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Information about foregone rewards impedes dynamic decision-making in older adults

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“Making an informed decision” implies that more information leads to better decisions, yet it may be the case that additional information biases decisions in a systematic and sometimes detrimental manner. In the present study, we examined the effect of additional information on older adults’ decision-making using a task for which available rewards were dependent on the participant’s recent pattern of choices. The optimal strategy was to forego the immediately rewarding option in favor of the option that yielded larger delayed reward. We found that providing information about true foregone rewards – the reward that would have been received had the participant chosen the other option – significantly reduced older adults’ decision-making performance. However, false foregone rewards – foregone rewards manufactured to make the long-term option appear more immediately rewarding – led older adults to perform at a level equal to younger adults. We conclude that providing information about foregone rewards biases older adults toward immediate rewards at a greater rate than younger adults, leading to poorer older adult performance when immediate rewards and long-term rewards conflict, but intact performance when immediate rewards and long-term rewards appear to align.

Keywords: decision-making; aging; foregone rewards; delayed rewards

In making daily decisions, one is often forced to weigh smaller immediate rewards against potentially greater delayed rewards. For example, an individual desiring to boost their energy level might ponder the choice between a sugary caffeinated energy drink and an alternate healthy snack. Indulging in the caffeinated beverage would provide the individual with higher, more immediate energy boost. On the other hand, choosing to maintain a healthier diet by consistently selecting a healthy item may lead to better-sustained energy over the course of time with a smaller immediate boost of energy. In this situation, foregoing the greater immediate reward can result in a greater long-term benefit. The same type of trade-off applies to many economic and health choices. Despite the prevalence of these choice scenarios, immediate temptations often prevail over long-term goals (Loewenstein, 1996; Rachlin, 1995). With this in mind, a recurring theme in reward-based decision-making centers on the distinction and preference between immediate and delayed reward (Bechara, Damasio, Damasio, & Anderson, 1994; Hariri et al., 2006; McClure, Laibson, Loewenstein, & Cohen, 2004).

The decisions that we make are rarely isolated events – the rewards that are available at any point are often dependent on our previous choices. Consider two individuals who both chose to exercise on the same day: one regularly exercises, and

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one rarely exercises. Although both individuals make the same single choice, the individual who regularly exercises will observe a greater benefit than the individual who rarely exercises because their reward (good physical health) is contingent on *many* previous choices. The dependence of available rewards on choice history is reflected in dynamic decision-making tasks that have been widely used to assess preference for future or delayed reward (e.g., Cooper, Worthy, Gorlick, & Maddox, 2013; Gureckis & Love, 2009; Worthy, Cooper, Byrne, Gorlick, & Maddox, 2014; Worthy, Otto, & Maddox, 2012).

In dynamic decision-making tasks in the laboratory, participants repeatedly choose between two reward options, one that is Short-Term optimal, and one that is Long-Term optimal. Selecting the Short-Term option gives a higher immediate reward on each trial, but selecting the Long-Term option causes the rewards available for both options to increase on future trials. The strategy that leads to optimal performance is to repeatedly forego the option that gives the higher immediate reward (Short-Term option) in favor of the larger delayed reward (Long-Term option), directly pitting long-term and short-term rewards against one another. Previous work from our labs using dynamic decision-making reveals an older adult advantage in learning to forego a more immediately rewarding option in favor of an option that leads to larger long-term rewards (Worthy, Gorlick, Pacheco, Schnyer, & Maddox, 2011; see also Cooper et al., 2013). While this advantage is exciting, decision-making environments in the real world are extremely variable, and more work is needed to understand the extent to which older adults are able to perform optimally in dynamic decision-making situations.

One critical aspect of real-life decision-making, which has yet to be explored in the older adult population, is that future choices may be informed not only by the rewards that have been received, but also by the rewards that could have been received had an alternative choice been made. This scenario is analogous to an executive who is able to observe the result of continued investment while simultaneously calculating the hypothetical cost savings of suspending investment (Otto & Love, 2010). Otto and Love (2010) considered a dynamic decision-making task in which people learned about the rewards resulting from both chosen *and* unchosen (foregone) options. Perhaps counterintuitively, they found that younger adults perform worse when given information about true foregone rewards. That is, when foregone rewards show that another option would have been more immediately rewarding, long-term performance suffers. This type of task parallels real-life decision-making in three key ways. First, similar to dynamic decision-making tasks, many real-world decisions are informed by past outcomes and many current situations are determined by past choices (Busemeyer & Pleskac, 2009). Second, and contrary to classic temporal discounting tasks, the participant is neither explicitly told of nor promised a larger delayed reward, but must discover the value of the Long-Term option by exploring the reward environment. Third, participants are able to learn from both the reward that they received and the reward that they could have received had they acted differently. Despite these similarities to real-world decision-making, little is known about the effect of foregone rewards on older adults' decision-making performance.

