumstances, compared to the short-term rewards of using a substance. As a result, individuals with elevated delay discounting may have higher rates of substance use during treatment and may be less likely to achieve and maintain abstinence (Loree et al., 2015). However, in comparison to the voluminous observational literature that has identified delay discounting as a robust risk factor for substance use, less research has examined the effects of delay discounting on substance use treatment outcomes.

Among studies that have examined the role of discounting in substance use treatment outcomes, substantial variability exists across study foci and methodologies employed. Studies have varied across the types of treatment outcomes examined (e.g., abstinence, relapse, use frequency), sample characteristics (e.g., adolescents vs. adults), and methodologies used to measure discounting (e.g., adjusting vs fixed choice tasks), which may contribute to variability in reported outcomes. Accordingly, the findings reported across studies have been inconsistent. For example, several studies have reported that higher delay discounting at the start of treatment for nicotine, alcohol, cocaine, and opioid use disorder was associated with lower rates of abstinence, more days of substance use, and higher relapse rates (Peters et al., 2013; Sheffer et al., 2014; Stanger et al., 2012). However, other studies reported that elevated delay discounting at treatment entry for the same aforementioned substances was not significantly associated with treatment outcomes, including abstinence, days to relapse, and frequency of use (Murphy et al., 2012; Passetti et al., 2011; Peters et al., 2013; Yoon et al., 2007). Thus, when examined overall, findings in the literature are inconsistent and a thorough review of the available evidence is needed to synthesize the literature and identify potential patterns across studies that used common methodologies.

Thus far, one prior systematic review of the literature examined the effects of delay discounting on outcomes for tobacco cessation treatment and characterized findings across one potential point of variability in the literature, sample characteristics (e.g., adult, adolescent, vulnerable populations) (Syan et al., 2021). Findings overall indicated that that elevated delay discounting at treatment entry was associated with poorer tobacco cessation treatment outcomes among most studies reviewed. Findings were less consistent among samples comprising adolescents and special populations such as pregnant and postpartum females (Syan et al., 2021). While the review was useful in understanding the potential role of discounting in tobacco cessation treatment outcomes among individuals from various populations, to what degree the findings may align with studies of individuals in treatment for other substances (e.g., alcohol, opioids) is unclear. Furthermore, findings may vary by outcome examined (e.g., abstinence vs. use frequency), but the prior review did not characterize findings by treatment outcome.

In addition to the remaining questions regarding substances (besides nicotine) and treatment outcomes, whether the methodology used to characterize discounting may contribute to the variability in findings observed in the literature is also unclear. Discounting measures may vary in their degree of specificity and resolution to characterize discounting, which may impact studies' abilities to detect meaningful associations between discounting and treatment outcomes. For example, studies typically measure delay discounting with adjusting choice tasks, such as the delay discounting task (DDT), or with fixed choice tasks such as the Monetary Choice Questionnaire (MCQ) (further detailed in the methods section). Both the DDT and MCQ ask participants to choose between small rewards (money) available now vs. a larger amount of money available at a delay. However, adjusting choice tasks present choices that are adjusted based on the participant's prior response, whereas fixed choice tasks present the same choices to all participants. Adjusting delay discounting tasks may therefore have more specificity than a static fixed choice measure of discounting to characterize discounting for individuals (da Matta et al., 2012; Epstein et al., 2003; Hamilton et al., 2015; Jaroni et al., 2004). Some studies have also assessed discounting with an experiential discounting task (EDT), which incorporates probabilistic reasoning and asks participants to choose between smaller immediate rewards, and a chance to receive larger amounts of money at a delay. EDT measures of discounting evaluate choices at shorter delay intervals (seconds to minutes) relative to DDT and MCQ measures (weeks to years) and provide probabilistic choices for the delayed reward (e.g., chance to receive $5 in x time delay), instead of stable (non-probabilistic) delayed reward ($5 in x time delay) used in DDT and MCQ measures. The use of shorter time intervals and monetary values in EDT measures may have different predictive utility for treatment outcomes relative to DDTs, which may also contribute to variability in the literature.

In addition to the type of discounting measure, the type of parameter used to characterize discounting has also varied across studies in the literature, with some using the value k to indicate steepness of discounting, others using a log transformed k to account for typical distributional properties, and others using area under the curve to characterize discounting (further detailed in the methods section). Thus, potential variability may also result from differences in the discounting parameter used in analyses, which may have different degrees of specificity in quantifying discounting. However, no prior research has examined whether discounting methodology may influence findings when examining associations between discounting and treatment outcomes.

The purpose of the current study was to systematically review the literature to characterize the role of delay discounting measured pretreatment in substance use treatment outcomes, with a focus on delineating findings based on 1) type of treatment outcome and 2) methodology used to assess and characterize discounting. Secondarily, the study characterized the role of discounting in treatment outcomes by sample characteristics, type of substance use disorder, and type of treatment.

2. Methods

2.1. Literature search

The systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Review guidelines (PRISMA; Moher et al., 2009). Independent reviewers searched PubMed and Academic Search Complete (EBSCOHost) to identify relevant studies for inclusion. Reviewers used the following substance use terms: “substanc*”, “addiction”, “drugs, “tobacco”, “smok*”, “nicotine”, “opioid”, “opiate”, “cocaine”, “alcohol”, “cannabis”, or “marijuana.” Reviewers crossed all substance use terms with the following intervention terms: “intervention” or “treatment,” and discounting terms “impuls*,” “discount*,” and “delay discounting.”

Inclusion criteria for study eligibility were as follows: 1) assessed

delay discounting at treatment entry (pre-treatment initiation), 2) tested an intervention for substance use behavior/disorder, and 3) reported at least one substance use–related treatment outcome. Exclusion criteria for study eligibility were as follows: 1) published in a language other than English, 2) were not peer-reviewed journal articles, 3) previously retracted, and/or 4) reported outcomes not specific to substance use (e.g., psychological distress, quality of life). The search identified all relevant articles through June 16, 2021.

2.2. Study selection

Two independent reviewers conducted a parallel search process to determine alignment with inclusion/exclusion criteria. A third reviewer addressed discrepancies. Fig. 1 shows a PRISMA flow diagram depicting the search process. After eliminating duplicates, the search yielded a total of 5803 articles. A total of $N = 17$ articles met the eligibility criteria.

