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BRIEF REPORT

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Predicting others' knowledge in younger and older adulthood

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Abstract

Our beliefs about aging affect how we interact with others. For example, people know that episodic memory declines with age, and as a result, older adults' memories are less likely to be trusted. However, not all aspects of remembering decline with age; semantic memory (knowledge) increases across adulthood and is relatively unaffected in healthy aging. In the current work, we examined people's awareness of this pattern. Participants estimated the knowledge of hypothetical younger and older adults; in some studies, they also predicted and demonstrated their own knowledge on the same measures. Across studies, both younger and older adults estimated that older adults would perform better on a knowledge test, demonstrating awareness that knowledge is not impaired with aging. Furthermore, people's beliefs about their own knowledge influenced the predictions they made about others' knowledge. We discuss how this work informs theories of metacognition and contributes to positive self-perceptions in older adulthood.

Keywords Metacognition · Beliefs · Aging · Semantic memory · Stereotypes

Introduction

People's beliefs about the abilities of others matter, affecting whom they interact with personally and professionally. Sometimes these beliefs appropriately guide behavior, such as when one considers a friend's ability to complete a strenuous activity (Snyder et al. 1983). Other times, beliefs have negative consequences, such as when employers view older adults as less trainable, personable, and agile than younger adults in the same applicant pool (Rupp et al. 2006). More generally, ageism is prevalent in society, with many believing older adults are incompetent, curmudgeonly, and forgetful (Cuddy and Fiske 2002; Ng et al. 2015; Schmidt and Boland 1986). Here, we focus specifically on people's beliefs about age-related changes in cognition. While it is well documented that younger adults (correctly) believe episodic memory abilities decline with age (Ryan and See 1993; Tauber et al. 2019), less clear is their awareness of cognitive abilities that are preserved in healthy aging. We investigate this metacognitive issue in seven experiments, examining beliefs about an ability that is spared (and sometimes improves) with age – knowledge.

Younger adults know that episodic memory declines with age, consistently estimating older adults' memory abilities as worse than their own. For example, when predicting memory for a list of medications and their side effects (e.g., Calamor – itching), younger adults estimate that a hypothetical older adult would remember 16% fewer pairs than would a hypothetical younger adult (Hargis and Castel 2019). Similar results occur when younger adults estimate the percentage of a word list an older adult would be able to recall in a hypothetical experiment (Tauber et al. 2019). Likewise, both younger and older adults consistently rate older adults' memory abilities as worse on a standard metamemory measure, the General Beliefs about Memory Instrument (GBMI, Lineweaver and Hertzog 1998).

While these beliefs are accurate – aging is associated with declines in remembering – they still have behavioral consequences. For example, when participants collaborate to remember a scene, younger adults are less likely to later repeat suggestions from older adult confederates (Davis and Meade 2013; Meade et al. 2017). The prevalence of this stereotype can lead to stereotype threat, potentially affecting older adults' physical abilities (Barber et al. 2020), cognitive performance (Hess et al. 2003), and general wellbeing

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(Levy et al. 2008; Weiss 2018). In the domain of memory, stereotypes exacerbate older adults' memory deficits, leading them to perform below their full potential (for review, see Barber 2017).

However, not all aspects of remembering decline with age; knowledge is a form of crystallized intelligence, which increases across the lifespan and generally remains intact in older adults (Craik and Bialystok 2006; Rönnlund et al. 2005). For instance, knowledge of vocabulary words and grammar increases throughout young adulthood and is maintained in older adulthood (Verhaeghen 2003; Wingfield and Stine-Morrow 2000). Similar preservation effects occur for knowledge of science, geography, and history (Salthouse 2003), as well as skills like playing an instrument (Krampe and Ericsson 1996).

When estimating the knowledge of others, the data support an anchoring-and-adjustment mechanism. That is, people are egocentric and use their own knowledge as a starting point when building a model for what others know (Nickerson 1999). For example, participants who knew the contents of a hidden message in a song (vs. those that didn't) estimated that a greater proportion of naïve listeners (55% vs. 16%) would also hear the message (Epley et al. 2004). Similarly, the estimated difficulty of unscrambling a series of anagrams was highly correlated with the time it took participants to solve the anagrams themselves (Kelley and Jacoby 1996). People are also egocentric when answering general knowledge questions and making predictions about a peer's ability to answer the same questions.

However, recent work questions whether anchoring on one's own knowledge is required when estimating the knowledge of others. For example, people discount their own knowledge when they can attribute their success to an outside source (e.g., preview of the answers; Thomas and Jacoby 2013). The Cue Utilization Model (Koriat 1997; Tullis 2018) posits that people use additional cues beyond one's own knowledge when judging others' knowledge. For instance, people realize that others will perform worse on misconception questions, regardless of what they themselves know.

