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Is it time? Episodic imagining and the discounting of delayed and probabilistic rewards in young and older adults

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Abstract

Remembering and imagining specific, personal experiences can help shape our decisions. For example, cues to imagine future events can reduce delay discounting (i.e., increase the subjective value of future rewards). It is not known, however, whether such cues can also modulate other forms of reward discounting, such as probability discounting (i.e., the decrease in the subjective value of a possible reward as the odds against its occurrence increase). In addition, it is unclear whether there are age-related differences in the effects of cueing on either delay or probability discounting. Accordingly, young and older adult participants were administered delay and probability discounting tasks both with and without cues to imagine specific, personally meaningful events. As expected, cued episodic imagining decreased the discounting of delayed rewards. Notably, however, this effect was significantly less pronounced in older adults. In contrast to the effects of cueing on delay discounting, personally relevant event cues had little or no effect on the discounting of probabilistic rewards in either young or older adults; Bayesian analysis revealed compelling support for the null hypothesis that event cues do not modulate the subjective value of probabilistic rewards. In sum, imagining future events appears only to affect decisions involving delayed rewards. Although the cueing effect is smaller in older adults, nevertheless, it likely contributes to how adults of all ages evaluate delayed rewards and thus, it is, in fact, about time.

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Keywords

probability discounting; delay discounting; aging; episodic cueing; intertemporal choice; future imagining

By remembering the past and imagining the future, we can simulate both how we and other people might feel and think in other conditions, places, and times. These personal, imagined experiences may allow us to plan for the future, consider different options, and engage in more precise, goal-directed decisions (Boyer, 2008; Kahneman & Miller, 1986; Taylor & Schneider, 1989). The extent to which episodic memory and imagining exert a modulatory effect on decision-making, however, may depend on both the age of the decision-maker and on whether the decision is future-oriented or involves a probabilistic outcome.

The adaptive value of episodic imagining for human decision-making has been well studied in the context of intertemporal choice, leading to a fruitful partnership between cognitive neuroscience and behavioral economic approaches. Boyer (2008) suggested that imagining and constructing future experiences may guide people towards suitable delayed outcomes and away from near-sighted choices, bringing long-term outcomes closer in subjective time to the present. This tendency may be enhanced when people are prompted with personal cues of vivid events or actions (for a review, see Bulley, Henry, & Suddendorf, 2016). Such effects of personal cues have been observed in diverse populations, including not only healthy young adults (for a meta-analytic review, see Rung & Madden, 2018), but also individuals with behavioral problems, such as gambling, alcohol abuse, and eating disorders (e.g., Appelhans et al., 2011; Bulley & Gullo, 2017; Mellis, Snider, Deshpande, LaConte, & Bickel, 2019; Wiehler, Bromberg, & Peters, 2015), as well as individuals living in poverty (O'Donnell et al., 2019) and adolescent children (Bromberg, Lobatcheva, & Peters, 2017; Bromberg, Wiehler, & Peters, 2015). This effect has been observed with different kinds of cues, for example, when participants are asked to imagine what they would do with consumable and non-monetary delayed rewards (e.g., Benoit, Gilbert, & Burgess, 2011), generate semantic uses for rewards (Palombo, Keane, & Verfaellie, 2016), reflect on general or specific future events involving themselves (e.g., Cheng, Shein, & Chiou, 2012; Dassen, Jansen, Nederkoorn, & Houben, 2016; Nan & Qin, 2018), or imagine an episode not previously experienced (e.g., Sasse, Peters, Büchel, & Brassen, 2015). The vividness, recency, and frequency of the cues have also been shown to affect the degree of discounting (e.g., Daniel, Said, Stanton, & Epstein, 2015; Lin & Epstein, 2014; Liu, Feng, Chen, & Li, 2013; Mellis et al., 2019).

To date, however, no consensus has emerged regarding the effects of aging on delay discounting (for a review, see Mohr, Li, & Heekeren, 2010), and little is known regarding the effects of episodic cueing in older adults. Choice of future rewards over immediate rewards in young adults may be positively influenced by imagining specific future episodes, but whether older adults obtain a similar benefit is less clear. Some researchers have argued that older adults have a more myopic view of the future (Liu et al., 2016; Read & Read, 2004; Seaman et al., 2016) and are more inclined to forego delayed gratification and to pursue immediate satisfaction, given the increased risk of poor health and financial instability that

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comes with aging (Carstensen, Isaacowitz, & Charles, 1999). Others, in contrast, have argued that increased self-control and changes to lifestyle factors in healthy aging (e.g., interpersonal social roles, health considerations, and prosocial altruism) may lead to reduced discounting of future rewards in older adults compared to young adults (Löckenhoff, O'Donoghue, & Dunning, 2011; Sparrow & Spaniol, 2018). Moreover, older individuals could experience time as being "more compressed and fast-paced" (Sparrow & Spaniol, 2016), and this change in how time is perceived could, in turn, reduce the subjective distance of future rewards (Kim & Zauberman, 2009; Lempert & Phelps, 2016; Rutt & Löckenhoff, 2016; Wittmann & Lehnhoff, 2005). Nevertheless, some studies that included comparisons of older adults with middle-aged adults or even with adults in their 30s, have failed to find age-related differences in delay discounting (Chao, Szrek, Pereira, & Pauly, 2009; Green, Myerson, Lichtman, Rosen, & Fry, 1996), while others have reported greater delay discounting by older adults (e.g., Read & Read, 2004), and still others have reported less discounting by older adults (e.g., Green, Fry, & Myerson, 1994; Löckenhoff et al., 2011; Reimers, Maylor, Stewart, & Chater, 2009).

Regardless of whether younger and older adults differ in the degree to which they discount the value of future rewards, there is reason to suspect that older adults may show smaller effects of episodic cueing. Indeed, in a recent study by Sasse, Peters, and Brassen (2017), older adults made choices involving delayed rewards while simultaneously imagining themselves interacting with another person at a café on the date of a delayed reward delivery; such cues failed to decrease the degree to which the value of the reward was discounted. In fMRI experiments on intertemporal choice, the effects of episodic imagining appear to be mediated by activity in the hippocampus, medial temporal lobe (MTL), and ventromedial prefrontal cortex (vmPFC), at least in young adults. Participants were more inclined to select larger, delayed rewards over smaller, immediate rewards when an episodic event cue was presented alongside the delayed reward option; this preference was accompanied by increased activity within, and coordination between, the hippocampus/MTL and vmPFC (Benoit et al., 2011; Peters & Büchel, 2010). Moreover, the degree of coupling of activity between these areas of the brain predicted the degree to which young adults discounted the value of future rewards (Peters & Büchel, 2010).

Although older adults' MTL and vmPFC are also engaged when they are imagining future events, this activation is lower than that observed in younger adults (Addis, Wong, & Schacter, 2007; Buckner & Carroll, 2007). From the perspective of Schacter and Addis' (2007) constructive episodic simulation hypothesis, age differences may occur because imagining future scenarios is more demanding than retrieving past episodes, and regions of the prefrontal cortex involved in such imaginings are known to change with age. Another possibility is that the difference in activation reflects older adults' decreased hippocampal volume and their greater reliance on semantic content when they imagine future events (Addis, Musicaro, Pan, & Schachter, 2010; Addis, Wong, & Schacter, 2008; Gaesser, Sacchetti, Addis, & Schachter, 2011; Grilli, Wank, Bercel, & Ryan, 2018; Levine, Svoboda, Hay, Winocur, & Moscovitch, 2002; St. Jacques & Levine, 2007). Our group (Kwan et al., 2012; Kwan, Craver, Green, Myerson, & Rosenbaum, 2013) reported that individuals with MTL damage and associated deficits in episodic imagining did not differ from controls in the degree to which they discounted delayed rewards. However, amnesic individuals were

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less likely to benefit from episodic cues, and the benefit they received may require that cues be both personally relevant and adjacent to the presented options (Kwan et al., 2015; Palombo, Keane, & Verfaellie, 2015). Therefore, the procedure in the present study was modeled after that used by Kwan et al. (2013) in order to determine whether older adults would show less of an episodic cueing effect than younger adults even under such conditions.

One important aspect of decision-making that has received little study concerns the role of episodic imagining in the discounting of probabilistic rewards. Just as the subjective value of future rewards decreases as the time until their receipt increases, the subjective value of probabilistic rewards decreases as the odds against their receipt increase. Both delay and probability discounting are best described by a hyperboloid function (for a review, see Green, Myerson, & Vanderveldt, 2014). Indeed, some have postulated that the same or, at least, largely overlapping processes underlie both delayed and probabilistic decisions-making (Rachlin, Raineri, & Cross, 1991). Moreover, it has been hypothesized that decisions regarding probabilistic rewards involve some form of episodic imagining by way of anticipating the regret that would follow the failure to receive a reward (e.g., Loomes & Sugden 1982; cf. Craver, Kwan, Steindam, & Rosenbaum, 2014). To date, however, few studies have examined the effect of cueing on probability discounting unconfounded by the effects of delay. One earlier study examined cueing on probability discounting involved a confounding paradigm where a small sample of participants made risky choices but in the context of future outcomes (Kaplan, Reed, & Jarmolowicz, 2016). A more recent study by Bulley et al. (2019) had participants imagine future events based on positively or negatively valenced word cues prior to completing a delay discounting task and a risk-taking task (i.e., balloon-analogue risk task; BART) and found that although both positive and negative episodic cues decreased delay discounting, they had no effect on risk taking. It should be noted, however, that the BART involves potential losses as well as gains, and thus comparisons of choices on the BART and the discounting of delayed rewards are confounded by differences in the valence of the outcomes. And for both studies described, the generalizability to an older adult population was not considered.