2.3. Risk of bias evaluation procedure

To assess risk of bias of the included studies, two independent reviewers used the modified Critical Appraisal and Data Extraction for Systematic Reviews of Prediction Modelling Studies (CHARMS-PF) checklist (Moons et al., 2014; Riley et al., 2019). The CHARMS-PF checklist is a measure designed specifically to assess risk of bias of intervention studies examining predictive and prognostic factors.

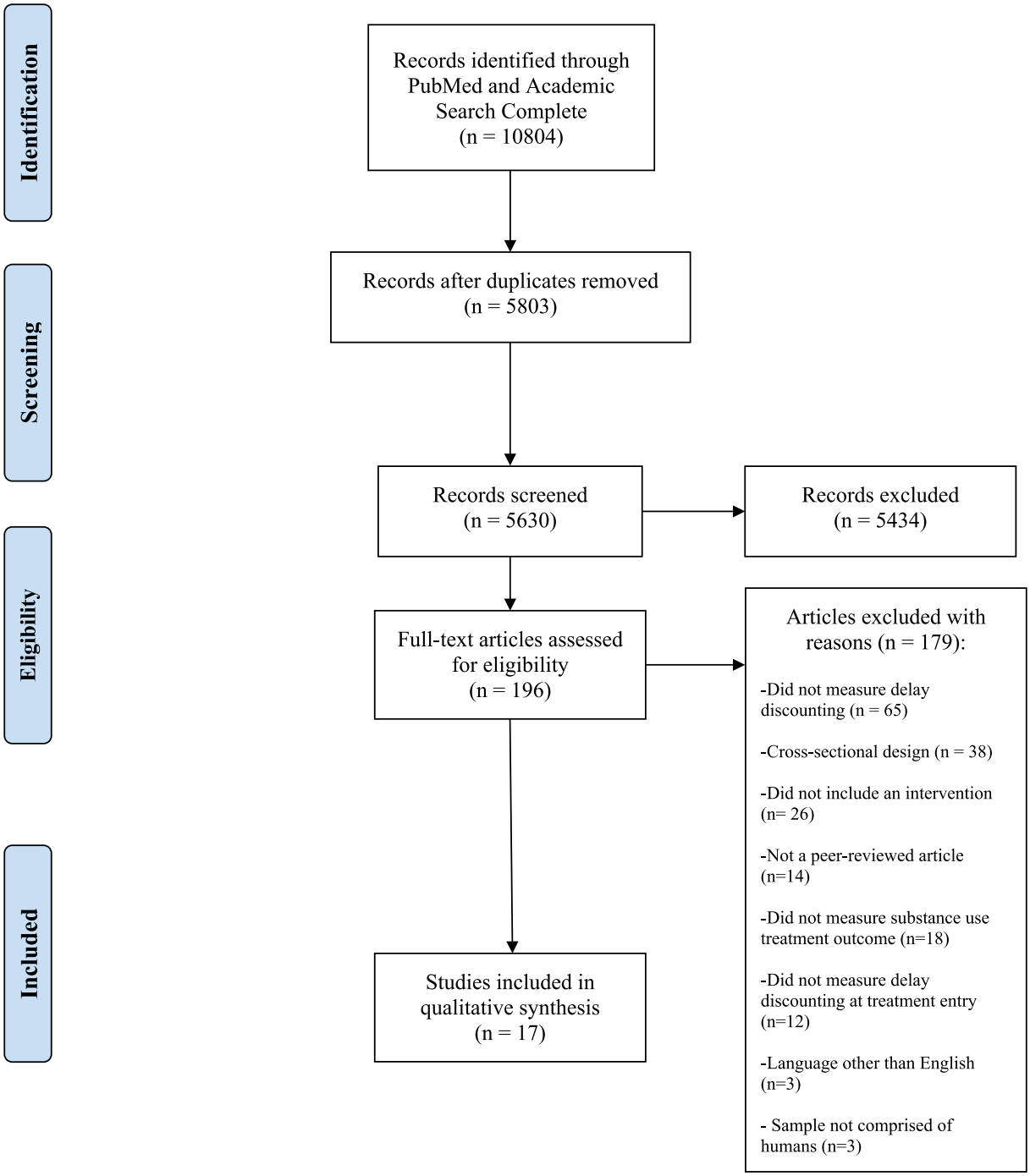

Fig. 1. PRISMA flow diagram.

Reviewers assessed studies on possible risk of bias across the following domains: data source, participants, outcomes, sample size, missing data, analyses, results, and interpretation. The reviewers calculated risk of bias scores by summing the number of points, with higher scores indicating higher risk of bias.

2.4. Discounting methodology

Studies typically use single-commodity discounting tasks with money as the commodity. In most studies, participants made choices between hypothetical amounts of reward; however, some studies provided participants with money corresponding to one of their choices to enhance the ecological validity of the task. Studies commonly measure discounting with three types of tasks: an adjusting delay discounting task (DDT), the fixed choice Monetary Choice Questionnaire (MCQ), or an experiential discounting task (EDT). Both the DDT and MCQ ask participants to choose between a series of options presenting a small amount of money available now vs. a larger amount of money available at a delay (e.g., Would you prefer $5 now or $25 in two weeks?). The MCQ presents a fixed set of choices to all participants and uses delays ranging from 1 to 187 days. In contrast, the DDT presents choices to participants adjusted based on their previous choices, and the specific timeframes and reward magnitudes are determined by the experimenter. Therefore, each task can vary in the amount of money used, the number of delays used, as well as the specific time delays used. Studies in the current review used money amounts of $10, $100, and $1000 and used between five and eight delay periods, ranging from 1 day to 25 years. Computer-administered EDTs ask participants to choose between smaller amounts of money available immediately, and a chance to receive larger amounts of money at a delay (e.g., Would you like 15 cents now or a 35 % chance to have 30 cents in 14 s). EDT measures of discounting evaluate choices at shorter delay interval periods relative to DDT and MCQ measures, provide real rewards based on participant choices instead of hypothetical rewards, and typically use smaller rewards. Despite the differences between DDT/MCQ and EDT measures, EDT studies were included in the review to report on their utility as predictors of treatment outcomes, consistent with the aim of the review.

