Psychology and Aging

Heuristic Decision-Making Across Adulthood

Morgan K. Taylor, Elizabeth J. Marsh, and Gregory R. Samanez-Larkin

Online First Publication, February 9, 2023. https://dx.doi.org/10.1037/pag0000726

AMERICAN PSYCHOLOGICAL ASSOCIATION

Psychology and Aging

ISSN: 0882-7974

https://doi.org/10.1037/pag0000726

Heuristic Decision-Making Across Adulthood

Morgan K. Taylor, Elizabeth J. Marsh, and Gregory R. Samanez-Larkin
Department of Psychology and Neuroscience, Duke University
Center for Cognitive Neuroscience, Duke University

In general, research on aging and decision-making has grown in recent years. Yet, little work has investigated how reliance on classic heuristics may differ across adulthood. For example, younger adults rely on the availability of information from memory when judging the relative frequency of plane crashes versus car accidents, but it is unclear if older adults are similarly reliant on this heuristic. In the present study, participants aged 20–90 years old made judgments that could be answered by relying on five different heuristics: anchoring, availability, recognition, representativeness, and sunk-cost bias. We found no evidence of age-related differences in the use of the classic heuristics—younger and older adults employed anchoring, availability, recognition, and representativeness to equal degrees in order to make decisions. However, replicating past work, we found age-related differences in the sunk-cost bias—older adults were more likely to avoid this fallacy compared to younger adults. We explain these different patterns by drawing on the distinctive roles that stored knowledge and personal experience likely play across heuristics.

Public Significance Statement
People often rely on shortcuts when making decisions. For example, they anchor on the asking price of a house when making an offer and overestimate the frequency of high-profile events like plane crashes. The present study demonstrates that older adults use these shortcuts at a similar rate as younger adults. This work highlights that certain decision-making strategies are preserved with age and is consistent with findings that semantic knowledge remains intact throughout older adulthood.

Keywords: heuristics, decision-making, knowledge, adulthood, life span

Supplemental materials: https://doi.org/10.1037/pag0000726.supp

Younger and older adults alike make many decisions on a daily basis. Some decisions (e.g., what to eat for breakfast, what to wear to work) are simple and require minimal effort, while others (e.g., where to invest your money, which medication to take) are more complex and tap into numerous cognitive resources. In the face of the aging population (Cire, 2016), researchers have begun to more closely examine how older adults make decisions, especially as they relate to the preservation or decline of various cognitive resources across adulthood (e.g., Finucane et al., 2002; Mata et al., 2015; Strough et al., 2020; Strough, Karns, & Schlosnagle, 2011). Much of this work has focused on older adults' use of simpler strategies or heuristic processing in general, but less published work has examined older adults' usage of classic heuristics (e.g., anchoring, availability), which younger adults often rely on to make decisions. Here, we investigate whether there are age-related differences in the use of four classic heuristics: anchoring, availability, recognition, and representativeness.

How can the existing literature on aging and decision-making inform whether there are adult age differences in classic heuristic use? In general, older adults' use of simpler decision strategies is well-documented. In a meta-analysis, Mata and Nunes (2010) found that compared to younger adults, older adults search for less information before making decisions. Older adults also favor smaller sets of options (Reed et al., 2008, 2013) and prefer to consider one important attribute (take-the-best) instead of several (weighted additive rule) when choosing between alternatives (Mata, 2007). These instances all reflect older adults' tendency to engage in satisficing behavior (Bruine de Bruin et al., 2016); they choose the option that is "good enough" for their purposes and not necessarily "the best" with respect to maximizing.

Researchers have proposed several explanations for why older adults rely on simpler strategies when making decisions. First, consistent with the theory of bounded rationality (Simon, 1990), older adults' declining fluid intelligence may leave them with fewer cognitive resources, making less demanding strategies appealing (Finucane et al., 2005). Supporting this idea, one study found that lower fluid cognitive ability mediated older adults' poorer performance on a battery of decision-making tasks (Adult Decision-Making Competence; Bruine de Bruin et al., 2012). Subsequent studies have documented associations between specific fluid and crystalized cognitive abilities and age-related differences in decision-making (for a review, see Strough et al., 2020). Second,

Morgan K. Taylor https://orcid.org/0000-0003-0628-2945
Morgan K. Taylor received funding from Grant 3980739 from the Charles Lafitte Foundation.

This work was previously presented at the 2022 Cognitive Aging Conference in Atlanta, Georgia. De-identified data are available at https://osf.io/pkhnd.
Correspondence concerning this article should be addressed to Morgan K. Taylor, Department of Psychology and Neuroscience, Duke University, 417 Chapel Drive, Durham, NC 27708, United States. Email: morgan.k.taylor@duke.edu

most laboratory decision-making tasks are hypothetical, and the choices made are often not meaningful outside of the lab; older adults may not be motivated to expend effort on these tasks because they are less relevant to their personal goals (Hess et al., 2013). On a more positive note, older adults have more knowledge and life experience, allowing them to adaptively adjust their decision-making strategies based on the context or environment (Mata, 2007; Queen et al., 2012).

Here, we make a distinction between using simplified strategies due to reductions in cognitive resources and using specific heuristics because they are cognitively efficient. Broadly, a heuristic is defined as "a strategy that ignores part of the information, with the goal of making decisions more quickly, frugally, and/or accurately than more complex methods" (Gigerenzer & Gaissmaier, 2011, p. 454). Classic work has highlighted many common heuristics and detailed how they may lead to biased and systematic errors (e.g., Tversky & Kahneman, 1974). Yet, more recent work contends that despite their occasional faults, heuristics can lead to more accurate inferences under uncertainty than more complicated strategies (Neth & Gigerenzer, 2015). Heuristics have developed and are continually used because they are simple, quick, and often yield accurate answers. Some research has focused on the development of such heuristics, examining differences in heuristic use in children and adolescents as compared to college-aged adults (e.g., Geurten et al., 2015; Jacobs & Potenza, 1991; Jetter & Walker, 2020). In contrast, there is a dearth of research on older adults' use of many of the classic heuristics outlined by Tversky and Kahneman (1974), even though adulthood provides many opportunities for individuals to learn that heuristics offer efficient ways to make good choices. As such, we predict that many common heuristics are implemented equally across the adult life span.

In this study, we examined the heuristics of anchoring, availability, recognition, and representativeness. We selected these heuristics because they are well known in the literature, remain highly cited (e.g., in 2021, there were 1,142 publications that cited; Tversky & Kahneman, 1974), and have few to no empirical studies conducted with older adults. In the anchoring heuristic, people make estimates by starting from an initial value and adjusting to the final answer. Different starting points garner different estimates, which are biased toward the initial values (e.g., participants' estimates of the percentage of African countries in the United Nations [25% vs. 45%] differed based on the initial value they were given [10% vs. 65%]; Tversky & Kahneman, 1974). Availability is used when the frequency or probability of an event is judged by the ease with which an example comes to mind (e.g., incorrectly estimating there are more R words in the English language because it is easier to recall words beginning with the letter R than words with R as their third letter; Tversky & Kahneman, 1974). In recognition, if one of two alternatives is recognized and the other is not, then one can infer that the recognized alternative has the higher value with respect to the criterion (e.g., incorrectly estimating that Minneapolis, Minnesota, has a higher population than Mesa, Arizona, because Minneapolis is the more familiar city; Pachur et al., 2009). Finally, representativeness involves evaluating the probability that something is true based on the degree to which one thing resembles another (e.g., assuming it is more likely that Steve, a shy, withdrawn man with a passion for detail, is a librarian instead of a salesman or physician; Tversky & Kahneman, 1974).