In the present study, we tested older adults' susceptibility to foregone rewards (called True Foregone Rewards) by providing information about the reward for the option that they chose as well as the reward that would have been received on each trial if the unselected option had been selected. In the True Foregone rewards condition, if a participant selected the choice that represented the "Long-Term" option on a given trial and was awarded 60 points, they would also be told what had they selected the other

choice, 70 points (note that participants do not initially know which option is Long-Term optimal or Short-Term optimal, but must discover it through trial-by-trial feedback). While information about foregone rewards does not affect the participant's current decision (since it has already been made), it can still affect their future decisions. In our energy example, this would correspond to someone choosing the healthy snack, foregoing the sugary caffeinated beverage, and observing a much more energized, caffeinated coworker. This information about true foregone rewards or "what could have been" may cause the individual to make a different decision when presented the same choice in the future.

It is possible that older adults, who may have a greater sensitivity to delayed rewards than younger adults (Green, Fry, & Myerson, 1994; Löckenhoff, O'Donoghue, & Dunning, 2011; Samanez-Larkin et al., 2011), are less affected than younger adults by true foregone rewards that highlight the immediate value of the Short-Term option. Another possibility is that older adults are *more* affected by foregone rewards than younger adults. Providing information about the foregone reward distinctly highlights the higher immediate value, or local superiority, of the Short-Term option, whereas in the absence of true foregone rewards, the immediate value of the Short-Term option is not as obvious. Highlighting the local superiority of the Short-Term option leads to poorer younger adult performance in this task (Otto & Love, 2010). Recent work using modified versions of the Iowa Gambling Task has found an age-related increase in hypersensitivity to reward, whereby the decisions of older adults are disproportionately influenced by prospects of receiving rewards as compared to younger adults (Bauer et al., 2013). Taken together, we hypothesize that older adults will be even more affected by the presence of foregone rewards that highlight the greater immediate reward of the Short-Term option, resulting in poorer performance relative to younger adults in this decision-making task when true foregone rewards are present.

We included an additional condition in our experiment, False Foregone Rewards, which provides additional information on each trial without highlighting the immediate superiority of the Short-Term option. We hypothesized that the presence of true foregone rewards would systematically shift value from the higher delayed reward (Long-Term option) to the higher immediate reward (Short-Term option) as a result of the highlighted local superiority of the Short-Term option. However, a second plausible explanation for an age-related performance decline in the True Foregone Rewards condition is that the additional information from foregone rewards simply causes confusion stemming from additional information. While older adults typically perform better than or equal to younger adults on this task under normal conditions (Cooper et al., 2013; Worthy et al., 2011; Worthy & Maddox, 2012), their performance is negatively affected by different types of increased task difficulty, including performance pressure (Cooper et al., 2013) and increasing the number of options (Worthy et al., 2014), thus their performance may decline simply because additional information makes the task more confusing. In the False Foregone Rewards condition, the reward associated with the chosen option was always true to the reward structure, but the foregone reward was fictional and skewed to dull the salience of the immediate reward of the Short-Term option on each trial (Otto & Love, 2010). This False Foregone Rewards condition was also used in Otto and Love to verify that performance in the True Foregone Rewards condition was not simply due to confusion stemming from additional information. In our energy example, the False Foregone Rewards condition is analogous to an individual choosing the healthy snack and (falsely) hearing that the caffeinated beverage was much less effective, encouraging

their future selection of the Long-Term option by making the immediate rewards of the Short-Term option less salient.

