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Think Fast: Rapid Assessment of the Effects of Episodic Future Thinking on Delay Discounting in Overweight/Obese Participants

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Abstract

Accumulating laboratory-based evidence indicates that reducing delay discounting (devaluation of delayed outcomes) with the use of episodic future thinking (EFT; mental simulation of future events) improves dietary decision-making and other maladaptive behaviors. Recent work has adapted EFT for use in the natural environment to aid in dietary and weight control by engaging participants in EFT repeatedly throughout the day. These efforts may benefit from minimizing the amount of time required for measurement and implementation of EFT. Using Amazon Mechanical Turk in the present study, we show that EFT effectively reduces delay discounting in overweight/obese participants ($N = 131$) using the recently developed 5-trial, adjusting-delay discounting task, which can be completed rapidly (25 s) and is therefore ideally suited for ecological momentary assessment. Moreover, measures of delay discounting from this task were strongly correlated with those from the commonly used adjusting-amount task ($r = .859$). Significant effects of EFT on discounting, however, depended on the number of future events participants generated and imagined. Use of a range of events and future time frames (as is typical in the literature) significantly reduced delay discounting, whereas use of only a single event did not.

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Compliance with Ethical Standards (remaining material in text):
Dr. Bickel 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. Dr. Epstein is a consultant for and has equity in Kurbo Health.
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Delay discounting describes the devaluation of delayed outcomes and is measured using tasks arranging choices between relatively small, immediate rewards and larger, delayed alternatives (for review, see Madden & Johnson, 2010). High rates of discounting are pervasive in obesity (for meta-analysis, see Amlung et al. 2016) and related disorders such as type 2 diabetes (e.g., Reach et al. 2011). Indeed, delay discounting may play an etiological role in development of these disorders (Bickel et al., 2012), as rapid devaluation of the future may promote behavior that produces immediate rewards but negative, delayed consequences (e.g., overeating, sedentary behavior). Fortunately, emerging evidence suggests that bias for immediacy can be mitigated through targeted interventions (Koffarnus et al. 2013).

One such intervention involves episodic future thinking (EFT), in which participants generate and vividly imagine a number of positive, future events. In laboratory-based studies, EFT robustly reduces delay discounting in overweight and obese participants (Daniel et al. 2013; Sze et al. in press) and produces concomitant reductions in both ad-libitum energy intake (Daniel et al. 2013) and the relative reinforcing efficacy of unhealthy foods (Sze et al. in press). Adapting these methods for use in natural settings has shown that EFT holds promise as a targeted weight loss treatment. For example, EFT has been used outside the laboratory to effectively reduce energy intake when administered both acutely (O'Neill et al. 2016) and as part of a web-based treatment to aid in dietary and weight control (Sze et al. 2015). Indeed, such covariance between EFT, delay discounting, and eating behavior further supports an etiological role of delay discounting in obesity.

Use of EFT interventions in natural treatment settings (Sze et al. 2015; O'Neill et al. 2016) could benefit from ecological momentary assessment of delay discounting, allowing real-time assessment of EFT-dependent changes in discounting and how these changes covary with dietary intake and other treatment-related behavior (e.g., adherence to exercise regimens). Moreover, discounting in the natural environment could be examined in the absence of EFT to identify fluctuating environmental conditions or times of day (e.g., stress, meal times) that individual participants would most benefit from enhanced self-control. However, one barrier to measuring discounting in the natural environment is the time required for assessment. Measurement of discounting using a traditional *adjusting-amount* task (for review, see Madden & Johnson, 2010) requires a large number of trials in which participants make repeated choices between a larger, delayed reward (e.g., $100) and a smaller, immediate reward amount that titrates across choices until the participant is indifferent between choice options (Du et al. 2002). This *indifference amount* indexes the discounted value of the larger reward. Repeating this titration process across multiple delays (e.g., 1 day-25 years) yields a discounting curve from which rate of discounting is derived.