For comparison purposes, we also examined the sunk-cost fallacy, a bias where there are known adult age differences. People are said to be susceptible to the sunk-cost fallacy when they continue a behavior or action because of their previously invested resources (i.e., time, money, effort), even if the behavior or action is no longer rewarding (e.g., continuing to watch a movie you dislike because you already paid for the ticket; Arkes & Blumer, 1985). Studies have shown that older adults, perhaps due to their decreased time horizons, greater life experience, or improved emotion regulation, are less susceptible to the sunk-cost fallacy than younger adults (e.g., Bruine de Bruin et al., 2014; Strough et al., 2008, 2014).

To our knowledge, there is only one study on adult age differences in the availability heuristic (Maley et al., 2000), two studies on adult age differences in the recognition heuristic (Pachur et al., 2009), and no existing studies on adult age differences in either the anchoring heuristic or representativeness heuristic. None of these studies found age differences between younger and older adults, but their sample sizes were small ($n = 18$ per age group in Maley et al., 2000; an average of 50 per age group in Pachur et al., 2009). Of course, there may be many unpublished studies that examine adult age differences in heuristics; studies showing null effects are much more likely to be relegated to the file drawer. Yet, null effects of aging are not uninteresting, as it is important to understand what abilities are spared with age (Isaacowitz, 2020; Lakens et al., 2020). Null results in this case would suggest that heuristic use is preserved as one gets older. Such results would be consistent with findings that crystallized intelligence, or the accumulated knowledge one gains about the world through socialization, experience, and education, increases and stabilizes across the life span (Craik & Bialystok, 2006) and contributes to the preservation and/or improvement in decision-making with age (Samanez-Larkin & Knutson, 2015). However, more research is needed to corroborate this hypothesis.

In the present study, a sample of over 300 participants aged 20–90 years completed a series of tasks to clarify potential similarities or differences in heuristic use across adulthood. Heuristic use is automatic and widespread among younger adults—even among experts (e.g., Brannon & Carson, 2003; Englich et al., 2006)—leading us to predict that older adults should be at least as likely as younger adults to rely on heuristics. Given the few existing studies that found null age effects and the lack of specific theoretical predictions for increased reliance with age, we hypothesized that we would not find any age differences across adulthood in the use of anchoring, availability, recognition, and representativeness. To preview, we found support for our hypothesis—we found no evidence for adult age differences in the use of these classic heuristics. In contrast (and consistent with previous literature), we found age differences in the sunk-cost fallacy; younger adults were more susceptible to this bias than older adults.

Method

Transparency and Openness

We report how we determined our sample size and describe all manipulations and measures in the study. The de-identified data, materials, and analytic code are available on Open Science Framework (see https://osf.io/pkhnd). Data were analyzed using JASP, Version 0.16.2 (JASP Team, 2022). This study's design and analyses were not preregistered.

Table 1
Participant Demographics

Demographic information	Ages 20–39	Ages 40–59	Ages 60–79	Ages 80–90
Number of participants	87	88	87	46
Average age (*SD*)	31.02 (5.21)	48.83 (5.95)	67.55 (4.64)	83.02 (2.98)
Number of female|male	57|30	58|30	47|40	4|42
% White|African American|Latinx	35%|32%|33%	34%|32%|34%	35%|33%|32%	91%|7%|2%
Average years of education (*SD*)	14.55 (2.02)	14.25 (1.87)	14.69 (1.90)	15.39 (2.79)

Note. For simplicity, age is grouped into four categories above but is treated as continuous in analysis. Only the oldest age group (80–90) significantly differs from the others in gender, ethnicity, and years of education; these demographics are equivalent in all other age groups.

Participants

Three hundred eight participants (M_{age} = 54.20, SD = 18.99, range = 20–90, 166 female, 42.8% White, 29.2% African American, 28% Hispanic/Latinx) were recruited through Qualtrics Panels (see Table 1). We undersampled White participants and oversampled African American and Hispanic/Latinx participants in order to address historical exclusions of the latter populations in cognitive aging research and increase the generalizability of our findings. All participants were included in the analysis. Our sample size was calculated in G*Power to be able to identify small main effects of age (f^2 = .03) with 0.85 power using an α of .05. This effect size was based on previous studies that found age-related differences in the sunk-cost bias (e.g., Bruine de Bruin et al., 2014; Strough et al., 2008, 2016). This study was approved by the Duke University Health System's institutional review board (Protocol No. Pro00101720: Online Studies on Decision Making Across the Lifespan).

Materials

Three to six scenarios demonstrating each heuristic were adapted from various sources (see Appendix). As these heuristics are prompted in different ways across the literature, we included three instances of anchoring, availability, representativeness, and sunk-cost fallacy in order to capture a fuller range of heuristic responding. We included six instances of recognition to allow for three examples each of the disease prevalence and city population inference tasks (Pachur et al., 2009).

Anchoring Heuristic

We used scenarios listed in Furnham and Boo (2011): height of the tallest redwood tree, length of the Mississippi River, and gestation period of an African elephant. Participants first decided whether the height, length, or gestation period were greater than or less than the given anchor and then estimated the exact measure.

Availability Heuristic

Adapted from Tversky and Kahneman (1973), we used a shortened version of the "famous names problem" that was implemented in Braga et al. (2015). Sixteen names were given: five were famous men and one was a famous woman (e.g., David Beckham, Britney Spears). The other 10 names were taken from the 2011 census list of the most frequent U.S. names (e.g., Richard Miller, Sarah Wilson). After the names were listed in random order one by one, participants decided whether more men or women's names were presented (note: an equal number of men's and women's names were shown). We also used the letter likelihood scenario from Tversky and Kahneman (1974) for the letters R and K. Participants decided whether it was more likely that a randomly sampled English word started with the target letter or had the target letter as its third letter (the correct answer is the third letter, but it is easier to recall words that begin with the target letter).

Recognition Heuristic

We adapted the disease prevalence and city population inference tasks used in Pachur et al. (2009). Participants saw two options and chose the one they believed has higher prevalence in the United States (e.g., shigellosis vs. E. coli) or has the higher population (e.g., Dublin vs. Minsk), respectively. Choice of the more familiar option (i.e., E. coli or Dublin) would indicate use of the recognition heuristic.

Representativeness Heuristic

We used the Linda problem from Tversky and Kahneman (1983), the lawyer versus engineer base rate problem from Kahneman and Tversky (1973), and the marble problem from Kahneman and Tversky (1972). In the Linda problem, participants were given a description of Linda (e.g., bright, outspoken 31-year-old woman concerned with issues of social justice) and asked to indicate whether it is more probable that Linda is (a) a bank teller or (b) a bank teller that is active in the feminist movement. In the lawyer versus engineer problem, participants were told that 30 engineers and 70 lawyers were interviewed by psychologists. They then received one randomly chosen description of one of the interviewees (e.g., Jack has no political interests and enjoys carpentry and math puzzles) and were asked to predict the probability (0%–100%) that the man is an engineer. In the marble problem, five children are playing a game and 20 marbles are distributed randomly among them. Participants selected which of two distributions (Distribution A: 4, 4, 5, 4, 3; Distribution B: 4, 4, 4, 4, 4) was more likely to occur after several rounds of the game. In all scenarios, reliance on the representativeness heuristic means choosing the option that matches one's expectations (i.e., knowledge about the characteristics of lawyers vs. engineers) rather than focusing on the probabilities.

Sunk-Cost Fallacy

We used three scenarios adapted from Bruine de Bruin et al. (2014) and Strough et al. (2014) and participants decided on a scale from 1 = *most likely to stick with plans* to 6 = *most likely to cancel plans* how willing they were to forego their plans. For example, participants read a scenario about losing interest in a project and then rated their likelihood to continue or stop working on it.

