Age differences in risky choice: a meta-analysis

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Abstract

Does risk taking change as a function of age? We conducted a systematic literature search and found 29 comparisons between younger and older adults on behavioral tasks thought to measure risk taking (N =4,093). The reports relied on various tasks differing in several respects, such as the amount of learning required or the choice framing (gains vs. losses). The results suggest that age-related differences vary considerably as a function of task characteristics, in particular the learning requirements of the task. In decisions from experience, age-related differences in risk taking were a function of decreased learning performance: older adults were more risk seeking compared to younger adults when learning led to risk-avoidant behavior, but were more risk averse when learning led to risk-seeking behavior. In decisions from description, younger adults and older adults showed similar risk-taking behavior for the majority of the tasks, and there were no clear age-related differences as a function of gain/loss framing. We discuss limitations and strengths of past research and provide suggestions for future work on age-related differences in risk taking.

Keywords

aging; risk; meta-analysis; decisions from description; decisions from experience

The 21st century is likely to become the century of centenarians: most babies born since 2000 in countries with already long life expectancies, such as Germany and France, may live to be 100 years old.[1] Rising life expectancy will likely lead to longer working lives and the need for people to make decisions that are fraught with uncertainty late in life. Risk and uncertainty pervades decisions about wealth and health across the life span, such as the decision to invest in stocks, bonds, or other investment vehicles, given the possibility of ever-faster cycles of booms and busts, or the decision about which of several medical treatment options to pursue (e.g., surgery, radiation, and chemotherapy), given their different chances of success and risks of severe side effects.[2] In addition, aging is associated with significant motivational and cognitive changes that are likely to affect decisions in predictable ways, and thus research in this domain provides an important test bed

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concerning the role of these factors on decision making. Is there evidence that decision making under risk changes systematically with advancing age?

Reviews on aging and decision making abound, yet there has been no systematic attempt to quantify age-related differences in risky choice across tasks and studies.[3–5] We aim to close this gap by applying meta-analytic methods to quantify adult age-related differences in risky choice. The review is organized as follows. First, we provide a brief overview of the theory and measurement of risky choice. Second, we present hypotheses about the link between aging and risky choice. Third, we report a meta-analytic summary of empirical studies on risky choice in younger and older adults. Finally, we discuss limitations of past studies and make recommendations for future work on the impact of aging on decisions under risk.

The economic and psychological definitions of risk

In economics, risk is usually defined as the variance or probability of possible outcomes.[6] As Frank Knight, a founder of the Chicago School of Economics, has pointed out, one should distinguish between different types of "probability situations," namely, *a priori* probabilities, statistical probabilities, and estimates.[7] According to Knight, *a priori* probabilities refer to situations in which the probability of an outcome is known or can easily be assigned via mathematical calculation. In turn, statistical probabilities refer to situations in which the probabilities must be gauged empirically through experience with similar outcomes. Finally, estimates refer to situations of extreme uncertainty in which there is no basis to empirically derive probabilities, for example, because one is dealing with unique events. In such cases, it is not clear how to assess the likelihood of an outcome. In the remainder of this paper, we will be concerned with the distinction between *a priori* and statistical probabilities.

Recent work on the psychology of risky choice seems to echo the distinction between *a priori* and statistical probabilities by emphasizing the different psychological requirements of decisions from description and experience: many studies in decision research have assessed risky behavior on the basis of people's choices between gambles or lotteries in which full information about probabilities and outcomes is provided—decisions from description. In contrast, decisions from experience provide no explicit information about probabilities, and individuals must rely on experience acquired through feedback. The evidence is mounting for the need to distinguish between these two types of decisions because of systematic differences between the two paradigms: when individuals make decisions from experience, rare events tend to have less impact than they deserve according to their objective probabilities; in turn, in decisions from description, people behave as if the rare events have more impact than they deserve.[8–11] A number of factors may contribute to these differences, including the reliance on modest samples of experience, memory effects (e.g., recency), and sampling strategies used to acquire information in decisions from experience.[11]

