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Practicing prospection promotes patience: Repeated episodic future thinking cumulatively reduces delay discounting

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Abstract

Background: Delay discounting, or the preference for smaller, sooner over larger, later rewards, has been associated with alcohol use disorder and problem drinking. Episodic future thinking has been suggested as an intervention to address steep delay discounting. In the present study, we examined the effect of up to six consecutive sessions of episodic future thinking.

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Contributors

AMM was contributed to manipulation design, data analysis, and manuscript preparation. SES contributed to experimental design, data collection, and manuscript preparation. HUD contributed to manuscript preparation. SML contributed to experimental design and manuscript preparation. WKB contributed to experimental design and manuscript preparation. All authors have approved of submission of this manuscript.

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, SES and WKB are both principals in BEAM Diagnostics, Inc.

WKB is also a principal of HealthSim, LLC; Notifius, LLC; and Red 5 Group, LLC. In addition, he serves on the scientific advisory board for Sober Grid, Inc.; Ria Health; US WorldMeds, LLC; and is a consultant for Alkermes, Inc. and Nektar Therapeutics.

AMM, HUD, and SLC have no disclosures to report.

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WKB is a principal of HealthSim, LLC and Notifius, LLC; a scientific advisory board member of Sober Grid, Inc. and DxRx, Inc.; and a consultant for ProPhase, LLC and Teva Branded Pharmaceutical Products R&D, Inc.

AMM, HUD, and SLC have no additional information to report.

Methods: Repeated, within-subject data were collected from current and recent problem drinkers (n=50) over six sessions. Linear mixed-effect models were used to estimate effects of repeated sessions and manipulations. Participants completed episodic future thinking interviews at up to six sessions, in which they generated personalized future events. Participants also engaged with cues of scarcity. At each session, participants completed three delay discounting tasks under: a no-cue baseline condition, a future cue condition, and a scarcity cue condition.

Results: Delay discounting in the no cue condition did not change over time. Discounting rates were reduced in the future cue condition, and these effects grew larger with repeated sessions. In the scarcity condition, discounting rates were slightly higher, with no effect of repeated sessions.

Conclusions: Episodic future thinking reduced delay discounting rate while future cues were presented, and these effects grew larger with repeated sessions. This suggests that repeated episodic future thinking may cumulatively potentiate repair of excessive preference for immediate reward.

Keywords

delay discounting; episodic future thinking; practice; alcohol; impulsivity; dose effects; alcohol use disorder

1. Introduction

Alcohol use disorder imposes annual costs exceeding 80,000 lives (Centers for Disease Control and Prevention, 2008) and $240 billion (Sacks et al., 2015). Excessive alcohol use is marked by repeated choices to consume alcohol despite the accumulation of negative social and physical consequences. These consequences are often delayed in nature; therefore choices to drink may be modeled as choices for the smaller, sooner reward of immediate intoxication over the larger, later reward of delayed sobriety, and subsequent health. This choice process is described by delay discounting (Ainslie, 1975). Delay discounting measures choice impulsivity by indicating the degree to which rewards lose value as a function of the delay to their receipt -- for example, preference between $500 now versus $1000 next week (Odum, 2011).

Preference between these smaller, sooner and larger, later rewards differs on an individual level and has been linked to many disease states (Bickel et al., 2012). Rates of delay discounting have been observed to be higher among individuals with substance use disorder than those without (MacKillop et al., 2011), and specifically to be higher among excessive alcohol users (Moody et al., 2017; Petry, 2001). Furthermore, the degree of alcohol use disorder severity is continuously associated with discount rate (Amlung et al., 2016), indicating that heavier drinkers tend to be more impulsive than lighter drinkers. Delay discounting has been proposed as a behavioral marker of addiction (Bickel et al., 2014), indicating not only a risk factor for problematic alcohol use, but a potential mechanism supporting decisions to drink and therefore promoting disease.