Thus, it remains unclear whether aging has similar effects on decisions involving delayed outcomes as it has on decisions involving probabilistic outcomes. A meta-analysis of age-related differences in risky choice by Mata, Josef, Samanez-Larkin, and Hertwig (2011) revealed that when decisions are based on explicit information about the risks involved, as in most standard risky choice and probability discounting tasks, there tend not to be age differences observed, regardless of whether the risky options involved gains or losses. In contrast, when the information about risk is not explicitly provided and participants have to acquire it based on their experience during the experimental session, as on the Iowa Gambling Task, age differences are usually observed. As noted previously, however, no consensus exists as to whether there are age- related differences in delay discounting, and little is known about whether age modulates the effects of episodic cueing on the discounting of either delayed or probabilistic rewards. Accordingly, the present study examined the effects of cueing in both young and older adults, not only on the discounting of delayed rewards (Experiment 1) but also, for the first time, on the discounting of probabilistic rewards (Experiment 2).

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1. Experiment 1

In previous studies examining the effects of episodic cueing on delay discounting in patients with MTL damage (Kwan et al., 2015; Palombo et al., 2015), cueing produced a significant decrease in discounting by the older adult control groups; however, Sasse et al. (2017) failed to replicate this finding at the group level, although when comparisons were made between older adults with higher and lower cognitive ability, those with higher ability were more affected by cueing than those with lower ability. Accordingly, our primary research questions for the present experiment concerned the reliability of episodic cueing effects in older adults, and, assuming the Kwan et al. (2015) findings replicate, whether there are age-related differences in the magnitude of such cueing effects. Previous studies have observed diminished ability to engage in future-oriented thought as a function of age (Addis et al., 2008, 2010; Gaesser et al., 2011), leading to the expectation that episodic cueing will affect older adults less than young adults. In the present experiment, delay discounting was studied with two amounts of delayed reward because it is well-established that larger rewards are discounted less steeply than smaller rewards (for a review, see Green & Myerson, 2004), and replication of this benchmark finding helps establish the validity of both our approach and our findings.

1.1 Method

1.1.1 Participants.—Sample size for the current study was based on the expected effect size. Re-analysis of the data from the age- and education-matched older adult control group in our previous study of episodic cueing and delay discounting in patients with MTL damage (Kwan et al., 2015) revealed that the size of the cueing effect in healthy older adults, averaged across two reward amounts, was large (Cohen's $d = .88$). According to Cohen (1988), samples of 26 participants per group would provide more than adequate power (>.80 with $\alpha = .05$) for an effect of this size; however, because of the discrepancy between the Kwan et al. (2015) and Sasse et al. (2017) results, larger samples were studied in the present experiment. The young adult group consisted of 58 undergraduate-level students from York University (26 females; $M = 20.0$ years, $SD = 2.82$); the older group consisted of 56 older adults (28 females; $M = 64.1$ years, $SD = 8.58$). Participants were screened for behaviors associated with steep discounting of delayed rewards (Madden & Bickel, 2010), including smoking and illicit drug use as well as alcohol and gambling problems, according to DSM-5 criteria. Participants included here do not include any individuals that meet criteria for any of the stated behaviours.

We emphasize that although the current report is divided into Experiments 1 and 2 for ease of understanding, this, in some cases, misrepresents the order in which the participants performed the two discounting tasks. Although some participants performed only the delay discounting task, the majority of the young and older adult participants performed both delay and probability discounting tasks, and for those participants, the order of the two tasks was counterbalanced. Importantly, the participants who performed both tasks did so on separate days (i.e., delay and probability discounting tasks were never presented within the same session), separated by at least one and no more than three weeks.

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All participants gave informed written consent in accordance with the Human Research Ethics Committees at York University and Baycrest Health Sciences and either received course credit (young adults) or monetary compensation (older adults) for their participation.

1.1.2 Procedure.—Participants completed a computerized delay discounting task (Kwan et al., 2013; Kwan et al., 2015; for a review, see Green & Myerson, 2004). Over a series of trials, participants viewed pairs of monetary amounts and were asked to choose between smaller, immediate reward amounts and larger, delayed reward amounts. For each of the two delayed amounts ($100 and $2000), participants were asked to make six choices at each of seven delays (waiting 1 week, 1 month, 3 months, 6 months, 1 year, 3 years, and 10 years before receiving the reward) presented in random order.

An iterative, adjusting-amount procedure was used in which the amount of the immediate reward was increased or decreased based on a participant's previous choices at that delay so as to converge on an estimate of the amount of immediate reward that was equivalent in subjective value to the delayed reward. The first adjustment was half of the difference between the immediate and delayed amounts presented on the first trial, with each subsequent adjustment being half of the preceding adjustment. For example, in the condition where a future reward of $2000 could be received in 3 years, the first choice presented to the participants would be "$1000 right now or $2000 in 3 years." If the participant chose "$2000 in 3 years", the choice on the second trial would be between "$1500 right now" and "$2000 in 3 years." If the participant then chose "$1500 right now", the choice on the third trial would be "$1250 right now or $2000 in 3 years." Following the sixth and final trial of each condition, the subjective value of the delayed reward was estimated as the amount of the immediate reward that would be presented on a seventh trial.

As in the study by Kwan et al. (2015), participants also completed a second version of the delay discounting task that included personal event cues for each of the delays but was otherwise identical to the task on which they had been tested previously. Prior to the cued version of the task, participants were asked to identify plausible and personally specific future events that were scheduled or likely to take place for use as cues, one for each of the seven delay periods used in the delay discounting task. The participants were instructed to generate personal cues that were emotionally neutral or positive future events to avoid anticipatory anxiety or distress. To facilitate the process of generating event cues, participants were encouraged to think about and imagine different scenarios, social settings, or interactive events that they have planned or were likely to plan for themselves or with family and friends. Participants were not specifically told that the events were likely to require money for associated expenses. If, however, the events a participant generated did not seem to involve the use of money, they were prompted to think of other events.

The cued condition proceeded in the same way as the standard, uncued condition, except that each block of choices involving a specific delay began with the corresponding temporally contiguous personal cue presented on the screen (see Fig. 1). Upon viewing the cue, participants were given time to imagine the event in as much detail as possible. The participants then pressed a button indicating that they were ready to proceed to the first block of choice trials. The corresponding personal cue remained at the top of the screen until

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the end of the block to reduce memory demands and ensure that the imagined future event remained active in participants" minds.

The standard, uncued version of the task provided a baseline for measuring the effect of personal cueing and was followed 1–1.5 hours later by the cued version. During the period between the uncued and cued versions of the discounting task, participants completed other, tasks, including simple cognitive measures, questionnaires, and other behavioural tasks unrelated to the discounting tasks. In both uncued and cued conditions, the position of the immediate reward option on the screen was randomized such that it was equally likely to be presented to the left or the right of the delayed reward option. As is common in discounting research, hypothetical rewards were used. Although monetary rewards may not have the same utility for young and older adults (Seaman et al. 2016; 2018), numerous studies has shown that actual and hypothetical monetary rewards are discounted similarly (e.g., Bickel, Pitcock, Yi, & Angtuaco, 2009; Johnson & Bickel, 2002; Locey, Jones, & Rachlin, 2011; Madden, Begotka, Raiff, & Kastern, 2003). While the repeated-measures design raises the possibility of practice effects, studies have demonstrated the relative stability of individual discount rates over repeated testing (Harrison & McKay, 2012; Ohmura, Takahashi, Kitamura, & Wehr, 2006).

The initial 20 participants in each age group were informally asked to provide their phenomenological experiences while performing the task. To gather more systematic data regarding the mediating role played by episodic imagery across our two age groups, we asked all subsequent participants to provide phenomenological ratings of their episodic imagining following completion of the discounting tasks (Young: n = 38, 16 females, M = 20.3 years, SD = 2.29, and Older: n = 36, 20 females, M = 61.2 years, SD = 8.08). For each of the seven cues associated with the seven different delays, participants rated the frequency (*How often did this evoke an imagined experience of the future event?*), vividness (*How vivid were these imagined experiences of the future event?*), and emotionality (*How much emotion would this event make you feel?*) of their imagined experiences on a scale from one (Never or None) to five (A Lot or Highly).

1.1.3 Analysis.—The degree to which participants discounted delayed rewards was measured as the area under their empirical discounting curves (AuCs). The AuC is a theoretically neutral, normalized measure of the degree of discounting calculated from the observed subjective values for each data point (Myerson, Green, & Warusawitharana, 2001). AuC values decrease as discounting becomes steeper and may range from 0.0 (maximal discounting) to 1.0 (no discounting).

1.2 Results

Fig. 2 presents the mean subjective values of the delayed rewards for the uncued and cued conditions as a function of the delay until receipt of the reward for both young and older adults. Both young and older adults showed clear evidence of delay discounting in both cued and uncued conditions, as indicated by systematic decreases in subjective value as delay increased. For both groups and both reward amounts, cueing appeared to decrease how steeply participants discounted the delayed rewards, but young adults appeared to discount more steeply than the older adults in the uncued conditions and less steeply than the older adults in the cued conditions.

The AuCs for each participant in each condition (see Table 1) were submitted to a 2 (Age Group: Young vs. Older) × 2 (Condition: Uncued and Cued) × 2 (Reward Amount: $100 and $2000) mixed design analysis of variance (ANOVA) using IBM SPSS version 25. Significant effects of Amount and Cueing were observed: $F(1,112) = 88.50$, $\eta^2_p = .44$, and $F(1,112) = 127.79$, $\eta_p^2 = .53$, respectively, both *p*s < .001. The effect of Age was not significant, but this must be interpreted in light of the significant Age × Cueing interaction: $F(1,112) = 13.73$, $p < .001$, $\eta_p^2 = .11$, which reflects the fact that, as mentioned previously, the age difference in the uncued conditions was in the opposite direction from that in the cued conditions (see also the box plots in Figure 3). In addition, there was a significant Amount × Cueing interaction, reflecting the fact that the effect of cueing was greater in the Large amount condition than in the Small amount condition, as may also be seen in Fig. 3: $F(1,112) = 6.52$, $p = .012$, $\eta_p^2 = .06$. Tests of Simple Main Effects verified that both age groups showed cueing effects (both *F*s > 38.0, both *p*s < .001) and that there was a significant Age difference in discounting in the Uncued conditions ($F = 5.75$, $p = .018$), although the Age difference in the Cued conditions (which as noted previously was in the opposite direction) failed to reach significance ($F = 3.40$, $p = .068$).

