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Cuing both positive and negative episodic foresight reduces delay discounting but does not affect risk-taking

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Abstract

Humans frequently create mental models of the future, allowing outcomes to be inferred in advance of their occurrence. Recent evidence suggests that imagining positive future events reduces delay discounting (the devaluation of reward with time until its receipt), while imagining negative future events may increase it. Here, using a sample of 297 participants, we experimentally assess the effects of cued episodic simulation of positive and negative future scenarios on decision-making in the context of both delay discounting (monetary choice questionnaire) and risk-taking (balloon-analogue risk task). Participants discounted the future less when cued to imagine positive and negative future scenarios than they did when cued to engage in control neutral imagery. There were no effects of experimental condition on risk-taking. Thus, although these results replicate previous findings suggesting episodic future simulation can reduce delay discounting, they indicate that this effect is not dependent on the valence of the thoughts, and does not generalise to all other forms of "impulsive" decision-making. We discuss various interpretations of these results, and suggest avenues for further research on the role of prospection in decision-making.

Keywords

Impulsivity; decision-making; prospection; emotion; episodic foresight; episodic future thinking

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Introduction

Humans have the capacity to simulate potential future events and to organise behaviour accordingly. This capacity has been called "episodic foresight" or "episodic future thinking" (Atance & Neill, 2001; Schacter, Benoit, & Szpunar, 2017; Suddendorf & Moore, 2011; Szpunar & Radvansky, 2015), and it is of enormous functional significance because it enables people to plan and prepare for anticipated future possibilities (Pezzulo, 2016; Suddendorf, Bulley, & Miloyan, 2018; Suddendorf & Corballis, 2007). Many different aspects of decision-making involve accounting for such possible future circumstances, including intertemporal choices—in which sooner and later outcomes are pitted against one another (Berns, Laibson, & Loewenstein, 2007).

Intertemporal choice and episodic foresight

Many decisions have consequences that emerge only after a delay, and these delayed outcomes may be, to varying degrees, integrated into decision-making mechanisms (Peters & Büchel, 2011; Story et al., 2013). Nonetheless, humans have a strong tendency to discount the value of future rewards relative to ones that are immediately available (Berns et al., 2007). This tendency for *delay discounting* varies substantially as a trait between people (Peters & Büchel, 2011) due to factors such as genetic heritability (Anokhin, Golosheykin, Grant, & Heath, 2011; Sanchez-Roige et al.,

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2018), and various aspects of developmental history or current environmental characteristics (Pepper & Nettle, 2017). As a somewhat distinct aspect of impulsivity—sometimes called *choice impulsivity* (Dawe, Gullo, & Loxton, 2004; Gullo, Loxton, & Dawe, 2014; Hamilton et al., 2015)—delay discounting in humans is perhaps best considered as an index of people's *preferences* for smaller, sooner rewards relative to larger delayed rewards when those rewards are in opposition. This is reflected in the measurement of the delay discounting construct, in which the standard instruments require participants to make forced choices between smaller but sooner and larger but later monetary amounts (e.g., Kirby, Petry, & Bickel, 1999). However, observable delay discounting also varies within individuals (Lempert & Phelps, 2015) based on the framing of the choice question, current mood state, other contextual variables, and ongoing cognitions (Berns et al., 2007). It stands to reason that ongoing prospective cognition focused on the future might be particularly important in determining the prioritisation of delayed relative to more immediate rewards.

Indeed, various lines of evidence have emerged recently to suggest that cueing episodic foresight can be sufficient to encourage preferences for larger, later rewards in intertemporal choice tasks (for reviews see Bulley, Henry, & Suddendorf, 2016; Schacter et al., 2017). In the first empirical studies on this topic, spurred by a theoretical article by Boyer (2008), participants completed modified intertemporal choice tasks to assess their preferences while simultaneously imagining personally relevant future events and undergoing functional magnetic resonance imaging (fMRI) scans. In Peters and Büchel's (2010) study, participants made a series of choices, for instance, between €20 now and €35 in 45 days, while being cued with an actual event they had planned in around 45 days' time. In the episodic cue condition, preferences shifted towards delayed rewards. A subsequent study observed a similar pattern of results (Benoit, Gilbert, & Burgess, 2011). The authors of these first studies suggested that the effect of episodic foresight on intertemporal choice was linked to a neural mechanism of functional connectivity between brain regions in the core network involved in episodic simulation and prefrontal hubs involved in valuation.

Since those first investigations, associations between imagining the future and intertemporal decision-making have been reported in many other studies, and links have been reported to various other decision-making profiles and behaviours that collectively fall under the umbrella of "impulsivity". For instance, cuing participants to imagine the future has been shown to reduce ad-libitum calorie intake in obese women and children (Daniel, Stanton, & Epstein, 2013; Daniel, Said, Stanton, & Epstein, 2015), as well as healthy undergraduate women (Dassen, Jansen, Nederkoorn, & Houben, 2016). Such cueing has also been shown to reduce hypothetical alcohol demand in alcohol-dependent people (Snider, LaConte, & Bickel, 2016) and undergraduates (Bulley & Gullo, 2017). However, in both of these latter studies the effects were somewhat selective; affecting certain alcohol purchase demand indices, but not others. Similar effects have been reported in the context of the intensity of cigarette demand (Stein, Tegge, Turner, & Bickel, 2018) and actual cigarette smoking among samples of smokers (Stein et al., 2016). Given that delay discounting itself has been linked to a range of negative behaviours and outcomes from obesity (Amlung, Petker, Jackson, Balodis, & Mackillop, 2016), to gambling (MacKillop et al., 2011; Wiehler & Peters, 2015), to lower life expectancy (Bulley & Pepper, 2017)—and is therefore considered an important trans-disease process (Koffarnus, Jarmolowicz, Mueller, & Bickel, 2013)—manipulations that can effectively influence this decision-making process are widely sought. As a consequence, there has been considerable recent excitement about the potential role of episodic foresight in developing (early) interventions for impulsivity-related disorders, although this excitement has been hedged with ongoing discussion about the limits, generalizability, and transferability of any effects (Bickel et al., 2018; Bromberg, Lobatcheva, & Peters, 2017; Noël, Jaafari, & Bechara, 2017; Sze, Daniel, Kilanowski, Collins, & Epstein, 2015; Sze, Stein, Bickel, Paluch, & Epstein, 2017).

The specific mechanistic interpretation of how episodic foresight might impact intertemporal choice has varied widely, from considerations about the potential of imagining the future in engaging higher level psychological construal (Cheng, Shein, & Chiou, 2012), to the "expansion" of the "temporal window" of reinforcement information (Snider, LaConte, & Bickel, 2016), greater identification or concern for one's "future self" (O'Connell, Christakou, & Chakrabarti, 2015), the extension of "temporal attention" (Kaplan, Reed, & Jarmolowicz, 2016), and the importance of framing effects (Jenkins & Hsu, 2017). In most cases, however, there is a common theoretical foundation suggesting that positive simulations of the future should lead to reduced discounting rates because the emotions engendered by these simulations can act as a "motivational brake" on immediate preferences (Boyer, 2008). For instance, imagining a future payoff may provide a sufficient reinforcement to motivate goal pursuit at the expense of shorter term alternatives. This is because imagining an emotional future event can trigger emotions in the here-and-now, "as if" the event were really occurring (Damasio, 2009; Gilbert & Wilson, 2007)—allowing people to anticipate the delayed value of their current patience. Indeed, there are a number of reasons to believe that the relationship between episodic foresight and intertemporal decision-making might ultimately depend on the emotional valence of the thoughts, including the catalogue of differences between the processes and consequences of positively and negatively valenced foresight (see Barsics, Van der Linden, & Argembeau, 2015; de Vito, Neroni, Gamboz, Della Sala, & Brandimonte, 2014).