Procedure

After providing informed consent, participants completed demographic information about their age, sex, education level, and ethnicity. They then completed three blocks of decision scenarios. Each block contained two recognition scenarios and one scenario tapping each of the following heuristics: sunk-cost bias, availability, representativeness, and anchoring. Presentation of each heuristic within a block was randomized and high versus low anchors were counterbalanced across participants. Finally, participants were asked seven open-ended response questions, including whether they looked up the answers to any questions and whether they had prior exposure to the scenarios used in the study. Then, for each of the five heuristics, participants were asked to describe what strategy they used to make their decision. Finally, participants were compensated for their participation directly through Qualtrics.

Results

Anchoring

First, we computed independent-samples t tests on participants' estimates to confirm that the items used in the study produced anchoring effects. Anchoring occurred when participants estimated the height of the tallest redwood tree and the length of the Mississippi River. The redwood tree was estimated as shorter ($M = 128$, $SD = 126$) when participants were given a low anchor (65 feet) versus a high anchor (500 feet; $M = 630$, $SD = 972$); $t(306) = -6.17$, $p < .001$, $d = -.71$. Similarly, the Mississippi River was estimated as shorter when participants were given a low anchor of 200 miles ($M = 939$, $SD = 1{,}729$) versus a high anchor of 20,000 miles ($M = 15{,}980$, $SD = 35{,}670$); $t(306) = -5.29$, $p < .001$, $d = -.60$. Participants did not show an anchoring effect when estimating the gestation period of an African elephant. Estimates were similar regardless of whether participants were given a low anchor (12 months; $M = 23.7$, $SD = 45.1$) or high anchor (32 months; $M = 25.2$, $SD = 12.1$); $t(306) = -.388$, $p = .698$, $d = -.044$.

Next, we put participants' estimates on the same scale by calculating the absolute proportional difference from the anchor. That is, we computed the absolute difference between the estimate and the anchor and divided it by the anchor. For completeness, we report the age effect results for the two items that showed anchoring and the one that did not separately below.

Height of Tallest Redwood Tree and Length of Mississippi River

To evaluate the effect of age on the use of anchoring, we computed a repeated-measures analysis of covariance (ANCOVA), with item (redwood height, Mississippi River length) as a within-subject factor and age (continuous) as a between-subject factor. The main effect of age was nonsignificant, $F(1, 305) = .034$, $p = .854$, as was the age by item interaction, $F(1, 305) = .000002$, $p = .999$, $\eta_p^2 < .001$. In other words, the degree of difference between estimates and their anchors did not vary based on age. The age effect remained nonsignificant after controlling for sex, ethnicity, and education, $F(1, 301) = .297$, $p = .586$.

Gestation Period of an African Elephant

Evaluating age effects for a single item eliminated the need for a categorical item factor, so we computed a simple linear regression. There was a nonsignificant main effect of age ($b = -.012$, 95% CI = [−.027, .004], $t = -1.48$, $p = .140$) which remained nonsignificant after controlling for sex, ethnicity, and education ($b = -.008$, 95% CI = [−.025, .009], $t = -.951$, $p = .342$). See Figure 1, for the age effects of each anchoring item separately.

Availability

A score of 1 was assigned to responses that followed the availability heuristic (i.e., selected that more men's names were presented in the list, selected first letter in a word). A score of 0 was assigned to responses that did not follow this heuristic. On average, participants chose the more available option over half of the time ($M = 59\%$, $SD = 35\%$). To evaluate the effect of age on the use of availability, we computed a repeated-measures ANCOVA, with item as a within-subject factor and age as a continuous between-subject factor. We found a small item by age interaction, $F(2, 612) = 3.17$, $p = .043$, $\eta_p^2 = .01$, driven by a positive relationship between age and heuristic use in the R letter likelihood scenario, $r(306) = .12$, $p = .036$. However, this interaction was not robust and did not remain significant after controlling for sex, ethnicity, and education, $F(2, 604) = 1.18$, $p = .309$, $\eta_p^2 = .004$. The main effect of age was nonsignificant, $F(1, 306) = .389$, $p = .533$, and remained nonsignificant after controlling for sex, ethnicity, and education, $F(1, 302) = .0006$, $p = .981$.

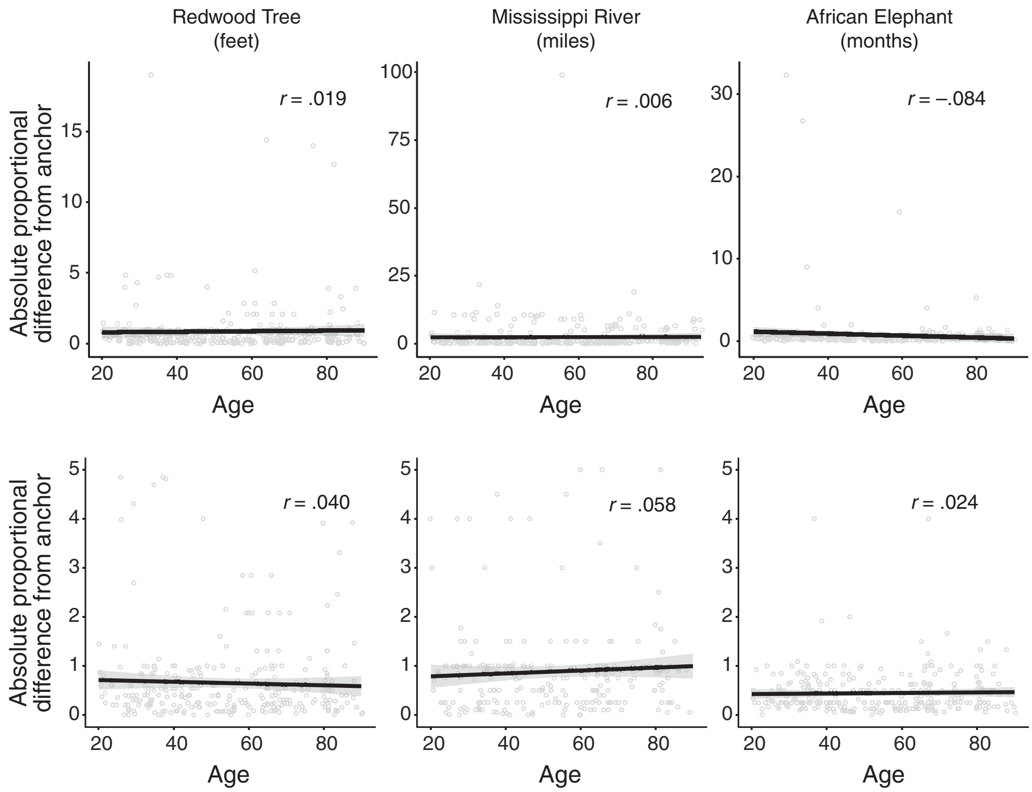
Recognition

A score of 1 was assigned to responses that followed the recognition heuristic (e.g., selected Dublin—the more familiar option—even though Minsk has the higher population). A score of 0 was assigned to responses that did not follow this heuristic. On average, participants chose the more familiar option most of the time ($M = 77\%$, $SD = 19\%$). To evaluate the effect of age on the use of recognition, we computed a repeated-measures ANCOVA, with item as a within-subject factor and age as a continuous between-subject factor. The main effect of age was nonsignificant, $F(1, 306) = .434$, $p = .511$, and there was no item-level interaction with age, $F(1, 306) = .018$, $p = .894$, $\eta_p^2 < .001$. The age effect remained nonsignificant after controlling for sex, ethnicity, and education, $F(1, 302) = .013$, $p = .909$.