We also compared young and older adults' phenomenological ratings of the imagined experiences elicited by the episodic cues. A 2 (Age Group) × 3 (Question) mixed design ANOVA revealed a small but significant effect of Question, $F(2,144) = 9.82$, $p < .001$, $\eta_p^2 = .12$, but no effect of Age, $F(1,72) < 1.0$, $\eta_p^2 < .001$, and no Age × Question interaction, $F(2,144) = 2.65$, $p = .074$, $\eta_p^2 = .04$. Summed across the cues for the seven delays, the group mean ratings for Question 1 (frequency), Question 2 (vividness), and Question 3 (emotionality) were 26.7, 26.1, and 27.7, respectively. With respect to possible sources of the age differences in cueing effects, it should be noted that tests of simple main effects revealed no age difference on any of the three questions, all *F*s < 1.0. These findings, however, must be interpreted in light of the finding that the phenomenological ratings were not significantly correlated with the cueing effects in either age group.

1.3 Discussion

As expected, Experiment 1 replicated previous findings of reduced temporal discounting in the presence of cues to engage in episodic prospection (Benoit et al., 2011; Kwan et al., 2015; Palombo et al., 2015; Peters & Büchel, 2010). When no cue was present, young adults discounted more steeply than older adults. Although there is no consensus in the literature on age differences in uncued discounting, the present results are consistent with previous findings of steeper discounting by young adults (Green et al., 1994, Löckenhoff et al., 2011, Reimers et al., 2009). Some have attributed this age difference to greater impulsivity on the part of young adults, but MacKillop et al. (2016) recently showed that the degree of discounting is unrelated to psychometric measures of impulsiveness. More importantly for current purposes, both young and older participants were more inclined to choose the larger, future reward over a smaller, immediate reward when directed to consider a personally meaningful episodic cue that was temporally contiguous with the corresponding future time

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period in the delay discounting task. In fact, young adults showed significantly larger cueing effects than older adults.

Examination of participants' self-reports revealed a relative lack of age-related differences in the frequency, vividness, and emotionality of imagined episodes despite the previous finding that older adults tend to generate less episodic content than young adults when asked to imagine future events or remember past experiences (Addis et al., 2008, 2010; Gaesser et al., 2011) and previous reports that episodic future thinking measures predict the degree of delay discounting (Benoit et al., 2011; Peters & Büchel, 2009). However, there may have been limitations in our assessment of the effectiveness of the episodic cues, as evidenced by a lack of correlation between the ratings and the degree of discounting in both age groups (all *p*s > .05). These problems may be due to the fact that ratings were made after completion of the discounting task rather than during the task itself. On the other hand, obtaining phenomenological ratings concurrent with decision-making could pose its own problems because such assessment might bias participants' choices. Taken together, these considerations suggest that the focus here should remain on the significant effects of episodic cueing on intertemporal choice.

2. Experiment 2

The results of Experiment 1 showed that personal, episodic cues decrease the discounting of delayed rewards in healthy adults, with young adults showing a greater cueing effect than older adults. However, it is unclear whether personally meaningful cues are themselves sufficient to positively influence financial decisions or if the decisions must be intertemporal in order for the cues to work. One way to investigate this question is to examine the effects of personal cues on a non-temporal reward discounting task. Probability discounting paradigms, in which the choice is between a smaller, guaranteed reward and a larger, uncertain reward, have been frequently used in the field of behavioral economics as a means of measuring risk-taking (e.g., Green & Myerson, 2010; Shead & Hodgins, 2009). Critically, probability discounting tasks vary the level of uncertainty, but the consequences (i.e., one either obtains a probabilistic reward or one does not) are assumed to be immediate.

Probability discounting has important properties in common with delay discounting. Both can be described with a similar, hyperboloid mathematical function (Green & Myerson, 2004). Notably, however, delay and probability discounting are differentially sensitive to variation in both the amount (Green, Myerson, & Ostaszewski, 1999) and type of reward (Charlton & Fantino, 2008; Estle, Green, Myerson, & Holt, 2007). As was seen in Experiment 1, smaller delayed rewards are discounted more steeply than larger ones. In contrast, smaller probabilistic rewards are usually discounted *less* steeply than larger ones. Individual differences suggest that delay and probability discounting reflect different traits as well as involve different neural mechanisms and cognitive processes (e.g., Myerson, Green, Hanson, Holt, & Estle, 2003; Seaman et al., 2018; Peters & Büchel, 2009; for a review, see Green & Myerson, 2013). As such, one cannot necessarily predict whether effects seen with a different task, delay discounting, with which it shares some but not all processes, will also be observed with probability discounting. Although older adults are often considered to be more risk-averse than younger adults, a recent meta-analysis of

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experiments on age differences in risky choice suggests that age-differences may predominantly reflect differences in learning the outcome probabilities, rather than differences in the choice process itself (Mata et al., 2011). Because participants in probability discounting tasks usually are provided the relevant probabilities, we predict no age-related differences in the uncued conditions of our probability discounting

Moreover, despite the clear findings with respect to age-related differences in the effects of cueing on delay discounting observed in Experiment 1, it remains an empirical question whether young and older adults' probability discounting will be affected to the same degree by personal cues due to the behavioural dissociations of delay and probability discounting noted above. Indeed, it also is an empirical question whether age-related changes across both groups will be affected by cueing at all. Both these questions are the focus of Experiment 2.

2.1 Method

2.1.1 *Participants.*—To evaluate the effects of personal cues on risky decision-making, 38 young and 36 older adults (a subset of the participants in Experiment 1) completed uncued and cued version of a probability discounting task previously used in a study of individuals with hippocampal amnesia and healthy controls (Kwan et al., 2012; 2013). According to Cohen (1988), these sample sizes provide more than adequate power (>.80 with $\alpha = .05$) to detect cueing effects of the sizes observed with delay discounting in Experiment 1 ($d \geq 1.0$). As noted in Experiment 1, administration of the delay and probability discounting tasks was separated by one to three weeks and their order was counterbalanced. At the end of their second session, participants also completed the Barratt Impulsiveness Scale (BIS-11; Patton, Stanford, & Barratt, 1995). The BIS- 11 is a 30-item self-report instrument that is widely used to assess the construct of impulsivity. All participants' scores were between 52 and 71, which are thought of as the normal range for impulsiveness (see Stanford et al., 2009, for a review).

2.1.2 *Procedure.*—Over a series of trials, participants were presented with pairs of hypothetical monetary amounts on a computer screen and asked to make choices between a smaller, certain reward and a larger, probabilistic reward. For each of two probabilistic amounts ($250 and $2000), participants were asked to make six choices at each of six probabilities (90%, 75%, 50%, 20%, 10%, and 5% chance of receiving the reward) presented in random order. As in Experiment 1, an iterative, adjusting-amount procedure was used in which the amount of the certain reward was increased or decreased based on a participant's previous choices at that probability so as to converge on an estimate of the amount of certain reward that was equivalent in subjective value to the probabilistic reward (see Kwan et al., 2013).

Following the standard, uncued condition, the participants completed a probability discounting task in which the choices were accompanied by personally meaningful event cues. Prior to the cued condition, which followed the same procedures as the standard (uncued) probability discounting condition, the participants were asked to identify six specific, personally meaningful events that they believed were plausible. The participants were told to envision activities or events that, unlike the events in the previous experiment,

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were not tied to a specific place or time, just as the possible rewards in the probability discounting task were not associated with a specific place or time. To facilitate the process of generating event cues, participants were encouraged to think about and imagine different scenarios, social settings, or interactive events they have considered engaging in or attending, either by themselves or with family and friends. As in Experiment 1, participants were asked to generate only emotionally neutral or positive events so as to avoid anticipatory distress. Again, participants were not specifically informed that the events that were to be identified for the study were ones that required money. If, however, the generated events did not seem to involve the use of money, then participants were prompted to think of other events, and only cues that suggested money would be needed for the associated event were used.

The cued version of the probability discounting task proceeded in the same way as the uncued version, except that each block of choice trials began with one of the six personal cues, which had been randomly assigned to the six probabilities. Upon viewing the cue, participants were given time to imagine the event in as much detail as possible. Participants then pressed a button indicating that they were ready to proceed to the first block of the task. The personal cue remained at the top of the screen until the end of the block to reduce memory demands and ensure that the event remained active in the participants‟ minds (see Fig. 4).

As in Experiment 1, the standard, uncued version of the discounting task was completed approximately 1.0–1.5 hours prior to the cued version as a baseline for measuring the effect of personal cueing and to ensure that any benefits from cueing did not influence the baseline discounting rates. Again, the tasks within the session included simple cognitive measures, questionnaires, and other behavioural tasks that were unrelated to the discounting tasks participants completed. To minimize potential carryover effects from the delay discounting task to the probability discounting task, different and unrelated cues were selected for the delay and probability discounting tasks. Following completion of both the uncued and cued versions of the probability discounting tasks, participants rated the experiences elicited by the cues on scales from one to five using the same three questions as in Experiment 1.

2.2 Results

Fig. 5 presents the mean subjective values of the probabilistic rewards for the uncued and cued conditions as a function of the odds against receiving those rewards (i.e., $(1 - p)/p$, where p is the probability of receiving the reward). As may be seen, both young and older adults showed clear evidence of probability discounting in both cued and uncued conditions, as indicated by systematic decreases in subjective value as the odds against increased.

The AuCs for each participant in each condition (see Table 2) were submitted to a 2 (Age Group: Young vs. Older) × 2 (Condition: Uncued and Cued) × 2 (Reward Amount: $250 and $2000) mixed design ANOVA using IBM SPSS version 25. There was a significant effect of Amount, reflecting the fact that, as expected, the larger reward amount was discounted more steeply than the smaller amount: $F(1,72) = 24.16$, $p < .001$, $\eta_p^2 = .25$. Importantly, however, neither the effect of Condition nor the effect of Age were significant, $F(1,72) = 1.92$, $p = .17$, $\eta_p^2 = .03$, and $F(1,72) < 1.0$, $p = .96$, $\eta_p^2 < .001$, respectively, nor were any of the

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interactions, all *F*s < 1.0. Box plots of the distribution of AuCs in each condition are shown in Fig. 6.