The anticipation of negative, harsh, dangerous or uncertain future environments or scenarios might be expected to lead to a preference for immediate rewards inasmuch as one expects that the delayed reward is unlikely to materialise in such circumstances (Frankenhuis, Panchanathan, & Nettle, 2016). In fact, one of the ultimate evolutionary explanations for delay discounting is that the future is uncertain, which might prevent one from being able to capitalise on delayed rewards (Bulley & Pepper, 2017). For example, in ecology, "interruption risks" refer to the possibility that rewards might be lost before they can be obtained (Henly et al., 2008; Stephens, 2002), and an organism's death, of course, eliminates its ability to capitalise on delayed rewards (Daly & Wilson, 2005; Pepper & Nettle, 2013). Accordingly, anticipating future dangers, or one's death, may therefore engender "impulsive" decision-making as a response to the likelihood that the future reward will not materialise, or that one will not be around to receive it (Bulley, Pepper, & Suddendorf, 2017; Santos & Rosati, 2015). In other words, there is good reason to suspect that decision-making profiles that have been labelled "impulsive" are actually adaptive in certain circumstances, and this extends from behavioural ecology to various other domains in daily living, for instance, in entrepreneurial endeavours where it is important to capitalise on fleeting opportunities (Gullo & Dawe, 2008). Thus, while impulsivity has been called "a predisposition toward rapid, unplanned reactions to internal or external stimuli without regard to the negative consequences of these reactions to the impulsive individual or to others" (Moeller, Barratt, Dougherty, Schmitz, & Swann, 2001), at least in some domains the "choice impulsivity" pattern of behaviour might be generated not only by impulsivity per se, but by careful deliberation (see also Brezina, Tekin, & Topalli, 2009; Dickman, 1990).

Several lines of empirical evidence hint at the possibility that episodic foresight might affect delay discounting selectively depending on the content or valence of the thoughts. For instance, visualisation abilities (considered key to imagining future events in sufficient detail to generate the effect on delay discounting) have been found to correlate with *steeper* delay discounting (Parthasarathi, McConnell, Luery, & Kable, 2017), even though one study on adolescents found the vividness of episodic foresight imagery to correlate with reduced delay discounting elsewhere (Bromberg, Wiehler, & Peters, 2015). In addition, a recent study found no association between delay discounting and *model-based control* (a formalisation thought to reflect the mechanism underpinning scene-construction and future event simulation; Solway, Lohrenz, & Montague, 2017). Higher levels of explicit worry (negatively valenced mental representations of future threat events) have been found to correlate with increased delay discounting (Worthy, Byrne, & Fields, 2014), as has imagining a stressful upcoming event (Lempert, Porcelli, Delgado, & Tricomi, 2012). There have also been two studies that directly examined the effect of negatively valenced episodic foresight on intertemporal choice, both of which found that imagining negative future scenarios generally encouraged choices of smaller, sooner rewards (Liu, Feng, Chen, & Li, 2013; Zhang, Peng, Qin, Suo, & Feng, 2018). However, this effect has only been studied twice, in small samples. By contrast, research on the relationship between delay discounting and positively valenced episodic foresight has been studied more than 20 times with largely homogeneous results.

Risk-taking

In some regards, intertemporal choice and risk-taking can be grouped together under the construct of "impulsivity", given that in both the decision-making domains there exists the opportunity to prioritise immediate or potential delayed consequences. For instance, "risky" alcohol use involves trade-offs between immediate benefits (e.g., tension-reduction, pleasure) and potential large long-term negative consequences (e.g., health deterioration, costs to personal relationships). Other risk-taking behaviours including sexual promiscuity, violence, and crime have a similar payoff structure, with high variance in potential outcomes—including trade-offs between immediate, highly rewarding outcomes and delayed, highly costly ones (Mishra, 2014; Mishra, Hing, & Lalumiere, 2015). Researchers are currently assessing the similarities and differences between the delay discounting and risk-taking constructs (Amir & Jordan, 2017; Luckman, Donkin, & Newell, 2017; Mishra & Lalumière, 2011). For example, risk-taking behaviour is often studied in the context of potential resulting punishments or harms (Lejuez, Aklin, Zvolensky, & Pedulla, 2003), whereas delay discounting is usually studied in the context of potential delayed rewards or benefits. There are a number of other key differences (Holt, Green, & Myerson, 2003), with the underlying personality variables that relate to each kind of decision process probably also being somewhat distinct—as evinced, for example, by the lack of significant correlations between common assessment tools (e.g., Xu, Korczykowski, Zhu, & Rao, 2013).

Whether or not episodic foresight affects impulsivity other than the kind expressed in strictly constrained intertemporal choice situations is of interest given the promise of such manipulations in modifying various real-world "impulsive" behaviours such as overeating or alcohol abuse (e.g., O'Neill, Daniel, & Epstein, 2015; Sze et al., 2017). While there have been some initial attempts to explore the potential influence of episodic foresight on probability discounting—which has analogues to risky behaviour (Kaplan, Reed, & Jarmolowicz, 2016; Mok, 2017; Monroe, Ainsworth, Vohs, & Baumeister, 2017)—as well as some studies showing evidence that other mindset or framing manipulations can affect behavioural risk-taking (Keller & Gollwitzer, 2017), to our knowledge, as yet there has been no test of the potential effect of episodic foresight on behavioural risk-taking. Thus, we sought to explore whether episodic foresight might affect behavioural risk-taking in a validated laboratory task—the balloon analogue risk task (BART), as it does in the context of laboratory intertemporal choice tasks. Given the conflicting evidence regarding the relationship between risk-taking and delay discounting, our analyses on this front were exploratory.

This study

In this study we therefore had two main aims. First, we aimed to replicate the effects of cuing positive and negative episodic foresight on delay discounting using a considerably larger sample than in prior studies. Second, we aimed to explore the effects of emotional episodic foresight on behavioural risk-taking for the first time. Participants completed modified laboratory measures of an intertemporal choice task (the 27-item Monetary Choice Questionnaire (MCQ)) and risk-taking (the BART). During both tasks, participants were prompted to imagine episodic future events or engage in neutral mental imagery. We hypothesised that cuing positively valenced episodic foresight would result in lower delay discounting than a control imagery condition, whereas cuing negatively valenced episodic foresight would result in higher delay discounting than a control imagery condition, in line with previous research. We were also interested in exploring the effect of positively and negatively valenced episodic foresight on risk-taking. All hypotheses were preregistered through the Open Science Framework, here: https://osf.io/rfndu/.

Method

Participants

Participants were 301 undergraduate students who took part in the study for course credit. The study was approved by the University of Queensland School of Psychology Human Research Ethics Committee. Some participants were excluded from all analyses for inconsistent responding on the intertemporal choice questionnaire (consistency scores lower than 75%; $n=4$), for discussion see Lemley, Kaplan, Reed, Darden, and Jarmolowicz (2016) and Kaplan, Amlung, et al. (2016). Thus, the final sample comprised 297 participants (mean age=19.72, $SD=4.03$) of which 200 (67%) were female.

Design and procedure

Participants attended a single session that lasted approximately 1 hr. They were allocated randomly by the computer program (and blindly to the experimenter) to one of three groups: (1) positive episodic foresight, (2) negative episodic foresight, and (3) control (non-temporal) mental imagery. Participants first completed a visual analogue mood scale upon entering the lab, followed by a modified intertemporal choice task to assess delay discounting and the BART to assess risk-taking. These latter two assessments were counterbalanced. During both of these tasks, participants were presented with cues to engage in positive future, negative future, or neutral non-temporal mental imagery, depending on their experimental condition. Participants also completed the self-report Barratt Impulsiveness Scale-Brief (BIS-Brief; Steinberg, Sharp, Stanford, & Tharp, 2013), Penn-State Worry Questionnaire (PSWQ; Meyer, Miller, Metzger, & Borkovec, 1990), and Patient Health Questionnaire-9 depression inventory (PHQ-9; Kroenke, Spitzer, & Williams, 2001), about which there were no explicit preregistered hypotheses. At the end of the session, participants rated various aspects of their mental imagery during the tasks and provided demographic information. Details of all measures are as follows.

Measures and manipulations

Episodic foresight manipulation. The episodic foresight event cue words were derived from the Affective Norms for English Words (ANEW) list (Bradley & Lang, 1999). Ten words for each of the positive, negative, and neutral valence conditions were selected (see Table 1). Short event descriptions were created with the selected words as the central component. Words were selected that enabled events to be created that were both plausible and simple, but also vividly imaginable (i.e., words were either action verbs or concrete nouns). The positive events were broadly those that participants would be likely to look forward to, while negative events concerned future threats (Blanchard, Hynd, Minke, Minemoto, & Blanchard, 2001). The neutral events were everyday activities without a temporal component. All of the event cues used in this experiment and ANEW valence ratings can be found in Table 1.