More recently, delay discounting has been indicated as a potential therapeutic target (Bickel et al., 2012). Indeed, delay discounting has been observed to be sensitive to interventions and manipulations in alcohol using populations. For example, Aklin and colleagues (2009)

found that after a 30-day residential treatment program, the discounting rates of individuals with substance use disorders decreased. Another study of cocaine- or cocaine-and-alcohol abusing individuals observed that a 36-week money management intervention attenuated both delay discounting and cocaine use (Black and Rosen, 2011). Each of these studies observed incidental reductions in delay discounting during periods of treatment with interventions for substance use disorder. However, manipulations specifically designed to target delay discounting (Koffarnus et al., 2013) have emerged more recently.

One such manipulation, episodic future thinking, prompts individuals to generate vivid, personal future events and consider these events while making choices (Atance and O'Neill, 2001). These future simulations have been shown to reduce delay discounting among normative populations (Peters and Büchel, 2010) as well as obese individuals (Daniel et al., 2015; Sze et al., 2017) and cigarette smokers (Stein et al., 2016). Furthermore, these effects of episodic future thinking may improve with working memory training, at least for the subset of individuals demonstrating the greatest choice impulsivity at baseline (Snider et al., 2018). Taken together, this research has supported the proposal of episodic future thinking as a potential therapy for problem substance use, including problem alcohol use (Bickel et al., 2016b).

Critically, the effects of episodic future thinking in the reduction of discount rate have also extended towards improving health behaviors. Snider and colleagues (2016) demonstrated that after generating future cues describing positive, personal, future episodes at five time points (ranging from 1 day to 1 year), participants showed both reduced delay discounting in the presence of future-cues compared to being exposed to the control cues. Furthermore, the future cues reduced the number of drinks purchased at various price points in an alcohol purchase task. Limited research has explored the effects of repeated engagement with episodic future thinking, however. A small feasibility study has indicated that repeatedly prompting individuals with personalized future cues over a four-week engendered weight loss among adults, but did not examine the effects of these cues on delay discounting (Sze et al., 2015). To date, the effects of repeated generation and presentation of episodic future cues on delay discounting have not yet been studied. Such an examination, could inform the development of episodic future cues for therapeutic use in alcohol use disorder.

In the present study, current and recovering alcohol-dependent individuals completed delay discounting tasks under three conditions over six sessions: one baseline task without presented cues or manipulations; one episodic future thinking (future) task with personalized future cues present during choices; and one scarcity task, using a hypothetical manipulation of scarcity. Our hypotheses were that episodic future thinking would decrease delay discounting compared to baseline at each session and generate a cumulative effect of reduction in delay discounting with repeated administrations.

2. Methods and Materials

2.1. Participants

Data reported both here and in our previous paper on episodic future thinking among alcohol users (Snider et al., 2018) were collected as part of a larger study. Participants were recruited

from Roanoke, VA, and local areas. Participants were eligible if they met at least three of the seven dependence criteria outlined in DSM-IV-TR (Association et al. 2000 , see Supplemental Material) and reported drinking alcohol in the past six months (see Snider et al., 2018 for additional screening and eligibility information). At the time of consent, half of the participants (n=24) reported attempting to quit or cut down their drinking within the past three weeks; the remainder did not report current attempts to cut down on their drinking. A total of 50 participants completed four assessment sessions (S1-S4); 48 completed a one-month follow-up session (S5), and 43 participants completed a 3-month follow up session (S6). Participants demographics were as follows: 39 participants (78%) male; mean age 42.4 (SD = 10.75) years; median of 13 years of education (IQR = 12 - 14 years); median baseline income of $248.50 per week (IQR = $38 - $782.75); 78% of participants smoked cigarettes; and median of 12 cigarettes smoked per day (IQR = 5.5 - 23.75 cigarettes). The sample recorded a mean peak lifetime AUDIT score of 23.38 (SD = 9.56) and a mean current AUDIT score of 14.84 (SD = 11.43). At baseline, the average natural-log-normalized delay discounting rate for $1000 was −3.39 (SD = 2.39). Finally, this study was part of a larger working memory study in which participants received working memory training (n=25 active; n=25 control training), as described elsewhere (Snider et al., 2018). While the working memory results are not included in the present manuscript, working memory training did not influence the effects of discounting manipulations (see Data Analysis and Results). Informed consent was required of all participants, and all procedures were reviewed by the Virginia Tech Institutional Review Board.