Representativeness

The representativeness scenarios used different scales, in that the Linda and marble problems require a binary choice and the lawyer versus engineering problem involves generating a percentage. To put all responses on the same scale, answers of 40% and above in the lawyer versus engineer problem were counted as heuristic responses. The correct percentage is 30% as there were 30 engineers

Figure 1
Anchoring Results



Note. The absolute proportional difference between participants' estimates and the anchors they were given for height of the tallest redwood tree (left), length of the Mississippi River (middle), and gestation period of an African elephant (right) did not differ across age groups. The top row includes all data points. The bottom row shows that the pattern of results is unchanged even after matching the ranges for absolute proportional difference by removing extreme values. In all plots, zero indicates estimates that were equal to the anchors provided. Plots depict simple regression lines with 95% confidence intervals (gray bands) and correlations (*r*) between age and anchoring use; analyses controlling for covariates are reported in the text.

in the sample. Technically, a response of 31% or higher suggests heuristic responding, but we chose 40% to select a value that is meaningfully different from 30%. Using a stricter cutoff (i.e., 35%) did not change the results. Across tasks, representative responses (i.e., selecting that Linda is a bank teller and feminist, selecting marble Distribution A) were scored as 1, and nonrepresentative responses were scored as 0. On average, participants chose the more representative option most of the time ($M = 76\%$, $SD = 24\%$). To evaluate the effect of age on the use of representativeness, we computed a repeated-measures ANCOVA, with item as a within-subject factor and age as a continuous between-subject factor. The main effect of age was nonsignificant, $F(1, 306) = .545$, $p = .461$, and there was no item-level interaction with age, $F(2, 612) = 2.28$, $p = .103$, $\eta_p^2 = .007$. The age effect remained nonsignificant after controlling for sex, ethnicity, and education, $F(1, 302) = .039$, $p = .843$ (see Figure 2 for availability, recognition, and representativeness results).

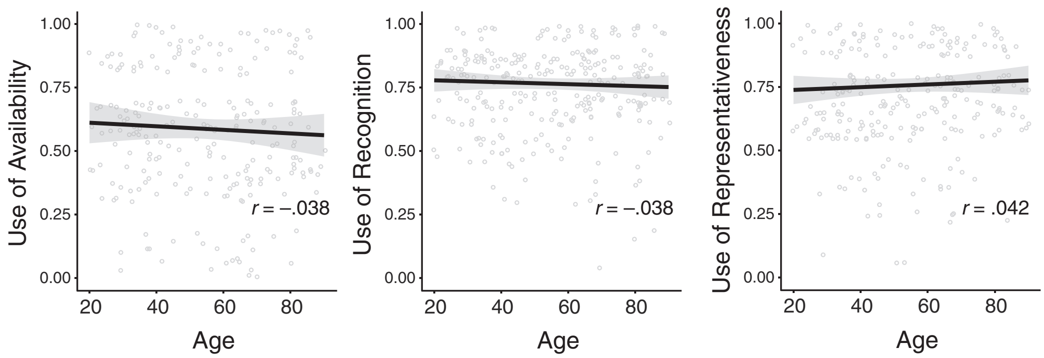
Bayesian Analyses of Age Differences in Anchoring, Availability, Recognition, and Representativeness

To assess the relative evidence in support of the null or alternative hypotheses, we conducted simple Bayesian linear regressions. Age was included as a predictor of anchoring, availability, recognition, and representativeness heuristic use. Consistent with our frequentist results, we found moderate evidence in favor of the null hypothesis ($BF_{01} > 6$), indicating that the data are at least six times more representative of the null hypothesis (there are no age-related differences in heuristic use) versus the alternate hypothesis (there are age-related differences in heuristic use). See Supplemental Table 2, for full results.

Sunk-Cost Fallacy

Across scenarios, participants were slightly likely to cancel plans (3.73 on a scale of 1–6; $SD = 1.16$). To evaluate the effect of age on the use of the sunk-cost fallacy, we computed a repeated-measures ANCOVA, with item as a within-subject factor and age as a continuous between-subject factor. There was no item-level interaction with age, $F(2, 612) = 1.44$, $p = .238$, $\eta_p^2 = .005$. However, there was a significant main effect of age, $F(1, 306) = 4.55$, $p = .034$ (see Figure 3). Simple linear regression confirmed that age significantly predicted avoidance of the sunk-cost fallacy—as age increased, so did the likelihood that participants would forego their plans ($b = .007$, 95% CI = [.0006, .014], $SE = .003$, $t = 2.13$,

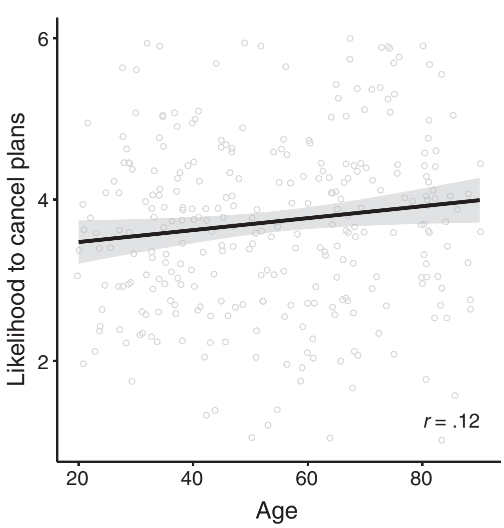
Figure 2
Availability, Recognition, and Representativeness Results



Note. Participants' average use of the availability heuristic (left), recognition heuristic (middle), and representativeness heuristic (right) across different scenarios did not differ across age groups. Plots depict simple regression lines with 95% confidence intervals (gray bands) and correlations (r) between age and heuristic use; analyses controlling for covariates are reported in the text.

$p = .034$). The age effect was not significant after controlling for sex, ethnicity, and education ($b = .007$, 95% CI = [–.0005, .014], $SE = .004$, $t = 1.84$, $p = .067$). However, the point estimate was identical, and the confidence interval was highly overlapping with the simple age effect. This effect is similar in size to what has been reported in previous studies that found age-related differences in the sunk-cost bias (Bruine de Bruin et al., 2014; Strough et al., 2016). Simple Bayesian linear regression found evidence in favor of the alternate hypothesis ($BF_{10} > 1$), indicating that the data are relatively more representative of the alternate hypothesis (there are age-related differences in the sunk-cost bias) versus the null hypothesis (there are no age-related differences in the sunk-cost bias). See Supplemental Table 3, for full results.

Figure 3
Sunk Cost Fallacy Results



Note. Age-related differences in participants' likelihood to cancel plans on a scale of 1 (*most likely to stick with plans*) to 6 (*most likely to cancel plans*). Plot depicts simple regression line with 95% confidence interval (gray band) and correlation (r) between age and avoidance of the sunk-cost fallacy; analyses controlling for covariates are reported in the text.

General Discussion

In this study, we found that classic heuristic use was common across adults of all ages. Age did not significantly impact (a) how far participants' estimates were from the anchors they were given (anchoring heuristic), (b) how often participants chose the more accessible option of a pair (availability heuristic), (c) how often participants chose the more familiar option of a pair (recognition heuristic), and (d) how often participants chose the option that most closely resembled a target description (representativeness heuristic). However, there were age-related differences in the sunk-cost bias. Older adults were more likely to avoid this fallacy and chose to forego their plans more often than younger adults.