Values representing k, lnk, and area under the curve (AUC) are most commonly used in the literature. The parameters of k and lnk quantify the steepness of the calculated hyperbolic discounting curve, and thus represent the subjective loss in value as a function of the delay. Higher values reflect higher or steeper rates of discounting (i.e., high k and lnk indicate the more frequent selection of smaller, sooner rewards). K is a score that represents the discounting rate. However, k values typically have positively skewed distributions and require logarithmic transformation for parametric analysis; thus, lnk values represent this logarithmic transformation and previous studies commonly used lnk values in analyses. The AUC is an atheoretical measure that quantifies the total area beneath the empirical discounting curve. AUC represents the subjective loss in value of delayed rewards; lower AUC values indicate steeper delay discounting (i.e., low AUC indicates more frequent selection of smaller, sooner rewards).

3. Results

3.1. Descriptive information

Table 1 presents details regarding study characteristics, methodology, and a summary of main findings. Table 2 displays participant characteristics and treatment conditions. Most studies (76 %; 13/17) had adult samples and four studies (24 %; 4/17) had adolescent samples. Studies focused on treatment for nicotine use in the form of cigarette smoking (65 %; 11/17), opioid use (12 %; 2/17), alcohol use (12 %; 2/17), or cannabis use (12 %; 2/17). Most studies used a biochemically verified measure of abstinence (59 % 10/17). Other outcomes included relapse (24 %; 4/17), use frequency and use-related problems (18 %; 3/17), and treatment adherence and dropout (18 %; 3/17). Most studies used the DDT (65 %; 11/17), whereas approximately one quarter used the MCQ (24 %; 4/17), and two used an EDT (12 %; 2/17). Studies used parameters of k (24 %; 4/17), lnk (41 %; 7/17), or AUC (35 %; 6/17) to characterize discounting.

Forty-seven percent (8/17) of the study samples were primarily White participants (>70 %), while 18 % (3/17) of the studies had >60 % representation of participants who identified as Black ($n = 2$) or from an unspecified racial or ethnic minority community ($n = 1$). Three studies (18 %; 3/17) did not report on the racial and ethnicity breakdown of their samples. Reporting of sex and gender was inconsistent across studies; however, most studies aligned with reporting of women and men. Thus, for the purpose of this article, the terms for gender (women/men) are used throughout. Most of the studies were conducted in the United States (82 %; 14/17).

3.2. Risk of bias evaluation

Table 1 presents the CHARMS-PF risk of bias score for each study. Independent reviewers rated 41 % (7/17) of the studies as having minimal risk of bias, 47 % (8/17) as having mild risk of bias, and 12 % (2/17) as having moderate risk of bias. The reviewers rated none of the studies as having a high risk of bias. Studies shared a consistent pattern in which they did not report a sample size justification (i.e., power calculation) and did not indicate whether their analytic models met modeling assumptions. Overall, findings from the risk of bias evaluation revealed minimal to mild evidence of reporting bias across most studies.

3.3. Results summary

When considered altogether, approximately half of studies (47 %; 8/17) reviewed reported that delay discounting at treatment entry was significantly associated with substance use treatment outcome(s) in some circumstances. Across studies, 29 % (5/17) reported entirely significant findings related to DD and treatment outcomes, 18 % (3/17) reported significant and nonsignificant findings, and 53 % (9/17) reported all nonsignificant findings. Findings are presented below in two sections focused on: 1) the role of discounting across treatment outcomes (e.g., abstinence, relapse, frequency of use and use-related problems, and treatment adherence/drop out) and 2) characteristics of the discounting tasks (DDT, MCQ, EDT) and discounting parameters (e.g., k, lnk, and AUC) used in analyses.

3.4. Discounting at treatment entry and treatment outcomes

Findings related to the relationship between delay discounting at treatment entry and substance use treatment outcomes are presented and summarized below in order of treatment outcomes, as follows: 1) abstinence; 2) relapse; 3) frequency of use, use reduction, and use-related problems; and 5) treatment adherence and dropout.

3.4.1. Abstinence ($n = 10$)

Abstinence was the most common treatment outcome examined across studies (59 % of studies; 10/17). Among these studies, more than half (60 %; 6/10) reported no significant association between discounting at treatment entry and abstinence at end of treatment and/or follow-up (Audrain-McGovern et al., 2009; Dallery et al., 2013; Landes et al., 2012; López-Torrecillas et al., 2014; Peters et al., 2013; Weckler et al., 2017). Studies focused on treatment for nicotine ($n = 4$), cannabis ($n = 1$), and opioid use (n = 1) reported null findings among adolescent ($n = 1$) and adult ($n = 5$) samples. Among the four studies that reported significant findings between baseline discounting and abstinence, three were among adults in treatment for nicotine use ($n = 2$) or opioid use ($n = 1$), and one was among adolescents using cannabis (n = 1). For example, one study of adults in treatment for smoking cessation reported that steeper discounting at baseline was predictive of a lower likelihood

Table 1
Summary of study characteristics, methodology, and findings ($N = 17$).

