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Original Research Report

Looking on the Bright Side: Aging and the Impact of Emotional Future Simulation on Subsequent Memory

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Abstract

Objectives: When younger adults simulated positive future events, subsequent memory is positively biased. In the current studies, we explore age-related changes in the impact of emotional future simulation on subsequent memory.
Methods: In Experiment 1, younger and older adults simulated emotional future events before learning the hypothetical outcome of each event via narratives. Memory was assessed for emotional details contained in those narratives. In Experiment 2, a shorter temporal delay between simulation and narrative encoding was used to reduce decay of simulation memory over time.
Results: Future simulation did not bias subsequent memory for older adults in Experiment 1. However, older adults performed similar to younger adults in Experiment 2, with more liberal responses to positive information after positive simulation.
Discussion: The impact of an optimistic outlook on subsequent memory is reduced with age, which may be at least partly attributable to declining memory for future simulations over time. This work broadens our understanding of the functional consequences of age-related declines in episodic future simulation and adds to previous work showing reduced benefits of simulation with age on tasks tapping adaptive functions.

Keywords: Emotion, Episodic future simulation, Older adults, Positivity bias

Simulating experiences that might occur in the personal future (i.e., episodic future thinking) is closely related to episodic memory (Addis, Wong, & Schacter, 2007). This is exemplified by healthy aging, which is characterized by declines in both episodic memory and simulation, with reduced generation of episodic information, and decreased activation of brain regions involved in episodic recall when remembering the past and imagining the future (for review, see Schacter, Gaesser, & Addis 2013). Furthermore, episodic future simulation has been linked with a variety of adaptive functions in younger adults, including prospective memory, delayed discounting, problem-solving, and prosocial intentions (see Schacter, Benoit, & Szpunar 2017), and recent work has shown that older adults exhibit reduced performance on such tasks (see Schacter, Devitt, & Addis 2018).

Despite overall age-related impairments on tasks tapping adaptive functions, some evidence suggests that younger and older adults display similar *benefits* of episodic future thinking on such tasks. For example, episodic specificity training improves performance on a means-end problem-solving task (Madore & Schacter, 2014), and episodic future thinking improves prospective memory performance to a similar degree in both age groups (Altgassen et al., 2015). However, there is also evidence for reduced benefits of simulation with age on tasks that tap prosocial intentions (Gaesser, Dodds, & Schacter, 2017), temporal discounting behavior (Sasse, Peters, & Brassen, 2017), and prospective memory (Terrett et al., 2016). Thus, it is uncertain whether a reduced capacity for episodic future simulation with age critically affects the benefits of simulation on tasks with functional consequences.

In this study, we extend research on aging and the adaptive functions of episodic simulation by examining the influence of future simulation on subsequent event memory. People frequently simulate possible future scenarios in everyday life (D'Argembeau, Renaud, & Van der Linden, 2011). Moreover, these simulations are often of events that eventually come to take place (Spreng & Levine, 2013; Weiler, Suchan, & Daum, 2010) and are remembered over time (Jeunehomme & D'Argembeau, 2017; McLelland, Devitt, Schacter, & Addis, 2015; Szpunar, Addis, & Schacter, 2012). We recently tested in younger adults whether simulating an emotional future event alters memory for the actual event once it comes to occur (Devitt & Schacter, 2018). We found that neutral events were remembered as more positive if they were first simulated in a positive way. This effect manifested as a more liberal response bias for positive information, where participants were more likely to claim that both true and false positive details were present in the original event. In contrast, negative future simulation did not influence subsequent memory. These results are broadly consistent with findings that healthy adults often adopt an unrealistically favorable future outlook (Sharot, 2011; Sharot, Korn, & Dolan, 2011).

Older adults spontaneously think about the future as often as younger adults (Warden, Plimpton, & Kvavilashvili, 2018), but it is unknown whether or how such simulations affect subsequent memory of those events after they occur. On the basis of age-related reductions in emotional episodic simulation (Jumentier, Barsics, & Van der Linden, 2018), and performance deficits in tasks tapping adaptive functions of future simulation (Schacter et al., 2018), positive simulation may have a reduced effect on subsequent memory for older adults. However, aging is also associated with deficits in source monitoring, leading to an increased susceptibility to memory distortions (see Devitt & Schacter 2016). In particular, older adults are prone to confusing imagined and actual events (Hashtroudi, Johnson, & Chrosniak, 1990; McDaniel, Lyle, Butler, & Dornburg, 2008), misattributing simulated future events as having actually occurred in the past (McDonough & Gallo, 2013), and mistaking counterfactual simulations as original occurrences (Gerlach, Dornblaser, & Schacter, 2014). If a failure in source monitoring is a prominent contributor to the impact of future simulation on subsequent memory, older adults may be *more* susceptible to the biasing effect of positive and negative simulation.