The distinction between experience and description is mirrored in the panoply of tasks that have been used to measure risky behavior (see Table 1 for task descriptions).[12,13] A number of tasks provide explicit information about outcome magnitudes, whether outcomes are positive (gains) or negative (losses), as well as their respective probabilities, but differ nevertheless in many other respects. For example, some tasks, like the Cambridge Gambling Task (CGT), present people with unavoidable risk by forcing them to choose between two or more monetary gambles that differ in their variance.[14] Other tasks demand a decision between a sure outcome and a risky gamble with a certain probability of gain or loss, thus allowing people to avoid risk altogether by choosing the safe outcome.[15] In these tasks, risk aversion is reflected in preferring the less risky (e.g., variable) of the two risky prospects or

the safe prospect over the risky one. To facilitate assessment of risk, probabilities are sometimes represented as frequencies in the form of cups or bowls, or the problems are presented in well-known formats, such as card games.[16,17] Finally, learning paradigms rely on participants' ability to learn the probabilities of outcomes from experience, and they differ in whether the riskier option is the more or less advantageous one. For example, some tasks, like the Iowa Gambling Task (IGT),[18] require participants to learn to avoid the initially attractive risky options with negative expected value in favor of the initially less-attractive risky options with positive expected value, whereas others, such as the balloon analogue risk task (BART),[19] favor learning to make riskier but potentially more lucrative choices.

Risky choice and aging

Economists, biologists, and anthropologists have theorized about how life cycle variables, such as reproductive potential and age, affect risky choice.[20–22] Overall, these theories propose that risk taking is a function of reproductive competition, which is usually more intense for younger men than women or older adults, thus suggesting that aging should be associated with reduced risk taking. Epidemiological data concerning sexual behavior and crime statistics suggest that risk taking peaks in young adulthood and declines with advancing age.[20] In this paper, we assess the empirical evidence from behavioral studies to quantify age-related differences in risk-taking behavior. In addition, we help assess how specific cognitive processes or task requirements contribute to such differences. In other words, we aim to clarify some of the proximal mechanisms underlying age-related differences in risky choice.

Aging is associated with structural and neuromodulatory changes thought to underlie age-related decline in some aspects of attention, memory, learning, and cognitive control.[23,24] Age-related decline in some basic cognitive abilities may lead to changes in risky choice in different ways. First, decline in some aspects of cognitive control, such as working memory, may affect strategy selection and application. Older adults seem to rely on simpler decision strategies that require less information search and/or integration of information.[25–27] Additionally, older adults make more errors when integrating information relative to younger adults, at least when many pieces of information must be combined.[27–29] In addition, deficits in reward learning can lead to difficulties in learning associations between objects and their payoffs and ultimately adapting decision behavior to specific task structures.[27,30–32] In contrast, age differences in both behavior and neural activity largely disappear when comparing decision tasks without a strong learning component.[33] Learning deficits seem particularly likely to affect decisions from experience in which decision makers must learn about options from feedback over time, and can thus contribute to different patterns of age-related differences in decisions from experience versus description (see also a related review by Eppinger, Hammerer, and Li in this volume[71]).

Aging is also associated with motivational and affective changes,[34,35] and both emotional and motivational states have been shown to affect risky choice.[36,37] Motivational theories suggest that aging may be associated with increased focus on emotional regulation, which can lead to biases in information processing.[38] For example, younger and older adults have been shown to differ in the anticipation of losses (but not gains) in simple decision tasks, with older adults showing less responsiveness to losses relative to younger adults.[39] However, there is also some evidence that older adults are more likely to work toward preventing losses relative to younger adults, who tend to strive for gains.[40] Age-related differences in anticipation or desired prevention of losses are thus also a potential mechanism leading to developmental differences in risky choice.

A meta-analysis of adult age differences in risky choice

The goal of the present work was to summarize extant research findings on age-related differences in risky choice as well as to test the hypothesis that the differences vary as a function of the nature of the task. Specifically, we aimed to test the expectation that age-related differences in risky choice are to a large extent a function of the learning requirements of a task. The underlying rationale is that, relative to decisions from description, decisions from experience are more likely to tax learning and memory components that are significantly affected by age-related cognitive decline. In addition, we tested the hypothesis that the domain (gains vs. losses) contributes to age-related differences in risky choice.