A significant older adult performance deficit relative to younger adults when false foregone rewards are presented would suggest that additional information about the reward environment confuses older adults and negatively affects their performance. Alternately, a lack of older adult performance deficit would indicate that the presence of additional information alone does not lead to poorer older adult decision-making. Older adults performing better than or equal to younger adults when false foregone rewards are present, but worse when true foregone rewards are present, would provide support for the hypothesis that older adults are more affected by true foregone rewards because they highlight the local superiority of the Short-Term option, a feature that results in a systematic bias toward the immediately rewarding option.

Method

Participants

Seventy-five younger adults between the ages of 18 and 28 ($M = 20.28$, $SD = 2.44$) and 58 older adults between the ages of 60 and 88 ($M = 67.17$, $SD = 5.25$) were recruited from the Austin, TX, community and compensated \$10/hr for their participation. Informed consent was obtained from all participants, and the experiment was approved for ethics procedures using human participants. Demographic information was collected for each subject (Table 1). Participants were randomly assigned to one of three conditions: No Foregone Rewards ($n_{\text{young}} = 25$, $n_{\text{old}} = 20$), True Foregone Rewards ($n_{\text{young}} = 26$, $n_{\text{old}} = 19$), or False Foregone Rewards ($n_{\text{young}} = 24$, $n_{\text{old}} = 19$).

Table 1. Neuropsychological scores and demographic information.

Neuropsychological test	No Foregone		True Foregone		False Foregone		ANOVA
	Mean	SD	Mean	SD	Mean	SD	P-value
Trail Making Test A	-0.60	0.76	-0.75	0.65	-0.43	0.70	0.33
Trail Making Test B	-0.53	0.55	-0.72	0.29	-0.32	0.58	0.37
Stroop Color-Word Test	0.33	0.79	0.44	0.73	0.32	0.52	0.83
Word Fluency Subtest (F-A-S)	0.46	0.93	0.17	1.06	0.01	1.03	0.37
Wechsler Memory Scale							
Immediate	1.21	0.80	0.97	0.94	0.31	1.04	0.01
30 Min Delay	1.38	0.79	1.15	0.88	0.44	0.75	0.01
California Verbal Learning Test							
Delayed recall (Free)	0.70	0.80	0.92	0.82	0.26	0.84	0.06
Immediate recall (Free)	0.55	0.81	0.92	1.06	0.45	0.74	0.23
Delayed recall (Cued)	0.58	0.73	0.68	0.71	0.21	0.98	0.18
Immediate recall (Cued)	0.63	0.70	0.71	0.79	0.29	0.84	0.22
Recognition false positives	0.00	1.03	-0.50	0.78	0.18	1.29	0.13
Recognition true positives	0.05	0.84	0.16	0.90	-0.11	1.01	0.68
Older adult demographic	12F/8M		12F/ 7M		9F/10M		
Age	66.05	3.68	67.11	4.81	68.42	6.85	0.38
Years of education	16.75	2.43	17.68	1.63	16.16	2.69	0.13
Younger adult demographic	11F/14M		19F/7M		17F/7M		
Age	19.84	1.91	19.81	2.84	21.25	2.29	0.06
Years of education	13.52	1.16	13.73	1.34	14.75	1.62	0.01

Materials and procedure

Neuropsychological testing

Older adults were given a series of standardized neuropsychological tests designed to assess general intellectual ability across attention, executive functioning, and memory. Tests included Wechsler Adult Intelligence Scale-III Digit Span (WAIS-III; Wechsler, 1997); WAIS-III Vocabulary (Wechsler, 1997); Trail Making Test A&B (TMT; Army Individual Test Battery, 1944); Stroop Color-Word Test (Stroop, 1935); F-A-S Word Fluency subtest of the Neurosensory Center Comprehensive Examination for Aphasia (Spreen & Benton, 1977); Wechsler Memory Scale Third Edition (WMS-III) logical memory subtests (Wechsler, 1997); and California Verbal Learning Test (CVLT; Delis, Kramer, Kaplan, & Ober, 1987). The tests were administered in one 2-hr session.

Normative scores for each subject were calculated for each neuropsychological test using the standard age-appropriate published norms. Table 1 shows the means and standard deviations of standardized z scores on each test for older adults in each condition. All WAIS subtest percentiles were calculated according to the testing instructions and then converted to standardized z scores. The CVLT standardized T scores were calculated according to testing directions and then converted to standardized z scores, and the TMT standard z scores were calculated according to the testing instructions. Participants were excluded from participation if they scored more than 2 SD away from the standardized mean on more than one neuropsychological test in the same area (i.e., memory, executive functioning, or attention) or more than 3 SD from the mean in a single area. Three participants were outside of normative ranges and were not included in the analysis. An analysis of variance (ANOVA) was conducted for each of the neuropsychological tests to determine if there were any differences between the three groups – the p -values of each of these tests are included in Table 1, and significant differences are discussed in the Results section.