A further consideration is that older adults display a positivity bias in attention and memory (Mather & Carstensen, 2005), including an increased tendency to falsely remember positive events (Fernandes, Ross, Wiegand, & Schryer, 2008; Piguet, Connally, Krendl, Huot, & Corkin, 2008; Werheid et al., 2010), and retrospectively consider the positive aspects of a negative event (Ford, DiBiase, & Kensinger, 2018). Recently, García-Bajos, Migueles, and Aizpurua (2017) asked participants to simulate emotional future events, and later recall those simulations. Compared to younger adults, older adults produced fewer negative future simulations, were more likely to recall positive future simulations, and were more likely to misremember negative future simulations as being positive. This positivity bias may mean that the effect of positive future simulation on subsequent memory is enhanced in an older population.

In this study, participants simulated positive and negative future events, and then read narratives describing the hypothetical outcome of each event, and events that had not been simulated. Each narrative was neutral overall in tone and contained positive and negative details. Memory for these narrative details was later assessed in a recognition test. We previously demonstrated that for younger adults, positive future simulation increases liberal responding for positive narrative details, conservative responding for negative details, and subjective positivity ratings of narratives in retrospect (Devitt & Schacter, 2018). For older adults, three outcomes are possible. If episodic simulation is the main driving force for this positive bias on memory, we expect the effect of simulation on subsequent memory to be reduced in older adults, with a similar response bias for narrative details following emotional simulation compared with no simulation, and a reduced influence of simulation on subjective valence ratings of narratives. We also expected participants who simulate events with more episodic detail to exhibit a greater positivity bias of simulation. If, however, source monitoring plays a prominent role, older adults may exhibit a larger subsequent memory effect after both positive and negative future simulation, with a liberal response bias for emotionally congruent details and conservative for incongruent details, and the subjective valence of narratives rated as consistent with simulation. Finally, given that older adults exhibit a positivity bias in attention and memory, we may observe a selective increase in the biasing effect of positive simulation on subsequent memory.

Experiment 1

Method

Participants

We recruited 27 older adults (aged 65–90 years) via postings around the Greater Boston area. All participants were fluent English speakers, with no history of neurological or psychiatric impairments, and had normal or corrected-to-normal vision. Participants were screened with an extensive neuropsychological battery and were considered cognitively healthy, with a mean Mini-Mental Status Examination (MMSE; Folstein, Folstein, & McHugh, 1975) score of 29.52 (SD = 0.59, range = 28–30). Participants gave informed consent in a manner approved by Harvard University's ethics board and were compensated with $45 for participation. One participant was excluded for noncompliance, and one for an MMSE score below 24. Therefore, data from 25 participants were included in analyses (7 men; M_{age} = 72.24, *SD* = 6.49). A power analysis (G*Power; Faul, Erdfelder, Lang, & Buchner, 2007) based on effect sizes from a similar study with younger adults (Devitt & Schacter, 2018) determined that a sample of at least 24 was necessary to detect an effect of simulation on response bias (power > .95, η^2_p = 0.13).

The comparison group of 25 younger adults (aged 18–30 years) was reported previously (Devitt & Schacter, 2018; Experiment 2, future simulation condition; 11 men; M_{age} = 21.72, *SD* = 3.25). Older adults had significantly more years of education (*M* = 16.48, *SD* = 2.66) than younger adults (*M* = 14.58, *SD* = 1.97; $t(46)$ = 2.82, p = .007).

Stimuli

We devised short narratives (*M* = 304 words, *SD* = 32) in second person for 18 scenarios that could plausibly be experienced within the next year (e.g., "Going to see a play"). Each narrative contained 12 target details (four each positive, negative, and neutral) and was neutral overall in tone. We devised two versions of each narrative to balance any item effects, with details of opposing valence (e.g., positive: "a beautiful sunny day", negative: "a miserable rainy day"; see Supplementary Information for an example narrative).

Verification of target detail and narrative valence was collected online through Qualtrics Panels from 49 younger adults (8 men, M_{age} = 27.69, *SD* = 4.70) and 46 older adults (14 men, M_{age} = 72.61, *SD* = 5.30). Each participant read through the narratives and rated the target details (presented underlined) and narratives overall for emotional valence (5-point scale, 1 = *strongly negative*, 3 = *neutral*, 5 = *strongly positive*). Overall, the narratives were rated as neutral in tone (*M* = 3.43, *SD* = 0.59). A 2 × 2 factorial analysis of variance (ANOVA) with group (younger, older) and version revealed that older adults rated narratives overall as more positive than younger adults ($F(1, 91)$ = 3.97, p = .049, η^2_p = 0.04, M_{diff} = 0.24). A 2 × 2 × 3 mixed ANOVA with group and narrative version as between-subjects variables, and detail type (negative, neutral, and positive) as a within-subjects variable, confirmed emotional categorization of target details. No group or version differences were found in target detail ratings (see Supplementary Information and Supplementary Table 1 for full statistical descriptions).