Here, we explore the Cue Utilization Model and investigate whether age is used as a diagnostic cue for what others know, examining whether people's judgments change when predicting the knowledge of an older versus a younger adult. Given that younger adults understand age-related declines in episodic memory, an age cue could produce a "negative halo effect" (Forgas and Laham 2016), with younger adults overgeneralizing their negative beliefs about aging and memory to knowledge. In contrast, age could be a positive cue. Younger adults may have a relatively accurate understanding of aging (through observation or more formal instruction), such that they associate aging with deficits in episodic memory but preserved or improved performance on knowledge tasks. That is, younger adults are mindful that older adults have more experience (Bowen et al. 2019) and may consequently be aware that healthy aging is not associated with declines in knowledge. A secondary question is whether an age cue eclipses the cue of one's own knowledge given that anchoring is not required in the Cue Utilization Model.

In seven studies, participants estimated the performance of hypothetical younger and older adults on general knowledge measures. The items varied in difficulty to test whether participants anchored on their own knowledge (as people are sensitive to their own struggles when answering difficult questions). People's assessment of their own knowledge was measured in all studies except the first. To preview, participants[1] predicted age-related decreases in episodic memory, but age-related increases in general knowledge.

Study 1

Method

Participants Two hundred adults were recruited through Amazon Mechanical Turk (MTurk) to complete the online study. Our study was modeled on that by Tauber et al. (2019), which averaged 48 participants per study; we doubled that number, given our between-subjects manipulation (memory vs. knowledge estimation). We further increased the number of participants in hopes of sampling a wider range of ages on MTurk. All participants were US residents, had completed at least 50 HITs, and had an approval rate greater than 90%. Ten participants were excluded from the analyses for failing the attention check at the end of the study (see below for details). Thus, data were analyzed from the remaining 190 individuals (M_{age} = 35.75 years, SD = 11.07, range = 19–72; 81 female, two other). All studies in this report were approved by the Duke University Campus Institutional Review Board.

Materials and procedure Participants were randomly assigned to one of two between-subjects conditions: memory estimation or knowledge estimation. After providing informed consent, they answered demographic questions about their age, gender, ethnicity, and education. Next, they read one of two scenarios (adapted from Tauber et al. 2019). In the memory estimation condition, they read:

[1] Table 1 includes all participants and Supplemental Table 1 (Online Supplemental Material, OSM) reports the results when the analyses were restricted to younger adults (18–40 years) in Studies 1–3. The results remained unchanged. Thus, we are confident that the few middle-aged/older adults in our samples did not drive the results presented in the main text.

Table 1 Summary of studies

	N	M_{age}(range)	Memory type	Knowledge type	Difficulty level	GBMI
Study 1	190	35.75 (19–72)	Word recall	General	---	---
Study 2a	183	37.83 (20–81)	---	General	Medium, Difficult	---
Study 2b	181	36.70 (18–73)	---	General	Easy, Difficult	---
Study 3	177	36.49 (19–77)	---	Vocabulary	Medium, Difficult	---
Study 4a	46	71.20 (65–82)	---	General	Medium, Difficult	---
Study 4b	44	29.73 (21–40)	---	General	Medium, Difficult	X
	48	74.23 (65–84)				
Study 5	104	29.33 (20–40)	---	General	Difficult	---
	110	72.94 (65–83)				

In a previous experiment, younger adults (roughly 18–21 years old) and older adults (roughly 65+ years old) were presented with a list of 28 words one after the other. Sample words included *tree* and *island.* Each word was presented for 5 seconds. The task was to study these words so they would be able to remember them for a later test. The memory test took place immediately after all of the words had been studied. On the test, younger and older adults were given unlimited time to list the words that they could remember in any order.

Participants in the knowledge estimation condition read:

In a previous experiment, younger adults (roughly 18–21 years old) and older adults (roughly 65+ years old) were presented with a list of 28 general knowledge questions one after the other. Sample questions included "*What is the name of the lightest wood known?*" and "*What island is the largest in the world excluding Australia?*" The task was to answer these questions without looking up the answers. On the test, younger and older adults were given unlimited time to answer the questions.

Depending on experimental condition, participants either estimated how many words were recalled or how many general knowledge questions were answered correctly; all participants made two estimates, one for a hypothetical younger adult and the other for a hypothetical older adult. The order in which they made these estimates was counterbalanced. Participants completed their estimates by typing in a number between 0 and 28. This task was self-paced.