2.2. Procedures

All participants completed a total of six assessment sessions wherein they completed a total of three delay discounting tasks under three conditions: 1) No cue, 2) Future cue, and 3) Scarcity cue. The no cue discounting task always occurred first, to avoid possible carryover effects. At each of the assessment visits, participants generated new episodic future thinking cues and the scarcity scenario presented was novel (see below). Moreover, the order of the future cue and scarcity cue delay discounting tasks was counterbalanced between participants to avoid order effects.

2.2.1. Episodic future thinking cue generation.—

At each session, participants completed an episodic future thinking interview as described elsewhere (Snider et al., 2018, 2016). Participants were guided through the process of vividly describing positive, personal events that could happen at five time points in the future: one day, one week, one month, three months, and one year. Participants were prompted to elaborate on the sensory details of this moment and then generate a future cue that would remind them of this experience (e.g., “In about 1 month, I will be at my son’s birthday party”), which was then presented during the future cue delay discounting task.

2.2.2. Delay discounting tasks.

2.2.2.1. No cue condition.: The adjusting amount delay discounting task was administered to all participants at all assessment visits prior to episodic future cue generation or presentation of any scarcity narrative. The No Cue version of the task was administered at the beginning of the assessment visit and served as the control discounting task for each

manipulation. Participants were presented with an adjusting-amount delay discounting task, with delays (1 day, 1 week, 1 month, 3 months, 1 year, 5 years, and 25 years) presented in randomized order. Only delays extending out to one year are analyzed here, to parallel discounting tasks completed in the future cue and scarcity cue conditions.

2.2.2.2. Future cue condition.: At each session, participants also completed a delay discounting task in the presence of the episodic future thinking cues generated during their guided interview. This task was identical to the no cue task, except (1) the delays presented extended only out to one year; and (2) at each delay, the vivid, positive, personal cue that individual had generated was presented during the delay discounting task.

2.2.2.3. Scarcity cue condition.: At each session, participants also completed a delay discounting task in the presence of one of six scarcity scenarios, describing experiences of hardship. These scenarios described bankruptcy (Session 1), a break-in and robbery (Session 2), a devastating storm (Session 3), a vehicular accident (Session 4), a house fire (Session 5), and loss of custody of a child (Session 6), see Supplemental Material for full scenarios. Scenarios were presented to all participants regardless of personal relevance (e.g., all participants engaged with the scenario describing loss of child custody, even if they did not report having custody of any children). This delay discounting task was identical to the no-cue condition, except that (1) the scarcity narrative was presented immediately before beginning the task, and participants were instructed to choose as if this narrative was happening to them right now; and (2) the task only extended up to the one-year delay. The scarcity cue and future cue tasks were completed in counterbalanced order.

2.2.3. Working memory training—These data were collected as a part of a broader working memory training study, and working memory training procedures are more fully described elsewhere (Snider et al. 2018). Briefly, participants were randomly allocated to receive 20 sessions of either active or control working memory training sessions using commercial software. In the active condition, tasks grew more difficult as participants progressed; in the control condition, tasks did not change in difficulty over repeated sessions.

2.3. Analysis

A hyperbolic discounting model was fit to indifference point data up to the one year for each of all three tasks using GraphPad Prism 7, and the resulting k parameter was then natural log transformed. The 50 enrolled participants completed a total of 838 delay discounting tasks across all six sessions and all three conditions. Data collected during tasks in which the participant demonstrated more than 1 incident of “bounce” (a violation of the first of Johnson and Bickel’s rules for orderly discounting data (Johnson and Bickel, 2008) was excluded (14 observations, or 1.7% of the data). However, observations that demonstrated a lack of discounting over the longest delay presented (a violation of the second of Johnson and Bickel’s rules) was included (177 observations, or 21% of the data), as the longest delay presented was relatively short (365 days into the future). This violation occurred more frequently (48% of tasks) in the episodic future thought condition, and individuals who hit

this floor on delay discounting were estimated to have natural log normalized delay discount rates of ln(k) = −10.5.

