American Psychological Association

Psychology and Aging

ISSN: 0882-7974

2019, Vol. 34, No. 7, 1005–1020
http://dx.doi.org/10.1037/pag0000397

Information Use in Risky Decision Making: Do Age Differences Depend on Affective Context?

Joshua A. Weller
Tilburg University

Marcie L. King
University of Iowa

Bernd Figner
Radboud Universtity

Natalie L. Denburg
University of Iowa

The current study focused on the degree to which decision context (deliberative vs. affective) differentially impacted the use of available information about uncertainty (i.e., probability, positive and negative outcome magnitudes, expected value, and variance/risk) when older adults were faced with decisions under risk. In addition, we examined whether individual differences in general mental ability and executive function moderated the associations between age and information use. Participants ($N = 96$) completed a neuropsychological assessment and the hot (affective) and cold (deliberative) versions of an explicit risk task. Our results did not find a significant Age × Hot/Cold Condition interaction on overall risk-taking. However, we found that older adults were less likely to use the full decision information available regardless of the decision context. This finding suggested more global age differences in information use. Moreover, older adults were less likely to make expected-value sensitive decisions, regardless of the hot/cold context. Finally, we found that low performance on measures of executive functioning, but not general mental ability, appears to be a risk factor for lower information use. This pattern appears in middle age and progressively becomes stronger in older age. The current work provides evidence that common underlying decision processes may operate in risk tasks deemed either affective or deliberative. It further suggests that underlying mechanisms such as information use may be paramount, relative to differences in the affective context. Additionally, individual differences in neuropsychological function may act as a moderator in the tendency to use available information across affective context.

Keywords: risk taking, decision making, age differences, cognitive aging, executive function

Supplemental materials: http://dx.doi.org/10.1037/pag0000397.supp

Older adults encounter unique decisions that involve uncertain, or risky, outcomes that may affect both their own health and well-being, as well as that of others. For instance, compared to their younger counterparts, older adults may be more likely to face decisions about undergoing medical procedures (e.g., surgeries, medications with side effects), moving into assisted care facilities, and spending retirement funds. Decisions like these require weighing potential gains and losses, and the probabilities that they occur, for each choice option available. Moreover, these decisions may vary in their affective context, leading an individual to choose when in a "hot" versus "cold" state. With an ever-increasing elderly population—in the United States alone the number of adults over the age of 65 in 2050 is projected to be double that observed in 2012 (Ortman, Velkoff, & Hogan, 2014)—it is important to characterize how cognitive aging may affect decision processes.

This article was published Online First October 3, 2019.

Joshua A. Weller, Department of Developmental Psychology, Tilburg University; Marcie L. King, Department of Neurology, Carver College of Medicine and Department of Psychological and Brain Sciences, University of Iowa; Bernd Figner, Behavioural Science Institute and Donders Institute for Brain, Cognition and Behaviour, Radboud University; Natalie L. Denburg, Carver College of Medicine, University of Iowa.

Joshua A. Weller and Marcie L. King share first authorship on this article and contributed equal work. We thank Maggie Elliot, Joshua Hartman, C. K. Mertz, Sarah Shivapour, and Jonathan Yuska for their assistance with data collection and management. Joshua A. Weller presented preliminary analyses of this study at the 2013 biennial meeting of the European Academy of Decision Making, Barcelona, Spain, and in a presentation given at the 2013 Judgment and Decision Making Winter symposium, University of Utah, Salt Lake City, Utah. This project was supported by grants from National Science foundation SES08-20585 (Joshua A. Weller, PI); National Institute on Aging Career Development Award (K01 AG022033; Natalie L. Denburg, PI).

Correspondence concerning this article should be addressed to Joshua A. Weller, Department of Developmental Psychology, Tilburg University, Warandelaan 2, 5037 AB Tilburg, the Netherlands. E-mail: j.a.weller@uvt.nl

To date, research findings have been mixed with respect to how aging impacts risky decision making processes. In one regard, self-reported risk-taking appears to decline over the life span (Josef et al., 2016; Mamerow, Frey, & Mata, 2016; Rolison, Hanoch, Wood, & Liu, 2014), seemingly confirming the stereotype of a risk-averse older adult (Okun, 1976). In contrast, for laboratory-based decision tasks that are designed to show differences in risky decision making processes, the results become much more varied, ranging from increased risk aversion to increased risk seeking for older adults (Brand & Markowitsch, 2010; Mata, Josef, Samanez-Larkin, & Hertwig, 2011; Peters, Dieckmann, & Weller, 2011; Samanez-Larkin & Knutson, 2015; Strough, Karns, & Schlosnagle, 2011; Yoon, Cole, & Lee, 2009; Tymula, Rosenberg Belmaker, Ruderman, Glimcher, & Levy, 2013; Weller, Levin, & Denburg, 2011). These heterogeneous results suggest that important contextual moderators may influence the degree to which age differences in risky decision making are manifest.

Notably, laboratory tasks are more specific to particular decision making processes than the complex range of factors that may influence real-life decision making. However, by examining how individuals attend to and use information for a given decision across different contexts, researchers can gain insights into how individuals may approach more complex choices that share similar characteristics. For instance, any decision with choice options that may involve weighing potential gains and losses, and the probabilities that they occur, would assumedly benefit from comparing the expected value (EV) of the choice options available. According to normative theories of rationality, such as expected utility theory (von Neumann & Morgenstern, 1947), advantageous decision making under risk hinges upon several factors, including the tendency to conduct an appropriate search for relevant information and accurately valuing possible outcome magnitudes related to potential gains, losses, and the likelihood that they occur. Integrating gain, loss, and probability information in a multiplicative, rather than additive, manner forms the basis of EV; consistently choosing an option with the most favorable EV tends to lead to outcomes that are more favorable over the long-run.

Older adults appear to be less sensitive to differences in EV among various choice options than younger adults (e.g., Brand & Markowitsch, 2010; Brand & Schiebener, 2013; Deakin, Aitken, Robbins, & Sahakian, 2004). Past work shows that the tendency to make EV-consistent choices, both for risks that involve potential gains and risks that involve potential losses, follows an inverted U-shaped pattern across the life span, increasing from childhood until middle adulthood and declining after 65 years of age (Weller et al., 2011). The observed differences in EV sensitivity for older adults may, in part, be due to declines in deliberative cognitive processes that are particularly susceptible to aging in general (Salthouse, 2004). Research has demonstrated substantial age-related differences on neuropsychological tasks designed to recruit cognitive processes associated with deliberative reasoning, such as fluid intelligence, processing speed, working memory, and executive functioning (Li, Baldassi, Johnson, & Weber, 2013; Salthouse, 2004, 2010; Zacks, Hasher, & Li, 2000). These cognitive processes appear to decline linearly across adulthood and have been implicated in the ability to make decisions that are more advantageous (Henninger, Madden, & Huettel, 2010; Li et al., 2004; Samanez-Larkin & Knutson, 2015). The declines observed in older adulthood are often considered to be associated with age-related cognitive declines of the prefrontal cortex, particularly the lateral areas of the prefrontal cortex (Brown & Park, 2003; Grady, 2000; Kennedy & Raz, 2009; MacPherson, Phillips, & Della Sala, 2002; Raz et al., 2005).

These results may also correspond with age differences in decision strategies when faced with risky choices. Consistent with the robustly reported declines in cognitive processes, older adults tend to perform more poorly than younger adults on tasks that involve effective information search, utilizing information integration strategies, or holding previously encountered information in working memory. For instance, older adults may default to associative, noncompensatory decision strategies that are simpler (Johnson & Drungle, 2000; Queen, Hess, Ennis, Dowd, & Grühn, 2012), and may even actively avoid obtaining additional information that could be relevant to the choice at hand (Cole & Balasubramanian, 1993; Mata, Wilke, & Czienskowski, 2013). Taken within the context of risky decision making, an individual could use a variety of approaches to arrive at a decision. The most comprehensive, and presumably computationally taxing, would involve the multiplicative integration of probability, gain and loss magnitude information (i.e., always choosing the option with more favorable EV). A less computationally demanding strategy would be to consider all the pieces of relevant information in an additive manner. Yet, an even simpler strategy would be to focus on a subset of information, most likely the most salient information.

In contrast to the aforementioned neurocognitive declines, older adults may demonstrate a relative preservation of affective processing abilities (Hasher & Zacks, 1984; Novak & Mather, 2007; Peters & Bruine de Bruin, 2012; Peters, Hess, Västfjäll, & Auman, 2007; Queen & Hess, 2010; Strough et al., 2011). In some cases, older adults rely more heavily on affective information, compared to younger adults (Blanchard-Fields, 2007; Fung & Carstensen, 2003). It is important to note that affective decision making strategies may sometimes be advantageous, allowing older adults to better use past experiences and wisdom to guide decisions, or to only selectively engage effortful processes when it is most relevant to them (Hess, 2014; Queen et al., 2012).

The broader literature demonstrating asymmetries in deliberative versus affective processing abilities suggests that age-related declines in information use (e.g., EV) will be attenuated as decisions become more experienced-based versus more descriptive (Huang, Wood, Berger, & Hanoch, 2013, 2015). This might especially be the case when choice options are limited, minimizing the need for information search processes (Frey, Mata, & Hertwig, 2015; Mata & Nunes, 2010). Further, decrements in description-based decision making quality may be further compromised by age-related declines in neurocognitive abilities related to executive function. Henninger et al. (2010) reported that tests of processing speed, a component of broader executive functioning, was associated with suboptimal decision making on the Cambridge Gambling Task (Rogers et al., 1999), but to a lesser degree on Balloon Analogue Risk Task (BART; Lejuez et al., 2002) and the Iowa Gambling Task (IGT; Bechara, Damasio, Damasio, & Anderson, 1994).

Though these effects suggest potential differences between tasks that more heavily weight deliberative versus affective processing, it is important to note that the decision structure of different risky-decision making tasks are often quite different. These differences can lead to divergences in decision preferences across task. For instance, with the presumably more affective/experiential tasks like the BART and IGT, older adults demonstrate different patterns of risk preference (risk avoidance in the former and greater risk taking in the latter; Mata et al., 2011). Thus, it is desirable to strive for similar decision architectures across the decision context. In an effort to quantify behavioral differences in risky decision making as a function of affective versus deliberative context, holding the presented trial information constant, Figner and colleagues (Figner & Voelki, 2004; Figner, Mackinlay, Wilkening, & Weber, 2009) developed the Columbia Card Task (CCT).

With the CCT-Hot, a decision-maker faces risky choices that involve incremental, stepwise decisions; with each card that is turned over, the probability of turning over a losing card becomes greater. As each trial progresses, the decision-maker must choose whether to continue turning over cards, or to stop and collect the amount won. In contrast, for the CCT-Cold, the decision-maker is asked to select how many cards they want to turn over if they were to make sequential choices, instead of selecting cards one-by-one as in the CCT-Hot. Because of these differences, the CCT-Hot has been found to be associated with greater emotional arousal, indexed by both self-report and skin conductance responses (e.g., Figner et al., 2009; Huang et al., 2013).