The experiment ended with an attention check (used by Stanley et al. 2019). Subjects were asked, "Do you feel that you paid attention, avoided distractions, and took the survey seriously?" Participants selected one of five answers: (1) no, I was distracted; (2) no, I had trouble paying attention; (3) no, I did not take the study seriously; (4) no, something else affected my participation negatively; or (5) yes. Participants were assured that their responses would not affect their payment or their eligibility for future studies. Only those participants who selected (5) were included in the analyses. Upon completion, participants were monetarily compensated for their efforts (as they were in all studies listed in this report).

Results

Replicating past work, participants estimated that younger adults would recall more words (M = .56, SD = .20) than would older adults (M = .44, SD = .18); $t(93) = 7.92$, $p < .001$, $d = .82$. In contrast, they estimated that younger adults would answer fewer general knowledge questions correctly (M = .50, SD = .19) than would older adults (M = .59, SD = .18); $t(95) = 4.99$, $p < .001$, $d = .51$.

Studies 2a and 2b

Studies 2a and 2b conceptually replicated Study 1 while also adding a measure of participants' own knowledge (to allow us to evaluate anchoring). The studies are reported together as the methods were identical and the materials only differed in difficulty.[2]

Method

Participants Four hundred adults (200 for Study 2a and 200 for Study 2b) were recruited through Amazon Mechanical Turk (MTurk) to complete the online studies. Our studies were modeled on that by Tauber et al. (2019), which averaged 48 participants per study; we doubled that number, given our between-subjects manipulation (level of question difficulty). We further increased the number of participants in hopes of sampling a wider range of ages on MTurk. The same inclusion criteria from Study 1 were used. Twelve participants (six from each study) were excluded for failing the attention check and 24 (11 from Study 2a and 13 from Study 2b) were excluded for looking up the answers to questions. Thus, the analyses included 183 individuals (M_{age} = 37.83 years, SD = 11.41, range = 20–81; 90 female) in Study 2a and 181 (M_{age} = 36.70 years, SD = 10.69, range = 18–73; 83 female) in Study 2b.

Materials Question difficulty was manipulated between-subjects based on Tauber et al. (2013); ten items were selected to be difficult (Probability of Recall (POR) range = .092 – .160; Studies 2a and 2b), ten were medium (POR range = .481 – .663; Study 2a), and ten were easy (POR range = .730 – .890; Study 2b). All questions appear in the Appendix. Sample difficult questions included "Which country was the first to use gunpowder? and "What is the name of the lightest wood known?" Sample medium questions included "What is the name of the legendary one-eyed giant in Greek mythology?" and "What is the name of a dried plum?" Sample easy questions included "What is the capital of France?" and "What is the name of the remains of plants and animals that are found in stone?"

Procedure Studies 2a and 2b had two parts: estimating the knowledge of others and demonstrating (and predicting) one's own knowledge. The same knowledge estimation scenario was used as in Study 1, except that ten sample questions followed the scenario. Participants estimated the number of questions (out of 28) hypothetical younger and older adults would answer correctly. The order in which they made these estimates was counterbalanced. Then, after making these estimates, participants answered the ten normed sample questions themselves in a randomized order. They were instructed to write "I don't know" for any answers they could not provide. Afterwards, participants estimated how many they believed they had answered correctly (out of ten). All estimates and answers were typed in by participants and the task was self-paced.

Finally, participants were asked if they looked up any answers to the questions and completed the attention check.

Data analysis In the remainder of studies herein, data were analyzed using SPSS and R with the 'lme4' (Bates et al. 2015) and 'lmerTest' (Kuznetsova et al. 2017) software packages. Significance for fixed effects was assessed using the Satterthwaite degrees of freedom method and 95% confidence intervals (CIs) around beta-values were computed using bootstrapping (n simulations = 1,000). The alpha level for all statistical tests was set at .05.

Results

Estimates of others' knowledge For each study, a 2 (hypothetical age: younger, older) × 2 (difficulty) repeated-measures ANOVA was computed on participants' estimates; the studies differed only in the specific difficulty levels tested. Participants were well calibrated in their estimates. In Study 2a, participants estimated people would answer more medium questions correctly (M = .59, SD = .19) than difficult ones (M = .46, SD = .20); $F(1, 181) = 17.71$, MSE = .08, $p < .001$, $\eta_p^2 = .09$. In Study 2b, participants predicted higher performance on easy questions (M = .63, SD = .20) versus difficult ones (M = .46, SD = .19); $F(1, 179) = 30.45$, MSE = .08 $p < .001$, $\eta_p^2 = .15$.

More importantly, in both studies older adults were predicted to know more. This effect was significant in Study 2a (older (M = .59, SD = .23) > younger (M = .45, SD = .21)); $F(1, 181) = 164.00$, MSE = .01, $p < .001$, $\eta_p^2 = .48$ and Study 2b (older (M = .60, SD = .23) > younger (M = .49, SD = .23)); $F(1, 179) = 83.22$, MSE = .01, $p < .001$, η_p^2 = .32. The interaction between hypothetical age and difficulty was not significant in either study ($Fs < 1$).