Article	Substance	Discounting measure (format)	Discounting commodity	Discounting parameter	Treatment outcome	Main discounting findings	Risk of Bias
Audrain-McGovern et al. (2009)	Nicotine	MCQ (Survey)	Money	k	• Abstinence post-treatment	• DD was not significantly associated with abstinence	Moderate
Dallery et al. (2013)	Nicotine	DDT (Computer-based)	Money	AUC	• Abstinence during treatment • Drinks per week • Binge drinking	• DD was not significantly associated with abstinence during treatment • DD was not significantly associated with drinks per week • DD was not significantly associated with binge drinking	Mild
Dennhardt et al. (2015)	Alcohol & Cannabis	DDT (Computer-based)	Money	k	• Alcohol-related problems • Days of cannabis use per month • Cannabis-related problems	• DD was not significantly associated with alcohol-related problems • DD was not significantly associated with days of cannabis use • DD was not significantly associated with cannabis-related problems	Mild
González-Roz et al. (2019)	Nicotine	DDT (Computer-based)	Money	AUC	• Relapse at 6-month follow-up	• DD was positively associated with likelihood of relapse at 6-month follow-up (OR = 0.18, p < .05)	Moderate
Harris et al. (2014)	Nicotine	DDT (Computer-based)	Money	–	• Smoking reduced by ≥50 % from baseline • Treatment dropout (attendance at <50 % of treatment sessions) • Change in CO breath level	• DD was not associated reduction in smoking • DD was not associated with treatment dropout rates	Mild
Harvanko et al. (2019)	Nicotine	DDT (Computer-based)	Money	AUC	• Treatment adherence (percentage of CO samples submitted during treatment)	• DD was negatively associated with change in CO level (beta = −8.5, $p = .049$) • DD was negatively associated with treatment adherence (F[1180] = 31.44, $p < .001$)	Mild
Landes et al. (2012)	Opioids	DDT (Computer-based)	Money	Weighted lnk and AUC	• Longest continuous period of abstinence during treatment • Total # of urine cotinine screens submitted during treatment	• DD was not associated with longest continuous period of abstinence • DD was not associated with total # of urine cotinine screens submitted	Low
López-Torrecillas et al. (2014)	Nicotine	MCQ (Survey)	Money	AUC	• Abstinence at 3-, 6-, or 12- months • Relapse at 3-, 6-, or 12-months • Treatment dropout at 3-, 6-, or 12-months	• DD was not associated with abstinence rate at 3-, 6-, or 12-months • DD was not associated with relapse at 3-, 6-, or 12-months • DD was not associated with treatment dropout at 3-, 6-, or 12-months	Low
MacKillop and Kahler (2009)	Nicotine	MCQ (Survey)	Money	k	• Number of days to smoking lapse	• DD was negatively associated with days to smoking lapse ($r = 0.27$, p < .05)	Low
Murphy et al. (2012)	Alcohol	MCQ (Survey)	Money	k	• Number of drinks consumed in a typical week • Frequency of heavy drinking episodes in the past month	• DD was not associated with number of drinks consumed in a typical week • DD was not associated with heavy drinking episodes in the past month	Low
Passetti et al. (2011)	Opioid	DDT (Computer-based)	Money	lnk	• Abstinence	• DD was not associated with abstinence	Mild

(*continued on next page*)

Table 1 (*continued*)

Article	Substance	Discounting measure (format)	Discounting commodity	Discounting parameter	Treatment outcome	Main discounting findings	Risk of Bias
Peters et al. (2013)	Cannabis	EDT (Computer-based)	Money	lnk	• Frequency of cannabis use • Percent days of abstinence during treatment • Longest period of abstinence during treatment • Percent of urine screens positive for cannabis during treatment • Treatment adherence (number of days in treatment and treatment sessions attended) • Percent days of abstinence during follow up period	• DD was not associated with frequency of cannabis use • DD was not associated with percent days of abstinence during treatment • DD was not associated with longest period of abstinence during treatment • DD was not associated with percent positive urine screens during treatment • DD was not associated with number of days in treatment or number of treatment sessions attended • DD was not associated with precent days of abstinence during follow up	Low
Sheffer et al. (2012)	Nicotine	DDT (Computer-based)	Money	lnk	• Abstinence at end of treatment	• DD was negatively associated with abstinence during treatment (OR = 0.623 to 0.684, $p = .021$ to 0.035)	Mild
Sheffer et al. (2014)	Nicotine	DDT (Computer-based)	Money	lnk	• Days to relapse • Continuous abstinence during treatment (4- and 8-weeks	• DD of small magnitude reward ($100) was negatively associated with days to relapse (HR = 1.45, p = .02); DD of large magnitude reward ($1000) was not associated with days to relapse • DD of small magnitude money reward ($100) was not associated with continuous abstinence at 4 or 8 weeks. • DD of large magnitude money reward ($1000) was negatively associated with continuous abstinence at 4 weeks (OR = 0.87, $p < .05$) and 8 weeks (OR = 0.82, $p < .05$) during treatment • DD of small magnitude cannabis reward (cannabis amount equivalent to $100) was not associated with continuous abstinence at 4 weeks or 8 weeks	Low
Stanger et al. (2012)	Cannabis	DDT (Computer-based)	Money; cannabis	lnk	• Continuous abstinence at end of treatment (14 weeks) • Total number of negative urine screens through end of treatment	• DD of large magnitude cannabis reward (cannabis amount equivalent to $1000) was negatively associated with continuous abstinence at 4 weeks (OR = 0.91, $p < .05$), but not 8 weeks during treatment • DD of small magnitude money reward ($100) was not associated with continuous abstinence at end of treatment • DD of large magnitude money reward ($1000) was negatively associated with continuous abstinence (beta = −0.20, $p < .05$) at end of treatment • DD of smaller magnitude cannabis reward (cannabis amount equivalent to $100) was not associated with continuous abstinence • DD of large magnitude cannabis reward (cannabis amount equivalent to $1000) was not associated with continuous abstinence • DD of small and large magnitude monetary rewards ($100 and $1000) was negatively associated with total number of negative urine screens (betas = −0.15, $p < .05$; −0.20, p < .05) • DD of small and large magnitude cannabis rewards (cannabis amount equivalent to $100 and $1000) was not associated with total number of negative urine screens	Mild

(*continued on next page*)

Table 1 (*continued*)

Article	Substance	Discounting measure (format)	Discounting commodity	Discounting parameter	Treatment outcome	Main discounting findings	Risk of Bias
Weckler et al. (2017)	Nicotine	EDT (Computer-based)	Money	AUC	• Abstinence at end of treatment	• DD was not associated with abstinence	Mild
Yoon et al. (2007)	Nicotine	DDT (Computer-based)	Money	lnk	• Smoking status (smoking vs not smoking)	• DD was negatively associated with smoking status at 6-month follow-up (OR = 1.82, $p = .01$)	Low

Note: All values related to main findings are standardized, unless otherwise noted.
Some studies reported results separately for small and large magnitude DD tasks. Findings are reported above as they were reported in the original articles, either overall or by magnitude condition.
– = Not reported in source article
MCQ = Monetary Choice Questionnaire
k = Delay discounting rate calculated via Mazur's hyperbolic discounting curve
DD = Delay Discounting
DDT = Delay Discounting Task
AUC = Area Under Curve
lnk = logarithmic transformation of k value to account for negatively skewed distributions
EDT = Experiential Discounting Task

of abstinence at the end of treatment and at the six-month follow-up, as evidenced by large effect sizes (OR = 0.62–0.68) (Sheffer et al., 2012). Two studies categorized participants post-hoc based on their abstinence status at the end of treatment (abstinent vs. not abstinent) and found that steeper discounting at baseline was associated with greater likelihood of being categorized as non-abstinent among adults engaged in treatment for nicotine use (Yoon et al., 2007) or opioid use (Passetti et al., 2011). Findings were less consistent among a sample of primarily male adolescents engaged in treatment for cannabis use; steeper discounting of both money and cannabis at baseline was associated with fewer periods of continuous abstinence (Stanger et al., 2012), with small sized effects (std. beta = −0.20–0.12) when assessed in the discounting tasks with large reward magnitudes for each commodity (i.e., $1000 money, $1000 equivalent of cannabis), but not among small reward magnitudes (i.e., $100 money, $100 equivalent of cannabis). Collectively, evidence across studies did not consistently report a significant association between baseline discounting and abstinence during and following substance use treatment.