In the only study, to our knowledge, to examine adult age differences in information use with respect to the CCT, Huang, Wood, Berger, and Hanoch (2015) found that younger adults appeared to adjust their decisions more readily in response to changes in probability of losses, gain amounts, and loss amounts, across trials, suggestive of increased deliberative processing. However, this study used a "warm" version of the task, which attenuates the affective qualities of the original "hot" version by not providing immediate trial feedback for choices. Moreover, the "cold" version was not assessed, leaving the degree to which age differences in risk taking and information use arise in more diverse decision contexts, as well as the degree to which neurocognitive variables are associated with information use open for further investigation. Further, although this study provided unique insights into older adults' decision processes, it operationalized information use as an additive construct (i.e., the sum of significant main effects from individual-level regression analysis; Huang et al., 2015). Although informative as a coarse indicator of sensitivity to change in contextual decision variables, this metric not only precludes a more fine-grained analysis of age differences in changes in the "decision primitives" (i.e., probability of loss, loss and gain magnitude amounts across trials), but also does not treat information integration as a multiplicative process, the latter of which defines EV.

The current study aimed to extend these findings in three major ways. First, using a within-subjects, linear mixed-models approach, we examined the degree to which age-related differences in risk-taking and information use appeared as a function of the decision's affective context. This approach allowed us to test the degree to which cognitive aging was differentially associated with specific components of decisions, namely probability level, potential gain amounts, and potential loss amounts. We predicted that age-related differences in information use (sensitivity to probability level, gain amount, and loss amount) would be smaller in the CCT-Hot than the CCT-Cold. Second, to examine EV and risk sensitivity on the CCT, we decomposed CCT decisions using a risk-return framework to identify how sensitivity to the riskiness of a choice (outcome variance) and its returns (EV) influenced participants' risk-taking decisions. This risk-return decomposition framework is a related approach to the one used in the fMRI version of the CCT (van Duijvenvoorde et al., 2015), but here we applied it to the regular behavioral CCT and applied it to both the "hot" and the "cold" CCT (not just the CCT-Hot, as in the fMRI study). This decomposition approach allowed us to derive an index of risk sensitivity (i.e., sensitivity to variance) and an index of EV sensitivity for each participant (see data analytic strategy section for methodological details and further explanations). We predicted that older adults would demonstrate lower EV sensitivity, especially in the CCT-Cold. Finally, we examined the degree to which executive function and general mental ability moderated the association between age and CCT task performance. We hypothesized that these measures would demonstrate interactions with CCT information use, especially for the "cold" version, and with complex information use strategies, such as the integration of probability and outcome magnitudes, which would be reflected in an EV sensitivity index. We base this last hypothesis on the assumption that the integration necessary for making EV-consistent choices more strongly depends on these neurocognitve variables than estimating the dispersion of potential outcomes, which would not involve integration of multiple information sources. In contrast, we did not make explicit hypotheses for age differences in risk sensitivity because past research has focused mostly on overt risk taking rather than on how individuals react toward changes in the outcome variance for a particular choice. Given the heterogeneity of results in prior risk-taking research (Mata et al., 2011), we consider age differences in risk sensitivity to be an open research question.

Method

Participants

Healthy adults who lived independently in the community were recruited from churches, organizations, and clubs, including a local senior center. The health of each participant was confirmed via a semistructured interview that assessed neurological status, current medications, alcohol/drug consumption, and mood (after Tranel, Benton, & Olson, 1997). We originally sampled 98 participants. One older adult reported vision problems and was removed from the analysis and another only completed one version of the CCT and was therefore not used. The final dataset included $N = 96$ (median age = 66.00 years, range = 24–84 years; 59% female). Participants had an average of 15.93 years of education (SD = 2.56, min = 11 years, max = 20 years). All participants were compensated $12.50/hr for their participation. The University of Iowa Institutional Review Board (IRB-01) approved the following studies relevant to this paper; (a) 200505721 "Economic decision making" and (b) 200406073 "Effects of Aging on Decision Making Behavior."

Procedure

Participants were asked to complete the "hot" and "cold" versions of the CCT, as well as tasks assessing basic neurocognitive functioning including premorbid intellectual ability, mental status screening, current intellectual functioning, executive functioning, and nonverbal anterograde memory. Neurocognitive assessments were conducted during a separate session. Self-report questionnaires unrelated to the current study separated completion of the two CCT versions. To maintain a standardized procedure across subjects, administration of the CCT-Hot always preceded administration of the CCT-Cold.

CCT. The CCT is a dynamic computer card game that assesses risk-taking levels and information use strategies (Figner & Voelki, 2004; Figner et al., 2009; Figner & Weber, 2011; van Duijvenvoorde et al., 2015). In both the hot and cold versions of the task, participants turn over cards with the objective of earning points. In each of the 24 rounds, they are told the number of loss cards (one or three) among the total 32 cards shown, the gain amount per gain card (10 or 30 points), and the loss amount (250 or 750 points; i.e., the amount of points subtracted from the current game round score if they turn over a loss card). As long as only gain cards are turned over, participants can choose to continue and turn over another card or to terminate the round. If a loss card is encountered, the loss amount is subtracted from the current game round score and the current round is over. Each new game round starts with a score of 0 and participants are told that the goal is to earn as many points as possible.

The probability of a loss (i.e., the number of loss cards in a game round) and the outcome magnitudes for gains and losses vary between rounds according to a full factorial 2 (loss probability: 1 or 3 cards) × 2 (gain magnitude: 10 or 30 points) × 2 (loss magnitude: −250 or −750 points) design. Both the likelihood of a loss and the outcome variability increase continuously as more cards are turned over; thus, turning over more cards is a riskier strategy than turning over fewer cards. Accordingly, the number of cards turned over serves as an indicator for participants' risk-taking levels. Each version of the CCT consists of 24 trials (three blocks of each iteration of probability, gain amount, and loss amount), with trial order randomized within block.

In addition, choices in the CCT were decomposed in two different ways. First, the primitives decomposition analyzes risk taking as a function of changes for the three CCT information factors (i.e., probability, gain amount, and loss amount). For each participant, it is possible to quantify how strongly they adjust the number of cards turned over as a function of a change in each of the three factors. For example, a participant who is very sensitive to changes in gain amounts might consistently turn over more cards in game rounds in which the gain amount is 30 points, compared to game rounds in which the gain amount is 10 points. Researchers have previously used repeated-measures analysis of variance (ANOVA) approaches for this decomposition approach (Figner & Voelki, 2004; Figner et al., 2009), and also have summed up the number of factors taken into account by each participant in an aggregated "information use" index, which sums the tendency to adjust one's decision to contextual factors (i.e., Huang et al., 2015). More recently, linear-mixed effects model analyses have been used to provide a more refined, but similar, strategy (e.g., Panno, Lauriola, & Figner, 2013; Somerville et al., 2018).

In addition, we also used a risk-return decomposition (see, e.g., Weber, 2010; applied to the fMRI version of the CCT, see van Duijvenvoorde et al., 2015), which conceptualizes and analyzes risk taking at the level of the binary decisions to turn over a card versus to stop as a tradeoff between the expected return (formalized as the EV of the decision to turn over the next card) and the expected risk (formalized as the variance or the standard deviation of the decision to turn over the next card). This analysis allows investigators to test participants' sensitivity to changes in both the EV and the risk of turning over another card. Although EV sensitivity is typically a positive value, risk sensitivity can vary across individuals from risk averse (i.e., values <0) over risk neutral to risk seeking (values >0) behavior.

Task-based emotional arousal and self-reported decision strategies. After each version of the CCT, participants responded to a series of self-report questionnaire items that assessed the strategies that they used when completing the task. We were interested in two specific types of decision processes: more affective/experiential and intuitive processes versus more deliberative processes. The items related to affective/experiential decision processes were "I mainly followed my feelings when making my decisions," "I made my decisions based on intuition," and "I solved the card game instinctively/on gut level." The items related to deliberative decision processes were "I tried to take all information into account and act systematically," "I tried to solve the task mathematically," and "I made my decisions through careful thinking." All items were answered on continuous visual analogue scales with end points marked "doesn't apply at all" and "strongly applies." Cronbach's alpha values were .80 and .86 for the affective and deliberative scales, respectively. In this manner, we also assessed individuals' perception of task-based emotional arousal when completing the two CCT versions with the single item, "At times during the game I felt a thrill."

Basic neurocognitive functioning. Various neurocognitive measures were used to characterize the cognitive functioning of the current sample. To ensure that participants (n = 95) were cognitively healthy, a mental status screening was conducted with the Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975). To measure premorbid intellectual ability participants (n = 91) completed the Wide Range Achievement Test-3 Reading subtest (WRAT-3; Wilkinson, 1993), a 42-item single-word reading task. We used the age-corrected standard score for analysis. To assess current intellectual ability, participants (n = 96) completed the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999). In addition, participants (n = 94) completed an eight-item measure of numeracy (Lipkus, Samsa, & Rimer, 2001).

Participants also completed various measures of attention, memory, and executive functioning. All participants (n = 96) completed the Rey-Osterrieth Complex Figure Test (REY-O; copy and 30-min delay; Rey, 1941; Lezak, 1995) as a measure of visuospatial abilities, memory, and planning during copy and 30-min delay conditions. The Rey Auditory-Verbal Learning Test (AVLT; Rey, 1964) was administered to all participants (n = 96) as a measure of ability to encode, consolidate, store, and retrieve verbal information (see Schmidt, 1996). Participants (n = 96) also completed the Trail Making Test (TMT-B), which is a general indicator of processing speed and switching coordination (which in part comprise executive functioning; Reitan, 1958; Tombaugh, 2004). We used the time(s) needed to complete the TMT-B as a measure of executive functioning. Individual differences in executive functioning were also assessed (n = 93) by the number of perseverative errors on the Wisconsin Card Sorting Task (WCST; Heaton, Chelune, Tally, Kay, & Curtis, 1993).

Data reduction of neurocognitive variables. Because we included several indicators of neurocognitive function, we conducted a principal components analysis (PCA) on the neurocognitive variables for the purpose of reducing the number of variables entered in the omnibus CCT models. Specifically, we focused on those most commonly related to executive function and general mental ability (i.e., WCST, Trail Making Test, and AVLT 1–5 performance for executive function, and Numeracy, WASI Performance IQ, and WASI Verbal IQ for general mental ability). Prior to these analyses, we conducted a missing values analysis because three participants did not have WCST scores and two did not have numeracy scores. Little's missing completely at random test was not significant, $\chi^2(11) = 9.255$, $p = .60$; thus, we replaced the missing values with the sample mean for these cases. We used a varimax rotation, with eigenvalues greater than 1 as a component retention criterion. A two-component solution accounted for 61.06% of the variance explained. This solution yielded two factors that conformed to our expectations. Namely, the PCA recovered a (a) general mental ability dimension (GMA), comprised of numeracy and the WAIS scores (factor loadings ranged between .72 and .82), and a (b) executive function dimension (EF), a bipolar scale comprised of WCST Perseverative Errors, TMT-B (both positively loaded), and AVLT 1–5 (negatively loaded) performance (loadings ranged from .70 to .79). No variable had a cross-loading $> .30$.