Role of participants' knowledge Participants were fairly accurate at judging their own performance (actual and estimated performance were highly correlated: Study 2a r = .88; Study 2b r = .92).[3] To examine anchoring on one's own knowledge, we computed a linear mixed effect model with estimates of hypothetical others' knowledge as the outcome

[2] We manipulated the difficulty of the general knowledge questions because we thought younger adults might not expect older adults to outperform them on easy questions (e.g. "What is the capital of France?"). We anticipated that predictions for younger and older adults would be the same in the easy and medium conditions (due to anchoring) but different (older adults outperform younger adults) in the difficult conditions.

[3] The OSM reports participants' performance on the general knowledge measures for all studies.

variable. Participants' age (continuous),[4] estimates of their own performance, and target age (hypothetical younger or older adult) were modeled as fixed effects. Participant was included as a random effect (random intercepts only). In both studies, participants' own knowledge significantly predicted the estimates they made for others: Study 2a: $b = .225$, $SE = .049$, $t = 4.60$, $p < .001$, 95% CI = [.137, .322]; Study 2b: $b = .290$, $SE = .043$, $t = 6.80$, $p < .001$, 95% CI = [.205, .378]. However, the age of the hypothetical target remained a significant predictor, even with the measure of individuals' knowledge entered into the model: Study 2a: $b = -.139$, $SE = .012$, $t = -12.84$, $p < .001$, 95% CI = [-.160, -.119]); Study 2b: $b = -.110$, $SE = .012$, $t = -9.13$, $p < .001$, 95% CI = [-.132, -.085]). Participants anchored their estimates on what they themselves knew – but the age of the hypothetical target explained additional variance.

Study 3

To ensure the generality of the results, Study 3 participants predicted performance on a different knowledge measure: the ability to define vocabulary words.

Method

Participants Two hundred adults were recruited through Amazon Mechanical Turk (MTurk) to complete the online study. Our study was modeled on that by Tauber et al. (2019), which averaged 48 participants per study; we doubled that number, given our between-subjects manipulation (level of vocabulary difficulty). We further increased the number of participants in hopes of sampling a wider range of ages on MTurk. The same inclusion criteria from Study 1 were used. Twenty-three participants were excluded from analysis for either failing the attention check (15) or looking up the vocabulary definitions (eight). Thus, data were analyzed from the remaining 177 individuals ($M_{age} = 36.49$ years, $SD = 11.35$, range = 19–77; 80 female, two other).

Materials and procedure This study differed from Studies 2a and 2b only in materials; participants were asked to estimate a younger or older adult's ability to define vocabulary words instead of general knowledge. The scenario adapted from Tauber et al. (2019) was changed to read as follows:

> In a previous experiment, younger adults (roughly 18–21 years old) and older adults (roughly 65+ years old) were presented with a list of 28 words one after the other (see sample words below). The task was to define these words without looking up the definitions. On the test, younger and older adults were given unlimited time to define the words.

Ten sample words were then listed, with difficulty differing across conditions. Difficult words (e.g., acerbic, fetid, droll) were selected from a list of GRE words, whereas medium words (e.g., opulent, amicable, vindicate) were selected from a list of SAT words. See the Appendix for the full list of words. Participants were asked to estimate how many words out of 28 the hypothetical younger and older adult would define correctly. The order in which they made these estimates was counterbalanced. After making these estimates, the participants defined the ten sample vocabulary words themselves in a randomized order. They were instructed to write "I don't know" for any words they could not define. After defining the words, participants estimated how many they believe they defined correctly. All estimates and answers were typed in by participants and the task was self-paced. Finally, participants were asked if they looked up the definition to any of the words and whether they paid attention throughout the study.

Results

Estimates of others' knowledge A 2 (hypothetical age) × 2 (difficulty) repeated-measures ANOVA was computed on participants' estimates. As expected, participants estimated people would define more medium words correctly ($M = .50$, $SD = .23$) than difficult ones ($M = .43$, $SD = .23$); $F(1, 175) = 4.30$, $MSE = .11$, $p = .04$, $\eta_p^2 = .02$. Critically, participants estimated that older adults would define more words correctly ($M = .50$, $SD = .26$) than younger adults ($M = .42$, $SD = .24$); $F(1, 175) = 29.84$, $MSE = .02$, $p < .001$, $\eta_p^2 = .15$. The interaction was not significant (F < 1).