Participants were provided with a list of these 10 events (positive, negative, or neutral depending on condition) and asked to select the 5 that were most relevant to them personally, to promote autobiographical episodic imagery during the task. The 5 events considered highest in personal relevance were then used as cues in the remainder of the experiment. Based on instructions for encouraging vivid imagination (D'Argembeau, Xue, Lu, Van der Linden, & Bechara, 2008; Damasio et al., 2000) participants were instructed before the task that when they saw the imagination instruction, they should: "take a few moments to imagine yourself experiencing the event as vividly as possible. Produce detailed images of the events being imagined and concentrate on those images attentively. Include as much emotional and background detail as you can (e.g., where are you, what do you do, who is with you, what does it look and sound like, how does it

Table 1. Event cues used in the experiment and their respective ANEW valence *M* and *SD*. The highlighted word is the keyword from the ANEW list around which the event was constructed.

Positive (*M, SD*)		Negative (*M, SD*)		Neutral (*M, SD*)	
Dinner party	7.16 (1.50)	Getting sick	1.90 (1.14)	Using a pencil	5.22 (.68)
Visiting loved ones	8.64 (.71)	Traffic accident	2.05 (1.19)	Leaning on a table	5.22 (.72)
Going on holiday	7.55 (2.14)	Hurt by animal	1.90 (1.26)	Using a bowl	5.33 (1.33)
Birthday party	7.84 (1.92)	Injury after falling	2.49 (1.76)	Entering a building	5.29 (1.15)
Seeing live music	8.13 (1.09)	Getting an infection	1.93 (1.87)	Opening a cabinet	5.05 (.31)
Success at university	8.29 (.93)	Assault by stranger	2.03 (1.55)	Sitting on a chair	5.08 (.98)
Going to the beach	8.03 (1.59)	Food poisoning	1.98 (1.44)	Picking up some scissors	5.05 (.96)
Hanging out with friends	7.18 (1.07)	Seeing an intruder	2.77 (2.32)	Holding a hammer	4.88 (1.16)
Winning an award	8.38 (.92)	Burn on hand	2.73 (1.72)	Opening curtains	4.83 (.83)
Spending time in nature	7.65 (1.37)	Venomous bite	2.68 (1.81)	Folding up paper	5.33 (1.37)

The highlighted words are the key words around which the event tags were created.

make you feel?)". During the task, participants were instructed to imagine the events taking place at a certain amount of time in the future for the positive and negative future event cues (details in the "intertemporal choice" section below). The neutral condition instructions made no mention of the temporality of the events; instead, participants were instructed to simply imagine this event, "as it would typically unfold, rather than remembering a particular occasion when you did this activity" (D'Argembeau et al., 2008). During the task, the imagination component was self-paced.

Intertemporal choice

The MCQ (Kirby et al., 1999) presents participants with 27 choices between a smaller but sooner amount of money and a larger but later amount available after a certain delay (7-182 days). The task has been shown to have high test–retest reliability (Kirby, 2009). The MCQ can be used to calculate a general delay discounting parameter ("*k*") for each participant, such that greater *k* values represent steeper delay discounting (see "data analysis," below). Episodic event cues were inserted into the code of the computerised task, to be presented before each decision in a manner that synchronised the temporal distance to both the possible future event and the delayed reward. For example, participants would be presented with a cue to imagine an event taking place in around 6 months before making a choice about a reward that was delayed by approximately that same amount of time. The event cues were presented on a screen preceding each of the 27 choice questions. Similar to previous studies on the effect of foresight on intertemporal choice (e.g., Lin & Epstein, 2014), participants were instructed that they did not need to relate their decision to the event they imagined, but just to picture the event actually happening before making their choice. The event cues were tailored such that the time of occurrence approximated the receipt of the delayed intertemporal choice option. Figure 1 (top) shows the trial order and choice format for the MCQ. Table 2 shows a full list of the MCQ items and the groupings of the questions for the sake of the foresight manipulations.

Risk-taking

Risk-taking was measured with a computerised version of the BART, (Lejuez et al., 2002) which was presented using E-Prime (Pleskac & Wershbale, 2014). Scores on the BART have been shown to predict risk-taking behaviours in a range of domains including unsafe driving, unprotected sex, gambling, stealing, and substance use (Aklin, Lejuez, Zvolensky, Kahler, & Gwadz, 2005; Lejuez et al., 2003; Lejuez et al., 2002; Wallsten, Pleskac, & Lejuez, 2005), and the measure has been shown to have adequate test–retest reliability (White, Lejuez, & de Wit, 2008).

In each trial of the task, participants were presented with an image of a balloon, which they could "inflate" by pressing the "F" key. Each button press slightly inflated the balloon and earned the participant 10 points. These points would accumulate during the trial but would all be lost if the balloon "popped." At any time during a given trial, the participant could choose to stop inflating the balloon before it popped, and opt instead to retrieve the money thus far collected on that trial by pressing the "J" key, moving it to a permanent "bank." The BART was programmed such that the optimal average number of pumps was 64 (for more details see Pleskac & Wershbale, 2014, p. 146). The "total points" accumulated thus far in the permanent bank was displayed throughout the task on the right-hand side of the screen alongside the points accumulated during the current trial. Event cues were presented on a separate screen preceding each balloon (before the fixation cross). Because the BART lacks an explicit temporal component, the event cues were entered with the same temporal specifications as the intertemporal choice questionnaire, but in an arbitrary order. On the event cue screen participants were instructed to "press space to continue," which would take them to the next trial of the task. Before the experimental trials began, participants were given a single practice trial where they were not cued to imagine