Our analysis followed two main steps. First, we conducted a systematic literature search for original empirical reports that compared risky choice of younger and older adults. We focused particularly on studies using a behavioral measure of risk and obtained 29 age comparisons, the majority of which focused on decisions concerning monetary rewards. Second, we used meta-analytic methods to summarize the differences between age groups. They provide an objective, quantitative, and transparent way to synthesize research and, therefore, help to go beyond qualitative reviews when summarizing any effect of interest.[41]

Method

Literature search

We used the following methods to locate articles dealing with the topic of age-related differences in risky choice:

1. a computerized literature search using PsycINFO, EBSCO, and Google with a combination of keywords relating to risk, including the names of specific behavioral measures of risk mentioned in literature reviews[3–5,12,13] (e.g., the game of dice task, the CGT, cups task, the probability-associated gambling task, blackjack, BART, the Devil's task, the risky gains task, IGT, the behavioral investment allocation strategy, risk, risk taking, risky choice, or gamble), and keywords related to age-related differences and aging (aging, older adults, elderly, or age differences); the literature search was limited to articles published in the period from 1900 to January 31, 2011;

2. a computerized search in PsycINFO and EBSCO for articles citing the original paper that reported any of the risk measures mentioned above;

3. a search for papers cited in reviews on aging and decision making;[3–5] and

4. a check of the references of the articles found through the searches above.

Inclusion criteria

We limited our analysis to those studies that met the following criteria (see Supporting Information for additional details and a list of excluded papers):

1. studies that reported data concerning at least one age group comparison between a group of younger (*ca*. 18–35 years) and older (*ca*. 65–85 years) adults, or this comparison was obtainable from the authors;

2. studies that reported results on a behavioral measure of risk, as opposed to self-report questionnaires or individuals' reports of personality traits related to risk taking;[12] the rationale was that behavioral measures would allow us to assess age-

related differences in risky behavior rather than people's descriptive or normative beliefs about age-related differences concerning risky behavior; and

3. studies that reported a measure of risky choice for each age group (mean, standard deviation) in numerical or graphical format, a test statistic that could be used to compute an effect size corresponding to age-related differences in risky behavior, or alternatively, this information was obtainable from the authors.

Tables 1 and 2 give an overview of the tasks and articles that investigate age-related differences in risky choice that are included in this meta-analysis.[15–17,32,42–64]

Data analysis

We first calculated Cohen's *d* for each study separately by computing the difference between the younger group mean minus the older group mean on the risk measure for each task and dividing this difference by the pooled standard deviation (see Supporting Information for details concerning the definition of risk used for each task and respective calculations). If means and standard deviations were not provided, we calculated *d* from available statistics. Although in some tasks higher scores represent risk-seeking behavior (e.g., BART), in other tasks higher scores represent risk-averse behavior (e.g., IGT). In order to standardize the meaning of the effects, we reversed the sign of effects for the former such that a positive effect size indicated more risk seeking of older adults relative to younger adults and a negative value indicated the opposite regularity. We then converted Cohen's *d* into Hedge's *g* to prevent biased estimation of effect sizes from studies with small sample sizes.[41] A few studies contributed with more than one effect size because the same individuals performed different tasks, and in such cases we calculated effect sizes separately for each task. Similarly, some studies presented participants with separate gain and loss problems. In such cases, we calculated an overall effect size across the two domains, as well as separate effects sizes for gains and losses.

Results

We were interested in assessing whether age-related differences in decisions from experience are similar to those found for decisions from description. Figures 1 and 2 present forest plots with the effect sizes (Hedge's *g*) and respective 95% confidence intervals (CI) for each study that investigated age-related differences in decisions from experience and description, respectively. A significance level of 0.05 can be inferred when zero is not contained within the 95% CI. The figures also show summary effect sizes for each task under a fixed-effects model. We also obtained summary effects based on random-effects models, but the pattern of results is very similar to those from fixed-effects analyses, so we report the simpler version here.

The meta-analysis suggests that there are significant age-related differences in risky choice in decisions from experience, but that the pattern of age differences varies as a function of the task (see Fig. 1). Older adults were more risk seeking relative to younger adults in both the IGT (0.28; 95% CI: 0.25, 0.31) and the BIAS (0.46; 95% CI: 0.39, 0.53), but older adults were more risk averse relative to younger adults in the BART (−0.38; 95% CI: −0.44, −0.31). When aggregating across tasks (but excluding a study in which the same participants completed multiple tasks),[63] one could conclude that older adults are more risk seeking relative to younger adults (0.28; 95% CI: 0.25, 0.31).

Concerning decisions from description (see Fig. 2), younger adults were slightly more risk seeking relative to older adults in two paradigms. The effects were negative but quite small for the Sure/Risky gamble tasks (−0.03; 95% CI: −0.05, −0.001) and Blackjack (−0.07; 95% CI: −0.11, −0.03); in turn, the effect for the CGT was somewhat larger but suggests

that older adults were more risk seeking relative to younger adults (0.47; 95% CI: 0.40, 0.54). Overall, aggregating across studies in decisions from description suggests no systematic age-related differences (−0.001; 95% CI: −0.02, 0.02).