Role of participants' knowledge Participants' estimates of their own performance were highly correlated with their actual performance, $r = .91$, $p < .001$. These estimates were used to predict estimates of others' knowledge using a linear mixed effect model. Participants' age (continuous) and target age (hypothetical younger or older adult) were also included in the model as fixed effects; participant was included as a random effect (random intercepts only). Consistent with an anchoring account, an individual's knowledge was a significant predictor of their estimates of others' knowledge: $b = .244$, $SE = .050$, $t = 4.91$, $p < .001$, 95% CI = [.142, .340]. However, target age still mattered, ($b = -.084$, $SE = .015$, $t = -5.48$, $p < .001$, 95% CI = [-.114, -.054]), beyond the effects of anchoring on one's own knowledge Figs. 1, 2 and 3.

[4] The main effect of age was not significant in Studies 2a, 2b, 3, or 4a (p > .05).

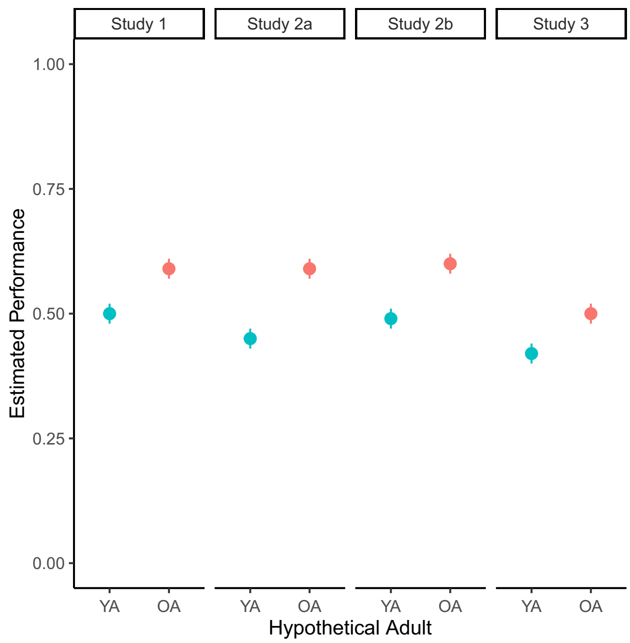

Fig. 1 Results from Studies 1–3, showing mean estimated performance (with standard error bars) on general knowledge (Studies 1–2b) and vocabulary definition (Study 3) tests for hypothetical younger adults (YA) and older adults (OA)

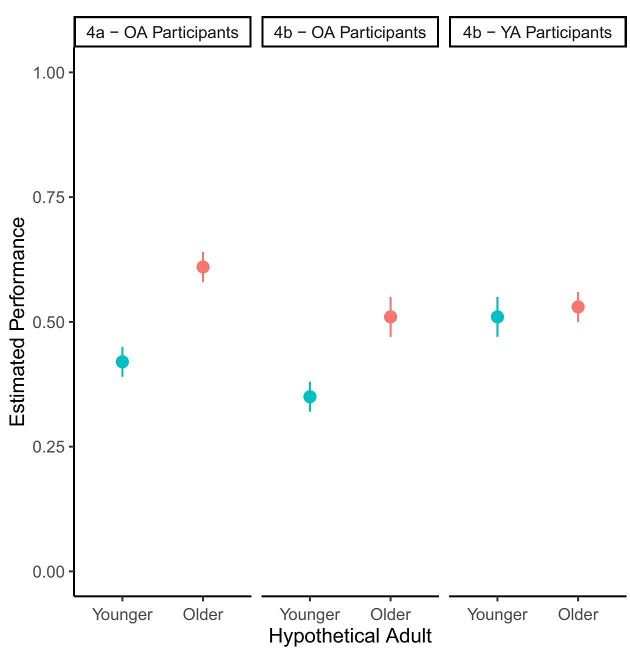

Fig. 2 Results from Studies 4a and 4b, showing mean estimated performance (with standard error bars) on general knowledge tests for hypothetical younger and older adults. For Study 4b, the results are displayed by participants' age group (older or younger)