Decision-making task

The experiment was performed on PC computers using Matlab software with Psychtoolbox 2.54 (Brainard, 1997; Pelli, 1997). Participants were told that they were going to have many trials to select between two decks of cards with a goal of maximizing their cumulative points. For each selection they received points that were added to their cumulative total. Participants in both of the foregone rewards conditions were instructed that in addition to the number of points they received from their current selection, they would also be shown the points they would have received had they selected from the other deck, the foregone reward.

At the beginning of each of the 150 trials, the participant was instructed, “pick a card,” and was able to select between a green card on the left side of the screen, and a purple card on the right side of the screen. After making their selection, the next screen would display the number of points that they received and their current total points. If they were in a foregone reward condition, the screen would also display the number of points that they could have received had they chosen differently (Figure 1). Participants were given a goal of 9,600 points, representing selecting the optimal choice on approximately 80% of trials.

Participants were not given any information about the underlying reward structure; however, the points that they were awarded on any given trial was dependent on their recent pattern of choices. Specifically, one of the options (the green card) corresponded to

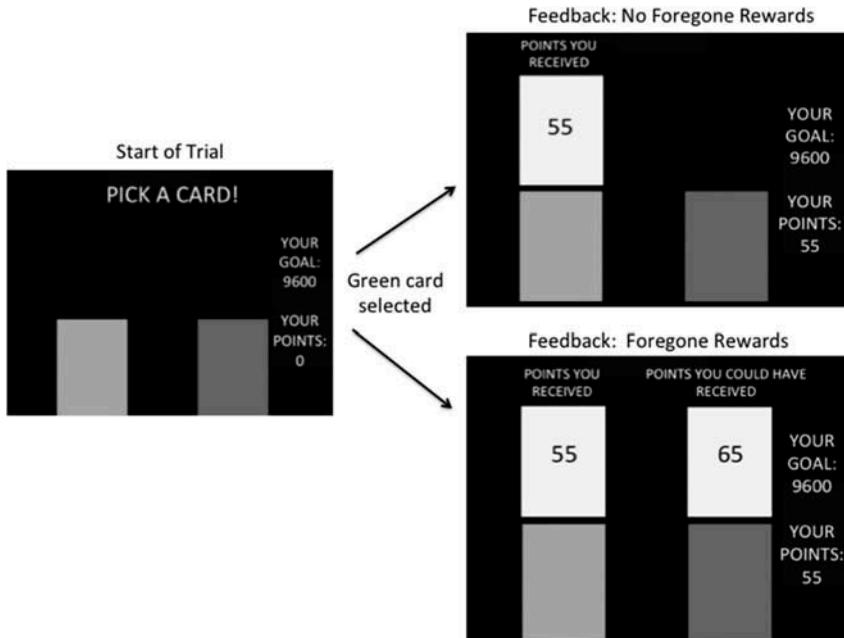


Figure 1. Sample trial from the experiment. After making a selection, participants in the No Foregone Rewards condition were only given feedback about the chosen option (top). Participants in the True Foregone Rewards and False Foregone Rewards conditions were given feedback about both the chosen and unchosen options (bottom).

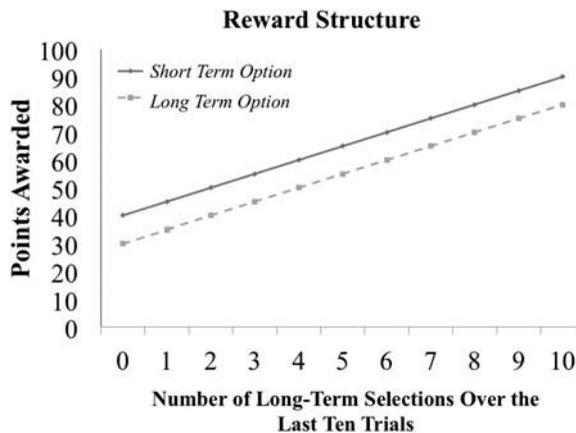


Figure 2. Rewards given for each option as a function of the number of times the Long-Term option was selected over the previous 10 trials. Selecting the Long-Term option 10 consecutive times will lead to a reward of 80 points on each trial, whereas selecting the Short-Term option 10 consecutive times will lead to a reward of 40 points on each trial.