Procedure

This study comprised two sessions, spaced 24-hr apart for older adults, and 48-hr for younger adults, to equate memory performance. Session 1 involved a simulation phase and an encoding phase. Session 2 involved a recognition test. Participants were tested individually in a private testing room. All stimuli were presented on a computer using E-prime, version 3 (Psychology Software Tools, Pittsburgh, PA).

In the simulation phase, participants were presented with 12 of the 18 scenarios (random selection), and for each were asked to simulate a future event that might happen in the next year, going either well (*positive condition*) or poorly (*negative condition*; six of each, random order). The remaining six scenarios were withheld to form the *no simulation condition*. Future events were to be plausible, not previously experienced by the participant, and to focus on one day within the next year. For each simulated event, participants described aloud as much information as possible within 3 min, while being audio-recorded. The experimenter remained in the room during the audio-recording, and provided general prompts if the participant stopped speaking before the 3 min were up (e.g., "Is there anything else that comes to mind?"). A bell sounded to indicate the end of the 3 min, then participants rated the simulation on a 5-point scale for emotional valence (1 = *strongly negative*, 3 = *neutral*, 5 = *strongly positive*), vividness, personal significance, plausibility, and similarity to previous experiences (1 = *low*, 5 = *high*) via keyboard responses.

The encoding phase followed a 15-min break. Participants were told to pretend that it was a year later, and they were going to find out how the events they simulated actually played out, via short narratives. Eighteen narratives were presented one at a time in random order: 12 corresponding to simulated events (positive and negative conditions), and six describing new events (no simulation condition). Participants were instructed to read each narrative carefully, self-paced, and then rate the narrative for emotional valence on a 5-point scale via a keyboard response. Valence ratings were intermixed with interest, visualization and plausibility ratings to mask the focus of the study on emotion.

In session 2, participants completed a recognition test for target narrative details. Participants were presented with a narrative title, followed by 12 details: four true details from the narrative (two positive, two negative), four false details of opposing valence from the narrative (two positive, two negative), and four neutral distractor details (two true, two false). Details were presented one at a time, and for each participants were asked to indicate whether they read that information in the narrative or not by pressing either 1 or 0 on the keyboard (mapping to "yes" or "no" was counterbalanced across participants). There was no response time limit. The neutral details were included to mask the purpose of the study for participants, and so are not included in the statistical analyses.

Statistical analyses

We calculated discriminability using *d*′, by subtracting the standardized proportion of false alarms from that of hits (Macmillan & Creelman, 2004). Higher *d*′ values indicate greater discrimination between true and false details. We calculated response bias using C, by multiplying the sum of the standardized hit and false alarm rates by −0.5 (Macmillan & Creelman, 2004). Higher C values indicate a more conservative response bias (i.e., more likely to say "false" regardless of memory status), whereas a lower C indicates a liberal bias (more likely to say "true"). To correct for response proportions of 0 or 1, we used 1/(2*N*) and 1–1/(2*N*), respectively. All statistical analyses were performed with SPSS, version 24 (SPSS Inc., Chicago, IL). Note that in *results* and *discussion*, we refer to the valence of details as presented in the recognition test. Descriptive statistics for hit and false alarm rates can be found in Supplementary Information.

To assess episodic detail, simulation descriptions from session 1 were transcribed, and the first six events from each participant were coded according to the Autobiographical Interview (AI; see Addis, Wong, & Schacter 2008, Levine, Svoboda, Hay, Winocur, & Moscovitch 2002). Transcripts were segmented into distinct pieces of information each conveying a unique idea, which were further classified as internal or external. Internal details referred to episodic information about the event, such as sensory, thought, time, and place information. External details were those not specific to the main event, such as semantic facts, episodic information outside the main event, generalized events, metacognitive statements, and repetitions. Audio-recordings from one younger adult and two older adults were lost due to recorder issues. Two raters scored the AI transcripts. To establish interrater reliability, raters scored a set of 20 recalled past and imagined future events obtained from a previous study (Addis et al., 2008). An intraclass correlation analysis revealed that reliability across raters was acceptable (two-way mixed model; standardized Cronbachs α: internal details .91; external details .79).