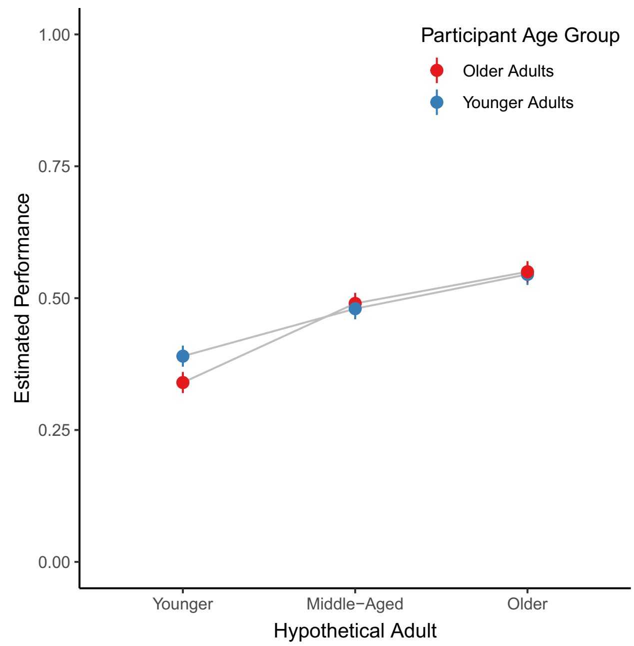

Fig. 3 Results from Study 5, showing mean estimated performance (with standard error bars) on general knowledge tests for hypothetical younger, middle-aged, and older adults. Results are separated into older adult participants' responses (red) and younger adult participants' responses (blue)

Studies 4a and 4b

The samples in the studies reported thus far skewed younger. Thus, Study 4a targeted older adults and Study 4b included both age groups to allow for direct comparison.

Method

Participants Study 4a included 52 older adult participants who were recruited from the Research Participation at Duke (RPad) database. Six were excluded for either failing the attention check (2) or looking up the answers to questions (4), leaving 46 participants eligible for analysis (M_{age} = 71.20 years, SD = 4.48, range = 65–82; 35 female). Study 4b included 92 adults recruited through Qualtrics. Forty-four were younger adults (M_{age} = 29.73 years, SD = 5.79, range = 21–40; 24 female, one other) and forty-eight were older adults (M_{age} = 74.23 years, SD = 5.87, range = 65–84; 24 female). All participants were included in the analysis. Studies 4a and 4b were modeled on that by Tauber et al. (2019), which averaged 48 participants per study.

Materials and procedure Both studies used the same materials and procedure as Study 2a with one exception. After predicting others' knowledge and demonstrating their own, participants in Study 4b completed the General Beliefs about Memory Instrument. They answered 27 items probing their beliefs about global (e.g., "Ability to remember in general") and specific (e.g. "Ability to remember faces," "Ability to remember the source of information") memory efficacy in an average, healthy adult. For each item, participants chose a value on a sliding scale between 0% and 100%. All participants completed the items twice, once for the average 30-year-old and once for the average 75-year-old (order was counterbalanced across participants).

Results

Estimates of others' knowledge For Study 4a, a 2 (hypothetical age) × 2 (difficulty) repeated-measures ANOVA was computed on participants' estimates. For Study 4b, the analysis also included the between-subjects factor of participant's age group (younger/older). Participants in 4b but not 4a predicted higher performance for medium than difficult items, $F(1, 88) = 6.46$, $MSE = .09$, $p = .013$, $\eta_p^2 = .07$.

More importantly, older adults were predicted to know more. The older adults in Study 4a predicted that an older adult ($M = .61$, $SD = .21$) would outperform a younger adult ($M = .42$, $SD = .20$); $F(1, 44) = 80.21$, $MSE = .01$, $p < .001$, $\eta_p^2 = .65$; target age did not interact with difficulty ($F < 1$). In Study 4b, hypothetical older adults ($M = .52$, $SD = .25$) were also predicted to outperform younger adults ($M = .43$, $SD = .26$); $F(1, 88) = 15.53$, $MSE = .02$, $p < .001$, $\eta_p^2 = .15$. This finding was qualified by an interaction with participants' age group, $F(1, 88) = 9.73$, $MSE = .02$, $p = .002$, $\eta_p^2 = .10$. Both groups estimated that older adults would know more; however, this effect only reached significance for older adult participants ($p < .001$).

Role of participants' knowledge Participants were accurate at estimating their own performance; actual and estimated performance were highly correlated for the older adults in Study 4a ($r = .88$, $p < .001$) as well as both younger ($r = .70$, $p < .001$) and older adults in Study 4b ($r = .90$, $p < .001$). We computed a linear mixed effect model with estimates of hypothetical others' knowledge as the outcome variable. Participants' age (continuous; Study 4a) or age group (younger or older adult; Study 4b), estimates of their own performance, and target age (hypothetical younger or older) were modeled as fixed effects. Participant was included as a random effect (random intercepts only). In both studies, participants' estimates of their own knowledge significantly predicted their estimates of others' knowledge: Study 4a: $b = .400$, $SE = .133$, $t = 2.98$, $p = .005$, 95% CI = [.144, .638]; Study 4b: $b = .284$, $SE = .071$, $t = 4.02$, $p < .001$, 95% CI = [.146, .422]. Participant age group was a significant predictor in Study 4b: $b = .118$, $SE = .043$, $t = 2.72$ $p = .007$, 95% CI = [.037, .201], but it did not interact with the age of the hypothetical target. Critically, the main effect of target age was significant in Study 4a ($b = -.196$, $SE = .022$, $t = -9.06$ $p < .001$, 95% CI = [-.237, -.154]) and Study 4b ($b = -.092$, $SE = .023$, $t = -3.92$, $p < .001$, 95% CI = [-.139, -.042]). Thus, participants' beliefs about their own knowledge influenced their estimates of others' knowledge, but so did the age of the hypothetical target.