3.4.2. *Relapse (n = 4)*

Four studies (24 %; 4/17) examined the association between discounting at treatment entry and relapse during or posttreatment, most of which (75 %; 3/4) reported that discounting was associated with greater risk of relapse, at least under some discounting conditions. For example, among a sample of adults engaged in combined cognitive behavioral therapy (CBT) and contingency management treatment for nicotine use, findings revealed that steeper discounting at baseline was associated with greater risk for relapse at end of treatment, with a small sized effect (OR = 0.18) (González-Roz et al., 2019). Similarly, after completion of a brief motivational intervention for nicotine use among adults, findings revealed that for every one-unit higher discounting at baseline, the risk of relapse increased by 40–50 % (MacKillop & Kahler, 2009). Among a sample of adults engaged in CBT for nicotine use, findings revealed that baseline discounting of the small reward magnitude ($100 money) was associated with greater risk of relapse (HR = 1.45); however, discounting of large magnitude reward ($1000 money) was not associated with risk of relapse (Sheffer et al., 2014). Finally, one study reported no significant relationship between baseline discounting and risk for relapse at three, six, or 12 months after treatment for nicotine use among a sample of adults (López-Torrecillas et al., 2014). Taken together, findings suggested that steeper discounting at baseline may be associated with greater risk for relapse after smoking cessation treatment, at least under some discounting conditions.

3.4.3. *Frequency of use and use-related problems (n = 3)*

Three studies (18 %; 3/17) evaluated continuous outcomes of frequency of substance use and use-related problems during treatment. Findings regarding substance use frequency were consistent across two studies, indicating that delay discounting at baseline was not significantly associated with days of cannabis use (Dennhardt et al., 2015) and number of drinks consumed in typical week (Dennhardt et al., 2015; Murphy et al., 2012) among young adults who completed a brief motivational interview intervention. In addition, delay discounting was not significantly associated with alcohol-related or cannabis-related problems among young adults who completed a brief motivational interview (Dennhardt et al., 2015). In addition to the null findings among brief treatment studies, null findings were also reported among a sample of adolescents engaged in 10 weeks of CBT treatment, in which delay discounting was not associated with a $\geq$ 50 % reduction in smoking over the course of treatment (Harris et al., 2014). Overall, findings indicated that baseline delay discounting may not be significantly associated with frequency of use or use-related problems during treatment for cannabis, alcohol, or tobacco; however, more research is necessary given the limited number of available studies.

3.4.4. *Treatment adherence and dropout (n = 3)*

Findings related to treatment adherence and dropout were limited; two studies (12 %; 2/17) examined treatment dropout and one study (6 %; 1/17) evaluated treatment adherence. Among the studies that tested the association between discounting at treatment entry and treatment dropout, no significant associations existed between baseline discounting and treatment dropout among both adolescent (Harris et al., 2014) and adults (López-Torrecillas et al., 2014) engaged in smoking cessation treatment. Findings indicated that delay discounting was negatively associated with adherence to contingency management for smoking cessation, such that adolescents with lower delayed discounting had stronger adherence to treatment (Harvanko et al., 2019). Overall, more research should seek to better characterize the relationship between delay discounting and treatment dropout and adherence.

3.5. *Delay discounting methodology*

Findings regarding type of discounting task and discounting parameter used in analyses are presented and summarized in the following order: 1) type of discounting task (DDT, MCQ, EDT) and 2) discounting parameter (k, lnk, AUC). One study did not report if their findings were calculated using the k, lnk, or AUC value, and thus, were not discussed in the relevant section below.

Table 2
Summary of sample and treatment characteristics.

Article	Sample characteristics					Treatment characteristics		
	Sample size	Target sample (adolescent or adult)	Age mean (SD)	Race/ethnicity	% Male	Treatment condition	Control condition	Length of treatment
Audrain-McGovern et al. (2009)	294	Adult	22.2 (2.9)	• 68 % White • 25 % Black • 7 % Asian	50	CBT + AR	CBT	7 weeks
Dallery et al. (2013)	77	Adult	39.7 (13.2)	• 83 % White • No other group reported	56	CM	CM with non-contingent reward	7 weeks
Dennhardt et al. (2015)	97	Adult	20.10 (2.2)	• 60 % White • 31 % Black • 9 % Other	41	BMI + SFAS	BMI + Education	1 session
González-Roz et al. (2019)	188	Adult	42.9 (12.9)	–	36	CM + CBT	CBT	6 weeks
Harris et al. (2014)	81	Adolescent	37.52 (1.3)	• 54 % White • 36 % Black • 10 % Other	42	CBT	–	10 weeks
Harvanko et al. (2019)	189	Adolescent	16.8 (1.5)	• 81 % White • 10 % Black • 9 % Other	50	CM	CM with non-contingent reward	5 weeks
Landes et al. (2012)	159	Adult	33.8 (15.2)	• 95 % White • No other group reported	52	CM + CRA	Standard Counseling	12 weeks
López-Torrecillas et al. (2014)	140	Adult	47.36 (8.2)	–	55	Varenicline Relapse Prevention + Education	–	–
MacKillop and Kahler (2009)	57	Adult	41.38 (13.2)	• 85 % White • 5 % Black • 5 % Hispanic • 4 % Multi-racial • 2 % Other	61	BMI + NRT	NRT + Progressive muscle relaxation	11 weeks
Murphy et al. (2012)	82	Adult	18.51 (0.7)	• 81.7 % White • 12.2 % Black • 2.4 % Hispanic • 1.2 % Asian • 1.2 % Native American	50	BMI + SFAS	BMI + Relaxation	2 sessions
Passetti et al. (2011)	80	Adult	36.55 (6.8)	• 20 % White • 80 % Other	71	Standard treatment in community or residential setting CBT	–	27–31 days
Peters et al. (2013)	93	Adult	26.1 (7.5)	• 19.4 % White • No other group reported	86	CM abstinence CBT + CM adherence CBT + CM abstinence	–	12 weeks
Sheffer et al. (2012)	97	Adult	48.16 (11.6)	• 61 % White • No other group reported	41	CBT	–	6 weeks
Sheffer et al. (2014)	131	Adult	47.5 (12.7)	• 77 % White • 13 % Black • 10 % Other	47	CBT + NRT	–	8 weeks
Stanger et al. (2012)	165	Adolescent	15.77 (1.3)	• 38 % White • 59 % Black • 2 % Multiracial • <1 % Native American	88	CBT CBT + CM CBT + CM + Family management	–	14 weeks
Weckler et al. (2017)	199	Adolescent	16.27 (1.3)	–	60	CBT + Nicotine-focused Cognitive bias modification training	CBT + Standard Cognitive bias modification training	4 weeks