Data Analytic Strategy

We first conducted correlational analyses to test the associations between age and the neuropsychological variables. CCT analyses were conducted using a Bayesian (generalized) linear mixed-effects model approach using the function brm of the package brms (Version 2.4.0; Bürkner, 2017, 2018) in R (R Core Team, 2018; see Somerville, Haddara, Sasse, Skwara, Moran, & Figner, 2018, for a similar data analysis approach with the CCT). The primary omnibus primitives model included the following fixed effects: A fixed intercept, the condition (hot vs. cold CCT) factor, age (continuous predictor) the three card game factors (probability, gain amount, and loss amount), a continuous predictor for block (indicating the three blocks of eight trials each), the two-way interactions between condition and task primitives (including block), the two-way interactions between age and the CCT task variables, and the three-way interaction terms involving Age, Condition, and each of the card game factors. All factors were coded using sum-to-zero contrasts and all continuous predictors were standardized (i.e., centered and scaled).

We followed Barr, Levy, Scheepers, and Tily's (2013) advice to use a maximal random-effects structure: The repeated-measures nature of the data was accordingly modeled by including a per-participant random adjustment to the fixed intercept ("random intercept"), as well as per-participant random adjustments to all within-subject predictors (namely hot/cold, probability, gain, loss, block, and the three two-way interactions between hot/cold and each of the 4 card game factors). In addition, we included all possible random covariance terms among the random effects. Finally, in the hot (but not the cold) CCT, game rounds can be "censored," that is, when a participant is stopped involuntarily from turning over another card because they turned over a loss card. The brm function can model this by specifying which game rounds were censored and which were not, thus accounting for the fact that on these hot CCT game rounds the participant might have turned over more cards if they had not been stopped from doing so by turning over a loss card. We used brms' default weakly informative priors and deemed a regression coefficient "significant" when the associated 95% posterior credible interval did not include 0. The models were run using six chains with 4,000 iterations each (2,000 of which were warmup samples) and were inspected for convergence of the chains.

For the risk-return decomposition, we first created a new data frame in which each binary decision to turn over a card or stop represented a separate row. For example, if a participant turned over five cards in Game Round 1 and then decided to stop, this would be represented in the new data frame as six rows of data, namely five rows in which the participant decided to turn over a card (coded as 1) and a 6th row in which they decided to stop (coded as 0). For each such binary decision whether to turn over another card or stop, we computed the EV (as indicator for the expected returns) and the standard deviation (as indicator for the expected risks). We used a Bayesian logistic mixed-effects model (specifying the family as Bernoulli) with the binary decision to turn over a card or stop as the dependent variable. The fixed effects included a fixed intercept and fixed effects for expected returns (i.e., EV, continuous; see the information for density plots in the online supplemental material), the expected risks (i.e., the standard deviation, continuous), task version (hot/cold, categorical), age (continuous), neurocognitive variables (continuous), and a continuous predictor of no interest ("decision number") that indicated whether, in each game round, it was the first, second, third, and so forth, binary decision. We added this latter predictor to capture possible decision strategies unrelated to expected returns or risks (see van Duijvenvoorde et al., 2015, for a similar approach). All categorical predictors were sum-to-zero coded and all continuous predictors were standardized. To account for the repeated-measures nature of the data, we included a per-participant random adjustment to the intercept as well as random slopes for expected returns, expected risks, and the decision-number predictor; we also estimated all possible random covariance terms. As in the primitives model, we used brms' default weakly informative priors and deemed a regression coefficient "significant" when the associated 95% posterior credible interval did not include 0. The models were run using six chains with 4,000 iterations each (2000 of which were warmup samples) and were inspected for convergence of the chains.[1]

Results

Task-Based Emotional Arousal and Decision Strategies

We conducted a generalized estimating equation analysis to test the degree to which the different CCT conditions (0 =hot; 1 = cold) differed in self-reported emotional arousal during the task. Standard errors were estimated using a robust variance estimator, and analyses were conducted with an unstructured working correlation matrix. Parameter estimates were achieved using hybrid maximum likelihood estimation. We also included age as a continuous predictor. As predicted, individuals reported greater excitement when making choices during the hot than the cold CCT, Wald's chi-square = 25.36, $p < .001$, $B = -13.97$, $SE = 2.77$. We

[1] All data, scripts, and syntax available upon request.

also found that the older adults reported overall less excitement on the CCT, regardless of condition, compared to younger adults, Wald's chi-square = 12.61, $p < .001$, $B = -.43$, $SE = .12$. For completeness, we reran the model including an Age × Condition interaction term, which was not significant, Wald's chi-square = .30, $p = .58$. These results confirm that participants perceived the CCT-Hot to be more emotionally arousing than the CCT-Cold.

We next tested the degree to which older and younger adults differed in their self-reported reliance on cold, deliberative and hot, affective decision strategies for each version of the CCT. To meet this end, we conducted two separate generalized estimating equations, regressing reported decision strategies on age and CCT condition.[2] For self-reported use of deliberative strategies, we found a main effect for condition, Wald's chi-square = 7.93, $p = .005$, $B = 5.61$, $SE = 1.99$, with greater self-reported reliance on deliberative strategies in the CCT-Cold than the CCT-Hot. In addition, we found a main effect for age, Wald's chi-square = 7.93, $p = .005$, $B = -.27$, $SE = .12$, with stronger reliance on deliberative strategies for younger adults, compared to older cohorts.

Self-reported reliance on intuitive decision strategies was stronger in the CCT-Hot than the CCT-Cold (Wald $\chi^2 = 5.95$, $p = .015$, $B = -4.92$, $SE = 2.02$). There were no age differences in self-reported intuitive strategies, Wald's chi-square = .60, $p = .438$, $B = .11$, $SE = .14$.

Taken together, these analyses demonstrate several points. First, participants were more likely to self-report using deliberative strategies for the CCT-Cold than the CCT-Hot. In contrast, they were more likely to report using intuitive strategies for the CCT-Hot than for the CCT-Cold. Second, compared to older adults, younger adults reported greater use of deliberative strategies in the CCT-Cold; however, there were no age differences for self-reported intuitive strategies for either the CCT-Hot or the CCT-Cold.

Neurocognitive Characterization of Sample

Table 1 shows the correlations between age and the neurocognitive variables. Notably, participants' performance on the neuropsychological instruments reflected normal, age-appropriate functioning. In terms of gross cognitive functioning, MMSE scores were close to ceiling ($M = 29.22$, $SD = 1.02$). In addition, mean WRAT scores ($M = 109.31$, $SD = 7.14$) and WASI full scale IQ scores ($M = 118.77$, $SD = 10.98$) fell in the average to high average range of intellectual functioning. Age did not significantly correlate with either premorbid or current intellectual functioning. In addition, we did not find a significant correlation between age and Rey-O copy scores; however, Rey-O delay scores and age were significantly, and inversely correlated.

As expected, age-related differences emerged on tasks assessing numeracy, memory, and executive functioning, such that age was negatively associated with performance on numeracy, the initial five trials of the AVLT, and the 30-min delay recall portion of the AVLT. In addition, older age was associated with slower completion of the TMT-B and increased perseverative errors on the WCST.

Table 1
Correlations Between Age and Neurocognitive Function

Variable	r_{age}
Age	—
MMSE	−.12
Verbal IQ (WASI)	.20
Performance IQ (WASI)	.01
Full Scale IQ (WASI)	.14
Premorbid IQ (WRAT reading)	.00
Numeracy	−.25*
AVLT (Trials 1–5)	−.58**
AVLT (30-min recall)	−.54**
Rey-O Copy	−.16
Rey-O Recall	−.32**
TMT-B (s)	.56**
WCST (perseverative errors)	.34**

Note. MMSE = Mini-Mental State Examination; WASI = Wechsler Abbreviated Scale of Intelligence; WRAT = Wide Range Achievement Test; AVLT = Rey Auditory-Verbal Learning Test; Rey-O = Rey-Osterrieth Complex Figure; TMT-B = Trail Making Test-B; WCST = Wisconsin Card Sorting Task.
* $p \le .05$. ** $p \le .01$.

Table 2
Linear Mixed Models Analysis for Columbia Card Task Performance

Fixed effects	Parameter estimate	*SE*	95% credible interval Low	High
(Intercept)	12.92	.59	11.78	14.03
Age	−.41	.57	−1.52	.71
Condition (hot/cold)	−1.79*	.30	−2.38	−1.21
Probability	2.20*	.18	1.84	2.56
Gain	.09	.11	−.13	.30
Loss	1.08*	.15	.77	1.39
Block	−.43*	.11	−.65	−.21
Age × Condition	.17	.29	−.39	.74
Probability × Condition	−.42*	.12	.18	.65
Gain × Condition	.35*	.08	.19	.52
Loss × Condition	.31*	.10	.11	.51
Block × Condition	.15	.11	−.06	.35
Probability × Age	−.39*	.18	−.72	−.05
Gain × Age	−.42*	.11	−.64	−.20
Loss × Age	−.93*	.16	−1.24	−.63
Block × Age	.48*	.11	.26	.70
Probability × Condition × Age	.12	.12	−.11	.35
Gain × Condition × Age	−.01	.08	−.17	.15
Loss × Condition × Age	−.03	.10	−.23	.16
Block × Condition × Age	−.13	.10	−.34	.08

* Indicates significance based on the 95% posterior credible intervals for the obtained parameter estimate.

CCT Analysis

Table 2 displays the parameter estimates for the omnibus CCT mixed-effects models analysis. The main effect for age was not significant. We found a main effect for task version; thus, participants were more likely to turn over more cards on the CCT-Hot than on the CCT-Cold. In addition, we found main effects for the

[2] We first conducted a model including an Age × Condition interaction term. This model yielded insignificant results for the interactions for both deliberative and intuitive strategies, Wald $\chi^2 = 1.16$, $p = .28$ and Wald $\chi^2 = .98$, $p = .32$, respectively. Given that we conducted these analyses to serve as a manipulation check, we only report the results from a model including only the main effects.

probability and loss magnitude CCT primitive factors. Participants selected more cards when (a) one loss card was present (compared to three loss cards), and (b) when the loss amount was 250 (compared to 750) points. We also observed a main effect for trial block, indicating that, as the tasks progressed, individuals turned over fewer cards, on average. As they learn to reduce this number, they typically will earn more points.

These effects were conditional on several interaction effects. We found significant two-way interactions at the task level. Specifically, CCT condition interacted with probability, loss magnitude, and gain magnitude, with each effect suggesting greater information use in the Cold version. Central to our study, we also observed significant two-way interactions between age and the task characteristics, holding other variables constant. Overall, older adults were less sensitive to changes in number of loss cards from 1 to 3 (i.e., probability level; Figure 1, Panel A), loss amount from 250–750 (Panel B), and gain magnitude from 10 to 30 (Panel C). Contrary to our hypothesis, we did not observe a significant Age × CCT Condition interaction, nor did we observe significant three-way interactions.