Although the ANOVA failed to reveal a significant difference between the cued and uncued probability discounting conditions (i.e., we failed to reject the null hypothesis), a limitation of classical statistical analyses like ANOVA is that it does not directly assess the evidence *for* the null hypothesis, which in this case is that there is no effect of cueing on probability discounting. We therefore used a Bayesian approach, which unlike classical null hypothesis significance testing, can directly compare the evidence for the null hypothesis with the evidence for the alternative hypothesis (i.e., there is an effect of cueing, Quintana & Williams, 2018). Bayesian paired samples *t*-tests were conducted on the cueing effects from both the young and older adults using JASP software. For the small reward amount in both the uncued and cued conditions, the Bayes factor was 0.269; for the large reward amount conditions, the Bayes factor was 0.222. These values, which compare the likelihood of the alternative hypothesis given the present data to the likelihood of the null hypothesis given the data, represent what Jeffreys (1961) termed substantial evidence for the null. They may be contrasted with the Bayes factors for the cueing effects in Experiment 1 that represent compelling evidence for the alternative hypothesis and against the null (both Bayes Factors > 150).

Finally, we compared the phenomenological ratings of the imagined experiences elicited by the personal cues. A 2 (Age Group) × 3 (Question) mixed design ANOVA failed to reveal effects of either Question or Age, both *F*s < 1.0, although there was a significant Age × Question interaction: $F(2,144) = 7.14$, $p = .001$, $\eta_p^2 = .09$. The source of this interaction appeared to be in the different patterns of mean ratings, which in the young adults were highest for Question 1 and lowest for Question 3 (23.3 vs. 21.2, respectively) but showed the reverse pattern in the older adults (21.9 vs. 23.1, respectively). It should be noted, however, that tests for simple main effects failed to reveal a significant age difference on any question (all *F*s < 2.9, all *p*s > .09). As was the case in Experiment 1, the phenomenological ratings were not significantly correlated with the cueing effects in either age group, again suggesting problems with the assessment of cue effectiveness after completion of the discounting task. This remains an interesting issue, but one that will have to be addressed in future studies.

2.3 Discussion

The primary research question in this experiment was whether personally meaningful cues, which were found to modulate the degree of delay discounting in Experiment 1 and previous studies, would similarly modulate other forms of decision-making. Specifically, the experiment examined whether such cues would affect choices on a (non-temporal) probability discounting task. Consistent with previous studies of uncued probability discounting, smaller probabilistic rewards were discounted less steeply than larger ones, the opposite of the amount effects observed with delay discounting (Experiment 1; for a review, see Green & Myerson, 2004), and no age differences were observed (Seaman et al., 2016; Seaman et al., 2018). More importantly, there were no differences observed in either young or older adults' probability discounting rates when they were cued to think about specific

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personal experiences and their discounting rates when they were not cued. Not only did the effect of cueing fail to reach statistical significance, but Bayesian analysis provided very compelling evidence for the null hypothesis that there was no cueing effect in decisions involving probability discounting.

3. General Discussion

The two experiments compared the effects of personally relevant cues associated with delayed rewards (Experiment 1) and probabilistic rewards (Experiment 2) on rate of discounting in young and older adults. In uncued conditions, older adults discounted delayed rewards less steeply than young adults, consistent with several previous studies (e.g., Green et al., 1994; Löckenhoff et al., 2011; Reimers et al., 2009), and hopefully contributing to a resolution of the controversy concerning this issue (e.g., Chao et al., 2009; Read & Read, 2004). As will be seen, the observed shallower delay discounting of older adults has important implications for interpretation of the age difference in cueing effects. In contrast to the results for uncued delay discounting, no age differences were observed in uncued probability discounting, also consistent with previous findings (Seaman et al., 2016; 2018).

With respect to the effects of cueing on delay and probability discounting, which were the focus of the present study, it is well-established that young adults discount delayed rewards less when presented with cues to imagine future events (e.g., Benoit et al., 2011; Peters & Büchel, 2010), but few studies have investigated whether such cues can have similar effects in older adults (Kwan et al., 2015; Palombo et al., 2015; Sasse et al., 2017). Such effects might not be observed because older adults generally tend to generate fewer episodic details of imagined future events compared to young adults (Addis et al., 2008; Schacter et al., 2013). In fact, Sasse et al. (2017) did not find an effect of event cues in an older adult sample. The results of Experiment 1 revealed that older adults can, indeed, show episodic cueing effects on delay discounting, although they also revealed that these effects were smaller than those observed in young adults. Experiment 2 examined whether the discounting of probabilistic rewards would also be affected by event cues and, if so, whether there are age-related differences in this effect. Notably, the present results provide clear evidence that although both young and older adults steeply discounted the value of probabilistic rewards, personally relevant event cues failed to modulate the degree of probability discounting in either age group (see Fig. 7).

3.1 Cueing and the discounting of delayed rewards

In Experiment 1, as expected, personally relevant event cues increased the tendency of the young participants to choose larger, future rewards over immediate, smaller gains. More specifically, young adults showed shallower discounting of future rewards when presented with cues related to personally meaningful events occurring around the same time as the delayed rewards relative to the discounting observed in the absence of such cues. Importantly, older adults were similarly affected by episodic cues but to a lesser extent.

As noted above, Sasse et al. (2017) reported that episodic cues did not reduce delay discounting in their older adult sample, and they suggested that older adults are less able to benefit from episodic cueing than younger adults due to differences in cognitive control. It

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should be noted that there are several methodological differences between the current study and that by Sasse and colleagues. In their study, participants in the episodic imagining conditions were asked to imagine spending time at a café, either with someone they knew or in order to conduct a media interview with a famous individual. Although in a previous study, Sasse et al. (2015) found that young adults‟ cueing effects did not depend on the nature of the cues provided, it is possible that, in fact, older adults are sensitive to the nature of episodic cues, and this could account for the difference in results. Perhaps the more important point, however, is that in both Sasse et al. (2017) and Experiment 1 of the present study, older adults‟ delay discounting was significantly less affected by episodic cues than that of young adults.

The finding that episodic cueing led to a larger reduction in the degree of discounting in young adults than in older adults, while consistent with the finding that older adults generate fewer episodic details than young adults when imagining future events (Addis et al., 2008; Lapp & Spaniol, 2017; for a review see Schacter, Gaesser, & Addis, 2013), raises additional questions as to the basis for these age-related differences. Construal Level Theory (Trope & Liberman, 2010) posits that temporally distant events are perceived more abstractly and in less detail than more temporally proximal events and that this is responsible, at least in part, for people preferring sooner rewards, whose representations are more concrete even when they are smaller than delayed rewards, which may be more abstractly conceived (Kim, Schnall, & White, 2013). Because personally meaningful cues can produce more concrete and detailed representations of future rewards, such cues could lead to reduced delay discounting. Indeed, older adults tend to report more „generic‟ memories with fewer specific details and show reduced episodic future imagining (Addis et al., 2008; Rubin & Umanath, 2015). Further, the established age-related differences in event memory and future imagining could account for the smaller cueing effects observed in older adults, but this interpretation will have to be reconciled by the finding that in the uncued conditions of Experiment 1, the older adults showed shallower discounting than younger adults (see also Green et al., 1994; Löckenhoff et al., 2011; Reimers et al., 2009).

The results of neurocognitive studies suggest an alternative approach to explaining the decreased effect of episodic cues on older adults’ delay discounting. Older adults show lower activation of both their MTL and vmPFC than young adults when imagining future events (Addis et al., 2007; Buckner & Carroll, 2007), and there is evidence that age-related changes to the hippocampus may lead to the decreased ability to access specific events in both remembering and future imagining (Gaesser et al., 2011; Schacter et al., 2013). In addition, older adults’ reduced event detail fluency may not only be specific to MTL episodic memory changes but also reflect age-related changes to frontal lobe structures (see Cabeza & Dennis, 2013; Raz, 2004 for reviews). Either or both of these neural changes may contribute to age-related declines in the ability to imagine future events, leading to a decreased ability to benefit from episodic cues like that observed in Experiment 1; however, this interpretation, like that of Construal Level Theory, would need to be reconciled with older adults’ shallower discounting of delayed rewards in the uncued conditions.

Part of the appeal of the Temporal Construal Theory and neurocognitive accounts just described is that they have implications for both uncued and cued discounting. It is also

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possible, however, that different processes are involved in these two situations and, indeed, both accounts have problems explaining the different patterns of age-related differences observed in the uncued and cued conditions of the present study. In previous studies, our group showed that individuals with MTL damage and deficits in episodic imagining discount delayed rewards to the same degree as healthy controls despite these deficits (Kwan et al., 2012; 2013). Although the delay discounting of individuals with MTL damage does differ from controls under some circumstances, studies by Kwan and colleagues established that episodic future thinking need not always be involved in delay discounting, particularly in the absence of episodic cues, and inferred that MTL patients could use a semantic, rather than episodic, strategy for future thinking in evaluating delayed outcomes. Semantic, unlike episodic, cognitive functions are relatively preserved in older adults (e.g., Devitt, Addis, & Schacter, 2017; Levine et al., 2002). If such functions predominate in the absence of specific episodic cues, this could explain why older adults do not show steeper discounting than young adults in the present study, though it would not explain why older adults show shallower discounting. Age-related decreases in cognitive control (Sasse et al., 2017) can also be ruled out as the explanation for the present results because such decreases predict steeper uncued discounting by older adults.