Results

Subjective ratings

Mixed 2 × 2 ANOVAs with group (between-subjects; younger, older) and simulation valence (within-subjects; positive, negative) were run for each simulation rating. Positive simulations (M = 3.90, SD = 0.57) were rated higher than negative simulations in valence (M = 2.29, SD = 0.77), confirming participants were following instructions ($F(1, 48) = 137.62$, $p < .001$, $\eta^2_p = 0.74$). Older adults rated simulations more positively overall (M = 3.32, SD = 0.55) than younger adults (M = 2.85, SD = 0.24, $F(1, 48) = 16.45$, $p < .001$, $\eta^2_p = 0.26$). For analyses on other subjective ratings of simulations, see Supplementary Information and Supplementary Table 2.

A mixed 2 × 3 ANOVA with group and simulation valence (positive, negative, no simulation) showed that older adults spent longer reading each narrative (M = 93.55 s, SD = 37.31) than younger adults (M = 59.67 s, SD = 23.42; $F(1, 48) = 16.38$, $p < .001$, $\eta^2_p = 0.25$). No effects of group or simulation were found on narrative valence ratings at encoding ($ps > .147$; Table 1). For ratings of emotional valence collected after the recognition test, a group by simulation interaction was found ($F(2, 96) = 3.21$, $p = .045$, $\eta^2_p = 0.06$), with pairwise comparisons showing that younger adults rated narratives preceded by positive simulation more positively than both negative ($p < .001$) and no simulation ($p = .024$), with no difference between negative and no simulation ($p = .052$). No significant differences were found for older adults ($ps > .059$; Table 1).

Recognition measures

To explore the influence of simulation valence on recognition of narrative details, separate 2 × 2 × 3 mixed ANOVAs were run with group (between-subjects; younger, older), recognition detail type (within-subjects; positive, negative), and simulation valence (within-subjects; positive, negative, no simulation), for discriminability (d') and response bias (C; Table 2).

For d', a main effect of detail was found ($F(1, 48) = 5.89$, $p = .019$, $\eta^2_p = 0.11$), with better discrimination for negative details.

For C (Figure 1a), we observed significant main effects of group and detail, with more liberal responses for older than younger adults ($F(1, 48) = 8.70$, $p = .005$, $\eta^2_p = 0.15$), and for positive than negative details ($F(1, 48) = 16.67$, $p < .001$, $\eta^2_p = 0.26$). A significant interaction between detail and simulation was found ($F(2, 96) = 5.11$, $p = .008$,

Table 1. Mean Emotional Valence Ratings of Narratives Preceded by Positive, Negative and No Simulation (Scale 1–5, 1 = *Strongly Negative*, 3 = *Neutral*, 5 = *Strongly Positive*). Ratings Collected After Narrative Encoding and Recognition

	Encoding		Recognition	
Simulation condition	Younger adults	Older adults	Younger adults	Older adults
Experiment 1				
Positive simulation	2.94 (0.48)	3.03 (0.60)	3.17_a (0.43)	3.10 (0.78)
Negative simulation	3.03 (0.33)	2.88 (0.67)	2.72_b (0.48)	2.93 (0.62)
No simulation	3.11 (0.33)	3.01 (0.73)	2.94_b (0.52)	2.90 (0.62)
Experiment 2				
Positive simulation	3.03 (0.41)	3.21 (0.55)	3.31_a (0.55)	3.40 (0.45)
Negative simulation	3.03 (0.35)	3.17 (0.43)	2.88_b (0.48)	3.32 (0.55)
No simulation	3.09 (0.30)	3.11 (0.41)	3.11 (0.36)	3.21 (0.42)

Note. SD in parentheses. Within a column, means with different subscripts are significantly different ($p < .05$).

Table 2. Mean Recognition Measures in Experiment 1 for Positive and Negative Details of Narratives Preceded by Positive, Negative and No Simulation (Discriminability [*d′*] and Response Bias [C])

		Younger adults		Older adults	
Recognition measure	Simulation condition	Positive details	Negative details	Positive details	Negative details
d′[b]	Positive	1.26 (0.73)	1.56 (0.89)	1.03 (0.69)	1.22 (0.98)
	Negative	1.10 (0.75)	1.31 (0.87)	1.12 (0.72)	1.28 (0.86)
	No simulation	1.29 (0.70)	1.21 (0.70)	1.12 (0.74)	1.33 (0.58)
C[a]	Positive	−0.24 (0.43)*	0.21 (0.37)*	−0.35 (0.41)*	−0.10 (0.50)*
	Negative	0.06 (0.36)	−0.02 (0.35)	−0.25 (0.37)*	−0.07 (0.47)*
	No simulation	0.00 (0.44)	0.06 (0.47)	−0.45 (0.40)*	−0.17 (0.43)*

Note. Where an interaction was found, within a row * indicates significant difference between conditions ($p < .05$). *SD* in parentheses. Highest level significant effect:
[a]Group by detail by simulation interaction.
[b]Main effect of detail.