First, delay discounting rates were compared between experimental and control conditions in two separate mixed-effects models, one for the future cue and one for the scarcity cue condition. These models allowed for a random effect of the subject, indicating that participant's responses may be interrelated. Delay discounting rate was then predicted with both condition (no cue or future cue; or no cue or scarcity cue) and session as fixed effects. In the episodic future thinking models, where the same manipulation was delivered sequentially across subsequent sessions, an autoregressive correlation structure was added, indicating that a participant's response to subsequent manipulation may be informed by their most recent response, and session was treated as a numeric variable representing the number of past exposures to the same future cue condition. In the scarcity cue model, session was treated as a categorical variable because distinct and unrelated scarcity scenarios were presented at each session, without an orderly or progressive relationship between cues and without a specified structure. Post-hoc tests comparing session-by-session effects were performed with Bonferroni's correction for multiple comparisons. Models were fit by restricted maximum likelihood estimation using the nlme package in R.

In exploratory analyses, additional covariates were added one by one, to each of these models to explore effects of demographic (gender, age, race, monthly income, education, baseline AUDIT score, peak lifetime AUDIT score, recovery status) and experimental (counterbalance group, the final session the participant completed, cue features, and working memory training dose) variables. Each variable was added to observe both main effects and interactions with the effect of condition (future cue, no cue, or scarcity cue).

3. Results

3.1. Episodic Future Thinking

3.1.1. Primary effects.—A single mixed effects model with subject as a random effect, and session number and condition as fixed effects was used to compare delay discounting rates between the episodic future thinking and no cue conditions. We observed both a significant main effect of the EFT condition ($\beta = -1.07$, $p = 0.011$), engendering lower discounting rates compared to the no cue condition, and a significant condition-by-session interaction ($\beta = -0.477$, $p < 0.001$), indicating that this difference grew over later sessions. Overall, we observed no significant main effect of session number on delay discount rate ($\beta = -0.11$, $p = 0.13$). Planned pairwise comparisons revealed no significant effect of episodic future thinking at the first session ($t(26) = -1.17$, $p = 0.25$), but significant reductions in delay discounting at each subsequent session (in all cases, $p > 0.0001$).

Caption: Figure 1. Repeated Episodic Future Thinking. Symbols represent raw mean discounting rate (ln*k*) over each assessment session for the No cue (square and Future cue (circle) conditions. Bars indicate CIs. * indicates a significant difference between conditions within a session, $p < 0.05$ in pairwise comparisons.

3.1.2. Secondary effects.—In exploratory analyses, mixed models were performed to determine main effects of session and additional covariates, allowing for interactions, one-by-one. We observed no significant effects on the difference between discounting in the no cue and future cue conditions for any potential covariate. However, we observed one significant interaction between session and monthly income ($\beta = 0.0002$, $p = 0.01$), suggesting that individuals with lower monthly incomes showed a larger effect of discount rates between the no cue and future cue conditions over the sessions.

Finally, we examined possible phenomenology of episodic future thinking that may have contributed to differences in discounting between the no cue and future cue conditions. However, neither vividness, importance, excitement, enjoyment, nor cue word length significantly contributed to this difference, or interacted with session number (in all cases, $p > 0.22$).

3.2. Scarcity

3.2.1. Primary effects.—A single mixed effects model with subject as a random effect, and session and condition as fixed effects was used to compare discounting rates between no cue and scarcity conditions. No significant effect of session on discount rates was observed ($\beta = -0.13$, $p = 0.076$). Discount rates in the scarcity condition were significantly higher ($\beta = 0.85$, $p = 0.029$). No significant interaction between condition and session emerged, suggesting that the scarcity effect was unrelated to session number. Planned pairwise comparisons revealed a significant effect of the scarcity condition at the second ($\beta = 1.02$, $p = 0.024$), third ($\beta = 2.35$, $p < 0.0001$), and fifth ($\beta = 0.82$, $p = 0.018$) sessions, after multiple comparison corrections.

Caption: Raw mean delay discount rates (natural-log-normalized *k*) ordered by study session. At each session, discounting rates were assessed in both a no cue (square) and scarcity cue (circle) condition. A single scarcity scenario was presented at each session (labels). Error bars indicate CIs. * indicates a significant difference between conditions within a session, $p < 0.05$.