In recent data collection by our group, a sample of 72 overweight and obese participants required 4.61 min on average to complete a single adjusting-amount discounting task (SD: ± 1.38[1]). Likewise, in a previous study, completing the same task required undergraduates 3.30 min (SD: ± 0.64; Koffarnus & Bickel 2014). Although this time is not prohibitive under

[1]This estimate reflects completion of 42 choice trials across seven delays (1 day to 25 years), administered using the amount titration algorithm described by Du et al. (2002).

most laboratory conditions, even modest amounts of time to measure discounting in the natural environment likely intrude upon participants' daily lives and may discourage participation or compromise data collection, especially when discounting is measured repeatedly throughout the day.

Toward this end, the primary purpose of the present study was to determine whether the recently developed *5-trial adjusting-delay* task (Koffarnus & Bickel 2014), which assesses discount rates rapidly (in approximately 25 s), would be sensitive to EFT's effects on discounting. Replication of previously reported effects would facilitate broad and rapid measurement of delay discounting in the natural environment (e.g., via mobile devices). In addition to examining the 5-trial adjusting-delay task, we also sought to compare the effects of EFT employing a wide range of future events and related text cues, as is typical in the literature (e.g., Daniel et al. 2013; Sze et al. in press), to its effects when employing a single event and cue. If effective in reducing delay discounting, employing only one cue would further reduce time required for intervention and increase EFT's ease of use in research and clinical settings. For all comparisons, we used *episodic recent thinking* (ERT) as a control condition, a commonly used method in which participants imagine real events that occurred in the recent past (e.g., Lin & Epstein 2014; Stein et al. 2016). This ERT condition serves to isolate the effects of prospection in EFT by ensuring that episodic thinking in both groups engages memory, features personal details, and is matched for vividness.

Method

Participants

We recruited participants from Amazon Mechanical Turk, a crowdsourcing platform that allows individuals to complete brief Human Intelligence Tasks (HITs) in exchange for monetary compensation. Participants received $3 upon completing all of the questions (requiring approximately 30 minutes). In addition, participants received a $3 bonus if delay-discounting data in the adjusting-amount task met standardized criteria indicating appropriate attention to the task (Johnson & Bickel 2008). These criteria required: 1) a non-negligible evidence of discounting across delays (1 day to 25 years), and 2) consistency in the effects of contiguous delays on discounted value (see Johnson & Bickel 2008 for more details).

All participants were required to be 18 years age or older; have a BMI (kg/m^2) of 25 or greater; have an mTurk approval rating indicating that submitted HITs have been of sufficient quality to be accepted at least 90% of the time; and score less than a 15 on the Patient Health Questionnaire-9 (PHQ-9; Kroenke et al. 2003), a screening instrument for depressive symptoms. We used PHQ-9 score as an exclusion criterion because prior data suggest that depression compromises prospective thought (MacLeod & Salaminiou 2001). A total of 137 participants meeting the eligibility criteria completed the study. These were randomly assigned to one of four groups: 1) EFT with 3 events/cues (EFT-3), 2) EFT with 1 event/cue (EFT-1), 3) ERT with 3 events/cues (ERT-3), and 4) ERT with 1 event/cue (ERT-1). Six participants were excluded from analysis for nonsystematic patterns of delay discounting (Johnson & Bickel 2008). This included 3 data sets violating Criterion 1 above (n = 1 each from the EFT-1, EFT-3, and ERT-1 groups) and 3 data sets violating Criterion 2

(n = 1 each from the EFT-1, ERT-1, and ERT-3 groups), leaving 131 participants included in the final analysis.

Compliance with Ethical Standards

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

Procedures

Study procedures were implemented using Qualtrics online survey software (Qualtrics, Provo, UT).