(*continued on next page*)

Table 2 (*continued*)

Article	Sample characteristics					Treatment characteristics		
	Sample size	Target sample (adolescent or adult)	Age mean (SD)	Race/ethnicity	% Male	Treatment condition	Control condition	Length of treatment
Yoon et al. (2007)	48	Adult	25.9 (5.1)	• 98 % White • No other group reported	0	CM	CM with non-contingent reward	12 weeks

– = Not reported in source article
CBT = Cognitive Behavior Therapy
AR = Alternative Reinforcers; intervention focused on helping adolescents identify, access, and engage with substitute reinforcers (e.g., hobbies, sports)
SFAS = Substance-Free Activity Session
BMI = Brief Motivational Interviewing
CRA = Community Reinforcement Approach
NRT = Nicotine Replacement Therapy

3.5.1. Delay discounting task (n = 11)

Over half of studies (65 %; 11/17) in the review used the adjusting DDT. Across the studies, 64 % (7/11) reported at least one significant finding, and effect sizes ranged from small to large in magnitude (std. beta = −0.20–12; HR = 1.45–1.49; OR = 0.18–1.82) (González-Roz et al., 2019; Harvanko et al., 2019; Passetti et al., 2011; Sheffer et al., 2012; Sheffer et al., 2014; Stanger et al., 2012; Yoon et al., 2007). Studies focused on treatment for nicotine use ($n = 5$) reported most of the significant findings, whereas one study focused on opioid use ($n = 1$) and one study focused on cannabis use (n = 1). Treatment outcomes included abstinence (Passetti et al., 2011; Sheffer et al., 2012; Stanger et al., 2012; Yoon et al., 2007), relapse (González-Roz et al., 2019; Sheffer et al., 2014), and treatment adherence (Harvanko et al., 2019). Four studies that used the DDT reported no significant findings among samples engaged in treatment for nicotine ($n = 2$), alcohol ($n = 1$) and opioid use (n = 1) (Dallery et al., 2013; Dennhardt et al., 2015; Harris et al., 2014; Landes et al., 2012). Studies focused on substance use frequency and use-related problems (Dennhardt et al., 2015; Harris et al., 2014), treatment dropout (Harris et al., 2014), or abstinence (Dallery et al., 2013; Landes et al., 2012). Overall, findings were somewhat more consistent across studies using the DDT, indicating a significant association between delay discounting and substance use treatment outcomes among more than half of studies, with most of the evidence focused on treatment for nicotine use.

3.5.2. Monetary choice questionnaire (n = 4)

Among the four studies (24 %; 4/17) that used the MCQ to measure discounting at baseline, only one study reported significant findings (25 %; 1/4) in a sample of adults in treatment for nicotine use (MacKillop & Kahler, 2009). Null findings were reported among three studies (75 %; 3/4) that examined baseline discounting and treatment outcomes among adults engaged in treatment for nicotine ($n = 2$) and alcohol ($n = 1$) use and that evaluated outcomes of abstinence (Audrain-McGovern et al., 2009; López-Torrecillas et al., 2014), relapse, treatment dropout (López-Torrecillas et al., 2014), and use frequency (Murphy et al., 2012). Collectively, findings were relatively consistent across studies using the MCQ, indicating a pattern of no significant association between baseline discounting and substance use treatment outcomes.

3.5.3. Experiential discounting task (n = 2)

Two studies (12 %; 2/17) used the EDT, and neither reported a significant association between discounting at treatment entry and abstinence from nicotine (Weckler et al., 2017) or cannabis (Peters et al., 2013) among adolescents. Neither study provided evidence that discounting as measured using the EDT was associated with abstinence from nicotine or cannabis; however, more work is needed given the limited studies available.

3.5.4. Discounting parameters: K and lnk (n = 11)

Most studies estimated delay discounting using lnk (41 %; 7/17) or k (24 %; 4/17) values. Of the studies that used lnk, most (71 %; 5/7) reported a significant association between delay discounting and abstinence (Passetti et al., 2011; Sheffer et al., 2012; Stanger et al., 2012; Yoon et al., 2007) and relapse (Sheffer et al., 2014). Observed effect sizes were small to large in magnitude (std. beta = −0.20–0.12; OR = 1.62–1.82; HR = 1.45–1.49). Significant findings were observed among both adolescent (Stanger et al., 2012) and adult samples (Passetti et al., 2011; Sheffer et al., 2012; Sheffer et al., 2014; Yoon et al., 2007) in treatment for nicotine ($n = 3$), cannabis ($n = 1$), and opioid use (n = 1). Conversely, two studies reported no significant association between delay discounting as estimated by lnk and abstinence among adults engaged in treatment for opioid (n = 1) or cannabis use (n = 1) (Landes et al., 2012; Peters et al., 2013). Among the four studies that estimated delay discounting using k, most (75 %; 3/4) reported no significant association between delay discounting and abstinence (Audrain-McGovern et al., 2009), use frequency (Dennhardt et al., 2015; Murphy et al., 2012), and use-related problems (Dennhardt et al., 2015). Overall, lnk as the discounting parameter was most consistently associated with treatment outcomes.