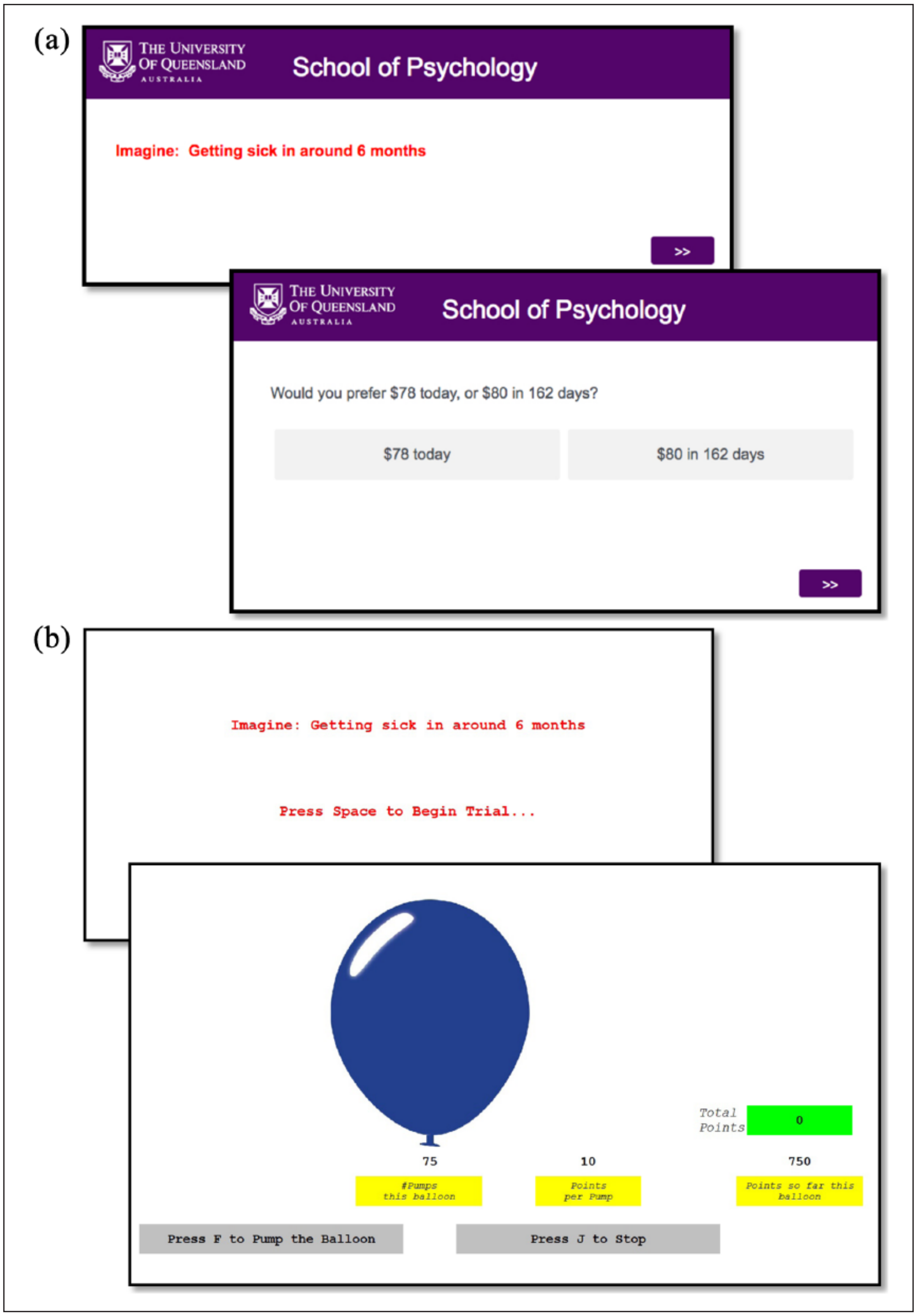

Figure 1. (a) Trial order in the MCQ—intertemporal choice task question with preceding episodic foresight event cue instructions. (b) Trial order in the BART—participants were presented with a future event before moving to each subsequent balloon.

anything. Figure 1 (bottom) shows the trial order and choice format for the BART.

Current affect: Participants completed a visual-analogue mood scale (a slider ranging continuously from sad to happy) upon entering the lab such that higher scores were indicative of more positive affect. This measure was included to control for any possible effect of participants' baseline affective state on the measures of interest, because there is some evidence for general mood effects on delay discounting (e.g., Hirsh, Guindon, Morisano, & Peterson, 2010). *Event cue ratings*: At the end of each session, participants rated the vividness, emotionality, and personal relevance of their imagination of each event cue on scale from 1 (*not at all*) to 7 (*very*). *Other measures*: General levels of worry were assessed with the PSWQ, a 16-item self-report questionnaire that measures the intensity of

Table 2. Summary of the 27 monetary choice questions in the MCQ sorted by delay (long to short).

Order	Monetary choice options			Delay	*k*-index	Rank	Magnitude
	Today (AU$)		Delayed (AU$)				
13	34	Or	35	186	.00016	1	S
20	28	Or	30	179	.0004	2	S
9	78	Or	80	162	.00016	1	L
6	47	Or	50	160	.0004	2	M
17	80	Or	85	157	.0004	2	L
26	22	Or	25	136	.001	3	S
12	67	Or	75	119	.001	3	L
1	54	Or	55	117	.00016	1	M
24	54	Or	60	111	.001	3	M
15	69	Or	85	91	.0025	4	L
16	49	Or	60	89	.0025	4	M
22	25	Or	30	80	.0025	4	S
10	40	Or	55	62	.006	5	M
2	55	Or	75	61	.006	5	L
3	19	Or	25	53	.006	5	S
21	34	Or	50	30	.016	6	M
25	54	Or	80	30	.016	6	L
18	24	Or	35	29	.016	6	S
14	27	Or	50	21	.041	7	M
23	41	Or	75	20	.041	7	L
5	14	Or	25	19	.041	7	S
19	33	Or	80	14	.1	8	L
8	25	Or	60	14	.1	8	M
7	15	Or	35	13	.1	8	S
11	11	Or	30	7	.25	9	S
27	20	Or	55	7	.25	9	M
4	31	Or	85	7	.25	9	L

Source: Based on Lemley et al. (2016) and Kirby et al. (1999).
The shading of the delay column represents the groupings used in the episodic foresight task to produce event cues with delays approximating those of the choice questions. The first column presents the order of choice presentations. Each question is assigned a rank based on its *k*-index. The final column presents the magnitude grouping of the monetary amount offered in the corresponding choice (S = small, M = medium, and L = large).

worry (Meyer et al., 1990). Severity of depression was assessed with the PHQ-9 depression inventory, a 9-item self-report questionnaire of depressive symptom frequency (Kroenke et al., 2001). Trait impulsivity was measured with the BIS-Brief (Steinberg et al., 2013), an 8-item version of the longer BIS-11 (Barratt, 1959; Patton, Stanford, & Barratt, 1995).

Data analysis

Hypotheses, measures, and our analytical plan were pre-registered with the Open Science Framework: https://osf.io/rfndu/. All statistical analyses were performed in R studio (R Core Team, 2008), including the following packages: apaTables (Stanley, 2017), dplyr (Wickham, 2016), ggplot2 (Wickham, 2009), lemon (Edwards, 2017), ggsignif (Ahlmann-Eltze, 2017), psych (Revelle, 2015), reshape2 (Wickham, 2007), and Rmisc (Hope, 2013). The R script used for all data processing and analyses is available as an Electronic Supplement to this article, as is the dataset and an information sheet about the included variables.

MCQ. A publicly available spreadsheet from Kaplan, Lemley, Reed, and Jarmolowicz (2014) was used to derive a temporal discounting ("*k*") value for each participant from the MCQ response data (Kaplan, Amlung, et al., 2016). The *k* value is a free parameter of a modelled hyperbolic discounting equation. A greater *k* value is indicative of steeper temporal discounting, (for individuals with a higher *k* value, rewards more quickly lose their subjective value with additional delays), and this acted as the primary outcome measure for the task. The data were normalised by a log-transformation of the raw values in accordance with our pre-registered plan and recommendations by Kirby and Maraković (1996). The MCQ has 27 questions, each with a different "*k*-index" used to calculate the indifference point (and thus overall *k* value) for each participant. These question-level discounting-rate parameters (*k*-index) range from

0.00016 to 0.25 and include rewards of three magnitudes: "small," 'medium,' and "large." Table 2 contains a summary of all the intertemporal choice questions, including information about their respective k-indices and their order of presentation. We chose to analyse the MCQ data overall rather than for each magnitude separately as is sometimes done, because we had no a-priori hypotheses about the effects of episodic foresight on discounting as a function of magnitude. Note that removing from analysis the participants who always chose the larger, later reward or always chose the smaller, sooner reward made no difference to the analyses below, and thus results are reported without excluding these participants.

BART. Scores were calculated as the average number of pumps per trial on trials in which the balloon did not burst (Lejuez et al., 2002), as is standard practice. The resulting adjusted pump scores approximated a normal distribution and were used in all analyses.

Inferential statistics. We created two linear regression models to test the effect of episodic foresight on both the MCQ and the BART.[1] We controlled for age, sex, and baseline affect in each model and included experimental condition as a dummy-coded categorical predictor. Some additional exploratory analyses can be found in the Supplementary Document, pertaining to the relationship between the MCQ and the BART, and the relationship between the MCQ and self-reported impulsivity. Controlling for BIS, PSWQ, and PHQ-9 scores in the main models assessing both MCQ and BART as outcome measures did not affect the pattern of findings.

Results

Descriptive statistics

Table 3 presents descriptive statistics for the main study variables.

Event cue ratings

Participants rated that they felt significantly more negative when imagining the events in the negative condition (M=2.37, SD=.70) than the neutral condition (M=4.48, SD=.58), t=22.79 $p<.001$, and significantly more positive when imagining the events in the positive condition (M=5.88, SD=0.67) than the neutral condition (M=4.48, SD=0.58), t=15.15, $p<.001$. Participants rated the event cue imagery as significantly more personally relevant in the positive (M=5.62, SD=0.73) than the neutral condition (M=5.10, SD=1.16), t=3.820, $p<.001$, and significantly less personally relevant in the negative condition (M=4.7, SD=0.95) than the neutral condition (M=5.10, SD=1.16), t=−3.32, $p<.01$. Controlling for this difference in personal relevance in latter analyses did not affect the results. There were no differences in participants'

Table 3. Descriptive statistics for study variables overall (n=297) and by experimental condition.