GBMI Results[5] A 2 (target age: younger, older) × 2 (participant age: younger, older) repeated-measures ANOVA on average estimated memory ability revealed the expected effect of target age: an average 30-year-old was rated as having better memory than an average 75-year-old[6], $F(1, 52) = 924.96$, $MSE = 5.77$, $p < .001$, $\eta_p^2 = .95$.

Study 5

An alternate explanation of our results is that participants believe knowledge declines from a peak in middle-age (i.e., an inverted-U relationship exists between knowledge and aging), as opposed to continuing to increase linearly across the lifespan. To test this idea, Study 5 participants made predictions for a hypothetical middle-aged adult in addition to hypothetical younger and older adults. Study 5 also described the hypothetical older adult as "healthy."

Method

Participants Two hundred and fourteen adults were recruited through Qualtrics. 104 were younger adults ($M_{age} = 29.33$ years, $SD = 5.87$, range = 20–40; 63 female) and 110 were older adults ($M_{age} = 72.94$ years, $SD = 4.45$, range = 65–83; 45 female). All participants were included in the analysis. Our study was modeled on that by Tauber et al. (2019), which averaged 48 participants per study; we doubled that number, given our within-subjects manipulation (knowledge estimate for hypothetical younger, middle-aged, and older adult) and further increased the sample size to accommodate younger and older adult participants.

Materials and procedure This study used the same materials and procedure as Study 2a with three exceptions. First, participants made a knowledge estimate for a hypothetical middle-aged adult, in addition to a younger and older adult. Next, we specifically referred to the hypothetical older adult as "healthy." Finally, only difficult general knowledge

[5] See OSM for full GBMI results.

[6] The GBMI estimates for word meaning, trivia, and knowledge are not inconsistent with our claim that younger adults are aware of older adults' preserved knowledge. The GBMI predominantly involves making estimates of episodic memory (e.g., ability to remember names, directions, faces, etc.), creating a context focused on people's belief that memory abilities decline with age.

questions were used, given our prior studies suggested that difficulty did not interact with the age of the hypothetical target. All participants read:

> In a previous experiment, younger adults (roughly 18–21 years old), middle-aged adults (roughly 40–50 years old), and healthy older adults (roughly 65+ years old) were presented with a list of *28 general knowledge trivia questions* one after the other (see *sample questions* below). The task was to answer these questions without looking up the answers. On the test, younger, middle-aged, and healthy older adults were given unlimited time to answer the questions.

After viewing the sample questions, participants estimated the number of questions (out of 28) hypothetical younger, middle-aged, and healthy older adults would answer correctly; the order of these estimates was counterbalanced across subjects. After making their estimates, participants answered the ten sample questions themselves in a randomized order. They were instructed to write "I don't know" for any answers they could not provide. Afterwards, participants estimated how many they believed they had answered correctly (out of ten). Participants typed in their estimates and answers at their own pace. Finally, participants were asked if they looked up any answers to the questions and completed the attention check.

Results

Estimates of others' knowledge A 2 (age group) × 3 (hypothetical age) repeated-measures ANOVA was computed on participants' estimates. There was a main effect of hypothetical age: $F(2, 424) = 84.61$, $MSE = .02$, $p < .001$, $\eta_p^2 = .29$. Hypothetical older adults ($M = .55$, $SD = .29$) were predicted to outperform both younger ($M = .37$, $SD = .28$, $t = -12.83$, $p < .001$) and middle-aged adults ($M = .48$, $SD = .28$, $t = -4.54$, $p < .001$). Younger and older adult participants responded similarly; there was no interaction between age group and hypothetical age ($F < 1$).

Role of participants' knowledge Actual and estimated performance were correlated for younger ($r = .64$, $p < .001$) and older participants ($r = .82$, $p < .001$). We computed a linear mixed effect model with estimates of hypothetical others' knowledge as the outcome variable. Participants' age group (younger or older adult), estimates of their own performance, and target age (hypothetical younger, middle-aged, or older) were modeled as fixed effects. Participant was included as a random effect (random intercepts only). Participants' estimates of their own knowledge significantly predicted their estimates of others' knowledge: $b = .178$, $SE = .058$, $t = 3.06$, $p = .003$, 95% CI = [.061, .294]. Yet, the main effect of target age was significant as well ($b = -.116$, $SE = .014$, $t = -8.32$, $p < .001$, 95% CI = [-.141, -.086]). Participants' beliefs about their own knowledge influenced their estimates of others' knowledge, but so did the age of the hypothetical target.