An important finding in Experiment 1 of the current study is that older adults showed smaller cueing effects than young adults. However, this finding should be considered in the context of differences between the age groups in the uncued condition, in which older adults showed shallower delay discounting. It is possible that the effect of cues on older adults' discounting is less pronounced than the effect on young adults' discounting because the subjective value of a delayed reward to older adults has less room to increase. Although this possibility cannot be ruled out, it is equally important to understand the significant difference in uncued discounting between young and older adults (e.g., Green & Myerson, 1994; cf Read & Read, 2004; see Green et al., 1996, for discussion of how socioeconomic differences may contribute to such discrepant findings). Another possibility is that the relative shallowness of uncued discounting in older adults can be understood through a social cognitive lens For example, a recent review investigated the relation between the perception of one's identity when faced with a pending life transition (e.g., graduation, retirement, death) and how this perception, in turn, drives behaviour (Moss & Wilson, 2018). The authors concluded that when one perceives their identity as enduring throughout (rather than ending at) the transition, they are motivated to act responsibly and to delay gratification. Moss and Wilson (2018) further reported that older adults tend to exhibit such identity continuity, whereas young adults more often perceive their identities as discontinuous at a transition point and are therefore motivated to act impulsively. Thus, there are numerous demographic, cognitive, and affective differences between young and older adults (e.g., age-related differences in affective responses to future outcomes and to the decision-making process itself; Löckenhoff et al., 2011; for reviews, see Ferraro & George, 2015; Schaie & Willis, 2016), and their roles in delay discounting will require further study (see Sparrow & Spaniol, 2016 for a brief review related to this topic).

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3.2 Cueing and the discounting of probabilistic rewards

Given the effects of episodic cueing on delay discounting in both young and older adults, the question arises whether personally relevant cues also affect other types of decision-making tasks, particularly ones that do not directly involve a substantial delay, and whether similar age differences are observed on both delay and probability discounting tasks. Accordingly, Experiment 2 examined the effects of personal cues on probability discounting in young and older adults. It should be noted, of course, that in probability discounting, the decisions may also involve anticipating the future. For example, people may ask themselves what it would be like to actually receive (or not receive) the probabilistic reward. In fact, such imaginings provide the basis for theories of risky choice in which decisions are based on anticipated regret (e.g., Loomes & Sugden, 1982), though a previous study of risky choice in a case of pronounced episodic amnesia (Craver et al., 2014), raises questions about the role of future thinking in risky choice. Despite the fact that episodic and semantic future imagining could play a role in probability discounting, cueing did not affect the choices of participants in either age group in Experiment 2, which is in sharp contrast to the results of Experiment 1 where episodic cueing substantially decreased the degree of delay discounting.

The difference in the effects of cueing on delay and probability discounting could reflect the differences in brain activity observed during intertemporal choice and risky decision-making. Despite a common system featuring the ventral striatum and the orbitofrontal cortex that may be involved in both delay and probability discounting, Peters and Büchel (2009) also described separate neural processes that could point to a dissociation in the decision-making mechanisms involved in intertemporal and risky choice. Probability discounting activated the superior parietal cortex and middle occipital areas. Delay discounting, in contrast, activated the frontal pole and subregions of the posterior cingulate cortex, leading Peters and Büchel (2009) to assign these regions a specific role in coding for value in the context of delays. Relatedly, these areas, along with the hippocampus and vmPFC, have been identified as central to episodic future thought and event construction (Addis et al., 2007; Schacter & Addis, 2009; Peters & Büchel, 2010; Szpunar, Watson, & McDermott, 2007).

Further evidence for the view that different mechanisms are involved in intertemporal and risky choice comes from a study by Bulley et al. (2019), in which young adult participants imagined future events based on positively or negatively valenced word cues prior to completing a delay discounting task and a risk-taking task. Their manipulation of event cues, which were valence-based but not personally meaningful like the cues generated in the current study, showed that both positive and negative episodic cues decreased discounting of delayed rewards but had no effect on risk taking, although, as noted above, the fact that the BART involves probabilistic losses as well as gains limits direct comparison with the discounting of delayed rewards.

A possible exception to the present findings comes from a novel study by Kaplan et al. (2016). Participants were cued by viewing age-morphed representations of themselves prior to rating the likelihood that they would give up a hobby if there was a chance that quitting would increase the likelihood of the participants being healthy (Experiment 1) or unhealthy (Experiment 2) in 30 years. As in a standard probability discounting task, the probability of

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these health consequences was varied. If the future health consequences of the hobby would be positive (albeit probabilistic), participants were more likely to continue their hobby when shown an age-morphed representation (probability discounting was shallower), whereas if the consequences would be negative, they were more likely to quit (probability discounting was steeper). The fact that cueing effects were observed on this modified probability discounting task might appear inconsistent with the present findings; however, the sample sizes in their two experiments were extremely small (*N*s of 5 and 6, respectively). Importantly, the choice consequences (better or worse health) would occur years in the future, and thus the observed cueing effects may still have been due to the fact that it was delayed events that were being imagined.

A possible concern involves the different nature of the cues presented in Experiments 1 and 2. In Experiment 2, participants were asked to imagine personal, "timeless" events. Whereas episodic events by definition involve a scenario with a specific time and place, the instructions in Experiment 2 were motivated by our desire to mirror the nature of the probability discounting task in which the rewards do not have a specified delay, though a reward obviously would occur after the choice is made. Participants were instructed to think about an event in which a monetary reward is useful, regardless of whether it was in the past or the future. This might have limited the cues' meaningfulness, as they were not tied to a specific point in time. It should be noted, however, that this situation mirrors the situation in gambling (e.g., the purchase of lottery tickets), where people may or may not have ideas about the specific use to which they would put any winnings. Nevertheless, in asking participants to describe a plausible event that is not constricted to a specific time, participants are not precluded from imagining a specific, singular event (e.g., buying ski equipment at the mall) or an "extended event" (e.g., a weekend ski trip in Vermont). Of course, these qualitative differences in cues may also exist for the more remote future time periods of the delay discounting task (e.g., travelling to Hong Kong with my grandchildren 10 years from now), and it may be presumed that differences in the self-generated cues will also generate differences in the way the cues are considered by the participants (e.g., in terms of phenomenological ratings). No significant differences were found in the ratings between Experiment 1 and 2, as evident in our findings, but only Experiment 1 produced a cueing effect. As a result, although it remains unclear whether it was the nature of the cues, the nature of the decision-making task, or both that were responsible for the differences between the results for the probability discounting and delay discounting tasks, the procedure used here has considerable ecological validity.

Taken together, the results of the two present experiments suggest personally relevant cues primarily influence decision-making processes that involve evaluating the duration of waiting involved in choice outcomes, consistent with the view that intertemporal choice and risk- taking decisions involve separate neural mechanisms and cognitive processes (Green & Myerson, 2004; 2013).

3.3 Do different types of discounting reflect different 'impulsivity' constructs?

The present findings have implications for understanding the relation between intertemporal choice, as exemplified by the delay discounting task in Experiment 1, and risky decision-

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making, as exemplified by the probability discounting task in Experiment 2. These two discounting tasks were constructed to be directly analogous to one another so they might better reveal similarities and differences between these forms of choice behavior (Green & Myerson, 2004). Early behavioral economic accounts often presumed that one process underlies both forms of discounting, although researchers have disagreed about which form is fundamental (Green & Myerson, 1996; Kagel, Green, & Caraco, 1986; Rachlin et al., 1991). After all, the longer the wait for a delayed reward, the greater the risk of not receiving it, and the lower the probability that one will receive a reward playing a slot machine, for example, the longer one will likely have to play before winning. Moreover, the iconic example of an impulsive person is a substance abuser, who is typically both a risk taker and someone who often chooses short-term rewards with blunted regard for long-term outcomes.

If both an inability to delay gratification and risk-taking were manifestations of a single ‘impulsivity’ construct, however, then in the context of discounting, impulsive individuals would show steeper delay discounting (suggesting greater sensitivity to delay) and shallower probabilistic discounting (indicating lower sensitivity to probability). Contrary to this expectation, however, analyses based on individual young and older adults’ AuCs in the uncued conditions of the present two experiments revealed that delay and probability discounting were not significantly correlated for either small or large rewards (all *p*s >.27). The hypothesis of a single impulsivity construct also predicts that analogous manipulations will have the same effects on both delay and probability discounting, but smaller delayed rewards were discounted more steeply than larger ones in Experiment 1, whereas smaller probabilistic rewards were discounted less steeply than larger ones in Experiment 2.

Both the lack of correlation between delay and probability discounting and the opposite effects of amount are consistent with previous results (for reviews, see Green & Myerson, 2010; Green et al., 2014). The present finding that event cueing strongly affects delay discounting (Experiment 1) but has no effect on probability discounting (Experiment 2) in either young or older adults further strengthens the argument against a single impulsivity construct, suggesting instead that different traits underlie these two kinds of discounting (Green & Myerson, 2013).

4. Conclusions

The primary issues in the present study are whether providing personal cues to imagine specific events during which money would be useful decreases the extent to which young and older adults discount delayed and probabilistic rewards and, if so, whether they do so to a different extent. Previous studies have observed age-related differences in the ability to engage in future-oriented thought, leading to the expectation that older adults would be less affected by event cueing, but the effect of similar, personally relevant event cueing on probabilistic rewards has received little previous study. Older adults are of special interest here because they are a population often faced with episodic memory deficits and, ostensibly, parallel deficits in episodic imagining changes (Addis et al., 2008, 2010; Gaesser et al., 2011). Because the cueing effect is assumed to result from imagining the cued events, one thus might expect that older adults would show smaller effects or might even be unaffected by such cues.

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Many behavioral problems covary with the degree of discounting (Madden & Bickel, 2010), with substance abuse, which may increasingly occur with older adults (e.g., Chhatre, Cook, Mallik, & Jayadevappa, 2017; Han, Moore, Sherman, Keyes, & Palamar, 2017), being the iconic example. Accordingly, much behavioral economic research is currently investigating interventions that might reduce the rate of discounting, with episodic future thinking being a major focus of such investigations (for a recent review, see Rung & Madden, 2018). Episodic future thinking techniques typically involve generating and then responding to episodic cues presented at the time when decisions are made, similar to the procedures used in the present study. If older adults are less affected by such manipulations, then episodic future thinking would be less likely to provide an alternative route or intervention to sustain typical decision-making in this population. Although, as predicted, older adults in the present study showed smaller cueing effects than young adults, episodic cues did significantly decrease older adults' discounting of delayed rewards, and therefore, we are hopeful regarding the prospects for successful use of episodic or personally relevant event cueing as an intervention to improve decision-making in this population.