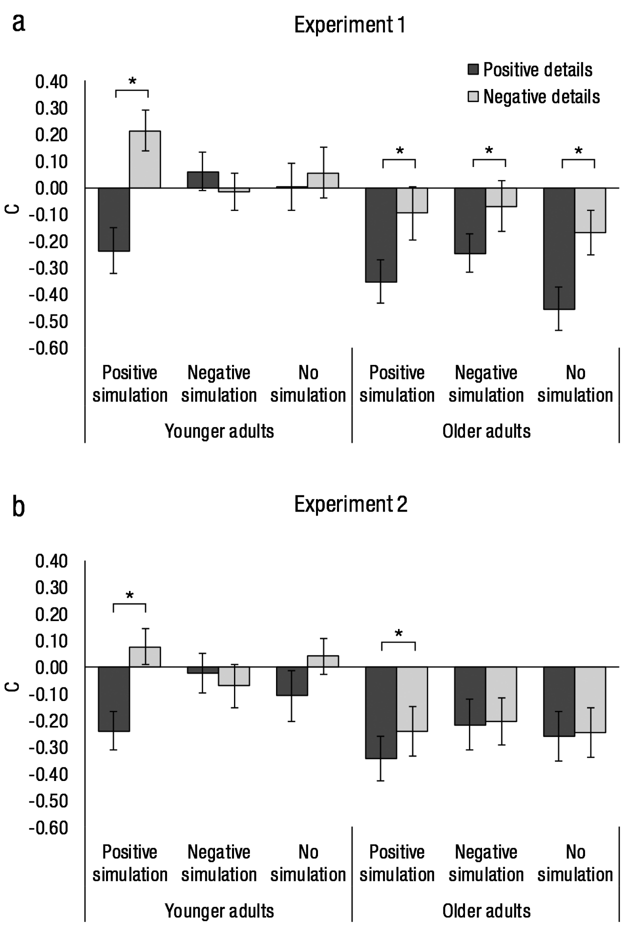

Figure 1. Mean response bias for (a) Experiment 1 and (b) Experiment 2, by group (younger, older), simulation valence (positive, negative, no simulation), and valence of narrative detail presented at recognition (positive, negative). Lower C values indicate more liberal responses. Error bars depict standard errors. Asterisks indicate significant differences between conditions.

$\eta^2_p = 0.10$). This interaction was qualified by a significant three-way interaction ($F(2, 96) = 3.43, p = .036, \eta^2_p = 0.07$). Splitting the results by group revealed that the detail by simulation interaction was significant for younger adults ($p = .001$), who had a more liberal response criterion for positive than negative details after positive simulation ($p = .001$). The detail by simulation interaction was not significant for older adults ($p = .714$), who were more liberal for positive details regardless of prior simulation valence ($p = .002$), and were more conservative overall after negative simulation ($p = .019$).

Older adults subjectively rated their simulations as more positive, arousing, vivid, and personally significant than younger adults (Supplementary Information). Similar age differences have been seen in episodic simulation elsewhere (Addis, Musicaro, Pan, & Schacter, 2010; Addis et al., 2008; Luchetti & Sutin, 2018). We included these ratings as covariates in the ANOVA exploring response bias and found no effects on the three-way interaction.

Episodic detail of simulation

A 2 × 2 mixed ANOVA with group and detail type (internal, external) revealed a significant interaction ($F(1, 46) = 8.25, p = .006, \eta^2_p = 0.15$), with younger adults generating more internal details overall ($M = 56.04, SD = 11.59$) than older adults ($M = 40.95, SD = 13.05, p < .001$), but no difference in external details ($M_{younger} = 21.87, SD = 7.30$; $M_{older} = 19.99, SD = 9.89$). To examine whether episodic detail contributed to the influence of simulation on subsequent memory, we correlated the number of internal details generated by each participant with a score of positivity bias, calculated as the difference in response bias scores between positive and negative details following positive simulation, compared to that of no simulation. We found no association between internal details and positivity bias for younger ($r = -.07, p = .752$) or older adults ($r = .21, p = .328$).

To examine the possibility that age differences were driven by a greater overlap between simulation and narrative content, a rater blind to the hypotheses of the study identified the number of narrative target details spontaneously generated during future simulation. Younger adults generated more target details ($M = 6.74, SD = 3.60$) than older adults (M = 4.74, SD = 2.94; $t(45) = 2.12$, p = .039). However, the number of target details generated during simulation did not correlate with the positivity bias for younger (r = −.03, p = .882) or older adults (r = −.13, p = .567), and including the number of target details generated as a covariate in the response bias ANOVA did not alter the three-way interaction.