Although the age difference in the sunk-cost fallacy is small, it is consistent with others in the literature. One possible explanation for age-related differences in this heuristic and not the others may be related to learning that occurs across the life span. The longer one lives, the more opportunities one has to learn that persistence is not always worthwhile. In fact, several studies have suggested that age-related improvements in the sunk-cost bias are related to affect and experience (Bruine de Bruin et al., 2007, 2012; Bruine de Bruin et al., 2014). And while self-reports should be taken with caution, 78% of participants reported that they relied on life experiences while rating their likelihood to cancel plans (see Supplemental Table 1). These findings are in line with research that suggests that age-related differences in certain decision-making tasks may be related to age-related differences in fluid and crystalized cognitive abilities. Similar to the sunk-cost fallacy, some tasks (e.g., making internally consistent probabilistic judgments of getting into a car accident vs. driving accident free) rely more on crystallized capabilities that improve with age, while other tasks (e.g., applying designated decision strategies when choosing between multiple products) rely more on fluid capabilities that decrease with age (Bruine de Bruin et al., 2012; Del Missier et al., 2013; Li et al., 2013; Strough, Karns, & Schlosnagle, 2011). Prior researchers have speculated about the role of age-related differences in specific fluid and crystalized abilities (Agarwal et al., 2009) or cognitive and affective abilities (Peters et al., 2007) in decision-making across adulthood, yet relatively few studies (e.g., Li et al., 2013, 2015) have directly measured multiple domains of cognitive (fluid and crystalized) or affective abilities across adulthood to confirm that they specifically account for age-related variance in choice (see review in Strough et al., 2020).

In contrast to life experience reducing susceptibility to the sunk-cost fallacy, experience might preserve the use of the classic heuristics because they often lead to the correct answer (Gigerenzer & Gaissmaier, 2011). Heuristics are shortcuts that reflect a common state of the world: in most cases, more populous cities are mentioned in the news, learned about in schools, and are common travel destinations. Thus, using the cue of familiarity would typically lead one to choose the correct answer. Even experts use these heuristics, although sometimes to a lesser degree. One review found that auditors tended to respond heuristically (e.g., use anchors, neglect base rates) in neutral tasks, but this behavior was mitigated in familiar and job-related tasks (Smith & Kida, 1991). Yet, some experts in other domains (e.g., real estate agents, legal professionals, nurses) are still susceptible to heuristic responding even when making decisions in their area of expertise (Brannon & Carson, 2003; Englich et al., 2006; Northcraft & Neale, 1987). Related work in finance reveals that the use of heuristic-like rules of thumb may increase with age as investors gain more experience (Korniotis & Kumar, 2011). Together these studies highlight the pervasive nature of heuristic use even after significant domain-specific experience.

Some views contend that we use heuristics to reduce effort, especially in the face of capacity limitations (e.g., limited time, motivation; Shah & Oppenheimer, 2008). With even fewer cognitive resources, older adults might be expected to be more likely to use heuristics. However, many of the cognitive mechanisms proposed to underlie these heuristics do not show declines with age. More specifically, accrued knowledge about the world plays a role in all of the heuristics that did not show age effects. Availability effects are linked to the ease with which information is retrieved from memory (Tversky & Kahneman, 1974). To the extent that the task is asking people to retrieve from semantic memory, we would not expect age-related differences. Older adults generate category examples at the same rate as younger adults (Light & Albertson, 1989), so we would expect them to be similarly able to generate words starting with K or with K as its third letter. The recognition heuristic also draws on stored knowledge. People rely on a global sense of familiarity as a way of choosing their answer (Pachur & Hertwig, 2006). The relative familiarity of two diseases or cities should not differ as a function of age given the obscurity of the unfamiliar option (Pachur et al., 2009). Finally, the representativeness heuristic draws on well-learned schemas and depends on the degree of similarity between the target person/event/sample and the population from which it is drawn (Galavotti et al., 2021). Schematic knowledge is preserved in healthy aging and is believed to be a major aid to memory when episodic details are forgotten (Siegel et al., 2020). Informally, participants reported drawing on their knowledge to solve all of these decision scenarios, especially the recognition (65%) and representativeness heuristic scenarios (66%; see Supplemental Table 1).

In contrast, it is less clear what role knowledge plays in the anchoring heuristic. Plausible anchors are more likely to sway decisions (Sugden et al., 2013), but specific expertise in a domain may reduce reliance on anchors altogether (Smith et al., 2013). In the present case, we do not have any reason to believe there are age-related differences in specific knowledge of the height and length of the tallest redwood tree or Mississippi River, respectively; thus, it is not surprising that we did not find age-related differences in anchoring.

These results are unlikely to be attributable to the online nature of the study. Paralleling earlier articles showing similar results across laboratory and Amazon Mechanical Turk samples (see Buhrmester et al., 2018, for review), research is now emerging, showing similar adult age effects across in-person and online samples from various data collection platforms (e.g., Greene & Naveh-Benjamin, 2022; Seaman et al., 2023). Furthermore, we found an age difference in the sunk-cost fallacy using our online sample, replicating an effect observed numerous times in the laboratory (Strough et al., 2008; Strough, Schlosnagle, & DiDonato, 2011). More generally, older adults have been the fastest growing users of the internet for over a decade, with the gap between younger and older adults' smartphone, tablet, and internet usage steadily decreasing over time (Faverio, 2022). Thus, aging samples in online studies are likely becoming more representative of the general aging population.

Future studies should address some of our limitations. While we attempted to recruit a diverse set of participants, this sample was not nationally representative, especially in the oldest-old group of 80- to 90-year olds, so our findings may differ when including people from other ethnic and educational backgrounds (though we note we have no specific predictions about how heuristic use might vary as a function of these factors). Additionally, Qualtrics Panels was unable to provide us with the number of invited individuals who did not participate, thus underlying differences may exist between those who participated and those who did not. This study was also cross-sectional instead of longitudinal, so age differences may reflect cohort differences instead of changes with age. However, it is not clear exactly what cohort difference might be predicted to explain these effects. Finally, and perhaps most importantly, the heuristic tasks used hypothetical scenarios; it is possible that participants' responses to these scenarios do not reflect their real-world decision-making. This concern is especially valid for older adults; in other domains (e.g., prospective memory), it has been shown that older adults behave differently in laboratory studies than they would in everyday life (e.g., Henry et al., 2004; Rendell & Thomson, 1999).

Moving forward, an interesting future direction for this research would be to explore whether these results would extend to individuals with age-related diseases. To the extent that cognitive impairment is mild and semantic knowledge is intact, we would not expect there to be differences in heuristic use between healthy and clinical populations. However, if a breakdown of semantic processing does occur, as is believed to be the case in Alzheimer's disease (AD; Verma & Howard, 2012), then we would expect to see differences from healthy controls. AD populations may have deficits in heuristic use because they are not readily able to rely on their semantic knowledge. For example, Balthazar et al. (2008) found that patients with amnesiac mild cognitive impairment performed normally on the Boston Naming Test, a semantic assessment that asks participants to name line drawings of objects of increasing difficulty (2008). Mild AD patients performed significantly worse on the Boston Naming Test but were able to boost their performance to that of amnesiac mild cognitive impairment patients and healthy controls after they were given semantic (i.e., a short explanation of the picture) and phonemic (i.e., the first phonemes of the target word) cues upon making a naming error. Thus, we can speculate that people with mild cognitive impairment, but not AD, would use heuristics to the same degree as healthy controls. People with AD may need certain cues and nudges in order to use heuristics effectively.

Overall, we believe it is important to highlight the skills and abilities that are preserved in healthy aging. Null age effects should not automatically be relegated to the file drawer; they may reveal something significant about the preservation of certain aspects of human cognition with age (Isaacowitz, 2020; Lakens et al., 2020). For example, the current work suggests that adaptive strategies like heuristics are used consistently throughout the adult life span; older adults are not more likely to use them than younger adults. These results challenge some earlier speculation that older adults might be more reliant on heuristic processing compared to their younger counterparts (Peters et al., 2000) and identify yet another preserved aspect of cognition in healthy aging. In fact, related prior research has shown that the simplifying decision strategies of older adults produce high-quality decisions in everyday life (Mata & Nunes, 2010). More generally, knowledge about what is preserved across adulthood could be useful when developing tools and strategies for optimizing older adults' decision-making.