3.2.2. Secondary effects.—Exploratory analyses were identical to those used to examine future cue effects. No significant main effects or interactions were observed (in all cases, $p > 0.16$).

4. Discussion

The present study's results replicated past findings that the presentation of episodic future cues decreases delay discounting rate, among both current and recovering alcohol users. We also demonstrated that differences in discount rates between a standard, no-cue task and a future-cued task increased cumulatively with repeated administrations of the episodic future thinking procedure. Furthermore, the effects of narratives of hardship (i.e., scarcity) on delay discount rates were content-specific, with no relationship between the effect of these narratives and the number of narratives that had previously been presented. These results will be discussed in terms of: 1) past research manipulating delay discounting rate; 2) comparison between repeated episodic future thinking and other psychosocial interventions

in AUD; 3) the stability of the discounting rate in the no-cue condition; 4) consideration of demand characteristics; and 5) interpretation of the effects of scarcity cues. Finally, limitations and future directions will be identified.

This study is the first to report the effects of repeated manipulations specifically targeting delay discounting rate. Research manipulating delay discounting rate with acute interventions has gained momentum in recent years, with a recent meta-analysis (Rung and Madden, 2018a) identifying 12 studies examining reductions in delay discounting rate with clinical interventions published prior to 2016. However, few studies have reported on the effects of intervention dose on delay discounting rate. One study by Yoon and colleagues (Yoon et al., 2009) compared the impact of one day versus fourteen days of rewards delivered contingent upon cigarette abstinence and observed decreased delay discounting and increased abstinence in the fourteen-day group compared to the one-day group. Another study delivered a money-management intervention to cocaine-only or cocaine-and-alcohol users (Black and Rosen, 2011), and observed significant heterogeneity in changes in discounting rates over time, although this report did not include session-by-session effects of the intervention on delay discounting. Neither of these studies employed manipulations specifically targeted towards discounting rate. Furthermore, past research using episodic future thinking has typically employed only single presentations of episodic future thinking (Benoit et al., 2011; Daniel et al., 2013a, 2013b; Dassen et al., 2016; Kwan et al., 2015; Lin and Epstein, 2014; Liu et al., 2013; Snider et al., 2016; Stein et al., 2016; Sze et al., 2017). The only study, to our knowledge, that has examined repeated future cue presentation over time remotely delivered episodic future thinking cues repeatedly over a four-week period using a Web-based system (Sze et al., 2015). Notably, participants did not repeatedly generate future cues, but were sent daily prompts to listen to audio recordings and read text of future cues generated at study intake. This study did not report effects on delay discounting or on differences in effects at first versus last sessions, but did observe promising trends towards reduction in body weight among adults repeatedly engaging with future cues over the four-week intervention period. As manipulations of delay discounting, particularly with episodic future thinking, grow in research interest, investigating the effects of the repeated intervention is crucial for understanding their translational impact. Future research may also benefit from further investigation of the effects of episodic future thinking on discounting of other commodities, as the majority of studies to date (including the present study) have interrogated discounting of monetary reinforcers.

Furthermore, these data indicate that the episodic future thinking effect grew with repeated administrations. A recent meta-analysis (Kramer Schmidt et al., 2018) has indicated that for psychosocial AUD treatment, neither planned nor actual duration of therapy is significantly associated with patient outcomes. This suggests that at clinically relevant doses, the effects of psychosocial interventions such as cognitive behavioral therapy, twelve-step facilitation, and motivational interviewing do not grow with repeated engagement. The observation of a growing effect of future cue presentation over time has multiple translational implications for the use of episodic future thinking manipulations. Primarily, these data may support the clinical relevance of repeatedly developing and being exposed to episodic future cues (i.e., that individuals may benefit from additional guided interviews even after the first administration--and that effects may be even greater with more administrations than the

number studied here). Future research examining whether these effects of episodic future thinking extend to other clinically-relevant outcome measures (e.g., alcohol valuation or real-world drinking behavior) may benefit from applying multiple sessions of future cue presentation.