Episodic cue generation—To generate episodic events, participants used a self-guided generation task (Sze et al. in press) similar to staff-guided tasks used in previous studies (Daniel et al. 2013; O'Neill et al. 2016; Stein et al. 2016; Snider et al. 2016). EFT participants generated personalized future events that they were looking forward to and could vividly imagine. EFT-1 participants generated an event to occur during one future time frame (7–12 months), whereas EFT-3 participants generated events for three future time frames (1, 2–6, and 7–12 months). The 7–12 month time frame was chosen for the EFT-1 group because EFT appears to exert its largest effects in the adjusting-amount task over this range of discounting delays (Stein et al. 2016; Snider et al. 2016). In contrast, ERT participants generated recent past events that they enjoyed and could vividly remember. ERT-1 participants generated an event for one recent time frame (7–12 days ago), whereas ERT-3 participants generated events for three different recent time frames (1, 2–6, and 7–12 days ago).

All participants were instructed to imagine and describe in detail events that were positive, specific, and vivid. To help participants think about autobiographical details of their events, participants rated the valence, salience, arousal, frequency, and vividness of each event from 1 (very low) to 5 (very high). Participants were also prompted to describe specific details of their events, including who was there, what was happening, where the event took place, and how they felt. Participants were instructed to describe the events as though they were currently happening. Detailed and positive event descriptions examples, along with vague and negative examples, were provided and labeled as "good" and "bad" to emphasize the importance of positivity, specificity, and vividness. In addition, a checklist of task requirements (i.e., positivity, vividness, specificity) was provided to use as a reference.

During generation of cues, we provided participants with calendars to aid in conceptualization of temporal distance. In addition, as a reference, we provided the range of calendar dates corresponding to each event time frame using Qualtrics' date feature (e.g., 7/01/16 – 12/01/16).

Adjusting-amount and 5-trial adjusting-delay discounting tasks—Next, participants completed the adjusting-amount and -delay tasks in random order. In the adjusting-amount task, participants made repeated hypothetical choices between $100 delivered after a delay and a smaller amount delivered immediately. The amount of the smaller reward was either increased or decreased (depending on the preceding choice) across consecutive trials until reaching an indifference amount (see Du et al. 2002). At this indifference amount, the subjective value of both rewards is approximately equal. This titration process was repeated at seven delays (1 day, 7 days, 1 month, 6 months, 1 year, 5 years, and 25 years; order randomized), with 6 trials at each delay.

In the adjusting-delay task, participants completed five trials in which they chose between $100 delivered after a delay and half of this amount ($50) available immediately. The delay to the larger amount started at 3 weeks and titrated over subsequent trials based on previous choices until reaching an *indifference delay* (possible range: 1 hour-25 years, in approximately logarithmically spaced intervals, as used by Koffarnus & Bickel, 2014). At the obtained indifference delay, subjective value of both rewards is approximately equal. Moreover, the indifference delay serves as a measure of half-life, or Effective Delay 50, at which the larger reward has lost half of its subjective value (Koffarnus & Bickel 2014).

Engagement in EFT/ERT—In both the adjusting-amount and -delay tasks, self-generated text narratives of each event and brief text cues were presented on the screen at each trial. Participants were instructed to carefully read and imagine these events as they made choices. For EFT-3 and ERT-3 participants, the time frame of the event/cue approximately matched the active delay in the adjusting-amount and -delay tasks (e.g., shortest event time frame paired with the shortest delays). In contrast, for EFT-1 and ERT-1 participants, the same event/cue was presented at every trial in these tasks.

Data Analysis

To calculate discount rates, we used Mazur's (1987) hyperbolic discounting model,

$$V = \frac{A}{1 + kD}$$

where V is discounted value, A is reward amount, D is delay, and k is a free parameter that indexes rate of discounting. Higher values of k indicate more rapid devaluation of the delayed reward, and hence greater impulsivity. For the adjusting-amount task, k was derived by fitting individual participants' indifference amounts across delays using nonlinear regression. For the adjusting-delay task, k was calculated as the inverse of the indifference delay (i.e., 1/indifference delay; Koffarnus & Bickel 2014). This expression is mathematically equivalent to solving for k when $V = 50$ (amount of the smaller option), $A = 100$ (amount of the larger option), and $D =$ the indifference delay (in days).