References

Agarwal, S., Driscoll, J. C., Gabaix, X., Laibson, D., & Papers, B. (2009). The age of reason: Financial decisions over the life cycle and implications for regulation. *Brookings Papers on Economic Activity*, *2009*(2), 51–117. https://doi.org/10.1353/eca.0.0067

Arkes, H. R., & Blumer, C. (1985). The psychology of sunk cost. *Organizational Behavior and Human Decision Processes*, *35*(1), 124–140. https://doi.org/10.1016/0749-5978(85)90049-4

Balthazar, M. L. F., Cendes, F., & Damasceno, B. P. (2008). Semantic error patterns on the Boston Naming Test in normal aging, amnestic mild cognitive impairment, and mild Alzheimer's disease: Is there semantic disruption? *Neuropsychology*, *22*(6), 703–709. https://doi.org/10.1037/a0012919

Braga, J. N., Ferreira, M. B., & Sherman, S. J. (2015). The effects of construal level on heuristic reasoning: The case of representativeness and availability. *Decision*, *2*(3), 216–227. https://doi.org/10.1037/dec0000021

Brannon, L. A., & Carson, K. L. (2003). The representativeness heuristic: Influence on nurses' decision making. *Applied Nursing Research*, *16*(3), 201–204. https://doi.org/10.1016/S0897-1897(03)00043-0

Bruine de Bruin, W., Parker, A. M., & Fischhoff, B. (2007). Individual differences in adult decision-making competence. *Journal of Personality and Social Psychology*, *92*(5), 938–956. https://doi.org/10.1037/0022-3514.92.5.938

Bruine de Bruin, W., Parker, A. M., & Fischhoff, B. (2012). Explaining adult age differences in decision-making competence. *Journal of Behavioral Decision Making*, *25*(4), 352–360. https://doi.org/10.1002/bdm.712

Bruine de Bruin, W., Parker, A. M., & Strough, J. (2016). Choosing to be happy? Age differences in "maximizing" decision strategies and experienced emotional well-being. *Psychology and Aging*, *31*(3), 295–300. https://doi.org/10.1037/pag0000073

Bruine de Bruin, W., Strough, J., & Parker, A. M. (2014). Getting older isn't all that bad: Better decisions and coping when facing "sunk costs". *Psychology and Aging*, *29*(3), 642–647. https://doi.org/10.1037/a0036308

Buhrmester, M. D., Talaifar, S., & Gosling, S. D. (2018). An evaluation of Amazon's Mechanical Turk, its rapid rise, and its effective use. *Perspectives on Psychological Science*, *13*(2), 149–154. https://doi.org/10.1177/1745691617706516

Cire, B. (2016). *World's older population grows dramatically*. National Institute on Aging. https://www.nia.nih.gov/news/worlds-older-population-grows-dramatically#:~:text

Craik, F. I. M., & Bialystok, E. (2006). Cognition through the lifespan: Mechanisms of change. *Trends in Cognitive Sciences*, *10*(3), 131–138. https://doi.org/10.1016/j.tics.2006.01.007

Del Missier, F., Mäntylä, T., Hansson, P., Bruine de Bruin, W., Parker, A. M., & Nilsson, L. G. (2013). The multifold relationship between memory and decision making: An individual-differences study. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *39*(5), 1344–1364. https://doi.org/10.1037/a0032379

Englich, B., Mussweiler, T., & Strack, F. (2006). Playing dice with criminal sentences: The influence of irrelevant anchors on experts' judicial decision making. *Personality and Social Psychology Bulletin*, *32*(2), 188–200. https://doi.org/10.1177/0146167205282152

Faverio, M. (2022, January 13). *Share of tech users among Americans 65 and older grew in past decade*. Pew Research Center. https://www.pewresearch.org/fact-tank/2022/01/13/share-of-those-65-and-older-who-are-tech-users-has-grown-in-the-past-decade/

Finucane, M. L., Mertz, C. K., Slovic, P., & Schmidt, E. S. (2005). Task complexity and older adults' decision-making competence. *Psychology and Aging*, *20*(1), 71–84. https://doi.org/10.1037/0882-7974.20.1.71

Finucane, M. L., Slovic, P., Hibbard, J. H., Peters, E., Mertz, C. K., & MacGregor, D. G. (2002). Aging and decision-making competence: An analysis of comprehension and consistency skills in older versus younger adults considering health-plan options. *Journal of Behavioral Decision Making*, *15*(2), 141–164. https://doi.org/10.1002/bdm.407

Furnham, A., & Boo, H. C. (2011). A literature review of the anchoring effect. *Journal of Socio-Economics*, *40*(1), 35–42. https://doi.org/10.1016/j.socec.2010.10.008

Galavotti, I., Lippi, A., & Cerrato, D. (2021). The representativeness heuristic at work in decision-making: Building blocks and individual-level cognitive and behavioral factors. *Management Decision*, *59*(7), 1664–1683. https://doi.org/10.1108/MD-10-2019-1464

Geurten, M., Willems, S., Germain, S., & Meulemans, T. (2015). Less is more: The availability heuristic in early childhood. *British Journal of Developmental Psychology*, *33*(4), 405–410. https://doi.org/10.1111/bjdp.12114

Gigerenzer, G., & Gaissmaier, W. (2011). Heuristic decision making. *Annual Review of Psychology*, *62*(1), 451–482. https://doi.org/10.1146/annurev-psych-120709-145346

Greene, N. R., & Naveh-Benjamin, M. (2022). Online experimentation and sampling in cognitive aging research. *Psychology and Aging*, *37*(1), 72–83. https://doi.org/10.1037/pag0000655

Henry, J. D., MacLeod, M. S., Phillips, L. H., & Crawford, J. R. (2004). A meta-analytic review of prospective memory and aging. *Psychology and Aging*, *19*(1), 27–39. https://doi.org/10.1037/0882-7974.19.1.27

Hess, T. M., Queen, T. L., & Ennis, G. E. (2013). Age and self-relevance effects on information search during decision making. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *68*(5), 703–711. https://doi.org/10.1093/geronb/gbs108

Isaacowitz, D. M. (2020). Doing more with null age effects: Introduction to the special section. *The Journals of Gerontology: Series B*, *75*(1), 42–44. https://doi.org/10.1093/geronb/gbz123

Jacobs, J. E., & Potenza, M. (1991). The use of judgement heuristics to make social and object decisions: A developmental perspective. *Child Development*, *62*(1), 166–178. https://doi.org/10.1111/j.1467-8624.1991.tb01522.x

JASP Team. (2022). *JASP* (Version 0.16.2) [Computer software]. https://jasp-stats.org/

Jetter, M., & Walker, J. K. (2020). At what age does the anchoring heuristic emerge? Evidence from Jeopardy! *Journal of Economic Behavior & Organization*, *179*, 757–766. https://doi.org/10.1016/j.jebo.2019.08.017

Kahneman, D., & Tversky, A. (1972). Subjective probability: A judgment of representativeness. *Cognitive Psychology*, *3*(3), 430–454. https://doi.org/10.1016/0010-0285(72)90016-3

Kahneman, D., & Tversky, A. (1973). On the psychology of prediction. *Psychological Review*, *80*(4), 237–251. https://doi.org/10.1037/h0034747

Korniotis, G. M., & Kumar, A. (2011). Do older investors make better Investment decisions? *The Review of Economics and Statistics*, *93*(1), 244–265. https://doi.org/10.1162/REST_a_00053

Lakens, D., McLatchie, N., Isager, P. M., Scheel, A. M., & Dienes, Z. (2020). Improving inferences about null effects with Bayes factors and equivalence tests. *The Journals of Gerontology: Series B*, *75*(1), 45–57. https://doi.org/10.1093/geronb/gby065

Li, Y., Baldassi, M., Johnson, E. J., & Weber, E. U. (2013). Complementary cognitive capabilities, economic decision making, and aging. *Psychology and Aging*, *28*(3), 595–613. https://doi.org/10.1037/a0034172