Interestingly, delay discounting in the no-cue condition remained stable over time. This data supports both the test-retest reliability of delay discounting measures (Ohmura et al., 2006) and addresses a further consideration in the translation of episodic future thinking toward a clinically-relevant intervention. The episodic future thinking effect did not transfer to the baseline, no cue condition, suggesting increased *sensitivity* to presented future cues with repeated exposures, rather than a change in underlying discounting rate. Importantly, the features of the cues generated within each session remained stable over time (including phenomenological ratings of future cue vividness, importance, enjoyment, and excitement, as well as cue length) and were unrelated to the magnitude of the future cue effect. Taken together, these data suggest that while the capacity to attend to future cues may increase over time, the effects of cue presentation itself are more acute. For episodic future thinking to impact real-world behavior, the future simulation must either become a habit (with individuals focusing on future events without cue presentation) or future cues must be presented frequently in the real decision-making environment (as in Sze etal., 2015).

One possible explanation for the observed increased sensitivity to future cues could be demand characteristics or the “good subject effect”, which has been recently explored in the context of episodic future thinking. Notably, two online experiments indicated that participants could readily deduce the experimental hypothesis that future cue generation may increase preference for larger, later rewards (Rung and Madden, 2018b). However, in another study, the effects of episodic future thinking on delay discounting and purchasing of cigarettes remained significant after controlling for measures of these demand characteristics (Stein et al., 2017). If demand characteristics were responsible for increasing sensitivity to future cue presentation in the present study, the same may have been hypothesized for the presentation of scarcity cues. However, sensitivity to scarcity cues did not seem to vary over time. Rather, these hypothetical manipulations of discount rate seemed to have purely content-dependent, not practice-dependent effects. The present study did not explicitly interrogate demand characteristics or ability to discern the experimental hypotheses. However, since demand characteristics likely extended to the scarcity manipulation as well and did not appear to drive differences in discount rate under this condition, the observed practice effect with future cues was likely driven by more than demand characteristics alone.

Past research on the effects of scarcity manipulations has observed significant increases in discounting rate under scarcity conditions (Bickel et al., 2016a; Mellis et al., 2018a, 2018b). In the present study, the effects of scarcity cues did not change over time, and appeared to be highly dependent on the content of particular scenarios presented. Notably, the scenarios describing a break-in, a natural disaster, and a fire were the only ones to induce steeper discounting rates in pairwise comparisons. In the present study, these scenarios primarily functioned as a control for the effects of repeated administrations of purely hypothetical manipulations (i.e., whether demand characteristics changed over time, with participant’s delay discounting rates becoming more sensitive to manipulations after greater study

engagement). That this effect was not observed in the scarcity condition strengthens the interpretation of a growing effect of future cues over repeated sessions. However since session number and scarcity scenario content were confounded, further research into the effects of repeated scarcity is needed to draw strong conclusions on the scarcity effect particularly.

The present study describes a within-subject manipulation of delay discounting using both episodic future thinking and a hypothetical scarcity manipulation, not a randomized controlled trial of the effects of repeated episodic future thinking compared to the effects of a repeated control manipulation. Thus, several problems related to study design (i.e., an escalating compensation scale across subsequent sessions, as well as the underlying working memory training study) cannot be fully dismissed as contributors to variability in discount rates. However, this design promoted the exploration of acute effects of both manipulations on the discount rate by collecting not only within-subject but also within-session baseline discount rates for each participant. Additionally, the present study used community recruitment and did not involve review of medical records to assess the possible contributions of other comorbidities or disorders that may play a role in episodic thinking. Future research using alternative designs, in alternative samples, may allow for more concrete determination of these effects.