	Overall (n=297)		Neutral (n=101)		Positive (n=99)		Negative (n=97)	
	M (SD)	Min-max (range)	M (SD)	Min-max (range)	M (SD)	Min-max (range)	M (SD)	Min-max (range)
Age	19.72 (4.03)	17.00-50.00 (33.00)	19.66 (4.03)	17.00-50.00 (33.00)	19.56 (3.46)	17.00-42.00 (25.00)	19.96 (4.56)	17.00-45.00 (28.00)
Affect (VAS)	6.96 (1.62)	1.00-10.00 (9.00)	6.98 (1.81)	2.00-10.00 (8.00)	6.99 (1.38)	3.00-10.00 (7.00)	6.90 (1.66)	1.00-10.00 (9.00)
MCQ k value	0.01 (0.03)	0.00-0.25 (0.25)	0.02 (0.02)	0.00-0.10 (0.10)	0.01 (0.03)	0.00-0.25 (0.25)	0.01 (0.03)	0.00-0.20 (0.20)
MCQ proportion (LL)	0.50 (0.17)	0.00-1.00 (1.00)	0.45 (0.14)	0.15-1.00 (0.85)	0.55 (0.18)	0.00-1.00 (1.00)	0.52 (0.16)	0.11-0.96 (0.85)
MCQ log k	−2.20 (0.60)	−3.80-0.60 (3.19)	−1.99 (0.50)	−3.80–−1.00 (2.80)	−2.35 (0.64)	−3.80–−0.60 (3.19)	−2.28 (0.61)	−3.80–−0.70 (3.09)
BART adjusted pumps	29.56 (11.98)	4.17-64.21 (60.04)	30.70 (12.01)	8.00-59.19 (51.19)	30.07 (11.39)	7.79-64.21 (56.42)	27.87 (12.46)	4.17-53.06 (48.89)
Worry (PSWQ)	55.42 (12.76)	18.00-80.00 (62.00)	55.33 (12.85)	21.00-78.00 (57.00)	54.51 (13.80)	18.00-80.00 (62.00)	56.44 (11.54)	33.00-79.00 (46.00)
Depression (PHQ-9)	7.43 (4.96)	0.00-24.00 (24.00)	7.46 (4.95)	0.00-24.00 (24.00)	7.08 (4.72)	0.00-22.00 (22.00)	7.76 (5.22)	0.00-24.00 (24.00)
Impulsivity (BIS-Brief)	16.38 (3.58)	8.00-29.00 (21.00)	16.28 (3.47)	10.00-25.00 (15.00)	16.74 (3.37)	8.00-27.00 (19.00)	16.11 (3.89)	8.00-29.00 (21.00)

VAS: Visual Analogue Scale; MCQ proportion (LL): proportion of larger, later rewards chosen in the Monetary Choice Questionnaire; PSWQ: Penn-state worry questionnaire; PHQ-9: patient health questionnaire 9; BIS-Brief: Barratt Impulsiveness Scale-Brief.

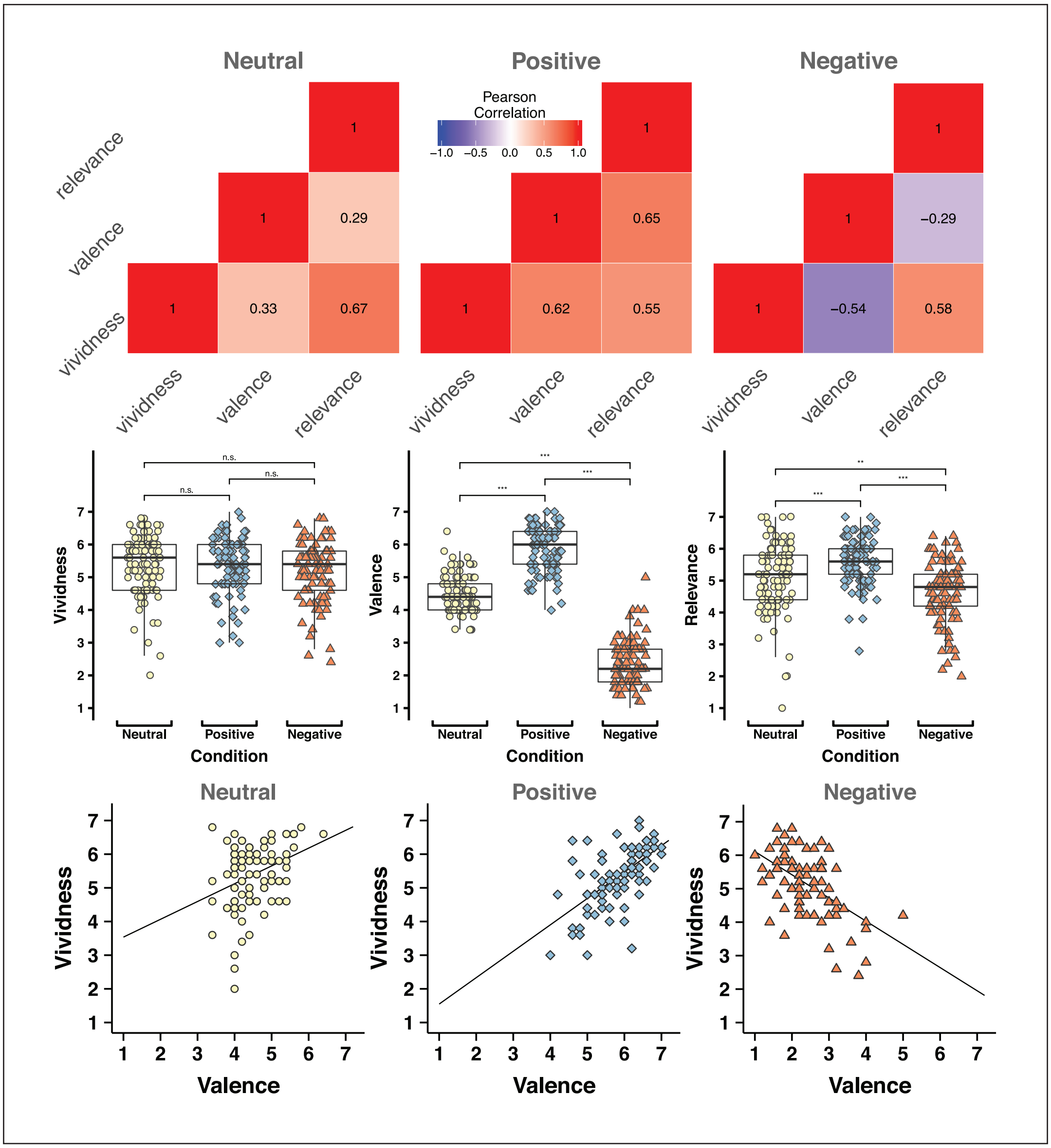

Figure 2. Post-task event cue ratings. Top: correlation matrix heat-maps of imagery ratings for each condition. Darker red means a larger positive correlation and darker blue means a larger negative correlation. Valence is scored from 1 to 7 such that low scores equate to negative valence and high scores equate to positive valence. All correlations: $p < .01$. Middle: event cue ratings of imagery vividness, valence, and personal relevance for each condition. Boxplot midline represents median. *** = significant at $p < .001$. Horizontal jitter and some minor vertical jitter ($< .01$ on y-axis) have been added to aid in discrimination between data points. Bottom: relationships between event cue ratings of imagery vividness and valence in each condition.

ratings of the vividness of their imagery between the three experimental conditions. Figure 2 (middle row) presents the valence, vividness, and personal relevance ratings separately for each experimental condition.

Correlations between the event cue ratings were explored separately for each experimental condition, and are presented in Figure 2 (top row). Despite there being no average differences between conditions in the vividness of imagination, this variable was differentially correlated with valence in each condition in the expected direction. This correlation was of large magnitude in the positive condition, $r = .62$, $p < .001$, and negative condition, $r = -.54$, $p < .001$, and of moderate magnitude in the neutral condition, $r = .33$, $p < .001$ (see Cohen, 1988). Figure 2 (bottom row) presents the relationships between the vividness and valence of the event cue ratings separately for each experimental condition. There was a similarly large positive relationship between the personal relevance of the events and the vividness with which they were imagined (0.55-0.67, all $p < .001$). Table 4 presents descriptive statistics for the event cue ratings separately for each condition.

Table 4. Descriptive statistics for event cue ratings in the neutral, positive, and negative experimental conditions.