Li, Y., Gao, J., Enkavi, A. Z., Zaval, L., Weber, E. U., & Johnson, E. J. (2015). Sound credit scores and financial decisions despite cognitive aging. *Proceedings of the National Academy of Sciences of the United States of America*, *112*(1), 65–69. https://doi.org/10.1073/pnas.1413570112

Light, L. L., & Albertson, S. A. (1989). Direct and indirect tests of memory for category exemplars in young and older adults. *Psychology and Aging*, *4*(4), 487–492. https://doi.org/10.1037/0882-7974.4.4.487

Maley, J. E., Hunt, M., & Parr, W. (2000). Set-size and frequency-of-occurrence judgements in young and older adults: The role of the availability heuristic. *Quarterly Journal of Experimental Psychology A: Human Experimental Psychology*, *53*(1), 247–269. https://doi.org/10.1080/713755883

Mata, R. (2007). Understanding the aging decision maker. *Human Development*, *50*(6), 359–366. https://doi.org/10.1159/000109836

Mata, R., Josef, A. K., & Lemaire, P. (2015). Adaptive decision making and aging. In T. M. Hess, J. Strough, & C. E. Lockenhoff (Eds.), *Aging and decision making: Empirical and applied perspectives* (pp. 105–126). Academic Press. https://doi.org/10.1016/B978-0-12-417148-0.00006-6

Mata, R., & Nunes, L. (2010). When less is enough: Cognitive aging, information search, and decision quality in consumer choice. *Psychology and Aging*, *25*(2), 289–298. https://doi.org/10.1037/a0017927

Neth, H., & Gigerenzer, G. (2015). Heuristics: Tools for an uncertain world. In R. Scott & S. Kosslyn (Eds.), *Emerging trends in the social and behavioral sciences* (pp. 1–18). Wiley. https://doi.org/10.1002/9781118900772.etrds0394

Northcraft, G. B., & Neale, M. A. (1987). Experts, amateurs, and real estate: An anchoring-and-adjustment perspective on property pricing decisions. *Organizational Behavior and Human Decision Processes*, *39*(1), 84–97. https://doi.org/10.1016/0749-5978(87)90046-X

Pachur, T., & Hertwig, R. (2006). On the psychology of the recognition heuristic: Retrieval primacy as a key determinant of its use. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *32*(5), 983–1002. https://doi.org/10.1037/0278-7393.32.5.983

Pachur, T., Mata, R., & Schooler, L. J. (2009). Cognitive aging and the adaptive use of recognition in decision making. *Psychology and Aging*, *24*(4), 901–915. https://doi.org/10.1037/a0017211

Peters, E., Finucane, M. L., MacGregor, D. G., & Slovic, P. (2000). The bearable lightness of aging: Judgment and decision processes in older adults. In P. C. Stern & L. L. Carstensen (Eds.), *The aging mind: Opportunities in cognitive research* (pp. 144–165). National Academy Press. https://www.ncbi.nlm.nih.gov/books/NBK44836/

Peters, E., Hess, T. M., Västfjäll, D., & Auman, C. (2007). Adult age differences in dual Information processes: Implications for the role of affective and deliberative processes in older adults' decision making. *Perspectives on Psychological Science*, *2*(1), 1–23. https://doi.org/10.1111/j.1745-6916.2007.00025.x

Queen, T. L., Hess, T. M., Ennis, G. E., Dowd, K., & Grühn, D. (2012). Information search and decision making: Effects of age and complexity on strategy use. *Psychology and Aging*, *27*(4), 817–824. https://doi.org/10.1037/a0028744

Reed, A. E., Mikels, J. A., & Löckenhoff, C. E. (2013). Preferences for choice across adulthood: Age trajectories and potential mechanisms. *Psychology and Aging*, *28*(3), 625–632. https://doi.org/10.1037/a0031399

Reed, A. E., Mikels, J. A., & Simon, K. I. (2008). Older adults prefer less choice than young adults. *Psychology and Aging*, *23*(3), 671–675. https://doi.org/10.1037/a0012772

Rendell, P. G., & Thomson, D. M. (1999). Aging and prospective memory: Differences between naturalistic and laboratory tasks. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *54*(4), 256–269. https://doi.org/10.1093/geronb/54B.4.P256

Samanez-Larkin, G. R., & Knutson, B. (2015). Decision making in the ageing brain: Changes in affective and motivational circuits. *Nature Reviews Neuroscience*, *16*(5), 278–289. https://doi.org/10.1038/nrn3917

Seaman, K. L., Juarez, E. J., Troutman, A., Salerno, J. M., Samanez-Larkin, S. P., & Samanez-Larkin, G. R. (2023). Decision making across adulthood during physical distancing. *Neuropsychology, Development, and Cognition. Section B, Aging, Neuropsychology and Cognition*, *30*(1), 53–65. https://doi.org/10.1080/13825585.2021.1962793

Shah, A. K., & Oppenheimer, D. M. (2008). Heuristics made easy: An effort-reduction framework. *Psychological Bulletin*, *134*(2), 207–222. https://doi.org/10.1037/0033-2909.134.2.207

Siegel, A. L. M., Whatley, M. C., Hargis, M. B., & Castel, A. D. (2020). Changes in memory and metacognition in older adulthood. In A. Drolet & C. Yoon (Eds.), *The aging consumer: Perspectives from psychology and marketing* (2nd ed., pp. 26–46). Routledge. https://doi.org/10.4324/9780429343780-3

Simon, H. A. (1990). Bounded rationality. In J. Eatwell, M. Milgate, & P. Newman (Eds.), *Utility and probability* (pp. 15–18). Palgrave Macmillan. https://doi.org/10.1007/978-1-349-20568-4_5

Smith, A. R., Windschitl, P. D., & Bruchmann, K. (2013). Knowledge matters: Anchoring effects are moderated by knowledge level. *European Journal of Social Psychology*, *43*(1), 97–108. https://doi.org/10.1002/ejsp.1921

Smith, J. F., & Kida, T. (1991). Heuristics and biases: Expertise and task realism in auditing. *Psychological Bulletin*, *109*(3), 472–489. https://doi.org/10.1037/0033-2909.109.3.472

Strough, J., Bruine de Bruin, W., Parker, A. M., Karns, T., Lemaster, P., Pichayayothin, N., Delaney, R., & Stoiko, R. (2016). What were they thinking? Reducing sunk-cost bias in a life-span sample. *Psychology and Aging*, *31*(7), 724–736. https://doi.org/10.1037/pag0000130

Strough, J., Karns, T. E., & Schlosnagle, L. (2011). Decision-making heuristics and biases across the life span. *Annals of the New York Academy of Sciences*, *1235*(1), 57–74. https://doi.org/10.1111/j.1749-6632.2011.06208.x

Strough, J., Mehta, C. M., McFall, J. P., & Schuller, K. L. (2008). Are older adults less subject to the sunk-cost fallacy than younger adults? *Psychological Science*, *19*(7), 650–652. https://doi.org/10.1111/j.1467-9280.2008.02138.x

Strough, J., Schlosnagle, L., & DiDonato, L. (2011). Understanding decisions about sunk costs from older and younger adults' perspectives. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *66*(6), 681–686. https://doi.org/10.1093/geronb/gbr057

Strough, J., Schlosnagle, L., Karns, T., Lemaster, P., & Pichayayothin, N. (2014). No time to waste: Restricting life-span temporal horizons decreases the sunk-cost fallacy. *Journal of Behavioral Decision Making*, *27*(1), 78–94. https://doi.org/10.1002/bdm.1781