In sum, the present data indicate that episodic future thinking attenuates delay discounting, and these effects grow with repeated administration. Further research is needed to determine whether these effects are driven by the repeated presentation or generation of future episodes, and to identify the dose of episodic future thinking with the greatest translational potential. Furthermore, a scarcity manipulation to increase discounting rate did not show a growing effect over time. These results provide a rich foundation for future research into the translational potential of delay discounting manipulations.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Highlights

- Impulsive discounting rates, an addiction marker, improve with episodic prospection
- Repeated episodic prospection cumulatively improved discounting rates in drinkers
- Another manipulation, hypothetical scarcity, did not show cumulative effects
- Episodic prospection targeting discounting shows translational potential

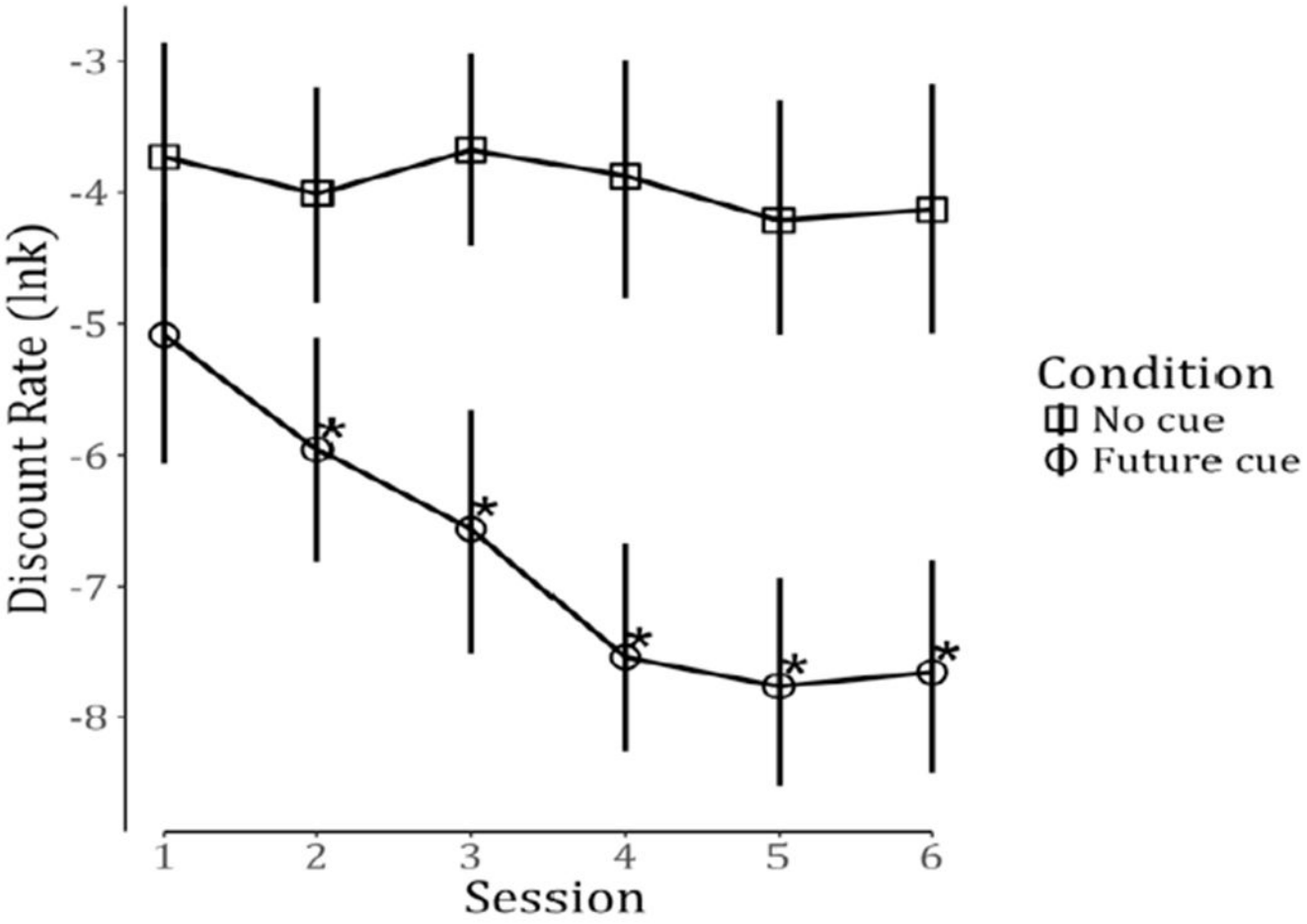

Figure 1.
Discounting by Session with Future Cues

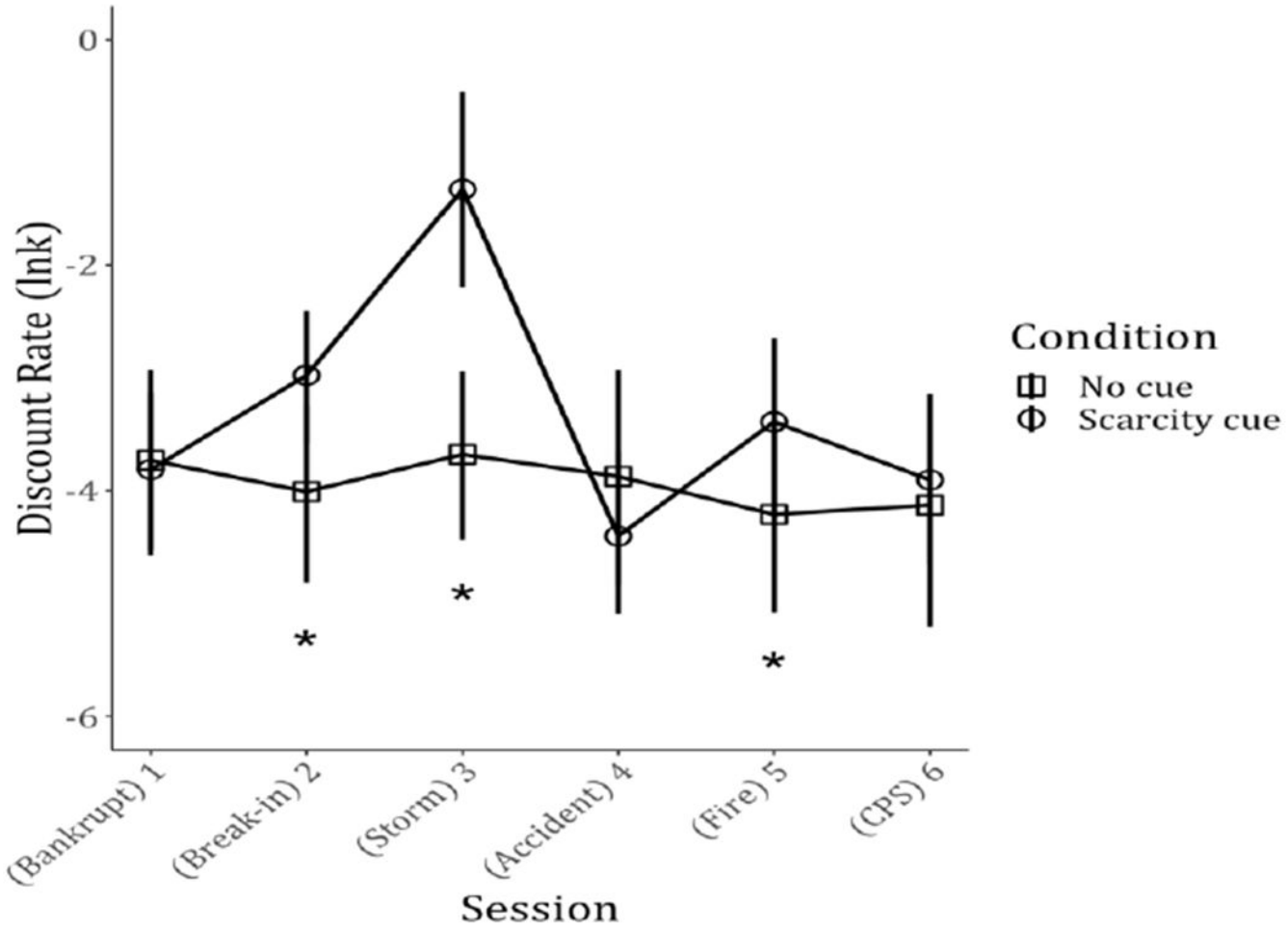

Figure 2.
Discounting by Session with Scarcity Cues