We also calculated an overall summary effect size that included all studies involving decisions from description and experience (excluding studies in which the same participants completed multiple tasks[48,63]) and as expected from the heterogeneous pattern of results, we found a negligible effect of age (0.07; 95% CI: 0.05, 0.09). Overall, these findings suggest that pooling across description and experience categories as well as tasks can obscure significant effects of age on risky choice. We discuss the heterogeneity of results as a function of task characteristics in the discussion.

We also aimed to assess whether the domain (gains vs. losses) had an impact on age-related differences in risky choice. Figure 3 presents the effect sizes (Hedge's g) and respective 95% CI for studies for which it was possible to compute effects separately for gain and loss domains. All studies involve a choice between a sure option and a risky gamble. As can be seen in Figure 3, the results show no effect of age regarding risky choice in either the gain domain (−0.05; 95% CI: −0.08, −0.03) or the loss domain (−0.05; 95% CI: −0.08, −0.02). In sum, existing studies suggest that younger and older adults show similar risk behavior in decisions from description regardless of gain/loss domain (a related discussion of the impact of gain versus loss frames appears in the review by Strough, Karns, and Schlosnagle in this volume).

Discussion

We conducted a systematic literature review and applied meta-analytic methods to quantify age-related differences in risky choice. We considered both tasks involving decisions from experience and decisions from description. In tasks involving decisions from experience, information about risk is not explicitly provided and participants must learn about the likelihood of outcomes across a number of trials. In decisions from description, the risk associated with each option is explicitly presented to participants. The results show that the pattern of age-related differences varies considerably as a function of the task used. In two tasks involving decisions from experience, the IGT and the BIAS, older adults were more risk seeking relative to younger adults. However, in another learning task, the BART, older adults proved to be more risk averse relative to younger adults. How can we reconcile these apparently contradictory findings within the decisions from experience category? In our view, the key to this riddle is that the IGT, BART, and BIAS differ systematically in their payoff structure. In the IGT, the suboptimal course of action is tantamount to choosing the negative expected value options: learning thus means to avoid taking cards from an initially attractive but ultimately disadvantageous deck of cards in favor of the more advantageous decks, particularly a low-risk (variance) deck.[63] This requires reversal learning, which may be impaired with aging.[65] In contrast, in the BART, participants' initial impulse is to pump substantially less than would be optimal (and thereby avoid the loss of the accumulated income): learning in the BART thus usually leads to taking more risk (i.e., more pumping on each balloon) and a more profitable payoff.[19] Clearly, there are likely to be various processes or traits implicated in age differences in BART, including a focus on immediate reward (points accrued), insensitivity to loss (balloons exploded), or a combination of the two. But regardless of which processes cause cautious pumping, learning deficits will play out differently in the BART and the IGT task, respectively. In the IGT, impaired learning purportedly results in fewer choices of the less risky but positive expected value deck and, thus, overall more risk-seeking behavior. In the BART, impaired learning results in fewer pumps and thus overall more risk-averse behavior. Even more complex dynamics are required to maximize earnings in the BIAS task. Participants learn to initially prefer the

certain option and then shift toward the best of the two risky options.[32] In the BIAS, a learning deficit may lead to more risk-seeking throughout the task. Consequently, the seemingly conflicting pattern of age-related differences within decisions from experience is consistent with an age-related decline in learning abilities.

The results from the decisions from description suggest that younger and older adults show similar risk-taking behavior when learning components are excluded from task demands, at least for two out of the three tasks we considered, namely those tasks involving a choice between a gamble and a safe amount or a task modeled on the Blackjack card game. Our analysis revealed significant age differences in the CGT. One explanation for this pattern of results is the strict trade-off involved between probability and outcome in the CGT task. A risky choice in the CGT corresponds to choosing a low probability outcome that leads to a high reward, while the safe (high probability) choice leads to a lower reward. This trade-off may be particularly challenging for older adults if they use simple strategies that focus on the highest payoff (e.g., maximax) and ignore or underweight probability magnitudes.[66] The safe/risky and blackjack paradigms do not involve such a strict trade-off and therefore a focus on reward magnitude may not lead to strong age differences.