	M	*SD*	Min	Max	Range
Neutral ($n=101$)					
Vividness	5.38	0.93	2.00	6.80	4.80
Valence	4.48	0.58	3.40	6.40	3.00
Personal relevance	5.10	1.16	1.00	7.00	6.00
Positive ($n=99$)					
Vividness	5.38	0.85	3.00	7.00	4.00
Valence	5.88	0.67	4.00	7.00	3.00
Personal relevance	5.62	0.73	2.80	7.00	4.20
Negative ($n=97$)					
Vividness	5.16	0.90	2.40	6.80	4.40
Valence	2.37	0.70	1.00	5.00	4.00
Personal relevance	4.65	0.95	2.00	6.40	4.40

Effect of positive and negative episodic foresight on intertemporal choice and risk-taking

Experimental condition as predictor was positively associated with log-transformed MCQ *k* values as outcome after controlling for age, sex, and baseline affect. Participants in the positive foresight condition ($M=-2.35$ $SD=0.64$) were on average more willing to wait for the larger, delayed rewards on the MCQ than participants in the neutral condition ($M=-1.99$, $SD=0.50$), $b=-0.36$, (95% confidence interval [CI] $=-0.52$, -0.19), $p<.001$, as were participants in the negative foresight condition, ($M=-2.28$, $SD=.61$), $b=-0.29$, [95% CI $=-0.45$, -0.13], $p<.001$. Table 5 presents the results of the regression with experimental condition as a categorical dummy-coded predictor with the neutral condition as the reference group. Analysing the data by the proportion of larger, later options chosen instead of *k* values produced the same results: on average, participants chose the larger later reward in 45% of the questions in the neutral condition, 55% of the questions in the positive condition, and 52% of the questions in the negative condition. For ease of interpretability, the proportion of larger, later options in each group is therefore presented in Figure 3 (top middle) alongside log-transformed MCQ *k* values.

Figure 3 (bottom row) presents the sample-level proportion of smaller, sooner rewards chosen (on the *y*-axis) for the varying *k*-indexes of the MCQ questions (on the *x*-axis). It indicates that the greatest magnitude of difference between the experimental conditions and the control condition pertained to those questions with ranks ranging from 4 to 6. Increasing rank is associated with larger discrepancies between present and delayed options and increasingly shorter delays (see Table 2). Thus, Figure 3 indicates that the effect of episodic foresight on delay discounting is greatest for those questions with moderate

Table 5. Results of the multiple linear regression model assessing experimental condition as a predictor of log MCQ *k* values as the criterion, adjusting for age, sex, and baseline affect.

Predictor	*b*	*b* 95% CI (LL, UL)	sr^2	Fit
(Intercept)	−1.79**	−2.25, −1.33		
Age	−0.00	−0.02, 0.02	.00	
Sex: male	0.14	−0.00, 0.28	.01	
Baseline affect	−0.03	−0.07, 0.01	.01	
Condition: positive	−0.36**	−0.52, −0.19	.06	
Condition: negative	−0.29**	−0.45, −0.13	.04	
				$R^2=.088$** 95% CI [.02, .14]

A significant *b*-weight indicates the semi-partial correlation is also significant. *b* represents unstandardised regression weights; sr^2 represents the semi-partial correlation squared. *LL* and *UL* indicate the lower and upper limits of the confidence intervals, respectively.
*Indicates $p<.05$.
**Indicates $p<.01$.

discrepancies between immediate and delayed options and with moderate delays, such that all participants almost invariably (a) chose the delayed option when it was much larger than the immediate option and available after a short delay, and (b) chose the immediate option when there was little difference with the delayed option accompanied by a long delay.

Experimental condition was not associated with BART scores in a model adjusting for age, sex, and baseline affect, and the overall model was not statistically significant. There were no differences in the number of adjusted pumps in the BART on average between the experimental conditions, as illustrated in Figure 3 (top right). Table 6 presents the results of the regression with experimental condition as a categorical dummy-coded predictor.

Discussion

In this study, we assessed whether and to what extent imagining positively or negatively valenced future events influence intertemporal choice and risk-taking. We tested the hypothesis that imagining positive future events during an intertemporal choice task shifts temporal preferences towards delayed rewards, and that imagining negative future events shifts preferences towards immediate rewards. The results were consistent with the first hypothesis, replicating the finding that imagining positive personally relevant future events reduces delay discounting. However, our results were inconsistent with the hypothesis that negative threat-related foresight encourages greater discounting, as has been

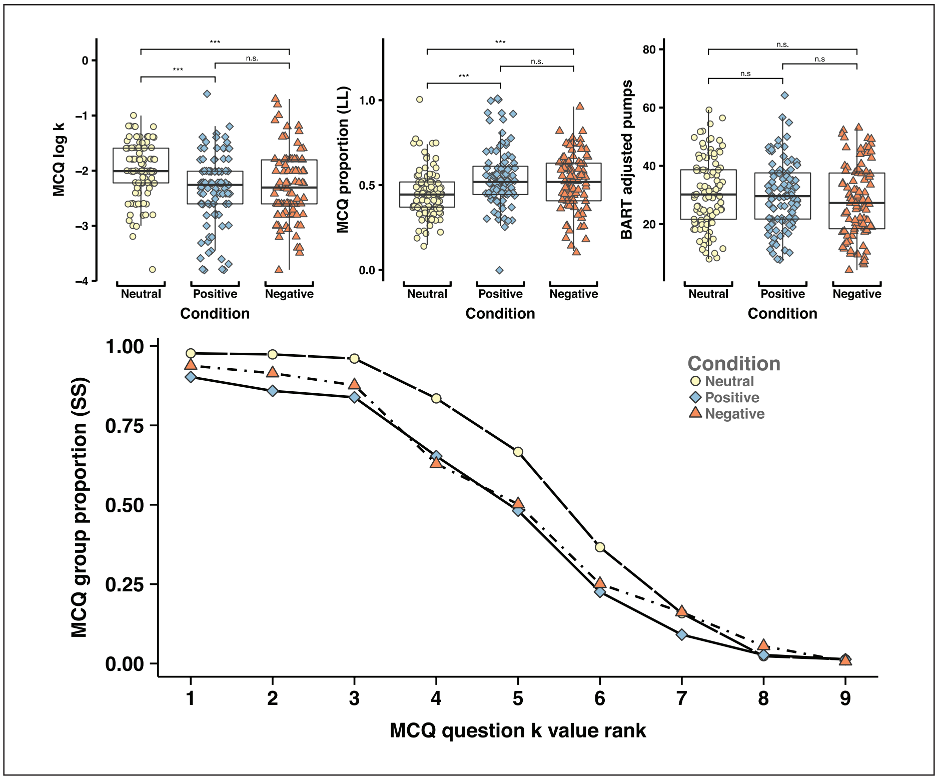

Figure 3. Top left: MCQ log *k* values by experimental condition. Top middle: MCQ proportion (larger, later choices) by experimental condition. Top right: BART adjusted pump scores by experimental condition. In each plot, boxplot midline represents median. ***= significant at $p < .001$. Horizontal jitter and some minor vertical jitter (<.01 on *y*-axis) have been added to aid in discrimination between data points. Bottom. Proportion of group that chose the smaller, sooner reward rather than the later, larger reward at each *k*-value of the MCQ. For a question with a higher *k*-value rank, more participants are expected to choose the larger, later reward—for example, the following choice has a *k*-value rank of 9: "$31 now, or $85 in 7 days." At each *k*-value rank, the presented proportion includes the participants' responses to three questions from the questionnaire. The proportions are plotted separately for each experimental condition.

Table 6. Results of the multiple linear regression model assessing experimental condition as a predictor of BART adjusted pumps as the criterion, adjusting for age, sex, and baseline affect.

Predictor	*b*	*b* 95% CI [LL, UL]	sr^2	Fit
(Intercept)	22.95**	13.50, 32.40		
Age	0.16	−0.18, 0.50	.00	
Sex: male	1.24	−1.69, 4.16	.00	
Baseline affect	0.60	−0.24, 1.45	.01	
Condition: positive	−0.62	−3.95, 2.71	.00	
Condition: negative	−2.84	−6.18, 0.51	.01	
				$R^2 = .022$ 95% CI [.00, .05]

A significant *b*-weight indicates the semi-partial correlation is also significant. *b* represents unstandardised regression weights; sr^2 represents the semi-partial correlation squared. LL and UL indicate the lower and upper limits of the confidence intervals, respectively.
*Indicates $p < .05$.
**Indicates $p < .01$.

observed in two previous studies (Liu et al., 2013; Zhang et al., 2018). Instead, we found that negative episodic foresight *reduced* delay discounting to a similar degree as positive episodic foresight. Furthermore, we observed no effect of imagining positive or negative future events on risk-taking in the BART. These findings will be discussed in turn below.