Finally, we identify that a major concern with older adults is potential vulnerability to scams and problems with financial decision-making, which are perhaps more related to problematic risk-taking than with delay of gratification. Although we observed no effect of cueing on either young or older adults' probability discounting in the present study, we also observed no age differences in uncued discounting. A previous study of cueing and probability discounting in young adults did report significant effects, although notably the probabilistic outcomes in that study were years in the future (Kaplan et al., 2016). This finding suggests a wider role for cueing, one that applies whenever future events are involved, regardless of whether they are probabilistic and delayed or simply delayed, raising the possibility of a broader applicability of interventions using episodic cueing techniques. It remains to be seen whether this expanded view of cueing's role will be confirmed in future studies, particularly those with older adults. If so, it could have both theoretical and applied implications for how competent and autonomous decision-making can be sustained by adults of all ages.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Highlights:

Is it time? Episodic imagining and the discounting of delayed and probabilistic rewards in young and older adults (COGNIT-D-19–00684)

- It is unclear if episodic cueing is specific to age group or reward discounting type.
- Young and older adults completed delay and probability discounting tasks with cues.
- Episodic cueing effects were less pronounced in older adults on delay discounting.
- Event cues showed no effect on probability discounting in either age group.
- Results expand the role of time specific cues across forms of decision-making.

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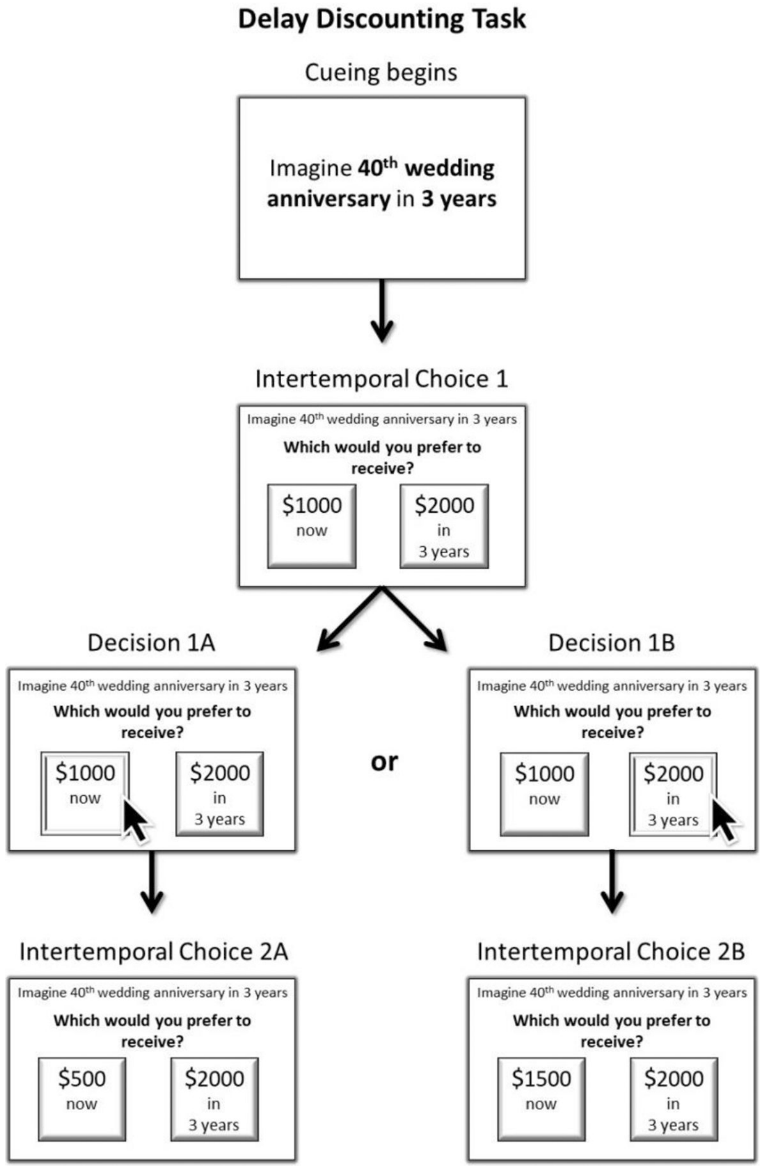

Figure 1.

Experimental paradigms for the cued condition of the delay discounting task of Experiment 1. Participants were presented with a self-generated episodic cue and asked to imagine a personal future experience occurring at a specific delay (e.g., 3 years). They then were presented with two reward options and indicated their choice between a smaller, immediate reward and a larger reward to be received after the specified delay.

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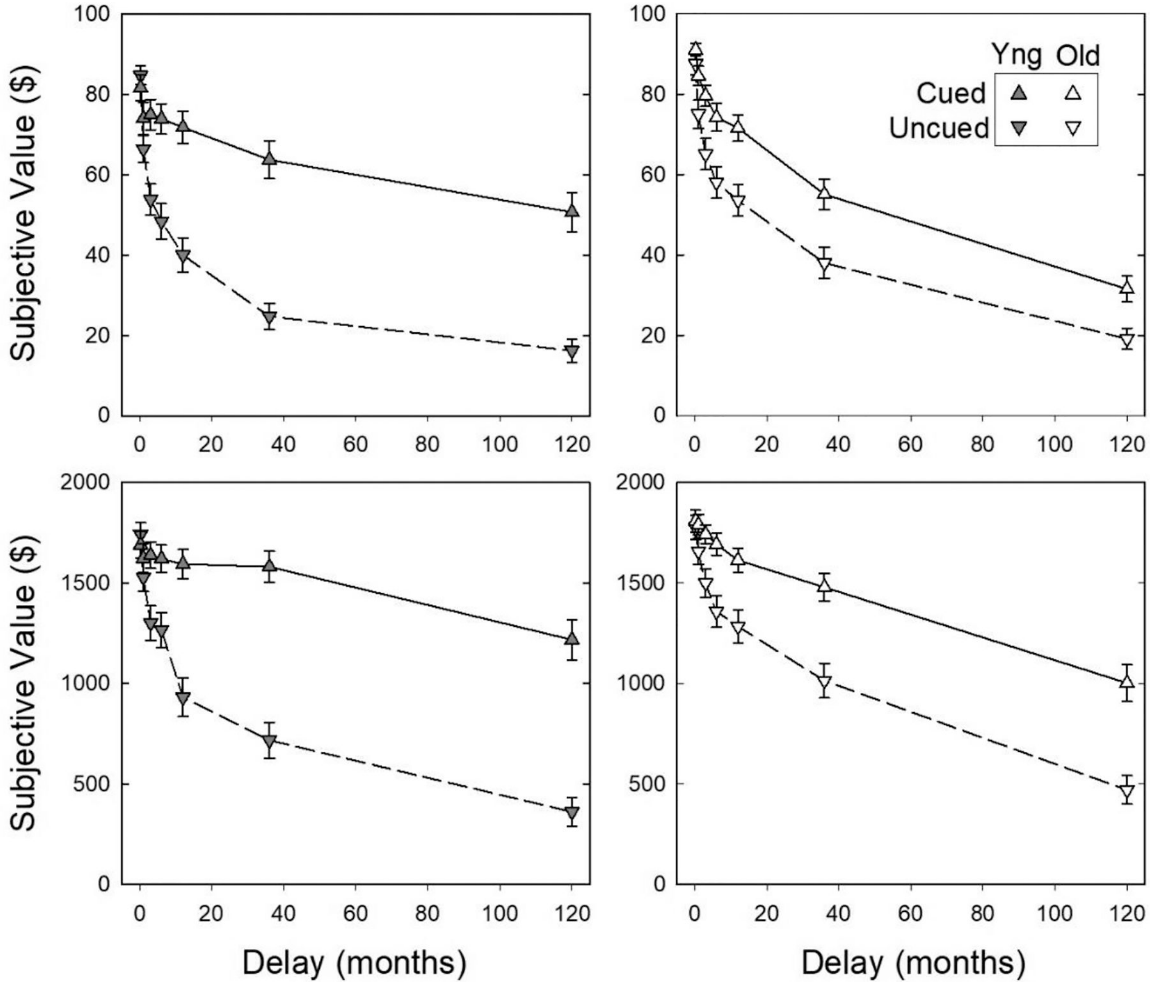

Figure 2.
Subjective value as a function of delay. The left and right panels present the data from the young and older adult groups, respectively, and the top and bottom panels present the data from the small and large amount conditions, respectively.