a Long-Term option and one option (the purple card) corresponded to a Short-Term option (Figure 2). On any given trial, the Short-Term option awarded a higher point value than the Long-Term option, but the rewards available for both options were dependent on the

number of times that the participant had selected the Long-Term option in the previous 10 trials. Although the Short-Term option gave the higher immediate reward, selecting the Long-Term option repeatedly lead to the higher cumulative reward and was the optimal choice. The reward for the chosen option was identical in the three conditions, described below. The three conditions varied critically in that one condition (No Foregone Rewards) did not include foregone reward information, while in the second condition (True Foregone Rewards), foregone rewards that highlighted the Short-Term option were presented. In the third condition (False Foregone Rewards), foregone rewards that did not highlight the Short-Term option were presented.

No Foregone Rewards. The rewards for the chosen option were determined by the equations $30 + 5 h$ for the Long-Term option and $40 + 5 h$ for the Short-Term option, based on the number of Long-Term selections in the previous 10 trials, h . In this version, participants were not given any information about the option that they did not select. This reward structure is identical to that used with older adults in Worthy et al. (2011) and Cooper et al. (2013).

True Foregone Rewards. The rewards for the chosen option were identical to the No Foregone condition. The foregone rewards for the True Foregone Rewards condition were determined by the equations $40 + 5 h$ when the Long-Term option was chosen, and $30 + 5 h$ when the Short-Term option was chosen. Note that the foregone reward displayed on each trial was the actual reward value that would have been awarded had the participant chosen the other option.

False Foregone Rewards. The decision-making task was identical to the True Foregone Rewards, with the exception that the foregone reward information that was presented did not highlight the immediate value of the Short-Term reward. The rewards for the chosen option were identical to the other two conditions. The foregone rewards for each trial were determined by the equation $25 + 5 h$ when the Long-Term option was chosen, and $45 + 5 h$ when the Short-Term option was chosen, based on the number of Long-Term selections in the 10 most recent trials (h). If the Short-Term option was selected and a reward of 55 points received, the participant was told that the Long-Term option would have given a reward of 60 points (when it really would have given 45). If the Long-Term option was chosen and 55 points awarded, the participant was told that the Short-Term option would have given 50 points (when it really would have given 65).

Results

Performance in this task was examined using the number of points that participants collected throughout the course of the experiment. We analyzed the data for each participant in three 50-trial blocks in order to assess the rates at which participants learned, or improved, across the course of the experiment. We evaluated this using a 2 (age) \times 3 (condition) \times 3 (block) ANOVA. The age \times condition \times block three-way interaction was not significant, $F(4, 254) = 1.598, p = .174$, partial $\eta^2 = .025$; however, we observed a main effect of block, $F(2, 254) = 18.007, p < .001$, partial $\eta^2 = .124$, indicating that overall performance improved from the first block to the last block of the experiment. The block \times condition effect was significant, $F(4, 254) = 10.314, p < .001$, partial $\eta^2 = .140$, indicating that participants in each condition learned at different rates. We also observed an interaction between age and foregone reward condition, $F(2,127) = 3.54, p = .032$,

partial $\eta^2 = .053$. The main effect of condition was significant, $F(2,127) = 54.27, p < .001$, partial $\eta^2 = .461$, while the main effect of age was not significant, $F(1,127) = .957, p = .330$, partial $\eta^2 = .007$.

Our main interest was whether or not providing information about true foregone rewards that highlighted the local superiority of the Short-Term option had a differential effect on decision-making performance between older and younger adults. We evaluated this effect using a 2 (age) \times 2 (condition) ANOVA on the points that participants collected throughout the experiment. The main effect of reward condition was significant, $F(1,86) = 26.343, p < .001$, partial $\eta^2 = .234$, indicating that overall participants performed worse when true foregone rewards were presented, while the main effect of age was not significant, $F(1,86) = 1.126, p = .292$, partial $\eta^2 = .013$. Importantly, we observed an interaction between age group and foregone reward condition, $F(1,86) = 6.265, p = .014$, partial $\eta^2 = .068$. We used independent sample *t*-tests to decompose the interaction between age and foregone reward condition. In the condition with no foregone rewards, we found a numerical (though not statistically significant, $p > .1$) older adult advantage ($M = 9619$) as compared to younger adults ($M = 9180$) consistent with previous work (Cooper et al., 2013; Worthy et al., 2011). We also observed that the learning rate across blocks interacted with age in the No Foregone Rewards condition, $F(2, 86) = 2.678, p = .074$, partial $\eta^2 = .118$ (Figure 3). Older adults performed numerically better than younger adults in the first and second blocks; however, performance was equated by the third block due to different learning rates. Importantly, in the True Foregone Rewards condition, we observed an effect of age; older adults who received foregone rewards ($M = 7295$) performed significantly worse than younger adults who received foregone rewards ($M = 8380$), $t(43) = 2.346, p = .024$, Cohen's $d = 0.716$. In the True Foregone Rewards condition, learning rate and age did not interact, $F(2, 86) = 1.275, p = .285$, partial $\eta^2 = .029$. Younger and older adults learned at similar rates, but older adults performed significantly worse than younger adults in all three blocks ($ps < .05$).

Consistent with previous studies (Byrne & Worthy, 2013; Otto & Love, 2010), younger adults in the No Foregone Rewards condition performed better than younger adults in the True Foregone Rewards condition, $t(49) = 1.753, p = .086$, Cohen's $d = .501$. Older adults in the No Foregone Rewards condition also performed better than older adults who received true foregone rewards, $t(37) = 6.519, p < .001$, Cohen's $d = 2.143$. The effect size (Cohen's d) for the effect of true foregone rewards on older adult decision-making was 4.28 times greater than the effect of foregone rewards on younger adult decision-making performance.

The difference in performance between older adults ($M = 10987$) and younger adults ($M = 10940$) in the False Foregone Rewards condition was nonsignificant, $t(41) = .152$,

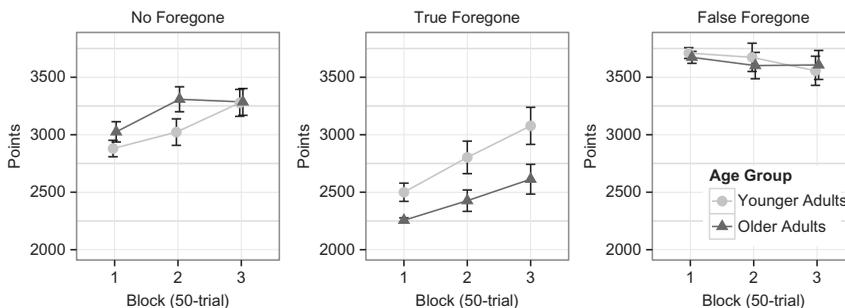


Figure 3. Performance in each condition by block. Error bars represent standard error of the mean.

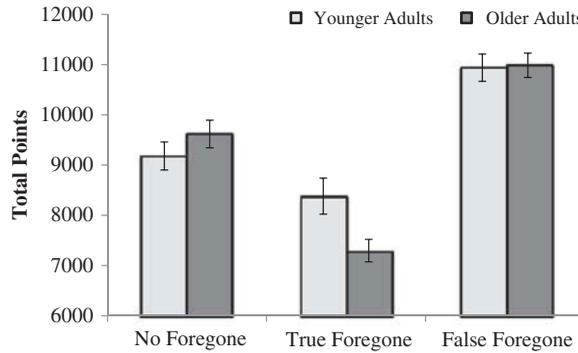


Figure 4. Average number of points collected by participants in each condition. Error bars represent standard error of the mean.

$p = .880$, Cohen's $d = .047$ (Figure 4). An analysis of the learning rate by block also shows that older and younger adults learned at similar rates, as block and age did not interact, $F(2, 82) = .415$, $p = .662$, partial $\eta^2 = .010$. In order to verify that these participants were not performing at ceiling, we compared their performance using proportion of optimal selections to perfect performance ($M = 1.0$) using one-sample t -tests. Neither the older adult group nor the younger adult group performed at ceiling levels, $ps < .001$. As points were correlated with the proportion of optimal (Long-Term) selections, all of our findings regarding points replicated with proportion of optimal selections.

For all three conditions, we examined correlations between task performance and neuropsychological scores. In the No Foregone Rewards condition, scores on the Stroop Inference neuropsychological task were most strongly correlated with performance, $r(19) = .419$, $p = .066$. p -Values for all other tasks were above 0.2. For the True Foregone Rewards condition, the neuropsychological tasks most strongly correlated with performance were CVLT immediate recall, $r(18) = .367$, $p = .123$, and Trails B, $r(18) = -.395$, $p = .094$. In the False Foregone Rewards condition, none of the neuropsychological tasks were correlated with performance, $ps > .2$. The only neuropsychological test in which we observed significant group differences (Table 1) was in WMS logical memory, in which older adults in the False Foregone Rewards condition performed lower than the other groups. However, performance in this neuropsychological test was not correlated with decision-making task performance.

The effect of demographic information on task performance was also examined. In a 2 (age) \times 3 (condition) \times 2 (gender) ANOVA, the main effect of gender was not significant ($p = .279$), nor did gender interact with age ($p = .681$) or condition ($p = .680$). Education was not correlated with performance in any of the conditions, $ps > .1$. Age was not correlated with performance in the False Foregone Rewards or No Foregone Rewards conditions, $ps > .4$. In the True Foregone Rewards condition, age was negatively correlated with performance $r(18) = -.398$, $p = .092$.

Switching between options

To verify that older and younger participants were exploring both reward options at similar rates, we analyzed the number of trials on which participants switched between

Table 2. Average number of switch trials in each condition.

	No Foregone	True Foregone	False Foregone
	Mean (<i>SD</i>)	Mean (<i>SD</i>)	Mean (<i>SD</i>)
Younger adults	45.04 (24.36)	23.28 (22.24)	12.33 (12.03)
Older adults	32.25 (17.02)	28.79 (26.68)	19.47 (20.02)

Note: Standard deviations are listed in parentheses.

options, defined by selecting a different option than on the preceding trial (Table 2). Using a 2 (age) \times 3 (condition) ANOVA on the number of switch trials, we found a significant main effect of condition, $F(2,127) = 12.912$, $p < .001$, partial $\eta^2 = .169$, and an age \times condition interaction, $F(2,127) = 3.063$, $p = .05$, partial $\eta^2 = .046$; the main effect of age was nonsignificant ($p = .982$). This effect was driven by the No Foregone Reward condition, in which younger adults switched between options slightly more often than older adults, $t(43) = 1.988$, $p = .053$. For both the True Foregone Rewards ($p = .155$) and False Foregone Rewards ($p = .463$) conditions, older and younger adults switched between options at similar rates. The similarity with which older and younger adult participants switched between options when foregone rewards were present provides an additional measure of evidence that older adults were systematically responding to the foregone information and not simply responding randomly due to confusion. For both older and younger adults, the greater number of switch trials was observed in the No Foregone Rewards condition ($M_{\text{younger}} = 45.04$, $M_{\text{older}} = 32.25$). This is not surprising as participants in this condition must explore the reward space to understand that one option causes future rewards to increase while the other causes future rewards to decrease. When foregone rewards highlighted the local superiority of the Short-Term option, the number of switch trials decreased numerically for both groups ($M_{\text{younger}} = 23.28$, $M_{\text{older}} = 28.79$).

Discussion

When making decisions, we are often able to compare the outcomes of our choices to the rewards that we could have had. For example, after selling a stock option, we may see that it continued to grow and would have given us a larger reward. While we might consider this information valuable in informing our future decisions, it may be the case that knowledge of “what could have been” biases our future decisions, leading us to make suboptimal choices that favor immediate rewards and fail to maximize our long-term gains. This effect has previously been observed in younger adults (Otto & Love, 2010), and in the current study, we find that older adults are even more susceptible to this effect.

These results expand on previous research that found that older adults show increased preference for long-term rewards in dynamic decision-making tasks (Worthy et al., 2011). We find that providing information about true foregone rewards causes older adults to perform significantly worse than younger adults. This performance decline is likely related to older adults’ hypersensitivity to rewards (Bauer et al., 2013). Providing information about true foregone rewards highlights the immediate superiority of the Short-Term option, causing younger adults to shift their preference to the immediately rewarding option (Otto & Love, 2010). Older adults, whose decision-making performance reflects hypersensitivity to rewards relative to younger adults (Bauer et al., 2013), showed an even

greater performance decline. We believe that older adults used the information provided by foregone rewards systematically to modify their future decisions toward the immediately rewarding option.

An alternate explanation for the older adult deficit when true foregone rewards were presented was that more information simply overloaded older adults, causing them to respond in a more random manner. However, when foregone rewards were skewed to highlight the Long-Term reward, older adults performed at levels similar to younger adults. Additionally, older and younger adults switched between options at similar rates in both of the foregone reward conditions. This indicates that the performance deficit was caused by the effect of the nature of the foregone reward information on older adult decision-making and whether it highlighted the superiority of the Short-Term or Long-Term option. In both True Foregone Rewards and False Foregone Rewards conditions, older adults showed a preference for the option that appeared to be more immediately rewarding.

Older adults' increased susceptibility to foregone rewards may be related to older adults' increased vulnerability to misinformation effects (e.g., Cohen & Faulkner, 1989; Karpel, Hoyer, & Toglia, 2001). Older adults are more susceptible to interference effects produced by a misleading prime (Jacoby, Bishara, Hessels, & Toth, 2005) and show a greater susceptibility to scams (Jacoby, 1999). The vulnerability to misleading information in older adults is thought to be linked to impairment in prefrontal cortex functioning (Denburg et al., 2007). Asp and colleagues (2012) suggest that older adults may have a vulnerability to believe deceptive or misleading information because ventromedial prefrontal cortex (vmPFC) dysfunction impairs normative doubt, a critical feature of successful decision-making. In our experiment, older adults may have been less doubting of the information presented by foregone rewards that highlights the local superiority of the Short-Term option, leading to greater difficulty learning that the Long-Term option is in fact more beneficial. Future studies with this task should examine the relationship between older adult performance with foregone rewards and vmPFC function.

The heightened effect of true foregone rewards on older adult decision-making may also be attributable to the implementation of different decision-making strategies by older and younger adults in dynamic decision-making tasks. Previous research (Worthy et al., 2014) finds that older adults in the No Foregone Rewards condition are best fit by models indicating the use of simple heuristic-based strategies, while younger adults are fit by a model that indicates the use of more sophisticated model-based strategies. The utilization of different strategies by older and younger adults likely contributes to the difference in learning rates (performance by block) that we observed in the condition without foregone rewards of the current study. Consistent with previous work (Worthy et al., 2014, 2011), in this condition, older adults initially performed better than younger adults but improved less over the course of the experiment, resulting in similar performance in later blocks. The presentation of true foregone reward information may interfere with the use of simple heuristic-based strategies utilized by older adults, negatively impacting their performance.

Worthy et al. (2014) hypothesized that the difference in strategy between older and younger adults may be due to age-related declines in fluid intelligence that prevent older adults from engaging in more computationally demanding model-based decision-making. Older adults have fewer resources available for use in these cognitive tasks (O'Sullivan et al., 2001; Salthouse, 2009; Salthouse, Atkinson, & Berish, 2003), and focusing on delayed reward relative to immediate reward takes additional cognitive resources (Bobova, Finn, Rickert, & Lucas, 2009; Worthy et al., 2012). Thus, when tasks get more demanding by providing information about the foregone reward, they may shift

(at a greater rate than younger adults) to the less cognitively demanding strategy. Our current study suggests that this shift in strategy may be associated with neuropsychological measures – older adult performance in the True Foregone Rewards condition was positively correlated with CVLT immediate recall, indicating that individuals who had better immediate recall were less affected by foregone rewards. Future work should further examine this relationship and the possibility that preserved short-term memory could lessen the effect of foregone rewards on older adult decision-making.

The results of the current study indicate that information from foregone rewards biases older adults toward the immediately rewarding option. These results have important implications regarding the effect of framing of decision-making tasks on older adult performance. Specifically, providing older adults information regarding foregone rewards (or what would have been received had they chosen differently) could lead to good performance when immediate rewards and long-term rewards coincide but could hurt performance when the immediately rewarding and long-term rewarding options conflict. Taking into consideration the congruence of immediate and delayed rewards, presenting or withholding information about foregone rewards has potential for improving older adult decision-making.

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