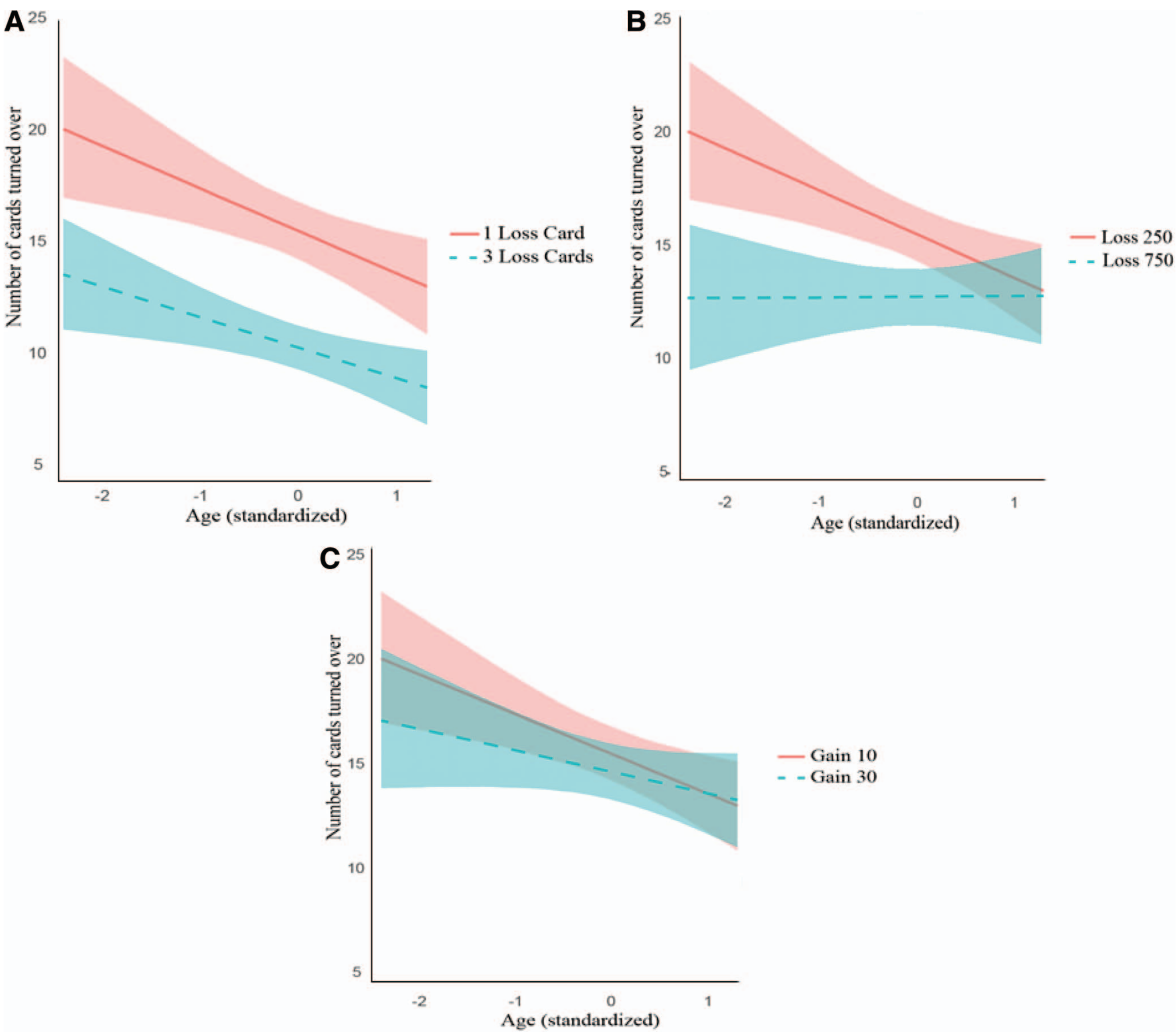

Figure 1. Mixed model analysis results: Age × Task Primitives. Age moderates the effects of task primitives on risk taking. Figure 1 shows the interaction effects of Age × Probability Level (A), Age × Loss Magnitude (B), and Age × Gain Magnitude (C). The *x*-axes show the standardized age of participants. The minimum (maximum) age in the sample was 24 (84) years, corresponding to a standardized value of approximately −2.36 (1.33). Accordingly, the *x*-axis labels of −2, −1, 0, and 1 correspond to untransformed ages of approximately 20, 46, 62, and 79 years of age. Error bars reflect 95% credibility intervals. See the online article for the color version of this figure.

To test the degree to which neurocognitive functioning moderated the effect of age, we next ran the same mixed-model analysis this time including the two PCA-derived neurocognitive variables. This analysis was identical to the prior analysis, with the exception that we included the main effects for the GMA and EF factors, two-way interactions between these variables and (a) age and (b) the CCT task variables (condition, probability, gain magnitude, loss magnitude, block). We also included three-way interactions for (a) Condition × GMA/EF × Probability/Gain/Loss/Block, and (b) Age × GMA/EF × Condition/Probability/Gain/Loss/Block. Finally, we included four-way interaction terms for Age × GMA/EF × Condition × Probability/Gain/Loss/Block. As shown in Table 3, significant effects at the main effect level did not differ from the simpler model, with the exception of a main effect for GMA, in which greater GMA performance was associated with fewer cards turned over. Additionally, we found a GMA × Gain Magnitude interaction, in which higher GMA was associated with greater adjustment in response to shifts in the gain amount across trials.

With respect to the EF composite, we found significant interactions with (a) loss magnitude, (b) gain magnitude, and (c) trial block, holding other variables constant, with greater EF being associated with greater information use and learning to take fewer risks as the task progressed. However, these interactions were conditional on two three-way interactions. First, we found a significant Age × EF × Loss Magnitude interaction (Figure 2, top). This figure reveals several trends. First, EF scores appear to more strongly discriminate risk-taking when a large loss is at stake, compared to a small loss. However, this pattern was moderated by age. Specifically, younger adults with lower EF still demonstrated sensitivity to losses, shown by a shift in risk taking for small versus large losses (Figure 2A). In contrast, for older adults, individuals with lower EF did not shift their risk-taking in response to changes in the loss magnitude (Figure 2C).

Following a similar pattern, we found a significant Age × EF × Gain Magnitude interaction (Figure 2, Bottom). This pattern was more modest than that observed with the loss domain, but this was to be expected considering that gain magnitude information in the CCT appears to be the least salient piece of contextual information (e.g., Figner et al., 2009). Nonetheless, we observed that younger adults adjusted their risk-taking in response to the gain amount, regardless of their EF level (Figure 2D). In contrast, older adults demonstrated lower sensitivity to gains, particularly those with low levels of EF (Figure 2F).

Risk-Return Decomposition Model

We followed these analyses by conducting a generalized linear mixed models analysis that tested the degree to which age and the neurocognitive variables interacted with EV and risk sensitivity parameters to account for variance in risk-taking (see Table 4). For the main effects at the task level, the EV parameter significantly predicted overall CCT risk taking; fewer risks were taken as the EV of a decision became less favorable. GMA was inversely associated with risk performance overall. Additionally, we found a GMA × EV, interaction; individuals with higher GMA were more likely to base their risk taking on the EV of the choice than those with lower GMA.

Table 3
Linear Mixed Models Analysis for Primitives

Variable	Estimate	*SE*	95% CI Lower bound	95% CI Upper bound
Intercept	12.60*	.76	11.12	14.04
Condition (hot = −1; cold = 1)	−1.25*	.39	−2.04	−.49
Age	−.86*	1.00	−2.86	1.06
GMA	−1.13*	.56	−2.22	−.01
EF	1.15	.88	−.61	2.88
Probability level	2.30*	.24	1.83	2.77
Gain amount	−.10	.14	−.36	.16
Loss amount	.79*	.21	.38	1.19
Block	−.35*	.15	−.64	−.05
Condition × Age	.14	.52	−.87	1.16
Condition × GMA	.30	.29	−.28	.88
Condition × EF	−.54	.46	−1.46	.36
Age × GMA	−.67	.65	−1.92	.61
Age × EF	.54	.77	−.98	2.05
Condition × Probability	.41*	.16	.10	.73
Condition × Gain	.34*	.11	.13	.56
Condition × Loss	.27*	.13	.01	.53
Condition × Block	.02	.14	−.26	.30
Age × Probability	−.69*	.32	−1.32	−.04
Age × Gain	−.08	.18	−.43	.28
Age × Loss	−.38	.28	−.93	.18
Age × Block	.22	.20	−.18	.63
GMA × Probability	.11	.18	−.24	.46
GMA × Gain	.45*	.10	.26	.64
GMA × Loss	.28	.15	−.03	.57
GMA × Block	−.08	.11	−.30	.13
EF × Probability	.38	.29	−.18	.95
EF × Gain	−.35*	.16	−.66	−.04
EF × Loss	−.54*	.25	−1.02	−.06
EF × Block	.38*	.18	.03	.73
Condition × Age × GMA	.22	.34	−.44	.88
Condition × Age × EF	−.85*	.40	−1.63	−.06
Condition × Age × Probability	.03	.21	−.40	.44
Condition × Age × Gain	−.05	.15	−.34	.24
Condition × Age × Loss	.20	.18	−.15	.56
Condition × Age × Block	.12	.19	−.25	.49
Condition × GMA × Probability	−.04	.12	−.27	.19
Condition × GMA × Gain	−.12	.08	−.28	.03
Condition × GMA × Loss	.05	.10	−.14	.24
Condition × GMA × Block	.00	.10	−.20	.20
Condition × EF × Probability	.12	.19	−.24	.49
Condition × EF × Gain	.06	.13	−.19	.32
Condition × EF × Loss	−.34*	.15	−.64	−.04
Condition × EF × Block	−.31	.16	−.63	.01
Age × GMA × Probability	−.20	.21	−.60	.21
Age × GMA × Gain	−.18	.11	−.41	.04
Age × GMA × Loss	−.16	.18	−.50	.18
Age × GMA × Block	−.24	.13	−.49	.01
Age × EF × Probability	−.14	.25	−.63	.34
Age × EF × Gain	.30*	.14	.02	.58
Age × EF × Loss	.48*	.21	.06	.90
Age × EF × Block	−.09	.16	−.41	.21
Condition × Age × GMA × Probability	.11	.13	−.15	.37
Condition × Age × GMA × Gain	.10	.09	−.08	.28
Condition × Age × GMA × Loss	.21	.11	−.01	.42
Condition × Age × GMA × Block	.10	.12	−.14	.33
Condition × Age × EF × Probability	.02	.16	−.31	.34
Condition × Age × EF × Gain	.01	.11	−.22	.23
Condition × Age × EF × Loss	.02	.14	−.25	.30
Condition × Age × EF × Block	.17	.15	−.12	.46

Note. GMA = general mental ability; EF = executive function.
* Indicates significance based on the 95% posterior credible intervals (CIs) for the obtained parameter estimate.