General discussion

Across seven studies, younger and older participants predicted that older adults would outperform younger adults on general knowledge tests. These predictions held regardless of whether participants estimated knowledge of facts or vocabulary words and irrespective of the difficulty of the information. These beliefs accurately reflect the larger literature on the relative sparing of knowledge with age. There was no evidence of a negative halo effect involving aging and knowledge, in contrast to other well-documented beliefs about aging and memory.

The results show clear evidence for anchoring-and-adjustment when estimating the knowledge of others – and yet this mechanism cannot fully explain our results. Consistent with the Cue Utilization Model, participants relied on a second cue when estimating knowledge: the age of the hypothetical adult. These results show an awareness that healthy aging does not negatively impact the retrieval of stored knowledge. More generally, our work shows that age is a flexible cue that takes on different meanings in different contexts: it is associated with poorer performance in the episodic memory domain but better performance in the knowledge domain.

Practically, this work may inform research on stereotype threat in older adulthood. Positive and negative age stereotypes have wide-ranging effects on the behavioral outcomes of older adults (Meisner 2012). However, the effects of negative stereotypes are generally stronger than those of positive stereotypes. For example, negative aging stereotypes can influence performance on tasks that do not normally show age declines (i.e., arithmetic). Such negative inductions are typically multi-faceted, with task instructions that emphasize memory, speeded responding, and comparisons to younger adults (Nicolas et al. 2019). In contrast, positive inductions typically only rely on subliminal priming (e.g., Levy et al. 2000). Our research suggests a way to strengthen positive inductions, by explaining how both younger and older adults recognize that older adults know more. This instruction would not lessen age-related declines in episodic memory but rather might motivate older adults to perform to their full potential.

Older adults with positive perceptions of their own aging practice more preventative health behaviors (i.e., eating a balanced diet, exercising) (Levy and Myers, 2004), recover faster from disease (Levy et al. 2006), and have a longer lifespan (Levy et al. 2002) compared to those with negative perceptions of their own aging. It is our hope that endorsing the fact that adults of all ages are aware of older adults' knowledge advantage will help promote positive age self-perceptions and improve health outcomes for the older population.

Appendix

General Knowledge Questions

Easy

- What is the capital of France? (Paris)
- What is the name of the supposedly unsinkable ship that sunk on its maiden voyage in 1912? (Titanic)
- What is the name of the molten rock that runs down the side of a volcano during an eruption? (Lava)
- What is the name of the long sleep some animals go through during the entire winter? (Hibernation)
- What is the name of the severe headache that returns periodically and often is accompanied by nausea? (Migraine)
- What is the last name of the author who wrote "Romeo and Juliet"? (Shakespeare)
- What is the name of the remains of plants and animals that are found in stone? (Fossils)
- What is the rubber object that is hit back and forth by hockey players? (Puck)
- What precious gem is red? (Ruby)
- What is the name of a dried grape? (Raisin)

Medium

- What is the name of the legendary one-eyed giant in Greek mythology? (Cyclops)
- What is the name of the island city believed since antiquity to have sunk into the ocean (Atlantis)?
- What is the name of the lizard that changes its color to match the surroundings (Chameleon)
- Which sport is associated with Wimbeldon (Tennis)?
- What is the name of a dried plum? (Prune)
- In what sport is the Stanley Cup awarded? (Hockey)
- What is the name of the ship that carried the pilgrims to America in 1620? (Mayflower)
- What is the name of the thick layer of fat on a whale? (Blubber)
- What is the name of the navigation instrument used a sea to plot position relative to the magnetic north pole? (Compass)
- In what park is "Old Faithful" located? (Yellowstone)

Difficult

- What island is the largest in the world excluding Australia? (Greenland)
- What is the name of the lightest wood known? (Balsa)
- What is the last name of the artist who painted "Guernica"? (Picasso)
- In which city is the U.S. Naval Academy located? (Annapolis)
- What is the name of the small Japanese stove used for outdoor cooking? (Hibachi)
- What is the name of the North Star? (Polaris)
- Which country was the first to use gunpowder? (China)
- What is the name of the furry animal that attacks cobra snakes? (Mongoose)
- What sport uses the terms "stones" and "brooms"? (Curling)
- What was the name of the zeppelin that exploded in Lakehurst, NJ in 1937? (Hindenburg)

Vocabulary Words

Medium	Difficult
opulent	capricious
amicable	acerbic
superfluous	fetid
boisterous	droll
intrepid	bucolic
camaraderie	demur
abdicate	gossamer
jubilation	urbane
vindicate	indolence
corroborate	laconic

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