Discussion

In Experiment 1, we found that positive simulation does not selectively influence memory for older adults. Negative simulation resulted in a more conservative bias overall for older adults, demonstrating an effect of prior simulation that is not selective to the congruency of the remembered details. The lack of influence of positive simulation supports our hypothesis that reduced episodic detail with age would reduce the effect of simulation on subsequent memory. However, we found no association between the episodic detail of simulation and the influence on subsequent memory. Age differences in response bias and narrative ratings were not due to differences in simulation phenomenology or the similarity between simulation and narratives. Given that older adults are less likely to remember future simulations over time (García-Bajos et al., 2017), another possibility is that memory for the simulations decayed more rapidly over the 15-min break between simulation and encoding of the narratives for the older group, thereby reducing the effect on subsequent memory. To determine whether a shorter time delay would result in a similar pattern of results in older and younger adults, in Experiment 2, participants encoded the relevant narrative immediately after simulating each event.

Experiment 2

Method

Participants

We recruited 30 younger adults and 25 older adults via postings at Harvard University and the Greater Boston area. Two younger adults were excluded for noncompliance, and three for a history of neurological or psychiatric disorders. Therefore, data from 25 younger adults (11 men; M_{age} = 21.68, SD = 2.94) and 25 older adults (10 men; M_{age} = 72.48, SD = 5.80) were included in analyses. All participants were fluent English speakers, with no history of neurological or psychiatric impairments, and had normal or corrected-to-normal vision. Older adults had a mean MMSE score of 29.28 (SD = 0.84, range = 27–30). Participants gave informed consent in a manner approved by Harvard University's ethics board. We chose our sample sizes to be consistent with Experiment 1. Younger adults were compensated with either course credit or $25 for participation, and older adults were compensated with $45. There were no age differences in years of education (M_{older} = 15.80, SD = 1.80; $M_{younger}$ = 14.88, SD = 1.69; $t(48) = 1.86$, p = .069).

Procedure

Experiment 2 followed a similar protocol as Experiment 1; however, the simulation and encoding phases in session 1 were intermixed. Participants would simulate a future event for 3 min, then immediately read the narrative, describing what really happened in that event. Narratives in the no simulation condition were preceded by 3 min of math problems, in which participants completed worksheets of simple addition and subtraction by hand. The ordering of the positive, negative, and no simulation trials was random. Session 2 was identical to that of Experiment 1.

Results

Subjective ratings

Mixed 2 × 2 ANOVAs with group (between-subjects; younger, older) and simulation valence (within-subjects; positive, negative) were run for each simulation rating. Positive simulations were rated higher than negative simulations in positive valence, confirming participants were following instructions ($F(1, 48) = 95.14$, $p < .001$, $\eta^2_p = 0.67$). Older adults rated simulations more positively overall than younger adults ($F(1, 48) = 11.21$, p = .002, $\eta^2_p = 0.19$). A group by valence interaction was found ($F(1, 48) = 5.49$, p = .023, $\eta^2_p = 0.10$), where older adults rated negative simulations (M = 2.95, SD = 0.95) as less negative than younger adults (M = 2.19, SD = 0.52, p = .001), with no difference in positive simulations (M_{older} = 3.99, SD = 0.58; $M_{younger}$ = 3.89, SD = 0.55, p = .525). For analyses on other subjective ratings of simulations, see Supplementary Information and Supplementary Table 2.

A mixed 2 × 3 ANOVA with group and simulation valence (positive, negative, no simulation) showed that older adults spent longer reading each narrative (M = 96.31 s, SD = 31.97) than younger adults (M = 64.69 s, SD = 20.76; $F(1, 48) = 17.09$, $p < .001$, $\eta^2_p = 0.26$), and both groups spent longer reading narratives that were not preceded by imagination ($M_{negative}$ = 74.89 s, SD = 29.27; M_{none} = 91.07 s, SD = 34.41; $M_{positive}$ = 75.54 s, SD = 33.65; $F(1.45, 69.77) = 31.89$, $p < .001$, $\eta^2_p = 0.40$). No effects of group or simulation were found on narrative valence ratings at encoding (ps > .183; Table 1). For ratings of emotional valence collected after the recognition test, a group by simulation interaction was found ($F(1.66, 79.75) = 3.50$, p = .043, $\eta^2_p = 0.07$), with pairwise comparisons showing that younger adults rated narratives preceded by positive simulation more positively than those preceded by negative simulation (p = .004). No significant differences were found for older adults (ps > .110; Table 1).