The effect of foresight on intertemporal choice

In this study, cuing positive and negative episodic future simulation increased the proportion of larger, later rewards chosen by 10% and 7% relative to control imagery, respectively. Although a number of studies have reported an effect of positively valenced episodic foresight on delay discounting of a similar magnitude, this is the first study to report that negatively valenced episodic foresight is associated with a similar reduction in delay discounting. We consider five possible interpretations of these effects below, after first comparing the current findings with two previous studies on the effect of negative episodic event cuing on delay discounting.

In both the previous studies, episodic event tagging with negative future events (similar to the ones used in this study) was associated with significantly increased delay discounting relative to a neutral condition (Liu et al., 2013; Zhang et al., 2018). It is unclear exactly why the current results diverge from these findings, but we note that the previous studies had substantially smaller sample sizes than the current one ($N=297$, between-subjects neutral imagery vs positive foresight vs negative foresight). In Liu et al. (2013), study one ($N=32$) employed a within-subjects design to compare control versus positive foresight, and study two ($N=31$) employed a within-subjects design to compare control versus negative foresight. Zhang et al. (2018) employed a between-subjects design to compare neutral prospection ($n=34$) versus positive prospection ($n=34$) versus negative prospection ($n=32$). Another difference in the design of the studies pertains to the control condition: Whereas Liu et al. (2013) used a passive control condition in which participants were not required to engage in prospection, Zhang et al. (2018) used an active control condition more akin to this study in which participants were required to engage in neutral prospection. Otherwise, however, the experimental designs are highly similar (including in terms of the event cues, event ratings, laboratory choice task, and analytical approaches). It is worth noting, however, that this study tested an Australian sample, while both previous studies examined Chinese participants. Thus, it is also possible that cultural differences may influence the way cued episodic foresight affects decision-making—though establishing this and potential underlying reasons would require dedicated studies.

With respect to the effect sizes of the studies, Liu et al. (2013) reported a medium effect size (Cohen's $d=.56$) of negative foresight on the proportion of immediate-to-total choices relative to their control condition, and a medium-to-large effect size (Cohen's $d=.67$) of positive foresight on the proportion of immediate-to-total choices compared with their control condition. Zhang et al. (2018) reported a large effect size (Cohen's $d=.89$) comparing the proportion of immediate-to-total choices between negative foresight and neutral conditions, and a large effect size (Cohen's $d=-.76$) comparing positive foresight and neutral conditions. This study yields a medium effect size when comparing immediate-to-total choices between negative foresight and neutral conditions (Cohen's $d=.45$) as well as when comparing positive foresight and neutral conditions (Cohen's $d=.63$). Note again, however, that in this study, cued negative foresight reduced the proportion of immediate-to-total choices (reduced delay discounting), whereas in both previous studies cued negative foresight increased the proportion of immediate-to-total choices (increased delay discounting). We think the effect sizes reported by Zhang et al. (2018) are inflated because they used a between-subjects design with approximately 30 participants in each group. In contrast, Liu et al. (2013) used a within-subjects design with approximately 30 participants and this study used a between-subjects design with approximately 100 participants in each group, and the effect sizes of these latter two studies are comparable.

Regarding the effects found in the current experiment, the first explanation is that the future event tagging manipulation might engender a generic change in "future orientation." For instance, Lempert and Phelps (2015) suggested that episodic future thinking "might serve to change time construal during choice." A central tenet of Construal Level Theory (Trope & Liberman, 2010) is that future events are more "psychologically distant" and are therefore "construed" more abstractly than present ones. Imagining future events in detail therefore changes the construal level of "future orientation" to a higher degree of concreteness (Cheng et al., 2012). This in turn may have made the delayed option more attractive. This explanation appears to align with data from a recent study that showed actively manipulating construal levels—by encouraging future scenarios to be imagined with more concrete details—caused greater reductions in delay discounting (Kim, Schnall, & White, 2013).

However, if this interpretation rests on the greater "future orientation" brought about by construal level changes, it may be challenged by a recent finding that remembering positive autobiographical events also reduces delay discounting (Lempert, Speer, Delgado, & Phelps, 2017)—though note that another recent study reported that there is no effect of episodic recollection on discounting (Daniel, Sawyer, Dong, Bickel, & Epstein, 2016). One way around this is to postulate that episodic memory affects discounting (if, indeed, this is borne out in further studies) because memories form the basis for future simulations—and that the function of memory is ultimately forward-facing (Bar, 2010; Klein, Robertson, & Delton, 2010; Lempert et al., 2017; Suddendorf & Henry, 2013). A problem with this conflation, however, is that despite the multiple convergences between memory and future simulation (Hassabis & Maguire, 2009; Schacter et al., 2012), they cannot be considered the same construct, with the same consequences (Klein, 2015; Suddendorf, 2010).

Nonetheless, given the possibility that episodic recall also results in reduced discounting, and the present results indicate that the emotional valence of episodic foresight does not have a differential effect on discounting, the second potential explanation of the current data pertains to the psychological effects of deliberative thinking *in general terms*. For instance, Bar (2010) in a response to Peters and Büchel (2010) notes that the effect might be "merely [because of] the fact that episodic information elicits richer associations and imagery, and it is this increased detail that improves valuation."

Dual process models of cognition have long emphasised the role of a slow, deliberative mode of thinking in decision-making (Kahneman, 2011), with the emphasis on how this mode can "overrule" more "impulsive" behaviour (for discussion and criticism see Koffarnus et al., 2013; Melnikoff & Bargh, 2018). Both of the above explanations about general deliberative thinking and general future orientation have received some support from studies suggesting that the effect of imagining the future on discounting appears to be relatively unrelated to some aspects of its content (e.g., imagining familiar vs unfamiliar scenarios, Sasse, Peters, Büchel, & Brassen, 2015). However, this is contentious because other evidence suggests that the content does indeed matter (Daniel et al., 2016; Dassen et al., 2016), for instance, with regard to its relevance to the respective decision or to one's personal goals (O'Donnell, Oluyomi Daniel, & Epstein, 2017). All three of the aforementioned studies were conducted with small sample sizes. However, if the findings reflect true effects, then it may be that there is a difference between the types of content assessed inasmuch as these differ in terms of the amount of deliberation they entail (e.g., personal goals and decision relevance may entail more deliberation than familiarity). Alternatively, as Schacter et al. (2017) argued: "The observation that the impact of episodic future thinking is contingent on the content of the imagined event indicates that it does not merely reflect a generic change in future orientation".

Third, the possible effect of the content of future simulations may be due to its preparatory and motivational aspects (Benoit, Berkers, & Paulus, 2018; Boyer, 2008; Bulley et al., 2016). For example, Stein et al. (2018) have suggested that: "One interpretation of these findings is that [episodic foresight] broadens the temporal window over which individuals integrate the value of reinforcement, thus facilitating consideration of a behaviour's negative, long-term outcomes (e.g., lung cancer from smoking)". This is in line with perspectives on episodic foresight that emphasise its ultimate goal-related functions (e.g., Cole & Berntsen, 2016; D'Argembeau, 2016), insofar as people's personal goals often pertain to long-term outcomes for which reinforcement information is necessarily delayed.

In the current experiment, it is possible that foreseeing a future threat event engaged preparatory motivation (Miloyan, Pachana, & Suddendorf, 2014; Miloyan & Suddendorf, 2015). For instance, planning for a future hardship might encourage people to choose a larger later reward to have the appropriate resources available when needed to manage the future circumstance effectively. In this context, it may be informative to assess the controllability of imagined future events: if a future threat is perceived to be more controllable, then preparatory behaviour (choosing the larger, later reward) may be more likely, whereas if the future threat is perceived to be outside of one's control, perhaps this would encourage a preference for smaller sooner rewards, given that the preparatory or motivational rationale for waiting for the larger reward is thereby undercut (Pepper & Nettle, 2014, 2017).