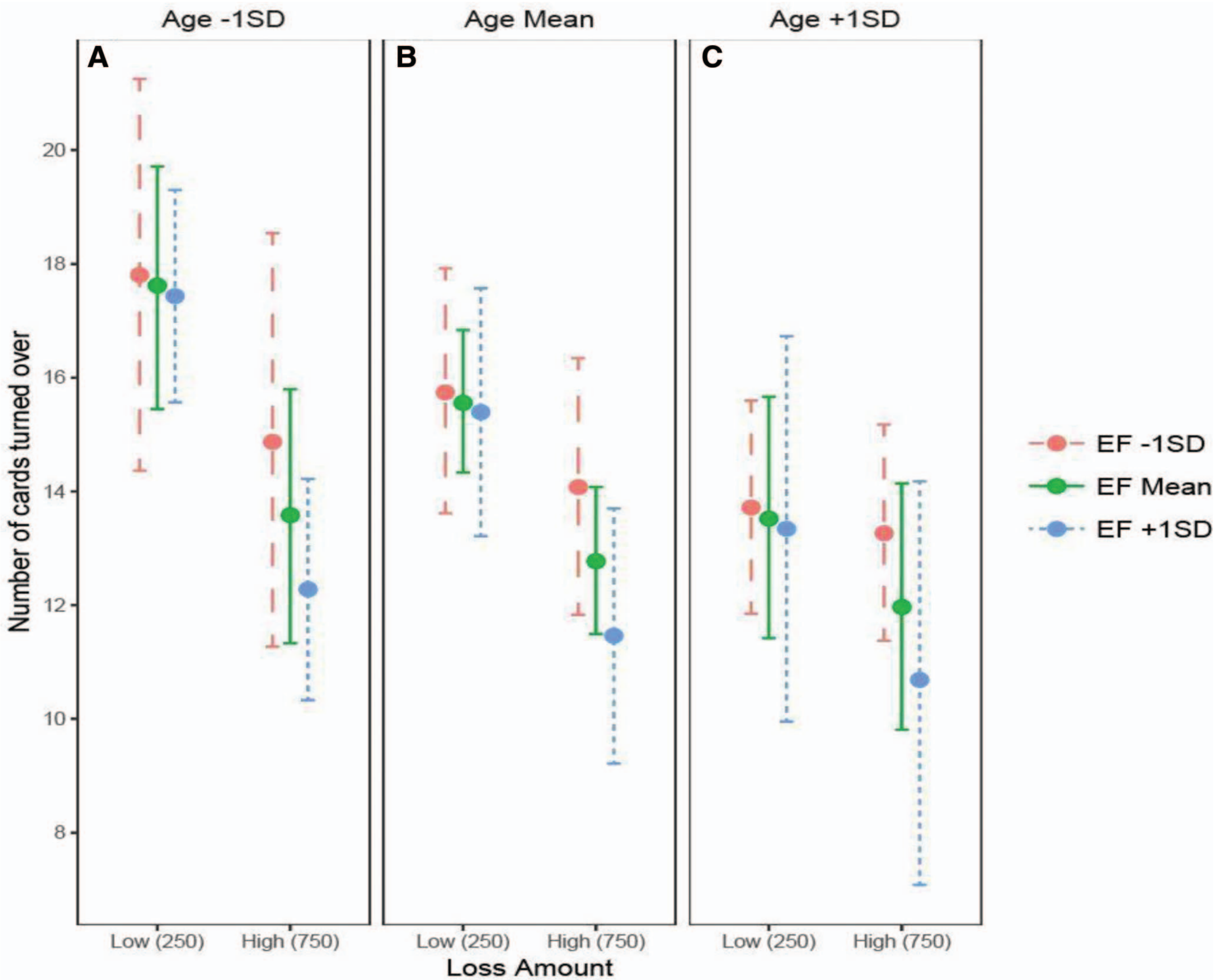

Figure 2. Moderation effects of executive functioning on the association between age and sensitivity to losses and gains shows the number of cards turned over as a function of both an Age × Executive Function × Loss Magnitude (Top) and Age × Executive Function × Gain Magnitude (Bottom) interaction. Because age is a continuous variable, it was split for illustration purposes in three panels (−1 *SD*, *M* age, +1 *SD*) in both parts of the Figure (A, B, C and D, E, F for the loss and gain magnitude interaction effects, respectively). Error bars reflect 95% credibility intervals. EF = executive function. See the online article for the color version of this figure. (*Figure continues on next page*)

An Age × EV interaction was also found; younger adults were more likely to use EV when making a choice than older adults. This interaction was conditional on an observed Age × EF × EV interaction. Figure 3 illustrates how EF score impact making choices based on EV as a function of age. Younger adults, regardless of EF level, tended to turn cards over as a function of changes in EV (Figure 3A). In contrast, older participants did not appear to use EV (Figure 3C). Specifically, for the middle age participants, we observed that individuals with low EF began to deviate from using EV to guide their decisions, whereas those with mean- or higher level EF still appeared to choose based on EV.

Discussion

In this study, we sought to address age differences in how individuals use information that is presented to them during a risky decision making task, the degree to which this may differ based on the affective context of the choice, and the extent to which neurocognitive functioning moderated these effects. Though our initial hypotheses predicted that older adults may experience difficulties making choices in "colder," more deliberative decision contexts compared to younger adults, our results demonstrate that age effects may be broader than originally anticipated. Our results suggest that older adults tend to use only a subset of information

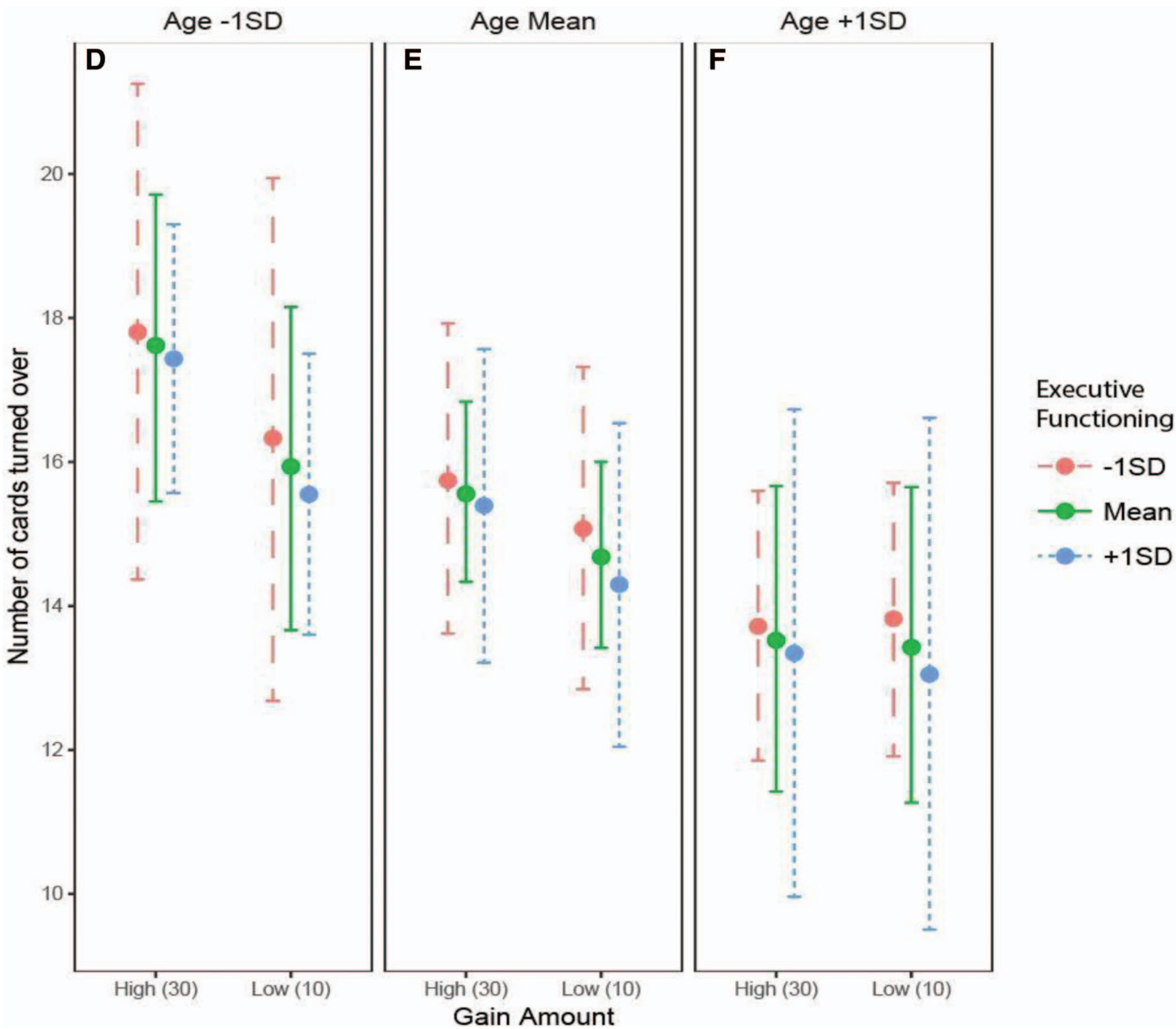

Figure 2. (*continued*)

available when making decisions. This tendency to use only a subset of information limits the ability to effectively integrate contextually relevant information which may lead to an EV-consistent choice. Age-related performance on the CCT appears overreliant on a noncompensatory decision strategy in which older adults strive to conserve effort in the face of declining cognitive resources. This sentiment is echoed by our findings that individual differences in executive function moderate these associations. Specifically, low performance on measures of executive functioning appears to be a risk factor for suboptimal decision making. This pattern seems to begin in middle age and progressively becomes stronger in older age.

Consistent with this account, we found that older adults, compared to younger adults, were less likely to adjust their choices based on shifts in the task primitive values. Notably, we observed that older adults appeared to primarily adjust their choices based on probability level, albeit at a more modest degree than younger adults. In contrast, older adults did not appear to modify their choices based on gain and loss magnitude information, which were less salient sources of information in general (i.e., for both younger and older participants) based on the coefficient magnitudes obtained in the mixed-model analyses. We posit that older and younger adults alike use probability information as the foundation of their decision strategy with the CCT, providing an information satisficing heuristic for "more" or "less" risk (see also Markiewicz & Kubińska, 2015). Younger adults, however, appear to more readily consider changes in the loss and gain amounts. The absence of observed three-way interactions involving CCT condition suggests that these effects are largely independent of a shift in affective versus deliberative decision context.