Because older adults subjectively rated negative simulations as less negative overall than younger adults, we excluded negative simulations that older adults rated positively (M = 2.08 events, SD = 1.84), and positive simulations rated negatively

(M = 0.42 events, SD = 0.65), to assess the impact on the interaction between group and simulation for subjective valence ratings of narratives at recognition. Younger adults rated simulations this way at a relatively low rate (negative: M = 0.46, SD = 0.72; positive: M = 0.17, SD = 0.48). One older adult rated all negative events as positive and so was excluded entirely. After excluding these events the group by imagination interaction remained ($F(1.66, 77.85) = 3.66$, $p = .038$, $\eta^2_p = 0.07$). For completion we also excluded these events in Experiment 1 (number excluded events for older adults, $M_{negative} = 1.44$, $SD = 1.80$, $M_{positive} = 0.20$, $SD = 0.50$), and the group by imagination interaction remained for subjective valence ratings of narratives at recognition ($F(2, 96) = 3.19$, $p = .045$, $\eta^2_p = 0.06$), and the three-way interaction for response bias was reduced but not eliminated ($F(2, 96) = 3.01$, $p = .054$, $\eta^2_p = 0.06$).

Recognition measures

Separate 2 × 2 × 3 mixed ANOVAs were run with group (between-subjects; younger, older), recognition detail type (within-subjects; positive, negative), and simulation valence (within-subjects; positive, negative, no simulation), for discriminability (d') and response bias (C; Table 3).

For d', main effects of group and detail were found, with better discrimination by younger than older adults ($F(1, 48) = 4.14$, $p = .048$, $\eta^2_p = 0.08$), and for negative than positive details ($F(1, 48) = 13.41$, $p = .001$, $\eta^2_p = 0.22$).

For C (Figure 1b), we observed significant main effects of group and detail, with more liberal responses by older than younger adults ($F(1, 48) = 5.25$, $p = .026$, $\eta^2_p = 0.10$), and for positive than negative details ($F(1, 48) = 4.59$, $p = .037$, $\eta^2_p = 0.09$). A significant interaction between detail and simulation condition was found ($F(2, 96) = 3.95$, $p = .022$, $\eta^2_p = 0.08$). Pairwise comparisons revealed that for narratives preceded by positive simulation, responses were more liberal for positive than negative details ($p = .001$). The three-way interaction was not significant ($p = .219$).

To further interrogate the null age interaction in response bias, we conducted Bayes factors and two one-sided tests (TOST) using the TOSTER package in R (Lakens, McLatchie, Isager, Scheel, & Dienes, 2018). The Bayes factor measures the strength of evidence for the null model of equivalence relative to the alternative model of a group difference. The TOST approach uses the traditional null-hypothesis significance testing logic to examine whether an effect is as or more extreme than the smallest effect size of interest; if both one-sided tests are significant, there is evidence of equivalence. The normally distributed alternative model and effect sizes of interest were based on Experiment 1. The Bayes factor revealed weak, inconclusive evidence for the null hypothesis ($B_{N(0, 0.42)} = 0.42$). The TOST procedure indicated that the observed effect size ($d = 0.13$) was not significantly within the equivalent bounds of $d = \pm 0.31$ (or in raw scores ±0.19; $t(47.34) = -0.62$, $p = .271$). Therefore, we cannot reject effect sizes that we still consider meaningful.

To summarize the results of Experiment 2, reducing the delay between simulation and narrative encoding increased the impact of simulation on response bias for older adults, yet age differences still emerged for subjective ratings of narrative emotion at recognition.

General Discussion

We previously demonstrated that for younger adults, simulating positive future events results in a positive bias in memory for neutral narratives (Devitt & Schacter, 2018). In Experiment 1, we found that older adults do not show this biasing effect of positive simulation. In Experiment 2, with increased temporal overlap between simulation and narrative memory, we replicated the impact of positive simulation for younger adults and found a similar (albeit reduced) impact on memory for older adults. In both experiments, younger adults subjectively rated narratives preceded by positive simulation more positively than those

Table 3. Mean Recognition Measures in Experiment 2 for Positive and Negative Details of Narratives Preceded by Positive, Negative and No Simulation (Discriminability [d'] and Response Bias [C])

		Younger adults		Older adults	
Recognition measure	Simulation condition	Positive details	Negative details	Positive details	Negative details
$d'^{a,b}$	Positive	1.16 (0.62)	1.63 (0.83)	1.11 (0.65)	1.15 (0.62)
	Negative	1.23 (0.60)	1.41 (0.55)	0.99 (0.75)	1.27 (0.74)
	No simulation	1.42 (0.60)	1.75 (0.68)	1.14 (0.72)	1.41 (0.80)
C[c]	Positive	−0.24 (0.36)*	0.08 (0.33)*	−0.34 (0.41)*	−0.24 (0.47)*
	Negative	−0.02 (0.38)	−0.07 (0.40)	−0.22 (0.48)	−0.20 (0.44)
	No simulation	−0.11 (0.47)	0.04 (0.33)	−0.26 (0.46)	−0.25 (0.46)