Values of k in both tasks were positively skewed and were thus natural log transformed prior to analysis. We examined measures of discount rate (ln k) using a single repeated-measures ANOVA, including a within-subjects main effect of task type (adjusting-amount and -delay) and between-subjects main effects of cue type (EFT and ERT) and cue quantity (3 and 1 cues).

Aggregate ratings of engagement and vividness of cue imagery were examined using separate ANOVAs, including between-subject effects of cue type and quantity. In all ANOVA models described above, we examined all possible 2- and (where appropriate) 3-way interactions between factors. Huynh-Feldt adjusted degrees of freedom were used in cases in which data violated sphericity. Where reported, we conducted planned post-hoc comparisons using sequential Bonferroni correction.

Finally, we examined correspondence in discount rate between tasks using Pearson *r* correlation coefficients. All inferential statistics were analyzed using SPSS (ver. 24; Chicago, IL).

Results

The distribution of demographic characteristics for participants assigned to varying groups, with *t* tests and chi-square results, are shown in Table 1. The analysis indicated no group differences in any of the demographic measures included.

Delay Discounting

Figure 1 presents estimates of discount rate in the adjusting-amount and -delay tasks in EFT and ERT participants as a function of cue quantity. We observed a significant main effect of both cue type ($F(1, 127) = 6.813$, $p = .010$) and task type ($F(1, 127) = 60.953$, $p < .001$). That is, overall, EFT reduced discount rate compared to ERT, with the adjusting-delay task producing higher estimates of discount rate than the adjusting-amount task. No other main effects or interactions were significant, including the Cue Type x Cue Quantity interaction ($F(1, 127) = 1.593$, $p = .209$). In planned post-hoc comparisons, we observed significantly lower discount rates in the EFT-3 compared to the ERT-3 group in both the adjusting-amount (p =.036) and -delay ($p = .008$) tasks. However, for EFT-1 and ERT-1 groups, we observed no significant difference in discount rate in either the adjusting-amount (.268) or -delay ($p = .489$) tasks.

Figure 1 also depicts the correlation between estimates of discount rate between the adjusting-amount and -delay tasks, collapsed across groups. Overall, estimates of discount rate were strongly correlated between adjusting-amount and -delay tasks ($r = .859$, $p < .001$). Correlations within individual groups (not depicted in Figure 1) remained significant in the EFT-1 ($r = .914$, $p < .001$), ERT-1 ($r = .866$, $p < .001$), EFT-3 ($r = .663$, $p < .001$), and ERT-3 ($r = .872$, $p < .001$) groups.

Imagery Ratings

We observed no main effects of cue type and cue quantity in aggregate and individual ratings of engagement and vividness of cue imagery for all measures ($p > 0.05$). We observed no interaction between cue type and cue quantity.

Discussion

Results of the present study replicate prior effects of EFT on delay discounting using the adjusting-amount task (Stein et al. 2016; Sze et al. in press; Snider et al. 2016) and extend these findings by showing that EFT also reduces delay discounting in the 5-trial adjusting-delay task. However, effects of EFT on delay discounting depended on the number of future events and related text cues employed. That is, generating only a single EFT cue was not sufficient to reduce delay discounting. Rather, only EFT featuring three cues (consistent with prior methods; Sze et al. in press) significantly reduced delay discounting. Finally, although estimates of discount rate were significantly higher overall in the adjusting-delay compared to the adjusting-amount task, estimates of discount rate were strongly correlated across tasks, demonstrating construct validity of the adjusting-delay task.