The tendency to engage in a noncompensatory decision strategy such as utilizing a subset of information limits the ability to base

Table 4
Linear Mixed Models Analysis for Risk Return

Variable	Estimate	*SE*	95% CI Lower bound	95% CI Upper bound
Intercept	3.36*	.22	2.94	3.78
Age	−.30	.29	−.87	.28
GMA	−.33*	.15	−.62	−.03
EF	.24	.25	−.25	.74
Condition (−1 = hot; 1= cold)	−.13*	.04	−.20	−.05
EV	.54*	.12	.32	.77
Risk	−.02	.09	−.19	.16
Decision number	−.90*	.10	−1.09	−.71
Age × GMA	−.16	.18	−.51	.19
Age × EF	.01	.22	−.42	.46
Condition × Age	.16*	.05	.06	.27
Condition × GMA	−.03	.03	−.08	.02
Condition × EF	−.14*	.05	−.22	−.05
Age × EV	−.55*	.16	−.86	−.24
Age × Risk	−.20	.12	−.44	.03
GMA × EV	.32*	.08	.17	.48
GMA × Risk	.07	.06	−.04	.19
EF × EV	.13	.13	−.13	.40
EF × Risk	.20*	.10	.01	.40
Condition × EV	−.13	.09	−.30	.04
Condition × Risk	−.16*	.07	−.29	−.01
Condition × Age × GMA	−.02	.03	−.08	.04
Condition × Age × EF	−.05	.04	−.13	.03
Age × GMA × EV	.04	.10	−.16	.23
Age × GMA × Risk	.06	.07	−.09	.20
Age × EF × EV	−.24*	.12	−.48	−.01
Age × EF × Risk	−.16	.09	−.34	.02
Age × Condition × EV	−.15	.12	−.39	.08
Age × Condition × Risk	−.18	.10	−.37	.02
GMA × Condition × EV	.07	.06	−.04	.18
GMA × Condition × Risk	.02	.05	−.07	.11
EF × Condition × EV	.14	.10	−.05	.33
EF × Condition × Risk	.24*	.08	.08	.40
Age × GMA × Condition × EV	.03	.07	−.12	.17
Age × GMA × Condition × Risk	−.03	.06	−.15	.08
Age × EF × Condition × EV	−.05	.09	−.22	.11
Age × EF × Condition × Risk	−.09	.07	−.23	.05

Note. GMA = general mental ability; EF = executive function; EV = expected value.
* Indicates significance based on the 95% posterior credible intervals for the obtained parameter estimate.

decisions on the EV of the choice options, and more broadly has the potential to lead to suboptimal choices. Without efficient and comprehensive processing of the CCT decision primitives, their integration is not possible; thus, EV might not be effectively used in older adults. Regardless of task condition, the tendency to adjust risk-taking decisions according to EV decreases with age. This point differed from our initial prediction that EV sensitivity would be diminished only in the context of the CCT-Cold for older adults. However, the observed global age-related differences in EV sensitivity supports the hypothesis that differences in decision making in older adults reflect changes in engaging in information integration strategies. In this regard, our results are consistent with past research investigating older adults' EV sensitivity. For example, Weller et al. (2011) found that older adults demonstrated age-related declines in EV sensitivity on the cups task (Weller, Levin, Shiv, & Bechara, 2007), a descriptive risk task. This pattern was invariant for risks involving potential gains and losses. In addition, given its static nature of payouts, one could interpret poor decision making on the IGT in a similar way: One must, at least implicitly understand the EVs associated with each deck in order to end with a positive net amount. Our results suggest that these differences are invariant to the affective context of the CCT condition, even when mixed gambles are involved (i.e., when the potential for gain and loss are present in the same trial).

Importantly, probability information was presented as frequencies (the number of loss cards) rather than percentages, the latter of which would have made processing more computationally taxing. In contrast, EV sensitivity is presumed to involve complex cognitive processes, such as executive functioning and working memory (Figner & Weber, 2011; Nassar et al., 2016; Samanez-Larkin & Knutson, 2015). Research shows that the relationship between age-related decision making differences and neurocognitive functioning may reflect structural and functional neural differences associated with age (e.g., Braver & West, 2008; Samanez-Larkin & Knutson, 2015). In support of this assertion, we found that individual differences in executive functioning, but not general mental ability, further moderated observed Age × EV interactions. Again, these differences appeared to result from differential tendencies to adjust choices based on gain and loss magnitude amounts. Contrary to our specific predictions that age-related differences in some decision making processes would be condition-specific, these findings support the idea that age-related differences in some decision making processes may be accentuated by lower executive function. Conversely, the preservation in these neurocognitive functioning domains may buffer age-related declines in decision-related information processing. Our robust patterns of associations between the neurocognitive variables and both the primitives and EV sensitivity parameters highlight that, as more information is presented, greater executive functioning is associated with the greater tendency to use this information, largely irrespective of the affective context.

These results significantly extend the work of Huang and colleagues (2013, 2015), who found age differences in self-reported deliberative decision making strategies, and differences in information use on the "warm" version of the CCT. Specifically, our results demonstrated the associations between neuropsychological variables, decision primitives, and risk-return indicators across task condition. Notably, the within-subjects design employed in the current study revealed global differences and patterns of associations that were opaque in prior studies. At a statistical level, the use of Bayesian linear mixed models allowed us to better address the issue of censored data in the CCT-Hot. Because a trial ends when a participant turns over a losing card, traditional ANOVA- or OLS regression-based CCT analyses using number of cards as a decision metric have been silent with respect to estimating how many trials would be turned over, presuming a loss card was not selected. With this in mind, our results contrast with Huang et al. (2013), who found greater risk-taking in the CCT-Cold than a warmer version of the task using OLS regression analyses. We recommend that researchers who use the CCT or similar tasks consider censored data and approach these analyses accordingly.

We propose that previous inconsistencies in findings regarding the effects of aging on decision making may be reconciled not only by acknowledging the degree to which particular decisions recruit deliberative versus affective/experiential processes, but also the degree to which more simplistic strategies are available to navigate

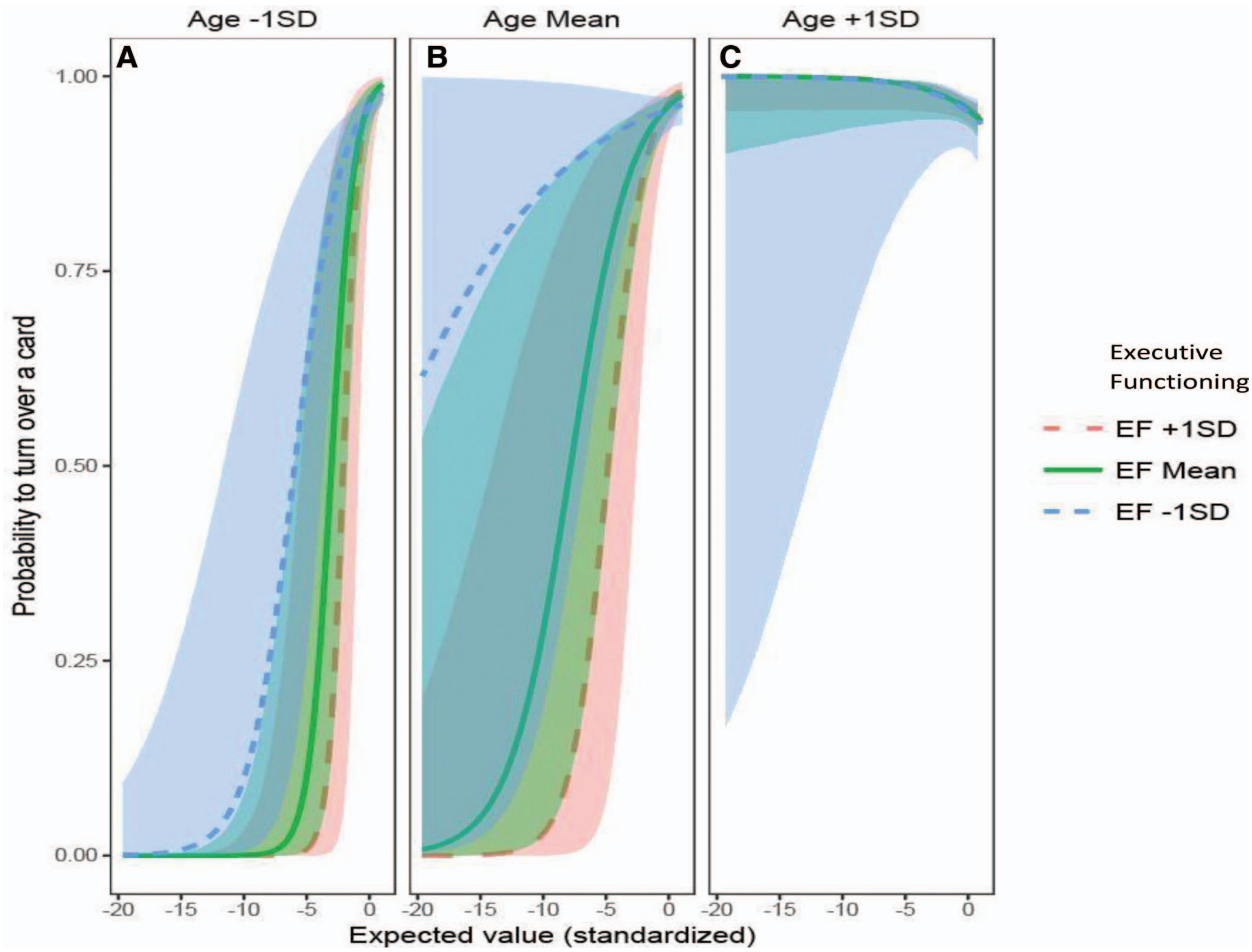

Figure 3. Moderation effects of executive functioning on the association between age and expected value sensitivity. Age × Executive Function × Expected Value interaction. Figure 3 shows the number of cards turned over as a function of both an Age × Executive Function × Expected Value. Because age is a continuous variable, it was split for illustration purposes in three panels, Panel A (−1 *SD*), Panel B (*M* age), and Panel C (+1 *SD*). Error bars reflect 95% credibility intervals. See the online article for the color version of this figure.

the task (Mata et al., 2011). Tasks that more heavily involve deliberative processes, such as using information integration strategies or holding previously encountered information in working memory, may be more difficult for older adults (Mata & Nunes, 2010). In turn, older adults may default to associative, noncompensatory decision strategies that favor avoidance of potentially negative outcomes (Frank & Kong, 2008), and may even actively avoid obtaining additional information that could be relevant to the choice at hand (Cole & Balasubramanian, 1993; Mata et al., 2013). Future research may benefit from restructuring the presentation of contextual information to further test this assertion. For example, had this information been presented as a percentage, older adults may have preferentially used another source of information to avoid deliberative processing demands, such as loss amount to guide their choices.

Although it extends beyond the current study, we acknowledge that potential motivational differences may be present across the life span, and these differences may have implications for decision making in affective versus deliberative contexts. According to Hess's (2006) selective engagement hypothesis, older adults selectively recruit deliberative processes to conserve mental effort. However, this motivation to engage in a cognitively taxing task can depend, in part, on the relevance of the task to the person (Hess, 2014; Queen & Hess, 2010). For instance, Hess, Germain, Rosenberg, Leclerc, and Hodges (2005) found that when personal relevance was high, older adults were less likely to use peripheral, affective cues to construct attitudes, and performed more similarly to younger adults on the task. In contrast, older adults were more likely to be influenced by peripheral, affective cues (e.g., source likability) when personal relevance was low. This theory would suggest that increasing the motivation level in a deliberative context may mitigate differences similar to those observed here. However, our results would suggest that, although motivation may serve to increase attention, its impact may be bounded by task difficulty/complexity given older adults' declines in underlying executive functioning.