3.5.5. Discounting parameter: Area under the curve (n = 6)

Six studies (35 %; 6/17) estimated delay discounting using AUC. The majority of studies (67 %; 4/6) reported no significant association between baseline discounting as measured by AUC and abstinence (Dallery et al., 2013; López-Torrecillas et al., 2014; Weckler et al., 2017), relapse, and treatment dropout (López-Torrecillas et al., 2014) among individuals in treatment for nicotine ($n = 3$) or opioid use ($n = 1$). Thus, most findings indicated that discounting as measured by AUC was not significantly associated with substance use treatment outcomes.

3.5.6. Sample characteristics: Adolescent vs. adults

Of the 17 studies, four studies (24 %; 4/17) used adolescent samples, whereas 13 studies (76 %; 13/17) used adult samples. Findings were consistently heterogenous across the adolescent and adult samples, with approximately half of the adolescent and half of the adult studies reporting significant associations between discounting and treatment outcomes. Findings from two of the four (50 %) adolescent studies revealed that elevated delayed discounting was associated with treatment adherence (Harvanko et al., 2019) and abstinence (Stanger et al., 2012). Among the adult studies, 41 % (7/17) reported significant associations between delay discounting and abstinence (González-Roz et al., 2019; MacKillop & Kahler, 2009; Passetti et al., 2011; Peters et al., 2013; Yoon et al., 2007) and relapse (Sheffer et al., 2014). Among the adolescent studies (Harris et al., 2014; Weckler et al., 2017) and adult studies (Audrain-McGovern et al., 2009; Dallery et al., 2013; Dennhardt et al., 2015; Landes et al., 2012; López-Torrecillas et al., 2014; Murphy et al., 2012) that reported null findings, delay discounting was not significantly associated with a variety of treatment outcomes, including abstinence, use frequency, use-related problems, treatment dropout, and relapse. Thus, no clear patterns emerged when examining potential

differences in baseline discounting and treatment outcomes by adolescent versus adult samples.

3.5.7. Type of substance use disorder

The majority of studies (65 %; 11/17) focused on treatment for nicotine use in the form of cigarette smoking and findings were inconsistent. Other studies had very small Ns and evaluated opioid use, alcohol use (12 %; 2/17), and cannabis use (12 %; 2/17). Approximately half (56 %) of the studies on treatment for nicotine use reported significant findings. Delay discounting at treatment entry was significantly associated with treatment adherence (Harvanko et al., 2019), relapse (González-Roz et al., 2019; MacKillop & Kahler, 2009; Sheffer et al., 2014), and abstinence (Sheffer et al., 2012; Yoon et al., 2007). However, studies examining nicotine use also reported null findings for similar outcomes (Dallery et al., 2013; Harris et al., 2014; López-Torrecillas et al., 2014; Weckler et al., 2017). Both studies focused on the treatment of cannabis use reported significant findings, suggesting delay discounting was associated with abstinence (Stanger et al., 2012) and use frequency (Peters et al., 2013). Both studies focused on the treatment of alcohol use reported null findings, suggesting delay discounting was not associated with use frequency (Dennhardt et al., 2015; Murphy et al., 2012), and use-related problems (Dennhardt et al., 2015). Among the studies examining opioid use, one study reported a significant association between delay discounting and abstinence (Passetti et al., 2011), whereas another study reported a null finding between discounting and abstinence (Landes et al., 2012). Overall, no notable patterns emerged from studies of discounting in tobacco treatment, and studies for alcohol, cannabis, and opioids were too few to draw any substantive conclusions.

3.5.8. Type of treatment

Wide variation existed in treatments tested across studies and findings were overall inconsistent. Five studies (29 %; 5/17) used cognitive behavioral therapy (CBT), four studies (24 %; 4/17) used contingency management (CM), three studies (18 %; 3/17) used variations of brief motivational interviewing (BMI), three studies (18 %; 3/17) used combined CBT and CM therapy, and two studies (12 %; 2/17) used alternative approaches including relapse prevention, psychoeducation, and residential treatment modalities. The three studies that used combinations of CBT and CM demonstrated the most consistency across findings, revealing delay discounting was significantly associated with abstinence (Stanger et al., 2012), use frequency (Peters et al., 2013), and relapse (González-Roz et al., 2019). The studies that used single treatment approaches reported more inconsistent findings, with one third to one half of studies reporting significant effects for CM (50 %; 2/4) (Dallery et al., 2013; Harvanko et al., 2019; Landes et al., 2012; Yoon et al., 2007), CBT (40 %; 2/5) (Audrain-McGovern et al., 2009; Harris et al., 2014; Sheffer et al., 2012; Sheffer et al., 2014; Weckler et al., 2017), and BMI (33 %; 1/3) (Dennhardt et al., 2015; MacKillop & Kahler, 2009; Murphy et al., 2012). The two studies that used alternative approaches both reported null findings (López-Torrecillas et al., 2014; Passetti et al., 2011). Collectively, findings were most consistent among studies that used combined CBT and CM, whereas findings were less consistent across studies that used single treatment approaches. However, the small number of studies across all treatment modalities limited the degree to which substantive conclusions could be drawn.

4. Discussion

A robust body of literature has identified elevated delay discounting as an important risk factor for substance use and related problems. Delay discounting may also present challenges in the treatment of substance use disorders, as individuals who prefer small, immediate rewards may find it difficult to wait for the larger, delayed rewards that come from abstinence over time. The current study conducted a systematic review of the literature to characterize the prospective effects of delay discounting on substance use treatment outcomes, with a focus on characterizing findings by treatment outcome (e.g., abstinence, relapse, use frequency) and methodology used to characterize discounting (discounting measure and discounting parameter). Secondarily, the study characterized the role of discounting in treatment outcomes by sample characteristics, type of substance use disorder, and type of treatment. Delay discounting at treatment entry was not consistently associated with substance use treatment outcomes across 17 studies when examined overall or by treatment outcome, sample characteristics (adolescents vs adults), type of substance use disorder, or type of treatment. Most studies that used a computer-based adjusting choice task or a discounting parameter that was transformed to address distributional properties (lnk) reported significant associations with a variety of substance use treatment outcomes. In contrast, most studies that used fixed choice or experiential tasks, or used discounting parameters of k or AUC did not report significant associations with treatment outcomes. Overall, findings suggested that methodology used to measure and characterize discounting at treatment entry may be important, with more fine-grained measures of discounting and parameter estimation being more commonly associated with a range of treatment outcomes.