A fourth possibility is that episodic event tagging during the task "primes" people to think about the future, which leads to reduced discounting through an enhancement of choices in line with this prime. This is consistent with one study that showed scrambled-sentence task priming of "future" concepts reduced desires to engage in hedonic activities that have long-term costs like excessive drinking (Cheng et al., 2012). However, there is evidence that the ability to create a coherent vivid mental scene is related to the strength of the episodic tagging effect (Peters & Büchel, 2010). Furthermore, older adults and people with amnesia, who show marked deficits in generating episodic detail do not appear to receive the effect of episodic event tagging during intertemporal choice (Palombo, Keane, & Verfaellie, 2016; Rosenbaum et al., 2015; Sasse, Peters, & Brassen, 2017)—though see Kwan et al. (2015) for some conflicting results in the context of hippocampal amnesia. Importantly, however, priming studies are being called into question due to repeated failures to replicate even well-known priming effects (similar to the proposed one at hand) such as social and goal priming (e.g., Harris, Coburn, Rohrer, & Pashler, 2013; O'Donnell et al., 2018).

A fifth possible explanation is that the apparent effects of episodic foresight on delay discounting are due to demand characteristics. In a recent study, Rung and Madden (2018) provided participants with vignettes of interactions between experimenters and subjects regarding a study of the association between episodic foresight and delay discounting. They found that most participants could guess the purpose of the study. This suggests that demand characteristics in such study designs may explain the apparent effect of episodic foresight on delay discounting. Note, however, that another recent study found that the results of the episodic foresight manipulation on delay discounting (and cigarette demand) remained significant after controlling for measures of demand characteristics such as expectancies about the experimental hypotheses (Stein et al., 2018). We recommend that future studies control for demand characteristics by assessing whether participants are aware of the study hypotheses as a covariate. It will also be important to determine what potential demand effects are at play in the context of specific hypotheses about the role of episodic future event cuing such as the role of emotion studied here.

Overall, it remains a challenge for future research to determine which of the above explanations is correct and in what circumstances they apply. One significant hurdle to overcome will be in accounting for (often subtle) differences between both the cuing manipulations—which vary in terms of key features such as whether or not participants are explicitly told that the imagination component of the task need not relate to the decision component—as well as the delay discounting tasks, which vary on dimensions including the magnitude of the rewards, time delays, and choice framing.

No effect of future thinking on risk-taking

The current results revealed that the average number of balloon pumps in the BART was not significantly different between the three conditions. Thus, there was no evidence that imagining the future, with any emotional valence, affects risk-taking in this laboratory paradigm relative to neutral imagery. One explanation of these data is that episodic foresight does not necessarily have a blanket influence on all choice domains under the "impulsivity" umbrella—that is, those without an explicit long-term outcome structure such as the BART.

While this is the first study to our knowledge to explore the effect of episodic cuing on behavioural risk-taking in the BART, three previous studies have examined the effect of cued episodic foresight on risk preferences in the context of probability discounting and risky investing. Probability discounting tasks assess the extent to which participants discount the subjective value of probabilistic outcomes (rather than delayed ones). Kaplan, Amlung, et al. (2016) assessed probability discounting of both gains and losses, and found that exposing people to age-progressed images of their own face (perhaps somewhat analogous to the episodic future event cuing) reduced this discounting. However, this study was conducted with only five participants in experiment one, and six participants in experiment two, presumably due to the difficulty of creating the age-progressed images of participants, and thus any inferences on the basis of this data are premature—as the authors acknowledge when they call the paper a "proof of concept."

In a study by Monroe et al. (2017), participants who wrote a letter to their "future self" favoured significantly less risky investments than participants who wrote a letter about their current self, suggesting that thinking about the future may heighten aversion to potential loss when considering long-term investments. In Mok et al. (2017), episodic future event cuing (similar to the manipulation used in this study) did not affect probability discounting, but did reduce delay discounting. These results are consistent with the current null effects of future episodic event cuing on behavioural risk-taking, as well as the interpretation that cueing episodic future events is not sufficient to influence all tasks that assess aspects of impulsivity. As mentioned earlier, this is probably due to the fact that impulsivity is a highly multidimensional construct. Indeed, it is unclear how the BART as an index relates precisely to other risk elicitation methods such as probability discounting (for review see Charness, Gneezy, & Imas, 2013).

It will be important to consider the potentially selective (domain specific) effects of episodic foresight in the development of cognitive and behavioural strategies that have future imagination at their core (Snider et al., 2016). Clinical translation of recent findings about the potentially causal role of foresight in decision-making will require appropriate caution given concerns regarding the potential for demand characteristics to explain these effects (Rung & Madden, 2018). The present findings are potentially in line with the idea that demand characteristics contributed to the effect of cued episodic foresight on decision-making, given that the manipulation only affected *choice impulsivity* domains with an *explicit* intertemporal trade-off, and not risk-taking—which lacks an explicit time component; and given that there was no temporal component in the neutral condition event cues for either task. Note, however, that there are other plausible reasons why we did not observe an effect of positive and negative foresight on risk-taking (e.g., due to the influence of unmeasured moderating variables such as the perceived "controllability" of the simulated events), and identifying these reasons should be an avenue for future research. For instance, future research could directly modify the timing of outcomes in a risk-taking task with episodic future event cuing to explore whether decisions pertaining to short-term consequences (such as in the BART) differ in their susceptibility to cuing relative to long-term consequences (such as in the Monroe et al. (2017) investment study that found reduced risk-taking after cuing future-oriented cognition).

Limitations

There are a number of limitations to this study that should be acknowledged. First, there may have been an unintended effect of repeated simulation, for instance, on the estimated likelihood of the events happening (Szpunar & Schacter, 2013). Relatedly, it is also possible that the act of repeated simulation caused participants to reduce their engagement in vivid imagination or to habituate to the emotional content therein. However, we did counterbalance the BART and the intertemporal choice task, so any between-task consequences of this reduction in episodic simulation detail with time should not have influenced the key contrasts of interest. Second, ratings of episodic simulations in response to the event cues were measured after the tasks were completed, meaning they were reliant on participant's recollection of their previous simulations, and may have therefore been more erroneous than immediate ratings. In the same vein, other than verbal self-report there is no way to verify that participants are actually following the task instructions and engaging in episodic foresight when cued due to the subjective nature of the manipulation. Third, demand characteristics may have played a role in the findings, as discussed above (Rung & Madden, 2018). Finally, it is also relevant to note that the intertemporal choices were hypothetical. Although there is generally good correspondence between real and hypothetical rewards in decision-making tasks (Lagorio & Madden, 2005; Madden, Begotka, Raiff, & Kastern, 2003), there are also important differences that should be considered (Camerer & Mobbs, 2017; Xu et al., 2016). Incidentally, the use of hypothetical rewards also limits the relevance of comparisons with non-human animals, who almost always actually experience the delays and receive the rewards when performing intertemporal choice tasks (see discussion in Palombo, Keane, & Verfaellie, 2015; and Redshaw & Bulley, 2018). Future studies of the role of foresight in tasks such as the "experiential discounting task," in which delays are actually experienced, will be informative (Reynolds & Schiffbauer, 2004). Finally, the relatively homogeneous nature of our sample restricts the generalizability of our findings (Henrich, Heine, & Norenzayan, 2010), as well as that of the majority of previous studies of the effect of foresight on delay discounting. This is particularly important in addressing any evolutionary claims about the potential adaptive function of episodic foresight in modulating decision-making.

Conclusion

To make decisions with outcomes that play out over time, humans can use information derived from mental simulations of possible futures. This study adds to a body of research demonstrating plasticity in intertemporal decision-making in response to such mental simulations of the future. We found that cuing the imagination of positive and negative future events, regardless of the affective content of these events, reduced delay discounting relative to control imagery. However, cued positive and negative episodic foresight had no effect on risk-taking in a standard laboratory task. These results thereby replicate previous findings suggesting positive foresight can reduce discounting, but are inconsistent with the hypothesis that anticipating a generally threatening future event would encourage a greater preference for immediate rewards, as reported in two previous studies. Finally, the present results suggest that the effect of foresight on "impulsive" decision-making is selective, insofar as it operates on delay discounting but not risk-taking.

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Supplemental material

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Note

1. In a change from the pre-registered analytical plan, we produced the analyses with regressions rather than ANCOVA for interpretability, but both analyses produce the same pattern of results.

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