Though these results are promising, we acknowledge several potential limitations of the current research. First, because this study was cross-sectional in design, it limits the ability to make inferences about the degree to which age-related differences in risky decision making are mediated by age-related declines in neurocognitive processes. Longitudinal methods designed to test these effects would help to reinforce our assertions. Second, the older adults in this study could be considered above average in terms of neurocognitive functioning. Consequently, these results should be approached with caution when generalizing to older adults with lower cognitive abilities. However, because we demonstrated that the lower functioning older adults in this sample already displayed substantial differences in their decision making tendencies, we would hypothesize that observed results may underestimate these effects. Third, though the CCT provides a viable paradigm to equivalently study different contexts in which risk-taking may occur, it is clearly not ideal, as the hot and cold versions do not differ solely on the affective versus deliberative dimension (for a discussion, see Figner et al., 2009) and as the CCT does only encompass a narrow segment of the larger universe of uncertainty-based decision making. For instance, this study cannot directly speak to the description–experience gap (Barron & Erev, 2003), intertemporal choice (e.g., Kirby, Petry, & Bickel, 1999), or decision making in the face of ambiguity (Tymula et al., 2013). Only by understanding the broader picture of decision making, may we see how these differences contribute to decision making differences in everyday life. Fourth, we must acknowledge that the task order was not counterbalanced. Though counterbalancing may be more desirable from an experimental perspective, its absence may have some advantages when studying individual differences as the absence of counterbalancing removes a source of between-subjects variation. Finally, CCT performance was not incentivized and thus, it is possible that performance does not mimic that which may have been observed when real money was involved. We feel, however, that the lack of incentivization was unlikely to explain the age differences and subsequent interactions that we observed. The results at the task level mimic those observed in past studies which involved incentives. Moreover, effects like the Age $\times$ EF $\times$ EV interactions would be unlikely to be explained simply by the addition of an incentive. It is also important to point out that "house money effects" (i.e., a tendency to be riskier with profits made than with one's initial investments) by definition, increase risk-seeking (Thaler & Johnson, 1990); however, most individuals demonstrated risk aversion, as evidenced by our risk-return decomposition.

Despite these limitations, we feel that our results have implications for communicating risk information to older adults in several ways. The current findings contribute to our understanding of how older adults approach uncertainty-based decisions, differentiating between specific processes that are prone to decline across the life span and those that may be preserved. Studies examining age differences in medical and financial decision making indicate that older adults demonstrate declines in the thoroughness of the information search process and in the amount of information used (Meyer, Russo, & Talbot, 1995; Meyer, Talbot, & Ranalli, 2007; Shivapour, Nguyen, Cole, & Denburg, 2012). In this regard, the current results have direct implications for the promotion of advantageous decision making of older adults. First, simply presenting more information may not be an effective means to convey risk information. Greater amounts of information may become especially burdensome from a processing standpoint. Second, consistent with emerging work in the domain of "choice architecture," these results imply the primary and most salient information presented in a choice should correspond with that most vital for guiding choices and promoting quality decisions (for review, see Münscher, Vetter, & Scheuerle, 2016). Third, if older adults are less likely to integrate numeric information, then decision aids could be constructed to help conduct these calculations and then present it back in more simplistic ways. Taken together, these insights may inform efforts to retain, or even improve, decision making in older adults.

Conclusion

Both the content of our decisions and how we approach them may differ over the life span. Past research has suggested that the affective context of the choice is a primary determinant of age-related differences in risky decision making. Our findings suggest the affective context of the choice does matter, as it may signal that more cognitive effort may be necessary to arrive at a choice. However, common underlying decision processes may operate in risk tasks deemed "affective" or more "deliberative," leaving us to conclude that underlying mechanisms such as information use and search may be paramount, relative to differences in the affective context. Thus, decision tendencies in older adults, especially, may be compromised as declines in executive functioning progress through the life span. We feel that these results significantly extend the current literature and provide opportunities to further test how older adults process risk information.

References

Barr, D. J., Levy, R., Scheepers, C., & Tily, H. J. (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language, 68,* 255–278. http://dx.doi.org/10.1016/j.jml.2012.11.001

Barron, G., & Erev, I. (2003). Small feedback-based decisions and their limited correspondence to description-based decisions. *Journal of Behavioral Decision Making, 16,* 215–233. http://dx.doi.org/10.1002/bdm.443

Bechara, A., Damasio, A. R., Damasio, H., & Anderson, S. W. (1994). Insensitivity to future consequences following damage to human prefrontal cortex. *Cognition, 50,* 7–15. http://dx.doi.org/10.1016/0010-0277(94)90018-3

Blanchard-Fields, F. (2007). Everyday problem solving and emotion: An adult developmental perspective. *Current Directions in Psychological Science, 16,* 26–31. http://dx.doi.org/10.1111/j.1467-8721.2007.00469.x

Brand, M., & Markowitsch, H. J. (2010). Aging and decision-making: A neurocognitive perspective. *Gerontology, 56,* 319–324. http://dx.doi.org/10.1159/000248829

Brand, M., & Schiebener, J. (2013). Interactions of age and cognitive functions in predicting decision making under risky conditions over the life span. *Journal of Clinical and Experimental Neuropsychology, 35,* 9–23. http://dx.doi.org/10.1080/13803395.2012.740000

Braver, T. S., & West, R. (2008). Working memory, executive control, and aging. In F. I. M. Craik & T. A. Salthouse (Eds.), *The handbook of aging and cognition* (3rd ed., pp. 311–372). New York, NY: Psychology Press.

Brown, S. C., & Park, D. C. (2003). Theoretical models of cognitive aging and implications for translational research in medicine. *The Gerontologist, 43*(Suppl. 1), 57–67. http://dx.doi.org/10.1093/geront/43.suppl_1.57

Bürkner, P. C. (2017). brms: An R package for Bayesian multilevel models using Stan. *Journal of Statistical Software, 80,* 1–28. http://dx.doi.org/10.18637/jss.v080.i01

Bürkner, P. C. (2018). Advanced Bayesian multilevel modeling with the R package brms. *The R Journal, 10,* 395–411. http://dx.doi.org/10.32614/RJ-2018-017

Cole, C. A., & Balasubramanian, S. K. (1993). Age differences in consumers' search for information: Public policy implications. *Journal of Consumer Research, 20,* 157–169. http://dx.doi.org/10.1086/209341

Deakin, J., Aitken, M., Robbins, T., & Sahakian, B. J. (2004). Risk taking during decision-making in normal volunteers changes with age. *Journal of the International Neuropsychological Society, 10,* 590–598. http://dx.doi.org/10.1017/S1355617704104104

Figner, B., Mackinlay, R. J., Wilkening, F., & Weber, E. U. (2009). Affective and deliberative processes in risky choice: Age differences in risk taking in the Columbia Card Task. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 35,* 709–730. http://dx.doi.org/10.1037/a0014983

Figner, B., & Voelki, N. (2004). Risky decision making in a computer card game: An information integration experiment. *Polish Psychological Bulletin, 35,* 135–139.

Figner, B., & Weber, E. U. (2011). Who takes risks when and why? Determinants of risk taking. *Current Directions in Psychological Science, 20,* 211–216. http://dx.doi.org/10.1177/0963721411415790

Folstein, M. F., Folstein, S. E., & McHugh, P. R. (1975). "Mini-mental state". A practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research, 12,* 189–198. http://dx.doi.org/10.1016/0022-3956(75)90026-6

Frank, M. J., & Kong, L. (2008). Learning to avoid in older age. *Psychology and Aging, 23,* 392–398. http://dx.doi.org/10.1037/0882-7974.23.2.392

Frey, R., Mata, R., & Hertwig, R. (2015). The role of cognitive abilities in decisions from experience: Age differences emerge as a function of choice set size. *Cognition, 142,* 60–80. http://dx.doi.org/10.1016/j.cognition.2015.05.004

Fung, H. H., & Carstensen, L. L. (2003). Sending memorable messages to the old: Age differences in preferences and memory for advertisements. *Journal of Personality and Social Psychology, 85,* 163–178. http://dx.doi.org/10.1037/0022-3514.85.1.163

Grady, C. L. (2000). Functional brain imaging and age-related changes in cognition. *Biological Psychology, 54,* 259–281. http://dx.doi.org/10.1016/S0301-0511(00)00059-4

Hasher, L., & Zacks, R. T. (1984). Automatic processing of fundamental information: The case of frequency of occurrence. *American Psychologist, 39,* 1372–1388. http://dx.doi.org/10.1037/0003-066X.39.12.1372

Heaton, R., Chelune, G., Tally, J., Kay, G., & Curtis, G. (1993). *Wisconsin card sorting manuals*. Odessa, FL: Psychological Assessment Resources.

Henninger, D. E., Madden, D. J., & Huettel, S. A. (2010). Processing speed and memory mediate age-related differences in decision making. *Psychology and Aging, 25,* 262–270. http://dx.doi.org/10.1037/a0019096

Hess, T. M. (2006). Adaptive aspects of social cognitive functioning in adulthood: Age-related goal and knowledge influences. *Social Cognition, 24,* 279–309. http://dx.doi.org/10.1521/soco.2006.24.3.279

Hess, T. M. (2014). Selective engagement of cognitive resources: Motivational influences on older adults' cognitive functioning. *Perspectives on Psychological Science, 9,* 388–407. http://dx.doi.org/10.1177/1745691614527465

Hess, T. M., Germain, C. M., Rosenberg, D. C., Leclerc, C. M., & Hodges, E. A. (2005). Aging- related selectivity and susceptibility to irrelevant affective information in the construction of attitudes. *Aging, Neuropsychology, and Cognition, 12,* 149–174. http://dx.doi.org/10.1080/13825580590925170

Huang, Y., Wood, S., Berger, D., & Hanoch, Y. (2013). Risky choice in younger versus older adults: Affective context matters. *Judgment and Decision Making, 8,* 179–187.

Huang, Y. H., Wood, S., Berger, D. E., & Hanoch, Y. (2015). Age differences in experiential and deliberative processes in unambiguous and ambiguous decision making. *Psychology and Aging, 30,* 675–687. http://dx.doi.org/10.1037/pag0000038

Johnson, M. M. S., & Drungle, S. C. (2000). Purchasing over-the counter medications: The influence of age and familiarity. *Experimental Aging Research, 26,* 245–261. http://dx.doi.org/10.1080/036107300404886

Josef, A. K., Richter, D., Samanez-Larkin, G. R., Wagner, G. G., Hertwig, R., & Mata, R. (2016). Stability and change in risk-taking propensity across the adult life span. *Journal of Personality and Social Psychology, 111,* 430–450. http://dx.doi.org/10.1037/pspp0000090

Kennedy, K. M., & Raz, N. (2009). Aging white matter and cognition: Differential effects of regional variations in diffusion properties on memory, executive functions, and speed. *Neuropsychologia, 47,* 916–927. http://dx.doi.org/10.1016/j.neuropsychologia.2009.01.001

Kirby, K. N., Petry, N. M., & Bickel, W. K. (1999). Heroin addicts have higher discount rates for delayed rewards than non-drug-using controls. *Journal of Experimental Psychology: General, 128,* 78–87. http://dx.doi.org/10.1037/0096-3445.128.1.78

Lejuez, C. W., Read, J. P., Kahler, C. W., Richards, J. B., Ramsey, S. E., Stuart, G. L., . . . Brown, R. A. (2002). Evaluation of a behavioral measure of risk taking: The Balloon Analogue Risk Task (BART). *Journal of Experimental Psychology: Applied, 8,* 75–84. http://dx.doi.org/10.1037/1076-898X.8.2.75

Lezak, M. D. (1995). *Neuropsychological assessment* (3rd ed.). New York, NY: Oxford University Press.