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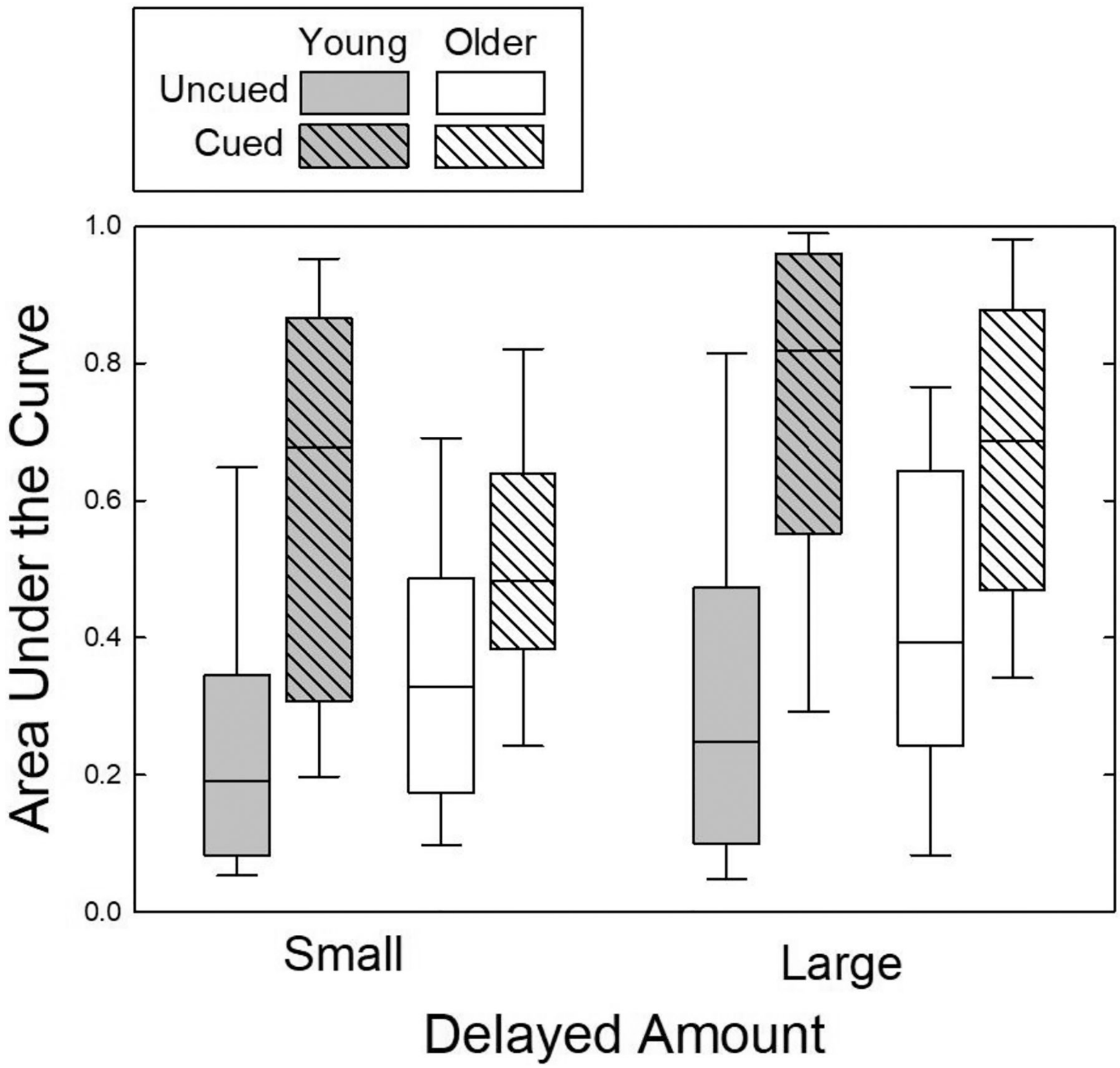

Figure 3.
Box plots depicting the distributions of AuCs for the young and older adults in all four conditions (small and large delayed rewards in the uncued and cued conditions) of Experiment 1. The bottom and top of each box represents the 25th and 75th percentiles; the horizontal line represents the median AuC; the bottom and top whiskers extend to the 10th and 90th percentiles.

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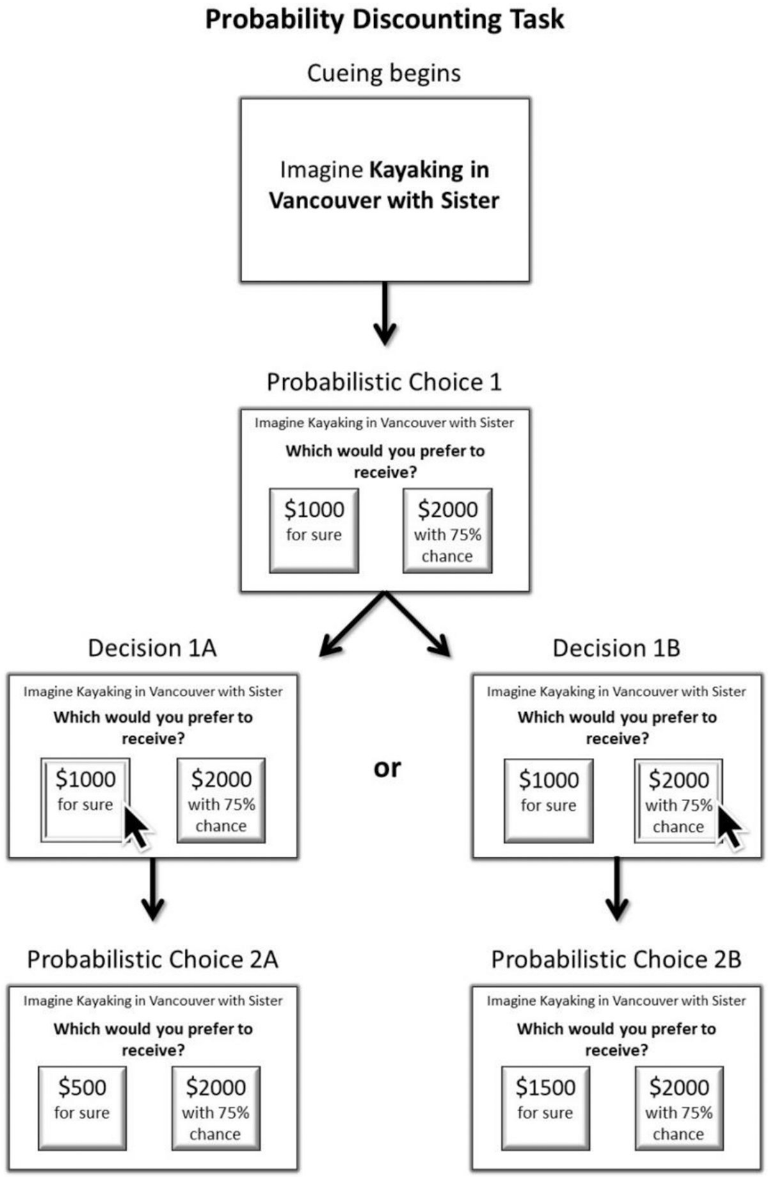

Figure 4.

Experimental paradigms for the cued condition of the probability discounting task of Experiment 2. Participants were presented with a self-generated personal cue and asked to imagine a personal experience that was not time specific. They then were presented with two reward options and indicated their choice between a smaller, certain reward and a larger reward that had a specified likelihood of being received.

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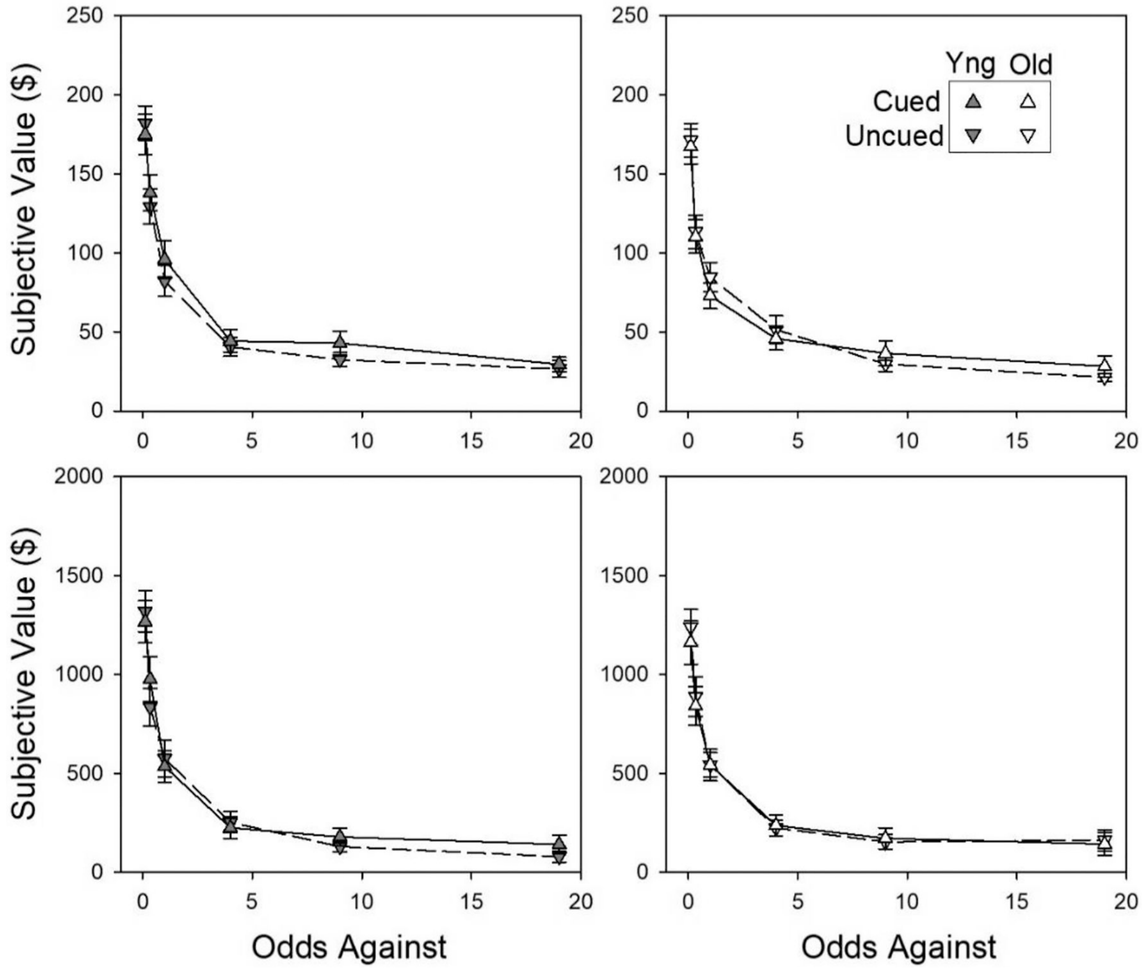

Figure 5.

Subjective value as a function of the odds against receiving a probabilistic reward. The left and right panels present the data from the young and older adult groups, respectively, and the top and bottom panels present the data from the small and large amount conditions, respectively.