These data demonstrate the feasibility of using the 5-trial adjusting-delay task to rapidly measure effects of EFT on delay discounting. Although estimates of time required for task completion could not be obtained in the present study due to constraints of the software platform (Qualtrics), prior data indicate that this task can be completed rapidly (25 s; Koffarnus & Bickel 2014), making it uniquely well suited to examine delay discounting non-intrusively and iteratively in the natural environment. The ability to measure real-time, EFT-dependent changes in delay discounting in the real world may enhance our understanding of mechanisms underlying this intervention's effects on dietary and weight control (Sze et al. 2015; O'Neill et al. 2016) and other maladaptive behaviors such as alcohol use (Snider et al. 2016) or cigarette smoking (Stein et al. 2016).

The present study is the first to suggest that the efficacy of EFT in reducing delay discounting depends on generation of cues across a range of time frames, as we observed no effect of EFT with the use of only a single cue. For the EFT-1 group, the majority of discounting trials featured an EFT event more than 6 months temporally removed from the delay being evaluated in the discounting task. Thus, the failure of a single EFT cue to reduce discounting suggests the importance of approximate correspondence between the episodic time frame and delays in the discounting task. However, future work is needed to reach firm conclusions, as the present study's null effects of the EFT-1 group may have been influenced by the specific time frame used (1 year) or the product of habituation to a single cue over repeated trials. Resolution of the role of quantity and temporal allocation of EFT cues will not only facilitate basic understanding of the mechanisms underlying EFT's effects, but may also reduce the amount of time required for EFT's implementation and therefore increase its adoption in research and treatment settings.

The finding that the 5-trial adjusting-delay task produced generally higher estimates of delay discounting than the adjusting-amount task also requires further investigation. In the absence of EFT, Koffarnus and Bickel (2014) also showed slightly higher discount rates in college undergraduates with the adjusting-delay task. Together with the present study, this discrepancy suggests that absolute values of discount rate following EFT in the adjusting-delay task cannot be precisely compared to prior studies using the adjusting-amount task. However, three observations mitigate concern over this discrepancy. First, despite differences in absolute values, measures of discount rate correlated strongly between adjusting-amount and -delay tasks in the present study ($r = .859$), supporting the construct validity of the adjusting-delay task. This replicates a prior report of correspondence between these tasks (Koffarnus & Bickel, 2014) and extends it to a different monetary magnitude ($100 instead of $1000) and a novel, more diverse population (crowdsourced overweight/

obese participants instead of college students). Second, absolute levels of delay discounting are often not the focus of EFT interventions; rather, *relative change* in this measure is more important. Third, and finally, few prior EFT studies use discount rate (ln k) as their measure of delay discounting (but see Sze et al. in press; Lin & Epstein 2014); thus, there is little prior data to serve as a comparator. Instead, the majority of studies have used area under the curve (AUC; Myerson et al. 2001) to estimate effects of EFT on discounting (Daniel et al. 2013; Stein et al. 2016; Snider et al. 2016; Sze et al. in press). AUC has historically been the preferred measure because most prior studies investigated a narrow range of adjusting-amount task delays over which participants are likely able to generate vivid, meaningful events (e.g., 1 day-1 year). Over this range of delays, EFT is so effective that it often produces little to no discounting (Stein et al., 2016), preventing application of nonlinear regression and hence estimates of discount rate. Indeed, only by investigating a broader range of delays in the present study (1 day-25 years) were we able to apply nonlinear regression and obtain discount rate from the adjusting-amount task.

Finally, use of the ERT conditions in the present study aligns with many prior investigations of EFT (e.g., Lin & Epstein, 2014; Snider et al. 2016; Sze et al. in press) and vividly controls for engagement of memory and vividness in episodic thinking. Effects of EFT on delay discounting cannot be attributed to the absolute difference in temporal distance between EFT and ERT cues (up to 1 year in EFT in the present study, but only several days in ERT), as recent data indicate that episodic thinking of the distant past does not affect future discounting (Daniel et al. 2016). Moreover, in a recent paper, we observed no differences in delay discounting between ERT and a group not engaging in episodic thinking (Sze et al., in press). Thus, ERT appears to exert no measureable influence on delay discounting. Nonetheless, despite these strengths of ERT as a control method, we support exploration of novel controls in future research to better understand EFT processes in delay discounting and other behavior.