The study sought to characterize findings by treatment outcome, given the range of treatment outcomes that previous studies have examined in the literature (e.g., dichotomous measures such as abstinence vs. continuous measures such as use frequency), which may contribute to variability in findings observed in the literature. Across most treatment outcomes, however, evidence did not consistently indicate that discounting at treatment entry was associated with poorer treatment outcomes. Less than half of studies (0–40 % depending on the outcome) reported significant associations with abstinence, use frequency, use-related problems, and treatment adherence among adolescents and adults engaged in treatment for tobacco, opioids, or cannabis use. Abstinence was the most common outcome examined, whereas a smaller pool of studies examined the other outcomes. However, for the most part, evidence did not consistently support the premise that elevated discounting at treatment entry may impede treatment success or adherence. One exception was among a small number of studies ($n = 4$) that examined relapse among individuals in treatment for tobacco cessation. Most of the studies indicated that elevated discounting at treatment entry was significantly associated with risk of relapse to smoking overall ($n = 2$) or in some discounting conditions examined ($n = 1$; large vs. small magnitude rewards). Thus, evidence from a small pool of studies indicated that elevated discounting at treatment entry may present a greater risk for relapse to smoking following tobacco cessation treatment; however, more studies are needed to replicate this finding. More studies should examine relapse among individuals in treatment for substances other than tobacco, to more fully indicate whether the finding may be generalizable.

When considering discounting methodology, most studies reported significant associations between discounting and treatment outcomes that used fine-grained characterizations of discounting. More specifically, the majority of studies (64 %) that used an adjusting computer-based delay discounting task reported a significant association between discounting at treatment entry and outcomes of abstinence, relapse, and treatment adherence among individuals in treatment for nicotine or cannabis use. In contrast, most of the studies (75 %) that used the MCQ, a fixed choice measure of discounting, reported that discounting at treatment entry was not significantly associated with treatment outcomes of abstinence, relapse, and treatment dropout among individuals in treatment for nicotine or alcohol use. Thus, findings across similar study outcomes and substances were distinct between studies that used the DDT compared to the MCQ. Given that the DDT adjusts choices presented to participants based on their prior responses, it likely provides better resolution to characterize discounting relative to the static choice MCQ. Thus, our findings indicate that DDT may have better utility in examining associations with treatment outcomes relative to the MCQ. Additionally, the two studies that used the experiential

discounting task did not find significant associations between discounting and abstinence among individuals in treatment for nicotine or cannabis use. The EDT uses time scales that are much smaller relative to DDT (e.g., seconds to minutes vs. weeks to years) and reward values that are much smaller relative to DDT (e.g., cents vs dollars). As such, the EDT may not capture discounting at the time scale that may provide the most utility for evaluating its impact on treatment outcomes, which typically occur in the extended future in a manner more consistent with timescales used in the DDT. Overall, findings suggest that using an adjusting measure of discounting and examining a timescale consistent with substance use treatment outcomes may provide the most utility in predicting substance use treatment outcomes.

The study also evaluated discounting methodology regarding characterization of discounting via parameters of k, lnk, and AUC. Most studies (71 %) that used lnk to characterize discounting reported significant associations between discounting and a range of treatment outcomes. In contrast, most studies (67–75 %) that used k or AUC did not find significant associations between baseline discounting and substance use treatment outcomes. K values typically have skewed distributional properties and may not satisfy the assumptions of some regression models that studies use to test associations with treatment outcomes in the literature. Lnk is recommended for use because it represents the log transformed k value which addresses the skewed distributional properties that are typically encountered with discounting measures (Mitchell et al., 2015). Thus, lnk may provide better resolution to detect associations with treatment outcomes relative to k (Epstein et al., 2003; Mitchell et al., 2015; Smith & Hantula, 2008). Discounting characterized by AUC was also not consistently associated with treatment outcomes among the studies reviewed, also possibly due to a measurement limitation. AUC differentially weights indifference points, which may result in a biased measure of discounting. For this reason, researchers have recently recommended using a transformed AUC term to address this issue (Borges et al., 2016). Therefore, the conventional AUC estimates that were used in the reviewed studies may have had greater imprecision in characterizing discounting, which may have precluded examining associations with treatment outcomes. Our findings provide evidence that using lnk as a discounting parameter may have greater utility in examining associations with substance use treatment outcomes, relative to k and AUC.

The study had several limitations. First, many of the studies that met inclusion criteria for the review focused on tobacco cessation treatment; thus, studies were less well-represented for other substances and may be less generalizable to some other substances (e.g., opioids). In addition, most of the studies reviewed comprised either primary White participants or did not report the race and ethnicity of their samples. Thus, to what degree the findings may generalize to individuals from other racial and ethnic communities is unclear. Theorists typically conceptualize discounting as an individual-difference factor that can be influenced by environmental factors, including inequities in access to resources (e.g., scarcity). Given that individuals from marginalized communities are likely to experience systemic inequities that may in some contexts exacerbate discounting (e.g., scarcity), understanding the ways in which discounting may be associated with treatment outcomes among individuals from marginalized communities, and ways in which systemic inequities may influence these relationships is important and should be the focus of a full review, when a body of literature is available.

5. Conclusion

Findings indicated that pre-treatment delay discounting was not a consistent predictor of substance use treatment outcomes across 17 studies when examined overall or by treatment outcome. However, patterns emerged when examined by discounting methodology; most studies that used an adjusting delay discounting task or a discounting parameter that was transformed to address distributional properties (lnk) reported significant associations with a variety of substance use treatment outcomes. Thus, findings of the review suggest that using more fine-grained measures to assess and characterize discounting may have better utility for examining associations with substance use treatment outcomes. Findings from the review provided some evidence that elevated delay discounting at treatment entry may be associated with a range of poorer treatment outcomes, particularly when using more fine-grained measures of discounting.

CRediT authorship contribution statement

Alexis Exum: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Data curation, Writing- Original draft.

Cassandra Sutton: Methodology, Investigation, Data curation, Validation, Formal analysis, Data curation, Writing- Original draft.

Joseph Bellitti: Investigation, Data curation, Validation, Formal analysis, Data curation, Writing- reviewing and editing.

Richard Yi: Methodology, Writing- reviewing and editing.

Tera Fazzino: Conceptualization, Methodology, Supervision, Writing- reviewing and editing.

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Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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