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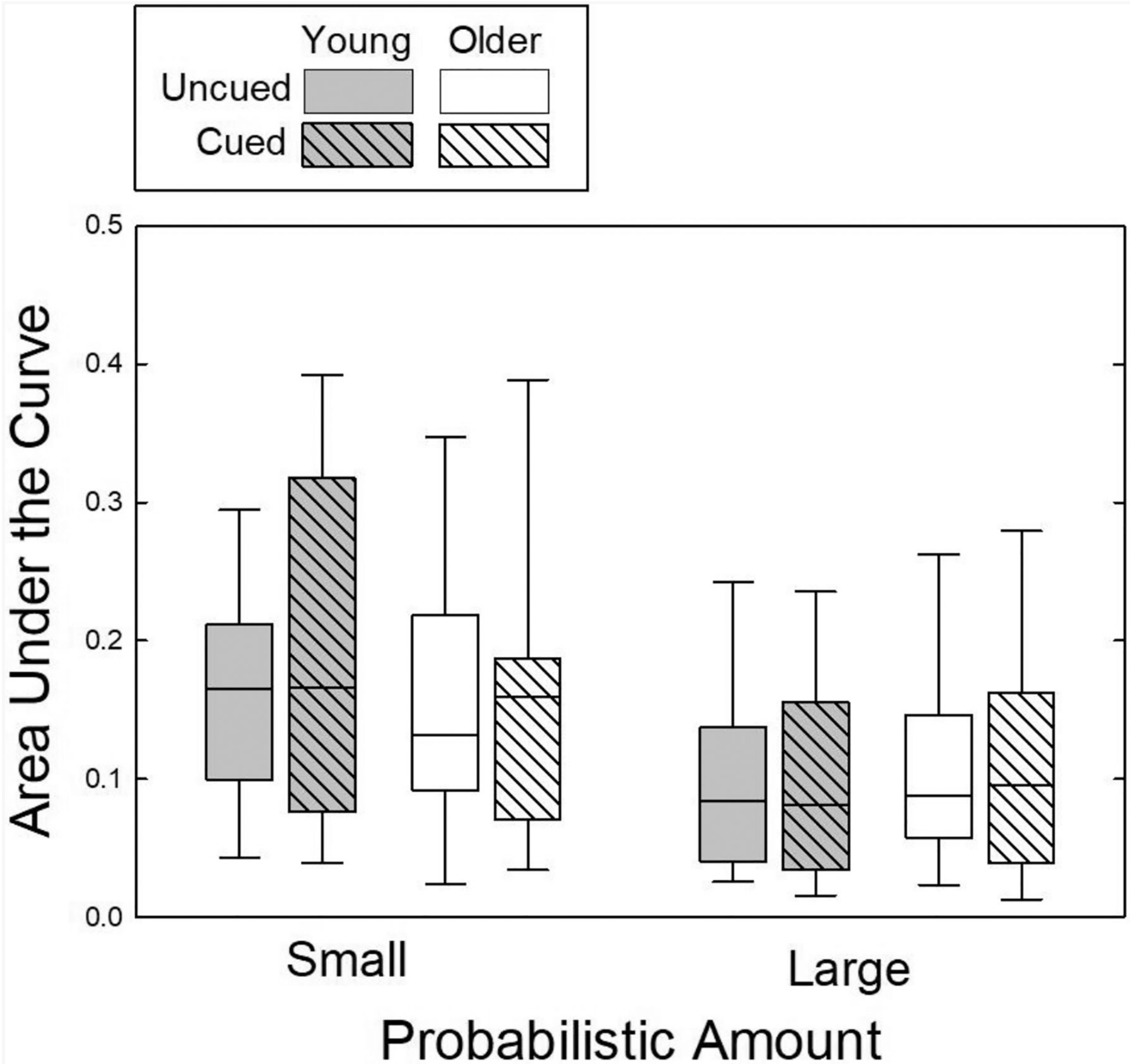

Figure 6.

Box plots depicting the distributions of AuCs for the young and older adults in all four conditions (small and large probabilistic rewards in the uncued and cued conditions) of Experiment 2. The bottom and top of each box represents the 25th and 75th percentiles; the horizontal line represents the median AuC; the bottom and top whiskers extend to the 10th and 90th percentiles.

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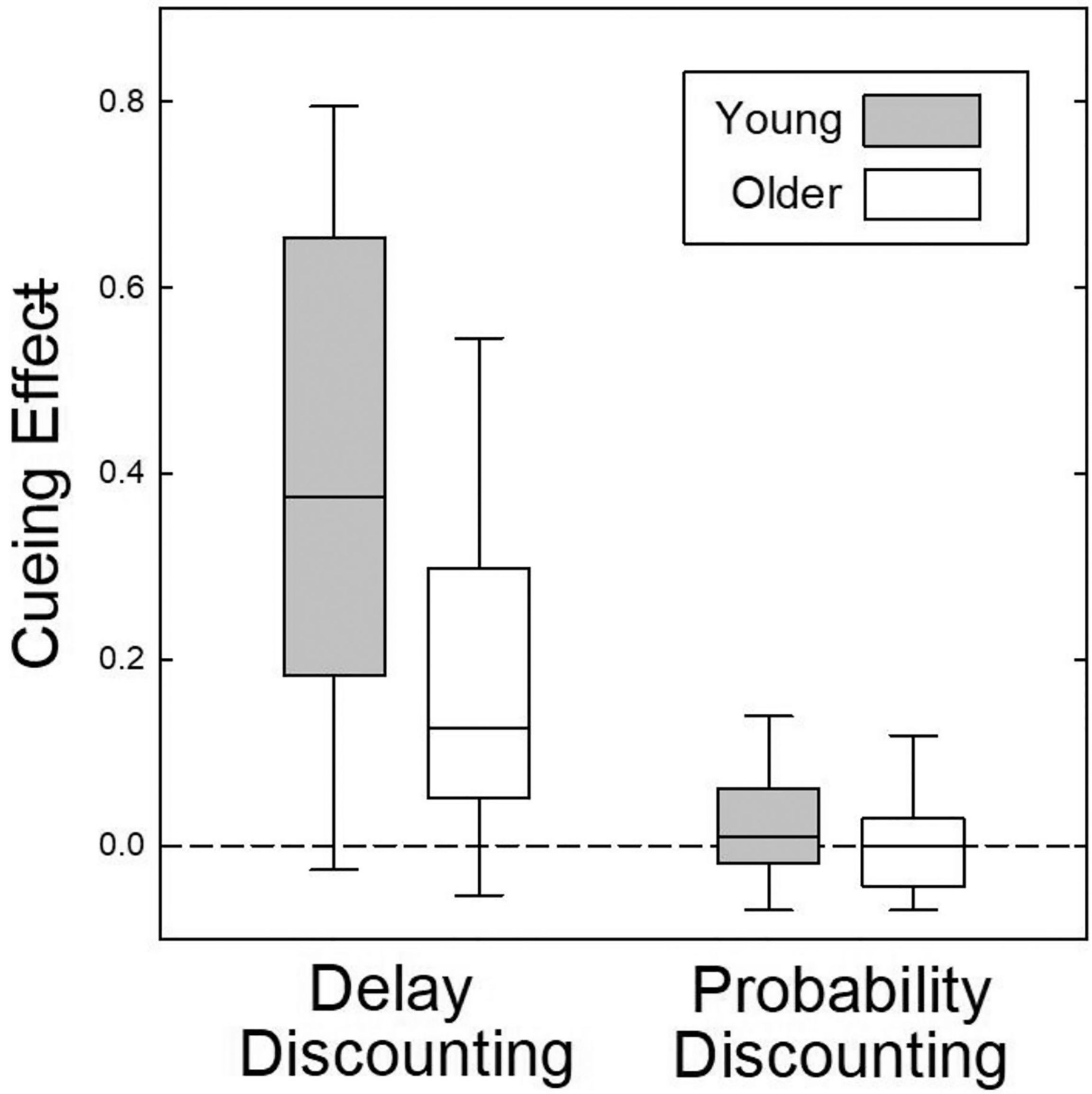

Figure 7.

Box plots depicting the distributions of cueing effects (calculated as the difference between the AuC for the cued and uncued conditions) for the young and older adults in Experiment 1 (delay discounting) and Experiment 2 (probability discounting). The horizontal dashed line represents no difference between the AuCs in the cued and uncued conditions, indicating no effect of episodic cueing.

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Table 1

Demographics and AuC values for participants in Experiment 1 (Delay Discounting)

	Young Adults	Older Adults
N	58	56
Sex (M:F)	32:26	28:28
Age in years	19.97 (2.82)	64.07 (8.58)
Uncued Condition AuCs		
Small Delayed Reward ($100)	0.25 (0.22)	0.35 (0.22)
Large Delayed Reward ($2000)	0.33 (0.28)	0.44 (0.26)
Cued Condition AuCs		
Small Delayed Reward ($100)	0.61 (0.29)	0.50 (0.21)
Large Delayed Reward ($2000)	0.73 (0.26)	0.67 (0.23)
Cueing Effect	0.38 (0.30)	0.19 (0.19)

Note: Age and Area-under-the-Curve (AuC) reported as means with standard deviations in parentheses. The cueing effect is the mean difference between the AuCs for the cued and uncued conditions, averaged across the two amount conditions.

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Table 2

Demographics and AuC values for participants in Experiment 2 (Probability Discounting)

	Young Adults	Older Adults
N	38	36
Sex (M:F)	22:16	16:20
Age in years	20.26 (2.29)	61.19 (8.08)
Uncued Condition AuCs		
Small Delayed Reward ($250)	0.16 (0.09)	0.16 (0.11)
Large Delayed Reward ($2000)	0.10 (0.08)	0.11 (0.09)
Cued Condition AuCs		
Small Delayed Reward ($250)	0.19 (0.13)	0.17 (0.14)
Large Delayed Reward ($2000)	0.12 (0.12)	0.13 (0.15)
Cueing Effect	0.02 (0.08)	0.01 (0.11)

Note: Age and Area-under-the-Curve (AuC) reported as means with standard deviations in parentheses. The cueing effect is the mean difference between the AuCs for the cued and uncued conditions, averaged across the two amount conditions.