Conclusions

The 5-trial adjusting-delay task is sensitive to EFT-related reductions in delay discounting and can facilitate rapid, real-time measurement of delay discounting in real-world EFT interventions. These reductions in delay discounting, however, may depend on imagining the future across multiple time frames.

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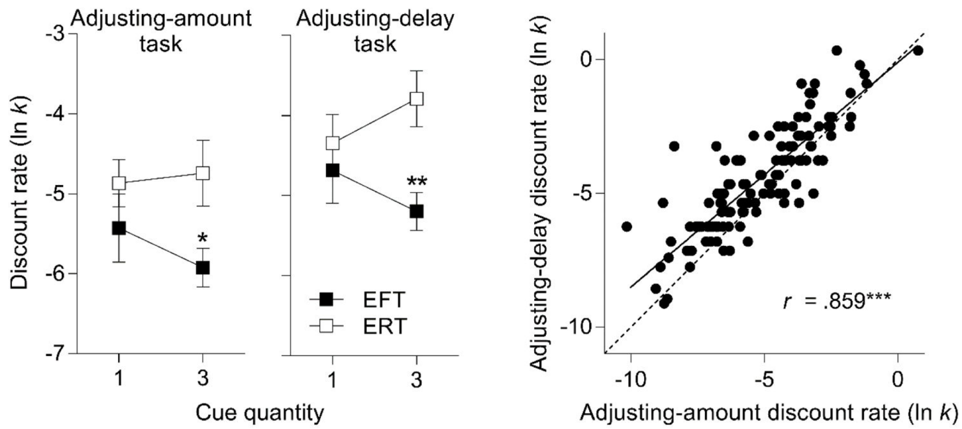

Figure 1.

Discount rate (ln *k*) for $100 in the adjusting-amount and -delay tasks in EFT and ERT participants assigned to the 1- and 3-cue groups (left panels). Error bars represent standard error of the mean. Also depicted is the correlation in discount rate between tasks (right panel). Solid line represents line of best fit in linear regression; dashed line represents unity. Asterisks indicate significant difference from ERT within the same cue quantity group (left panels) or significant Pearson r correlation (right panel). *$p < .05$; **$p < .01$; ***$p < .001$.

Table 1

Demographic characteristics.

	Group				
	1 cue (*n* = 64)		3 cues (*n*=67)		
Characteristics	**EFT (*n* = 33)**	**ERT (*n* = 31)**	**EFT (*n* = 34)**	**ERT (*n* = 33)**	***p* value**
% Female	57.6	55.2	55.9	60.6	0.764
% White	84.8	77.4	88.2	75.8	0.480
% Married	39.4	45.2	47.1	39.4	0.650
% Education level					
High school diploma	33.3	37.9	38.2	33.3	
Associates degree	21.2	24.1	14.7	18.2	
Bachelors degree	36.4	24.1	29.4	39.4	0.839
Masters degree	09.1	10.3	17.6	9.1	
Other	00.0	03.4	00.0	00.0	
PHQ-9 (±SD)	7.18 (3.5)	6.23 (4.5)	5.71 (3.3)	7.15 (3.4)	0.295
Household Income (±SD)	51,969.70 (35,771.3)	59,166.73 (42,932.9)	56,764.71 (40,035.63)	56,515.15 (40,744.7)	0.909
BMI (±SD)	33.32 (5.9)	32.77 (6.4)	30.80 (4.2)	33.28 (6.8)	0.259
Age (±SD)	35.03 (11.5)	36.41 (10.1)	38.26 (10.9)	33.27 (10.8)	0.287