Li, S.-C., Lindenberger, U., Hommel, B., Aschersleben, G., Prinz, W., & Baltes, P. B. (2004). Transformations in the couplings among intellectual abilities and constituent cognitive processes across the life span. *Psychological Science, 15,* 155–163. http://dx.doi.org/10.1111/j.0956-7976.2004.01503003.x

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

Lipkus, I. M., Samsa, G., & Rimer, B. K. (2001). General performance on a numeracy scale among highly educated samples. *Medical Decision Making, 21,* 37–44. http://dx.doi.org/10.1177/0272989X0102100105

MacPherson, S. E., Phillips, L. H., & Della Sala, S. (2002). Age, executive function, and social decision making: A dorsolateral prefrontal theory of cognitive aging. *Psychology and Aging, 17,* 598–609. http://dx.doi.org/10.1037/0882-7974.17.4.598

Mamerow, L., Frey, R., & Mata, R. (2016). Risk taking across the life span: A comparison of self-report and behavioral measures of risk taking. *Psychology and Aging, 31,* 711–723. http://dx.doi.org/10.1037/pag0000124

Markiewicz, Ł., & Kubińska, E. (2015). Information use differences in hot and cold risk processing: When does information about probability count in the Columbia Card Task? *Frontiers in Psychology, 6,* 1727. http://dx.doi.org/10.3389/fpsyg.2015.01727

Mata, R., Josef, A. K., Samanez-Larkin, G. R., & Hertwig, R. (2011). Age differences in risky choice: A meta-analysis. *Annals of the New York Academy of Sciences, 1235,* 18–29. http://dx.doi.org/10.1111/j.1749-6632.2011.06200.x

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

Mata, R., Wilke, A., & Czienskowski, U. (2013). Foraging across the life span: Is there a reduction in exploration with aging? *Frontiers in Neuroscience, 7,* 53. http://dx.doi.org/10.3389/fnins.2013.00053

Meyer, B. J. F., Russo, C., & Talbot, A. (1995). Discourse comprehension and problem solving: Decisions about the treatment of breast cancer by women across the life span. *Psychology and Aging, 10,* 84–103. http://dx.doi.org/10.1037/0882-7974.10.1.84

Meyer, B. J. F., Talbot, A. P., & Ranalli, C. (2007). Why older adults make more immediate treatment decisions about cancer than younger adults. *Psychology and Aging, 22,* 505–524. http://dx.doi.org/10.1037/0882-7974.22.3.505

Münscher, R., Vetter, M., & Scheuerle, T. (2016). A review and taxonomy of choice architecture techniques. *Journal of Behavioral Decision Making, 29,* 511–524. http://dx.doi.org/10.1002/bdm.1897

Nassar, M. R., Bruckner, R., Gold, J. I., Li, S.-C., Heekeren, H. R., & Eppinger, B. (2016). Age differences in learning emerge from an insufficient representation of uncertainty in older adults. *Nature Communications, 7,* 11609. http://dx.doi.org/10.1038/ncomms11609

Novak, D. L., & Mather, M. (2007). Aging and variety seeking. *Psychology and Aging, 22,* 728–737. http://dx.doi.org/10.1037/0882-7974.22.4.728

Okun, M. A. (1976). Adult age and cautiousness in decision: A review of the literature. *Human Development, 19,* 220–233. http://dx.doi.org/10.1159/000271530

Ortman, J. M., Velkoff, V. A., & Hogan, H. (2014). *An aging nation: The older population in the United States. United States Census Bureau*. Retrieved from https://www.census.gov/prod/2014pubs/p25-1140.pdf

Panno, A., Lauriola, M., & Figner, B. (2013). Emotion regulation and risk taking: Predicting risky choice in deliberative decision making. *Cognition and Emotion, 27,* 326–334. http://dx.doi.org/10.1080/02699931.2012.707642

Peters, E., & Bruine de Bruin, W. (2012). Aging and decision skills. In M. K. Dhami, A. Schlottmann, & M. R. Walmann (Eds.), *Judgment and decision making as a skill: Learning, development and evolution* (pp. 113–160). New York, NY: Cambridge University Press.

Peters, E., Dieckmann, N. F., & Weller, J. A. (2011). Age differences in complex decision making. In K. W. Schaie & S. L. Willis (Eds.), *Handbook of the psychology of aging* (7th ed., pp. 133–151). Burlington, MA: Academic Press. http://dx.doi.org/10.1016/B978-0-12-380882-0.00009-7

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,* 1–23. http://dx.doi.org/10.1111/j.1745-6916.2007.00025.x

Queen, T. L., & Hess, T. M. (2010). Age differences in the effects of conscious and unconscious thought in decision making. *Psychology and Aging, 25,* 251–261. http://dx.doi.org/10.1037/a0018856

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,* 817–824. http://dx.doi.org/10.1037/a0028744

Raz, N., Lindenberger, U., Rodrigue, K. M., Kennedy, K. M., Head, D., Williamson, A., . . . Acker, J. D. (2005). Regional brain changes in aging healthy adults: General trends, individual differences and modifiers. *Cerebral Cortex, 15,* 1676–1689. http://dx.doi.org/10.1093/cercor/bhi044

R Core Team. (2018). *R: A language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing. https://www.R-project.org/

Reitan, R. M. (1958). Validity of the trail making test as an indicator of organic brain damage. *Perceptual and Motor Skills, 8,* 271–276. http://dx.doi.org/10.2466/pms.1958.8.3.271

Rey, A. (1941). L'examen psychologique dans les cas d'encéphalopathie traumatique. (Les problems.) [The psychological examination in cases of traumatic encephalopathy. Problems]. *Archives de Psychologie, 28,* 215–285.

Rey, A. (1964). *The clinical examination in psychology*. Paris, France: Presses Universitaire de France.

Rogers, R. D., Everitt, B. J., Baldacchino, A., Blackshaw, A. J., Swainson, R., Wynne, K., . . . Robbins, T. W. (1999). Dissociable deficits in the decision-making cognition of chronic amphetamine abusers, opiate abusers, patients with focal damage to prefrontal cortex, and tryptophan-depleted normal volunteers: Evidence for monoaminergic mechanisms. *Neuropsychopharmacology, 20,* 322–339. http://dx.doi.org/10.1016/S0893-133X(98)00091-8

Rolison, J. J., Hanoch, Y., Wood, S., & Liu, P.-J. (2014). Risk-taking differences across the adult life span: A question of age and domain. *The Journals of Gerontology Series B, Psychological Sciences and Social Sciences, 69,* 870–880. http://dx.doi.org/10.1093/geronb/gbt081

Salthouse, T. A. (2004). What and when of cognitive aging. *Current Directions in Psychological Science, 13,* 140–144. http://dx.doi.org/10.1111/j.0963-7214.2004.00293.x

Salthouse, T. A. (2010). Selective review of cognitive aging. *Journal of the International Neuropsychological Society, 16,* 754–760. http://dx.doi.org/10.1017/S1355617710000706

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

Schmidt, M. (1996). *Rey auditory verbal learning test: A handbook*. Los Angeles, CA: Western Psychological Services.

Shivapour, S. K., Nguyen, C. M., Cole, C. A., & Denburg, N. L. (2012). Effects of age, sex, and neuropsychological performance on financial decision-making. *Frontiers in Neuroscience, 6,* 82. http://dx.doi.org/10.3389/fnins.2012.00082

Somerville, L. H., Haddara, N., Sasse, S. F., Skwara, A. C., Moran, J. M., & Figner, B. (2018). Dissecting "peer presence" and "decisions" to deepen understanding of peer influence on adolescent risky choice. *Child Development*. Advance online publication. http://dx.doi.org/10.1111/cdev.13081

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,* 57–74. http://dx.doi.org/10.1111/j.1749-6632.2011.06208.x

Thaler, R. H., & Johnson, E. J. (1990). Gambling with house money and trying to break even. The effects of prior outcomes on risky choice. *Management Science, 36,* 643–660. http://dx.doi.org/10.1287/mnsc.36.6.643

Tombaugh, T. N. (2004). Trail Making Test A and B: Normative data stratified by age and education. *Archives of Clinical Neuropsychology, 19,* 203–214. http://dx.doi.org/10.1016/S0887-6177(03)00039-8

Tranel, D., Benton, A., & Olson, K. (1997). A 10-year longitudinal study of cognitive changes in elderly persons. *Developmental Neuropsychology, 13,* 87–96. http://dx.doi.org/10.1080/87565649709540669

Tymula, A., Rosenberg Belmaker, L. A., Ruderman, L., Glimcher, P. W., & Levy, I. (2013). Like cognitive function, decision making across the life span shows profound age-related changes. *Proceedings of the National Academy of Sciences of the United States of America, 110,* 17143–17148. http://dx.doi.org/10.1073/pnas.1309909110

van Duijvenvoorde, A. C. K., Huizenga, H. M., Somerville, L. H., Delgado, M. R., Powers, A., Weeda, W. D., . . . Figner, B. (2015). Neural correlates of expected risks and returns in risky choice across development. *The Journal of Neuroscience, 35,* 1549–1560. http://dx.doi.org/10.1523/JNEUROSCI.1924-14.2015

von Neumann, J., & Morgenstern, O. (1947). *Theory of games and economic behavior* (2nd ed.). Princeton, NJ: Princeton University.

Weber, E. U. (2010). Risk attitude and preference. *WIREs Cognitive Science, 1,* 79–88. http://dx.doi.org/10.1002/wcs.5

Wechsler, D. (1999). *Manual for the Wechsler Abbreviated Intelligence Scale (WASI)*. San Antonio, TX: The Psychological Corporation.

Weller, J. A., Levin, I. P., & Denburg, N. L. (2011). Trajectory of risky decision making for potential gains and losses from ages 5 to 85. *Journal* *of Behavioral Decision Making, 24,* 331–344. http://dx.doi.org/10.1002/bdm.690

Weller, J. A., Levin, I. P., Shiv, B., & Bechara, A. (2007). Neural correlates of adaptive decision making for risky gains and losses. *Psychological Science, 18,* 958–964. http://dx.doi.org/10.1111/j.1467-9280.2007.02009.x

Wilkinson, G. S. (1993). *WRAT-3: Wide Range Achievement Test administration manual*. Wilmington, DE: Wide Range, Incorporated.

Yoon, C., Cole, C. A., & Lee, M. P. (2009). Consumer decision making and aging: Current knowledge and future directions. *Journal of Consumer Psychology, 19,* 2–16. http://dx.doi.org/10.1016/j.jcps.2008.12.002

Zacks, R. T., Hasher, L., & Li, K. Z. H. (2000). Human memory. In F. I. M. Craik & T. A. Salthouse (Eds.), *The handbook of aging and cognition* (pp. 293–357). Mahwah, NJ: Erlbaum Publishers.

Received September 7, 2018
Revision received August 15, 2019
Accepted August 20, 2019 ■