In sum, our findings do not match expectations from life-history theories,[16,44,61] which predict general differences in risk-taking behavior with increased age. Instead, our results emphasize the importance of understanding how different task characteristics engender age-related differences in risky choice. Our results thus present a starting point for future work examining the conditions that foster competent decision making by the elderly.

Limitations and recommendations for future work

Our work has a number of limitations due to the current state of the field. First, we based our analyses on a relatively small number of papers and tasks, which may provide an incomplete or, even worse, a biased view of age-related differences in risky choice. Second, life-history theories suggest that the pattern of age-related differences in risky behavior change considerably from young adulthood to middle age and less so afterwards.[20] Unfortunately, few studies have tested participants across the full adult age range, which prevented us from studying the link between age and risky behavior across the complete adult development continuum. However, the design that most studies have adopted, namely, contrasting a sample of young adults with a sample of older adults, should boost the chances of finding differences in risky behavior with age (to the extent they exist), because according to life-history theories, risk taking should differ most between younger and older adults. Third, the studies analyzed cannot assess the role of cohort effects in risk-taking behavior, yet historical trends could prove a powerful determinant of financial behavior.[67] Finally, a further limitation concerns our inability to gauge age-related differences as a function of theoretically meaningful but unavailable manipulations, such as reward or probability magnitudes. For example, the well-known fourfold pattern of risky choice suggests that both domain (gain vs. loss) and probability magnitudes determine choice.[68] However, the studies we analyzed did not systematically distinguish between low- and high-probability outcomes, thus ruling out an analysis that considers both domain (gain/loss) and probability magnitude.

Another limitation of the literature to date, and by extension of our review, is that it has rarely quantified age-related differences in decision making that may be related to the accumulation of life experience. It is important to keep in mind that the decisions from experience tasks described here require relatively rapid learning from a limited amount of feedback in a novel environment. This experience-based learning should be distinguished from the learning that occurs over the lifetime and accumulates. It is possible that this form of decision making based on learning from limited experience indexes a more fluid

component of cognition, whereas decisions that are made based on accumulated life experience may index a more crystallized component of cognition.[69] We hope that future studies will more systematically examine how both of these experience measures may differentially contribute to risky decision making.

Still another limitation of this review is its almost exclusive focus on more traditional incentive-based tasks (where participants attempt to maximize points or monetary earnings). Age-related differences in the motivational value of money may have contributed to poorer learning from feedback. Consequently, it would be important to assess whether a similar pattern of results would emerge in other domains for which the objective is not the maximization of money but of some other dimensions equally treasured by young and old people (e.g., social relationships, sexual behavior, recreational activities). Unfortunately, there are currently far fewer studies that focus on these types of risky choice, and what does exist does not fit well within the taxonomy of tasks that we adopted from the Decision Making Individual Differences Inventory.[12] As this area of literature continues to expand, we will be increasingly able to examine the domain specificity or generality of age-related differences in risky choice.

Our review also identified some general limitations of previous research on the topic of risky choice and aging. First, we found that many of the studies were underpowered. Specifically, we calculated the power of each study given its sample size and an effect of the magnitude indicated by our aggregation of studies separately for each task ($\alpha = 0.05$), and found that more than 90% of studies were underpowered (power < 0.8). Meta-analyses can overcome power limitations by pooling across studies, but such a state of affairs is undesirable for individual studies because failure to detect significant results may be due to lack of power rather than negligible effects. For example, one paper reported no significant differences in risk taking between an older ($n = 18$) and a younger ($n = 18$) group, even though the age effect was of medium size ($g = -0.45$).[16] Second, there is room for methodological improvement, for example, concerning the provision of clear incentives.[70] Only 51% of the studies paid participants for participation, and an even smaller amount, 28%, paid participants in a performance-contingent fashion. We conducted exploratory analyses to assess the impact of performance-contingent payment on the size of age-related differences but found no evidence for a moderating role of hypothetical versus actual payment. Nevertheless, the use of performance-contingent payment in future research could help ensure that any age-related differences found are not due to unclear reward structures or varying effects of hypothetical payoffs.

Finally, this review points to voids in the literature. Only a minority of the studies identified in our search presented participants with different decision tasks and thus were able to compare performance on decisions from description and experience.[48,63] Unfortunately, even these studies did not fully equate the structure or information provided in the different tasks. Consequently, it is hard to interpret the differences found. Future work with paradigms that equate decisions from experience and description would allow researchers more direct assessment and comparison of how search, integration, and decision components can lead to age-related differences in risky choice. