# The interaction of curiosity and reward on long-term memory in younger and older adults

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## Abstract

**Objectives:** The study was conducted to examine the individual and joint effects of extrinsic motivation, manipulated via monetary reward, and curiosity, a form of intrinsic motivation, on long-term memory, in healthy younger and older adults.

**Method:** During the incidental encoding phase on Day 1, 60 younger and 53 older participants viewed high- and low-curiosity trivia as well as unrelated face stimuli. Half of the participants in each age group received financial rewards for correctly guessing trivia answers. On Day 2, participants completed old-new recognition tests for trivia and face stimuli.

**Results:** Both curiosity and reward were associated with enhanced trivia recall, but the effects were interactive, such that only low-curiosity items benefitted from monetary reward. Neither curiosity nor reward affected face recognition performance in either age group. This patterns was similar for younger and older adults.

**Discussion:** The current data indicate that individual and joint effects of intrinsic and extrinsic motivation on long-term memory are preserved in healthy aging. This finding highlights the viability of motivational strategies for memory enhancement into old age. Identifying conditions under which memory for unrelated information benefits from motivational spillover effects is a priority for future research.


*Keywords:* undermining effect, interest, motivated cognition

**The interaction of curiosity and reward on long-term memory in younger and older adults**

Why are some facts easily retained while others are forgotten? One contributing factor is epistemic curiosity, the intrinsic motivation to acquire information for its own sake rather than its instrumental utility (Berlyne, 1965; Loewenstein, 1994). Acute states of epistemic curiosity can influence encoding and retrieval. Much like we are likely to remember information learned while anticipating extrinsic rewards (e.g., money; Adcock et al., 2006), we are also more likely to remember information encoded while curious (Kang et al., 2009). Beyond enhancing memory for interesting tidbits, curiosity may affect memory in a more general manner, extending to irrelevant information encountered in close temporal proximity to interesting facts (Gruber et al., 2014). Such effects have been documented in younger adults and in educational settings (Reio, 2004). However, curiosity also benefits memory in older adults (Galli et al., 2018; McGillivray, 2015), potentially offering a motivation-based intervention for mitigating age-related memory decline. An open question, however, is how intrinsic and extrinsic sources of motivation interact to influence older adults' memory processes. Extrinsic reward has been previously shown to undermine the learning benefits of intrinsic motivation in younger adults (Murayama et al., 2010; Murayama & Kuhbandner, 2011). In settings where motivation sources may overlap (e.g., health, education), it is important to understand the interactive effect of intrinsic curiosity and extrinsic reward on older adults' cognitive function.

Several studies have used trivia paradigms to investigate the effect of curiosity on memory for interesting information (Duan et al., 2020; Kang et al., 2009; Marvin & Shohamy, 2016; McGillivray et al., 2015; Murayama & Kuhbandner, 2011) and temporally-contiguous, unrelated information (Galli et al., 2018; Gruber et al., 2014; Stare et al., 2018). In this approach, first established by Kang et al. (2009), participants complete an incidental encoding task (but see

Duan et al., 2020, for an intentional version) in which they encode high- and low-curiosity trivia items. High and low-curiosity designations are established either through a pre-screening for each participant (e.g., Gruber et al., 2014) or based on normed ratings of trivia databases (e.g., Murayama & Kuhbandner, 2011). In some studies, irrelevant stimuli, such as pictures of faces, are presented during the interval between the presentation of the trivia question and the answer, when curiosity is assumed to be at peak. Then, after some delay, a retrieval task tests participants' recall for high- and low-curiosity trivia answers. In studies with irrelevant information included, participants also complete a face recognition task for old faces associated with high- and low-curiosity items. Such studies report significantly higher recall of high-curiosity answers compared to low-curiosity answers in both younger adults (Duan et al., 2020; Kang et al., 2009; Marvin & Shohamy, 2016; Murayama & Kuhbandner, 2011) and older adults (Galli et al., 2018; McGillivray et al., 2015). Moreover, studies have also reported a curiosity-driven benefit for recognition of incidental information (e.g., face stimuli) in younger adults (Gruber et al., 2014; Stare et al., 2018) and in youth (Fandakova & Gruber, 2020), such that faces associated with high-curiosity trivia items are better recognized than those associated with low-curiosity items. One study also demonstrated this effect in older adults in one experiment (Galli et al., 2018; Exp 1), but failed to replicate this finding in a second experiment (Galli et al., 2018; Exp 2). In summary, there is a reliable effect of curiosity on memory of interesting information, but the effect on temporally-contiguous irrelevant information is less well established, particularly in older adults.

The beneficial effect of curiosity on memory has been likened to that of extrinsic reward. For younger and older adults, extrinsic motivation is linked to better memory for items associated with high point value (Castel et al., 2011; Castel et al., 2016), items encoded during

anticipation of financial reward (Spaniol et al., 2014), and items followed by monetary reward feedback (Mather & Schoeke, 2011). The putative mechanism for reward-enhanced memory is dopaminergic modulation of the hippocampus (Adcock et al., 2006; Bowen et al., 2020; Wittmann et al., 2005). Studies investigating the effect of curiosity on memory have implicated many of the same neural substrates as studies investigating the effect of reward on memory, including hippocampus, dopaminergic midbrain and striatal regions (e.g., substantia nigra/ventral tegmental area and nucleus accumbens; Duan et al., 2020; Gruber et al., 2014). This overlap suggests a common neural mechanism underlying intrinsic and extrinsic motivation for supporting memory processes. In other words, receipt of information following a state of curiosity may function similarly to monetary gain following reward anticipation in the brain.

The effects of extrinsic reward on memory for reward-unrelated information diverge from the effects of curiosity. Instead of boosting memory for irrelevant stimuli, reward motivation tends to narrow attention, increasing the selectivity with which target information is remembered (Braver et al., 2014; Chiew & Braver, 2011). This reward-related selectivity effect has been demonstrated in both younger and older adults (for a review, see Swirsky & Spaniol, 2019). For example, both age groups show enhanced selective attention when anticipating monetary gain on a flanker task (Williams et al., 2017), they both bind less incidental details to item memory for high-value items comped to low-value items (Hennessee et al., 2018), and older adults successfully ignore superimposed distractor stimuli at encoding when motivated by virtual points (Swirsky & Spaniol, 2020). One possible mechanism for reward-induced selectivity effects is offered by arousal-biased competition theory (ABC; Mather & Sutherland, 2011). This theory states that noradrenergic arousal, which can accompany reward anticipation/receipt, works to enhance processing of salient or goal-relevant stimuli while dampening processing of

nonsalient or goal-irrelevant information (Lee et al., 2014). In sum, current evidence suggests that intrinsic curiosity and extrinsic reward have similar effects on memory for salient details, but have opposite effects on memory for incidental details.

A final consideration relevant to the current study is the interaction between intrinsic curiosity and extrinsic reward. According to self-determination theory, motivation from extrinsic sources can undermine the benefits of intrinsic motivation on learning (Deci et al., 1999; Ryan & Deci, 2000). For example, younger adults show reduced willingness to voluntarily engage in a task when performance-contingent incentives are offered for performing the task (Murayama et al., 2010). The undermining effect has also been demonstrated in the context of a curiosity-inducing trivia paradigm. In this study with younger adults, half of the participants completed a typical trivia paradigm as described above, while the other half completed the same task but with monetary reward at stake for correctly guessing trivia items during encoding. Results showed that financial reward and curiosity had interactive effects, such that reward enhanced memory for low-curiosity items, but not for high-curiosity items (Murayama & Kuhbandner, 2011). Contrary to these findings, one recent study (Duan et al, 2020) failed to replicate the undermining effect using a similar paradigm with younger adults. Here, memory for trivia showed additive, rather than interactive, effects of financial reward and curiosity. However, there were critical differences between the paradigm used by Duan et al. (2020) and Murayama and Kuhbandner (2011). Specifically, the encoding task was intentional rather than incidental, and reward was contingent on recall performance rather than correct guesses during the encoding task. First, intentional memorizing and incidental learning likely rely on distinct encoding processes. Second, since curiosity operates during encoding, introducing reward motivation at retrieval rather than encoding may reduce the chance of interaction between reward and curiosity. Thus, it

is possible that the undermining effect occurs specifically under implicit learning conditions, and only when intrinsic/extrinsic motivators overlap (both at encoding, rather than one at encoding and one at retrieval).

The undermining effect of reward on curiosity has not yet been documented in older adults. However, compared to younger adults, older adults may be less sensitive to financial incentives during learning (Eppinger et al., 2012) which is consistent with the well-documented age-related decline in dopaminergic and serotonergic transmission (Bäckman et al., 2010; Eppinger et al., 2011). For example, unlike younger adults, older are less enticed by immediate rewards and may show less temporal discounting, which was also associated with lower reward-related striatal activity (Eppinger et al., 2012; but see Seaman et al., 2020, for a meta-analysis that shows no age difference in temporal discounting). Moreover, older adults show reduced incentive-based modulation of attention (Williams et al., 2018). At the same time, it should be noted that older adults' intentional and incidental encoding has been shown to benefit from financial incentives to a similar extent as younger adults (Mather & Schoeke, 2011; Spaniol et al., 2014). Despite some evidence of preserved effects of financial incentives, older adults' weakened sensitivity to financial reward not only suggests that intrinsic motivation may be a preferable route to boosting memory in older adults, but also that older adults may be less susceptible to the undermining effect.

The current study had two main objectives. First, to replicate the curiosity-driven benefit to memory for interesting information and irrelevant, temporally contiguous information in both age groups. Second, to investigate age differences in the interaction of intrinsic and extrinsic motivational influences on memory. To address these aims, older and younger adults completed a typical trivia paradigm with irrelevant face stimuli included in the encoding task and memory

tested at a ~24-hour delay. Critically, half of each age group were in the extrinsic reward condition. Our hypotheses were as follows. First, we expected to replicate prior reports of curiosity effects on memory for trivia and for unrelated faces in the absence of extrinsic motivation (Gruber et al., 2014). Second, based on prior observations of the undermining effect (Murayama & Kuhbandner, 2011), we expected that the curiosity-driven boost to younger adults' memory would be smaller in the reward condition than in the control condition. By contrast, we expected older adults to show curiosity-driven effects in both conditions, with little or no evidence of undermining by extrinsic reward. An alternative hypothesis was that curiosity and reward would show additive rather than interactive effects (e.g., Duan et al., 2020).

## Method

### Participants

Participants were 60 younger adults (aged 18-35; 40 female) and 53 older adults (aged 60 or older; 33 female). The a priori total sample size ($N$ = 76) was determined based on a power analysis run via G-Power (Faul, Erdfelder, Lang, & Buchner, 2007) to achieve a power of at least .95 to detect a medium-sized interaction of two between-subjects factors and a within-subjects factor, assuming an alpha error probability of .05 and a correlation among levels of the within-subjects factor of .50 or higher. Younger adults were recruited from the community. Older adults were recruited from the Ryerson Senior Participant Pool, a database of community-dwelling seniors. Eligibility criteria included normal (or corrected-to-normal) vision and absence of neurological, psychiatric, or cardiovascular conditions that might affect cognitive performance. See supplementary materials for additional details about participant exclusions.Participants in each age group were randomly assigned to the control condition or the reward condition. All participants received CAD 36 for participation (CAD 24 after Session 1; CAD 12 after Session

2). Participants in the reward condition received an additional performance-contingent bonus of up to CAD 12.75 after Session 1. All participants provided written informed consent, and study procedures were reviewed and approved by the Ryerson University Research Ethics Board.

**Materials**

Experimental tasks were programmed in E-Prime 2.0 software (Psychology Software Tools, Pittsburgh, PA) and presented on a 17-inch computer display. Text was black and set to size 32, Arial font. For the screening task, stimuli included 282 trivia questions drawn from various online trivia databases (see Appendix A for full list of trivia items used). For the encoding task, stimuli included a participant-specific subset of 100 trivia questions from the screening task. Based on each participants' responses during the screening task, the 100 trivia questions used in the encoding task were classified as high-curiosity (n = 40), low-curiosity (n = 40), or known (n = 20). The encoding task also included 100 gray-scale, emotionally neutral faces (50 younger-adult and 50 older-adult faces) taken from the CAL/PAL Face database (Minear and Park, 2004).

For the face recognition task in Session 2, stimuli included 80 faces from the encoding task (40 each from high-curiosity and low-curiosity trials) as well as 40 new faces. Half of the faces in each of these sets were younger-adult faces and half were older-adult faces. The trivia recall task included a total of 80 trivia questions including 40 high-curiosity questions and 40 low-curiosity questions.

**Procedure**

Figures depicting encoding and retrieval tasks (Fig. S1 and S2) can be accessed in the supplementary materials file.

***Session 1***

**Screening Task.** Participants viewed trivia questions presented in random order. Each trivia question was followed by a confidence rating ("How confident are you that you know the answer?") and a curiosity rating ("How curious are you to find out the answer?"). These trials continued until participants had identified 40 unknown high-curiosity questions (confidence rating < 6 and curiosity rating > 3), 40 unknown low-curiosity questions (confidence rating < 6 and curiosity rating < 4) and 20 known questions (confidence rating = 6). See Figure S1a for a schematic of the screening task.

**Encoding Task.** After the participant had completed unrelated paper-and-pencil questionnaires (approximately 10 minutes), the experimenter administered the encoding task. Throughout the encoding task, participants gave verbal responses and the experimenter entered these responses using the number keys for rating screens or letter keys for trivia guesses which appeared as visible text on the screen for participants to see. This was done to remove demand from typing for older adults. The paradigm combined elements of the encoding tasks employed by Gruber et al. (2014; incidental face stimuli) and by Murayama and Kuhbandner (2011; guessing and rewarding trivia answers). On each trial, a trivia question appeared on the screen, followed by a face stimulus and a judgment screen ("Do they know the answer?"). Participants were then prompted to guess the answer to the trivia question or pass. The final screen revealed the correct answer. Participants in the reward condition earned $0.25 per correct answer. All answers that were guessed correctly were removed from subsequent analyses. See Figure S1b for a schematic of the encoding task.

***Session 2***

On the following day (~24 hours post-encoding), participants returned to the laboratory and received a surprise face recognition task and trivia recall task. The order of these tasks was

counterbalanced across participants within each age group and condition. There was no difference in the tasks for those in the control condition versus the reward condition.

**Face Recognition Task.** On each trial, participants saw an old or new face stimulus and indicated using the left and right arrow keys whether they recognized the face from Session 1. Participants then rated their confidence in their recognition decision. See Figure S2a for schematic of the face recognition task.

**Trivia Recall Task.** On each recall trial, participants saw a high- or low-curiosity trivia question from the encoding task for 6 s, followed by a prompt to recall the answer or pass. Participants answered verbally and the experimenter recorded their responses. See Figure S2b for a schematic of the trivia recall task.

## Results

To assess overall performance on the trivia recall task, the proportion of correctly recalled trivia answers was calculated for each participant (see Table 1 and Figure 1b). Any trivia items that were correctly guessed during the encoding task were removed from the recall analysis. Answers were scored by two independent coders and discrepancies were resolved via discussion. Interrater reliability was near ceiling (98.3% agreement). Trial-level recall outcomes (0 = not recalled, 1 = recalled) served as the dependent variable in all subsequent mixed model analyses.

To assess overall face recognition accuracy, the corrected recognition rate (hit rate minus false-alarm rate) was calculated for each participant (see Table 1 and Fig. 1a). Trials in which confidence was rated as “1” were removed from the analysis to account for guessing. While accuracy provided information about overall recognition performance, only the responses to old items were informative about differences related to encoding conditions (control versus reward;

high versus low curiosity). Therefore, trial recognition outcomes (0 = miss, 1 = hit) were used as the dependent variable in a series of mixed model analyses, described below.

**Mixed Model Analyses**

To account for the clustered data structure of trials within participants and the dichotomous nature of the dependent variables (trial-level recognition and recall outcomes), logistic mixed effects models were estimated for both dependent variables. See supplementary materials file for more information on model building and specification.

**Trivia Recall**

Results of the logistic mixed model estimation are reported in Tables 2 and 3. To test the main effects of curiosity rating, age group, and condition, the final model included trial-level recall accuracy regressed on trial-level curiosity rating, age group, and condition, as well as their two-way interaction terms. The three-way interaction term was not significant and was dropped to improve model AIC. Results from this model indicated significant main effects of curiosity rating, $\chi^2(1) = 80.38$, $p < 0.001$, and condition, $\chi^2(1) = 5.36$, $p = 0.02$. These effects were qualified by a significant Curiosity x Condition interaction, $\chi^2(1) = 4.74$, $p = 0.03$. The effect of age group (see Figure 1b) and its two-way interactions were not significant, Age: $\chi^2(1) = 2.04$, $p = 0.15$; Age x Condition: $\chi^2(1) = 0.95$, $p = 0.33$; Age x Curiosity: $\chi^2(1) < .01$, $p = 0.98$.

To probe the Curiosity x Condition interaction, two additional models were estimated with the control condition dummy-coded as 0 and the reward condition coded as 1, and vice versa, to isolate the curiosity effect within each condition. Odds ratios from these models indicated that a 1-unit increase in curiosity ratings made correct trial-level recall 1.31 times more likely in the control condition but only 1.18 times more likely in the reward condition. In other words, as curiosity increased, the odds that a trivia item was recalled increased more in the

control condition than in the reward condition (Figure 2). See Table 3 for the fixed-effect estimates from the models used to probe the interaction. Consistent with our hypothesis, we replicated the "undermining effect" reported by Murayama and Kuhbandner (2011), but unexpectedly, the effect occurred in both age groups.

**Face Recognition**

Results of the face recognition logistic mixed model analysis are reported in Table 2. The final model regressed trial-level accuracy (hits vs. misses) on trial-level curiosity rating, age group, and condition, as well as the two-way interaction terms. The three-way interaction term was non-significant and was dropped to reduce model complexity and improve model AIC. Results from this model indicated no significant effects of curiosity rating, $\chi^2(1) = 0.44$, $p = 0.51$, age group, $\chi^2(1) = 1.49$, $p = 0.22$, or condition, $\chi^2(1) = 0.83$, $p = 0.36$. Likewise, none of the interactions was significant; Curiosity x Condition, $\chi^2(1) = 0.42$, $p = 0.52$; Curiosity x Age, $\chi^2(1) = 0.56$, $p = 0.45$; Condition x Age, $\chi^2(1) = 0.17$, $p = 0.68$. In other words, contrary to our hypotheses and prior work, an increase in the curiosity rating during encoding did not increase the odds of subsequent successful face recognition (odds ratio = 1.01).

In summary, the likelihood of recognizing incidentally encoded faces was not modulated by differences in intrinsic and extrinsic motivation at encoding. By contrast, the likelihood of recalling trivia was greater for high-curiosity trivia and for participants in the reward condition. However, the curiosity-driven boost to recall performance was stronger in the control condition than in the reward condition. Again, this pattern was similar in younger and older adults.

## Discussion

The current study sought to investigate the effects of intrinsic and extrinsic motivation on memory in younger and older adults. Participants encoded trivia answers that elicited varying

levels of curiosity, an intrinsic motivator. Half of the participants were also motivated extrinsically, by the opportunity to earn money for correctly guessing answers to questions. Both sources of motivation improved memory for trivia answers in both age groups. Furthermore, the two sources of motivation interacted, such that participants in the reward condition benefitted less from curiosity than those in the control condition. However, neither type of motivation affected memory for unrelated faces encountered amidst curiosity-inducing trivia.

Our hypothesis about the effects of curiosity on memory for target and incidental information was partially supported. As predicted, we replicated the canonical curiosity-driven boost to memory for interesting facts in both age groups. By contrast, this effect did not extend to recognition of unrelated faces. Our next hypothesis about the interaction of curiosity and financial reward was also partially supported. The effect of curiosity on trivia recall was stronger in the control condition than in the reward condition. However, contrary to expectation, this interaction was present in both younger and older adults.

It is unclear why we did not replicate the effect of curiosity on incidental face memory (Galli et al., 2018; Gruber et al., 2014; Stare et al., 2018). However, as with any small effect, it is not expected to emerge in every dataset (e.g., Galli et al., 2018, reported the effect in Experiment 1 but not Experiment 2). The current study, and most prior studies, had relatively small sample sizes and are underpowered to detect small effects. In addition, there were important differences between the encoding task used in the current study and typical prior studies that have demonstrated curiosity-driven boosts to incidental face recognition memory. First, our task borrowed aspects of a procedure used by Murayama and Kuhbandner (2011) to test the interaction of curiosity and financial reward on memory. Therefore, the contiguity between the incidental face stimulus and the trivia answer was disrupted by a guessing screen. If incidental

face memory depends more on curiosity satisfaction (Marvin & Shohamy, 2016), surprise (Baranes et al., 2015), or post-answer interest (McGillivray et al., 2015) than on the anticipation associated with curiosity, then this disruption may have disrupted the effect. However, recent work suggests that incidental memory enhancement from curiosity is contingent on proximity to curiosity elicitation rather than curiosity satisfaction (Murphy et al., 2020). If curiosity elicitation is the critical component process, the obstruction should not have influenced curiosity-enhanced memory for incidental faces.

Another notable difference between the current paradigm and prior studies testing the effect of curiosity on incidental face recognition was that the experimenter acted as a scribe. Rather than interfacing with the task directly, participants dictated their responses aloud to the experimenter to enter on their behalf. This may have influenced participants' level of engagement with face stimuli and introduced an element of social desirability when participants had to indicate whether the person shown in the picture was likely to know the answer to the trivia question (e.g., "I don't want to seem judgmental, so I'll say yes").

An alternative perspective on the current findings relates to memory selectivity effects of reward anticipation and arousal. According to ABC theory, noradrenergic arousal, associated with states of reward anticipation (Knutson & Greer, 2008) and curiosity (Sakaki et al., 2018), biases attention and memory processes toward task-relevant stimuli while suppressing task-irrelevant stimuli (Mather & Sutherland, 2011). However, this perspective is not consistent with our results, as it would predict greater memory selectivity associated with high-curiosity than low-curiosity trials.

One interpretation of our results is that financial reward undermines the effects of curiosity on learning (see Murayama & Kuhbandner, 2011). In support of this view, participants'

trivia recall in the control condition benefitted more from their level of curiosity than those in the reward condition who were motivated by the prospect of financial reward. An alternative interpretation is that those in the reward condition reached a performance ceiling, such that there was less room for improvement in trivia recall as low-curiosity memory performance was already relatively high. This interpretation is consistent with Duan et al.'s (2020) finding that intrinsic curiosity and extrinsic reward have additive, rather than interactive, effects on trivia learning.

The different interpretations are not mutually exclusive and future research should aim to disentangle the conditions under which reward undermines or complements curiosity-driven learning. Regardless of the precise nature of the interaction between reward and curiosity, our findings suggest that intrinsic motivation to learn from curiosity leads to an almost identical increase in the probability of correctly recalling a trivia answer as extrinsic motivation from reward. Therefore, interventions aimed at enhancing memory and learning outcomes can target intrinsic motivation states (e.g., curiosity, interest, satisfaction, and surprise; Ozono, et al., 2020; Ryan & Deci, 2000;) instead of extrinsic contingencies of reinforcement (e.g., monetary bonuses, testing grades; Slavin, 2010; Stan, 2012)

Lastly, older adults demonstrated the same pattern of performance as younger adults. The results thus do not support the prediction that older adults' memory would show reduced sensitivity to extrinsic motivation. This finding is particularly interesting in the face of well-documented dopaminergic decline and changes in reward-related brain activation (Bäckman et al., 2010 ; Dreher et al., 2008; Eppinger et al., 2011), age differences in temporal discounting of reward (Eppinger et al, 2012), and changes in motivational priorities across the lifespan (Carstensen et al., 1999), which may increase older adults' preference for non-financial rewards

(e.g., social rewards; Rademacher et al., 2014). The current findings suggest that both intrinsic curiosity and financial reward remain a viable method for boosting memory in older adults.

The current study had several limitations. First, its sample size, while based on an a priori power analysis and comparable to other studies, was relatively small. Second, the findings should not be generalized beyond the populations included in this research (predominantly White, urban, highly educated, and healthy younger and older adults). Third, the study used a purely behavioural design. While this was adequate to test the hypotheses-of-interest, a multi-method approach to studying the impact of extrinsic reward on curiosity-enhanced memory could give insight into the neural substrates of this interaction which are likely to be a shared resource (but see Duan et al., 2020). Similarly, the use of eye-tracking could provide insight into the contributions of arousal during pre-answer anticipation and post-answer satisfaction to subsequent memory performance (Baranes et al. 2015; Kang et al., 2009). Lastly, the decision to use the experimenter as a scribe in the incidental encoding task may have differentially influenced participants' level of engagement with the trivia and face stimuli to a degree that we are unable to measure and account for in the current design.

In summary, the current study demonstrates that older adults may retain the ability to prioritize information that they are curious about and that their learning is influenced by concurrent sources of intrinsic and extrinsic motivation, similar to younger adults. The finding that older adults' memory is sensitive to their level of curiosity can be used to inform interventions, in much the same way that curiosity induction is integrated in educational contexts to improve academic outcomes in younger adults. Beyond its downstream effects for cognition, curiosity is also an important motivational factor in physical and mental health across the lifespan (Sakaki et al., 2018) and thus represents a promising target to promote healthy aging.

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*Table 1. Descriptives for task performance on face recognition and trivia recall.*

| | | Younger Adults | | | | Older Adults | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Control | | Reward | | Control | | Reward | |
| | Overall | Lo Cur | Hi Cur | Lo Cur | Hi Cur | Lo Cur | Hi Cur | Lo Cur | Hi Cur |
| Face Recognition | | | | | | | | | |
| Hit rate | 0.56 (0.50) | 0.52 (0.50) | 0.53 (0.50) | 0.55 (0.50) | 0.54 (0.50) | 0.57 (.50) | 0.56 (0.50) | 0.61 (0.50) | 0.61 (0.50) |
| False Alarm rate | 0.10 (0.10) | — | — | — | — | — | — | — | — |
| Corrected accuracy | 0.46 (0.39) | — | — | — | — | — | — | — | — |
| Trivia Recall | | | | | | | | | |
| Proportion correct | 0.60 (0.49) | 0.49 (0.50) | 0.59 (0.49) | 0.62 (0.49) | 0.65 (0.48) | 0.57 (0.50) | 0.66 (0.47) | 0.60 (0.49) | 0.66 (0.47) |

*Notes.* Means (standard deviations) for memory performance. Lo = low. Hi = high. Cur = curiosity. Low and high curiosity were binned according to prior studies that used a 6-point curiosity rating scale (e.g., Gruber et al., 2014; Galli et al., 2018); low = 1-3, high = 4-6.

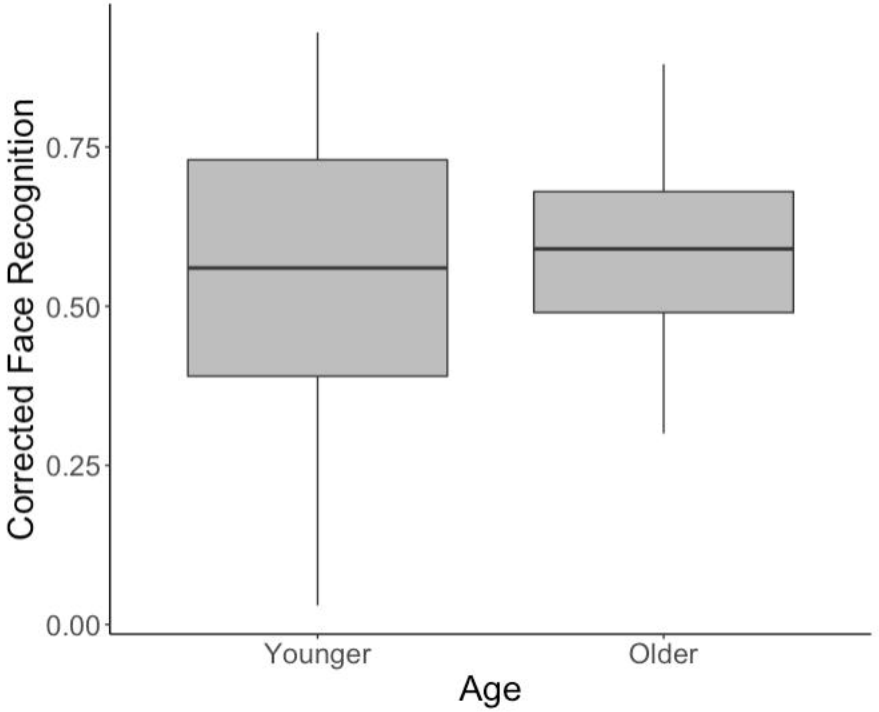
*Table 2. The estimates of the coefficients of the fixed effects for the final models*

| | Estimate | SE | z | p | Odds ratio |
|---|---|---|---|---|---|
| Trial-level face recognition accuracy | | | | | |
| Intercept | 0.29 | 0.08 | 3.52 | **<.01** | 1.34 |
| Curiosity (mean-centered) | 0.01 | 0.01 | 0.58 | 0.56 | 1.01 |
| Age group (effects-coded) | 0.10 | 0.08 | 1.22 | 0.22 | 1.11 |
| Condition (effects-coded) | 0.07 | 0.08 | 0.94 | 0.35 | 1.08 |
| Curiosity * Age Group | -0.01 | 0.01 | -0.75 | 0.45 | 0.99 |
| Curiosity * Condition | -0.01 | 0.01 | -0.65 | 0.52 | 0.99 |
| Condition * Age Group | 0.03 | 0.08 | 0.41 | 0.68 | 1.03 |
| | Estimate | SE | z | p | Odds ratio |
| Trial-level trivia recall accuracy | | | | | |
| Intercept | 0.50 | 0.07 | 7.57 | **<.01** | 1.65 |
| Curiosity (mean-centered) | 0.22 | 0.03 | 8.66 | **<.01** | 1.25 |
| Age group (effects-coded) | 0.09 | 0.07 | 1.43 | 0.15 | 1.10 |
| Condition (effects-coded) | 0.15 | 0.07 | 2.19 | **0.03** | 1.16 |
| Curiosity * Age Group | <0.01 | 0.03 | 0.02 | 0.98 | 1.00 |
| Curiosity * Condition | -0.05 | 0.02 | -2.18 | **0.03** | 0.95 |
| Age Group * Condition | -0.06 | 0.07 | -0.98 | 0.33 | 0.94 |

*Table 3. The estimates of the coefficients of the fixed effects for the models used to probe the Curiosity * Condition interaction effect on trial-level trivia recall accuracy*

| | Estimate | SE | z | p | Odds ratio |
|---|---|---|---|---|---|
| Model 1: Condition dummy-coded with control as the reference group | | | | | |
| Intercept | 0.36 | 0.09 | 3.81 | **<.01** | 1.43 |
| Curiosity (mean-centered) | 0.27 | 0.03 | 7.88 | **<.01** | 1.31 |
| Age group (effects-coded) | 0.16 | 0.09 | 1.70 | 0.09 | 1.17 |
| Condition (dummy-coded) | 0.29 | 0.13 | 2.19 | **0.03** | 1.34 |
| Curiosity * Age Group | <0.01 | 0.03 | 0.02 | 0.98 | 1.00 |
| Curiosity * Condition | -0.11 | 0.05 | -2.18 | **0.03** | 0.90 |
| Age Group * Condition | -0.13 | 0.13 | -0.98 | 0.33 | 0.88 |
| | Estimate | SE | z | p | Odds ratio |
| Model 2: Condition dummy-coded with reward as the reference group | | | | | |
| Intercept | 0.65 | 0.09 | 6.90 | **<.01** | 1.91 |
| Curiosity (mean-centered) | 0.17 | 0.04 | 4.59 | **<.01** | 1.18 |
| Age group (effects-coded) | 0.03 | 0.09 | 0.32 | 0.75 | 1.03 |
| Condition (dummy-coded) | -0.29 | 0.13 | -2.19 | **0.03** | 0.75 |
| Curiosity * Age Group | <0.01 | 0.03 | 0.02 | 0.98 | 1.00 |
| Curiosity * Condition | 0.11 | 0.05 | 2.18 | **0.03** | 1.11 |
| Age Group * Condition | 0.13 | 0.13 | 0.98 | 0.33 | 1.14 |

A)




B)

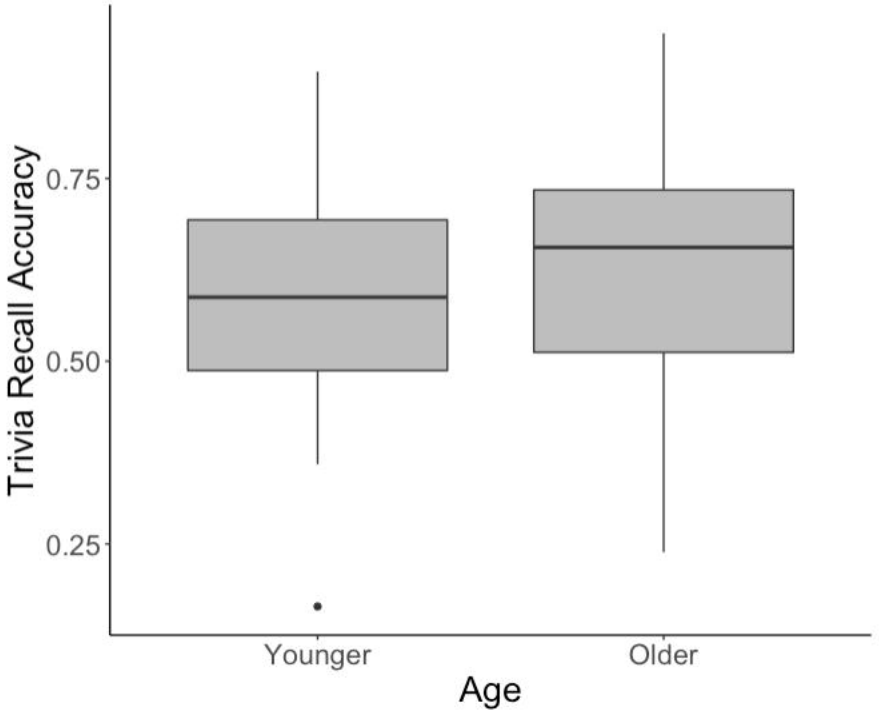



*Figure 1.* A) Older and younger adult performance on the face recognition task. B) Older and younger adult performance on the trivia recall task. Error bars represent standard error of the mean.

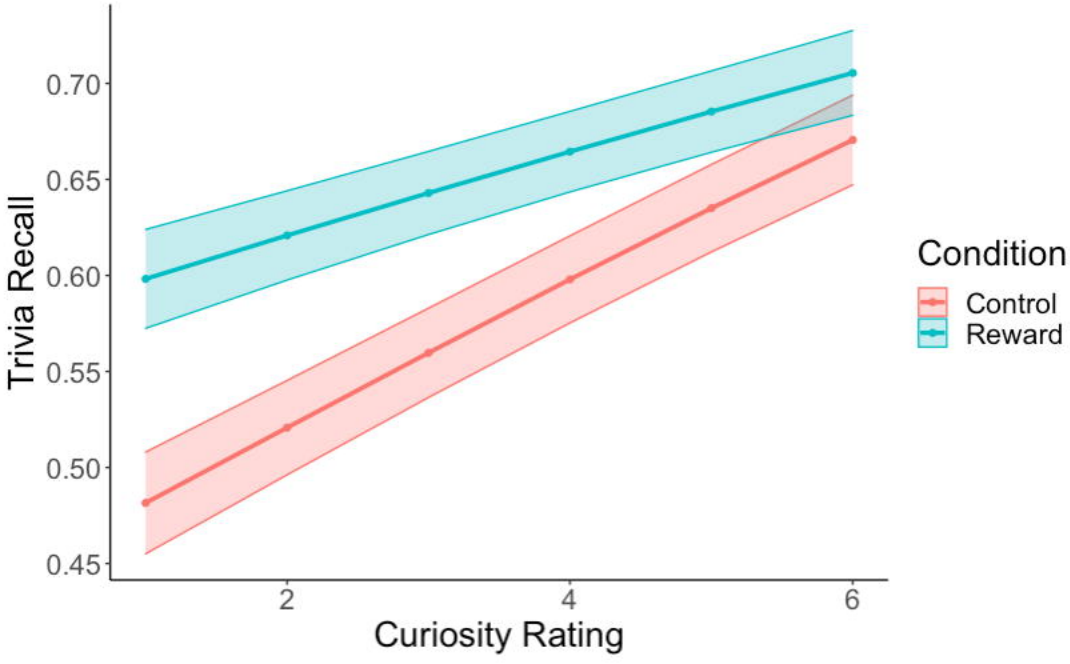



*Figure 2.* Predicted probability of correct trivia recall according to curiosity rating and condition. While the extrinsic reward condition boosts the probability of correct recall of low-curiosity information, this boost almost disappears for high-curiosity information. In other words, answers were just as likely to be recalled when motivated by extrinsic reward or intrinsic curiosity. Confidence bands represent standard error of the mean.