Strough, J., Wilson, J., & Bruine de Bruin, W. (2020). Aging and financial decision making. In T. Zaleskiewicz & J. Traczyk (Eds.), *Psychological perspectives on financial decision making* (pp. 167–186). Springer. https://doi.org/10.1007/978-3-030-45500-2_8

Sugden, R., Zheng, J., & Zizzo, D. J. (2013). Not all anchors are created equal. *Journal of Economic Psychology*, *39*, 21–31. https://doi.org/10.1016/j.joep.2013.06.008

Tversky, A., & Kahneman, D. (1973). Availability: A heuristic for judging frequency and probability. *Cognitive Psychology*, *5*(2), 207–232. https://doi.org/10.1016/0010-0285(73)90033-9

Tversky, A., & Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases. *Science*, *185*(4157), 1124–1131. https://doi.org/10.1126/science.185.4157.1124

Tversky, A., & Kahneman, D. (1983). Extensional versus intuitive reasoning: The conjunction fallacy in probability judgment. *Psychological Review*, *90*(4), 293–315. https://doi.org/10.1037/0033-295X.90.4.293

Verma, M., & Howard, R. J. (2012). Semantic memory and language dysfunction in early Alzheimer's disease: A review. *International Journal of Geriatric Psychiatry*, *27*(12), 1209–1217. https://doi.org/10.1002/gps.3766

Appendix

Heuristic Scenarios

Representativeness

Linda Problem

Adapted from "Extensional Versus Intuitive Reasoning: The Conjunction Fallacy in Probability Judgment," by A. Tversky and D. Kahneman, 1983, *Psychological Review*, *90*(4), pp. 293–315 (https://doi.org/10.1037/0033-295X.90.4.293). Copyright 1983 by the American Psychological Association.

Linda is 31 years old, single, outspoken, and very bright. She majored in philosophy. As a student, she was deeply concerned with issues of discrimination and social justice and also participated in antinuclear demonstrations.

Which is more probable?

- Linda is a bank teller.
- Linda is a bank teller and is active in the feminist movement.

Base Rate Problem

Adapted from "On the Psychology of Prediction," by D. Kahneman and A. Tversky, 1973, *Psychological Review*, *80*(4), pp. 237–251 (https://doi.org/10.1037/h0034747). Copyright 1973 by the American Psychological Association.

A panel of psychologists have interviewed and administered personality tests to 30 engineers and 70 lawyers, all successful in their respective fields. On the basis of this information, descriptions of the 30 engineers and 70 lawyers have been written. Below, you will find one of those descriptions, chosen at random from the 100 available descriptions.

Jack is a 45-year-old man. He is married and has four children. He is generally conservative, careful, and ambitious. He shows no interest in political and social issues and spends most of his free time on his many hobbies which include home carpentry, sailing, and mathematical puzzles. What is the probability that Jack is an engineer (0%–100%)?

Marble Problem

Adapted from "Subjective Probability: A Judgment of Representativeness," by D. Kahneman and A. Tversky, 1972, *Cognitive Psychology*, *3*(3), pp. 430–454 (https://doi.org/10.1016/0010-0285(72)90016-3). Copyright 1972 by Elsevier Inc.

Five children (Alan, Ben, Carl, Dan, and Ed) are playing a game. On each round, 20 marbles are distributed at random among them. Consider the following distributions:

A: 4, 4, 5, 4, 3

B: 4, 4, 4, 4, 4

In many rounds of the game, will there be more results of Distribution A or Distribution B?

Sunk-Cost Fallacy

Adapted from "Getting Older Isn't All That Bad: Better Decisions and Coping When Facing 'Sunk Costs'," by W. Bruine De Bruin, J. Strough, and A. Parker, 2014, *Psychology and Aging*, *29*(3), pp. 642–647 (https://doi.org/10.1037/a0036308). Copyright 2014 by the American Psychological Association and "No Time to Waste: Restricting Life-Span Temporal Horizons Decreases the Sunk-Cost Fallacy," by J. Strough, L. Schlosnagle, T. Karns, P. Lemaster, and N. Pichayayothin, 2014, *Journal of Behavioral Decision Making*, *27*(1), pp. 78–94 (https://doi.org/10.1002/bdm.1781). Copyright 2013 by John Wiley & Sons, Ltd.

You have driven halfway to a vacation destination. Your goal is to spend time by yourself. You feel sick. You feel that you would have a much better weekend at home. You think that it is "too bad" you already drove halfway because you would much rather spend the time at home. Please think about what you would do if you were in this situation. Would you be more likely to stick with your plans (1) or to cancel your plans (6)?

After a large meal at a restaurant, you order a big dessert with chocolate and ice cream. After a few bites, you find you are full and you would rather not eat any more of it. Would you be more likely to eat more (1) or to stop eating it (6)?

You have been working on a project related to one of your hobbies. Lately, you have lost interest in the project. Whenever you work on it, you are bored and wish that you were doing something else. You must decide what to do. Would you be more likely remain committed to the project (1) or stop working on it (6)?

(*Appendix continues*)

Table A1
Anchoring

Scenario	Low anchor	High anchor	Source
Is the height of the tallest redwood tree less than or greater than__feet?	65	500	Adapted from "A Literature Review of the Anchoring Effect," by A. Furnham and H. C. Boo, 2011, *Journal of Socio-Economics*, *40*(1), pp. 35–42 (https://doi.org/10.1016/j.socec.2010.10.008). Copyright 2010 by Elsevier Inc.
Is the length of the Mississippi River greater than or less than__miles?	200	20,000	
Is the gestation period of an African elephant less than or greater than__months?	12	32	

Table A2
Availability

Scenario	Option 1	Option 2	Source
Suppose one samples a word (of three letters or more) at random from an English text. Which of the following is more likely?	Word starts with R	R is the third letter	Adapted from "Judgment Under Uncertainty: Heuristics and Biases," by A. Tversky and D. Kahneman, 1974, *Science*, *185*(4157), pp. 1124–1131 (https://doi.org/10.1126/science.185.4157.1124). Copyright 1974 by the American Association for the Advancement of Science.
Suppose one samples a word (of three letters or more) at random from an English text. Which of the following is more likely?	Word starts with K	K is the third letter	
Now you will see a list of names one by one* Did the list we just presented contain more _________?	Women's names	Men's names	Adapted from "The Effects of Construal Level on Heuristic Reasoning: The Case of Representativeness and Availability," by J. N. Braga, M. B. Ferreira, and S. J. Sherman, 2015, *Decision*, *2*(3), pp. 216–227 (https://doi.org/10.1037/dec0000021). Copyright 2015 by the American Psychological Association.

* The list contained an equal number of male names (Thomas Anderson, Richard Miller, David Beckham, Michael Jordan, George Clooney, Brad Pitt, Chris Brown, Paul Jones) and female names (Jennifer Moore, Elizabeth Clark, Barbara Smith, Linda Johnson, Britney Spears, Sarah Wilson, Louise Martin, Sandra Murphy).

Table A3
Recognition

Scenario	Option 1	Option 2	Source
Which illness has the higher annual incidence in the United States?	Spotted fever rickettsiosis	Malaria	Adapted from "Cognitive Aging and the Adaptive Use of Recognition in Decision Making," by T. Pachur, R. Mata, and L. J. Schooler, 2009, *Psychology and Aging*, *24*(4), pp. 901–915 (https://doi.org/10.1037/a0017211). Copyright 2009 by the American Psychological Association.
Which illness has the higher annual incidence in the United States?	Tetanus	Leptospirosis	
Which illness has the higher annual incidence in the United States?	Shigellosis	E. coli	
Which Mexican city has the higher population?	Cancun	Ecatepec	
Which European city has the higher population?	Minsk	Dublin	
Which African city has the higher population?	Cape Town	Abidjan	

Received April 28, 2022
Revision received December 21, 2022
Accepted January 2, 2023 ■