Note. Where an interaction was found, within a row * indicates significant difference between conditions ($p < .05$). SD in parentheses. Highest level significant effect:
[a]Main effect of group.
[b]Main effect of detail.
[c]Detail by simulation interaction.

preceded by negative simulation, whereas older adults' subjective valence ratings were not contingent on prior simulation valence. These findings add to previous work showing reduced benefits of simulation with age on other tasks tapping adaptive functions, such as prospective memory (Terrett et al., 2016), prosocial thinking (Gaesser et al., 2017), and temporal discounting (Sasse et al., 2017).

The reduced impact of simulation on subsequent memory with age is in line with our hypothesis that decreased episodic detail of simulation would reduce the subsequent memory effect. However, speaking against this theory, we did not find an association between the episodic detail of simulation and positivity bias in Experiment 1 for either age group. It has recently been demonstrated that the amount of detail generated when describing memories and the proportion of memories describing distinct events (i.e., memory specificity) are not associated, indicating that memory detail and specificity reflect different constructs (Kyung, Yanes-Lukin, & Roberts, 2016). Although older adults exhibit deficits in both constructs, the amount of internal details generated is an indirect assessment that may not be capturing the relevant dimension of episodic specificity. Our paradigm was not designed to measure episodic specificity as defined as the degree to which participants generate distinct events; therefore, the possibility that this aspect of episodic specificity is associated with the subsequent memory effect remains to be assessed. It is also possible that correlational measures are too weak to detect a subtle effect of episodic detail or specificity.

Alternatively, Experiment 2 demonstrated that at least part of the reason older adults are immune to the impact of simulation on subsequent memory may be due to an inability to retrieve the simulated event during narrative encoding. When we supported simulation memory and increased overlap with narratives by having participants encode relevant narratives immediately after each simulation, we found no age differences in response bias, though null-hypothesis testing revealed only weak, inconclusive evidence for a lack of group effect. Interestingly, age differences in the impact of simulation on subjective ratings of narrative emotion made at retrieval remained even with no delay between simulation and narrative encoding, highlighting a disconnect between objective memory and subjective experience that has also been demonstrated elsewhere (e.g., Addis et al., 2010, 2008; Luchetti & Sutin, 2018).

Our results also align with work showing that older adults are less effective at updating memories with new information (Attali & Dalla Barba, 2013; St. Jacques, Montgomery, & Schacter, 2015), memory distortions due to misinformation (Umanath, Dolan, & Marsh, 2014; Umanath & Marsh, 2012). In a similar vein, older adults may be protected against interference from future simulation due to a reduced tendency to "update" the authentic event memory. Future research should delineate the links between decreased episodic detail, reduced memory updating and impaired memory for simulations with age, and the resulting impact on memory accuracy. An experimental manipulation of episodic detail would be informative in this regard (e.g., Madore, Gaesser, & Schacter, 2014).

Although older adults demonstrate a positivity bias in memory (e.g., Mather & Carstensen, 2005), prior studies have been mixed regarding whether this positivity bias extends to the future. Although some have found that older adults' future thoughts are more positive overall than younger adults (Gallo, Korthauer, McDonough, Teshale, & Johnson, 2011; García-Bajos et al., 2017), others have found no age differences (Chessell, Rathbone, Souchay, Charlesworth, & Moulin, 2014; Grysman, Prabhakar, Anglin, & Hudson, 2015), and even a reverse effect when thinking about the distant future (Durbin, Barber, Brown, & Mather, 2018). In the current studies, we found that older adults rated all simulations more positively than younger adults in Experiment 1, whereas this was only true for negative events in Experiment 2. On the whole, these results speak toward an age-related increase in future optimism for events in the immediate future.

It should be noted that there were more women than men in all our participant samples, and this gender imbalance was particularly pronounced for older adults in Experiment 1. Evidence regarding gender differences in the processing of emotional stimuli is mixed (e.g., Piefke & Fink, 2005), and as such, this gender imbalance is a limitation of the current studies.

In summary, we replicated the finding that adopting an optimistic outlook results in a rosy memory for younger adults, and demonstrated that this effect is reduced with age, which may be at least partly attributable to impaired memory for future simulations over time. This work broadens our understanding of the functional consequences of age-related declines in episodic future simulation.

Supplementary Material

Supplementary data are available at *The Journals of Gerontology, Series B: Psychological Sciences and Social Sciences* online.

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Conflict of Interest

None reported.

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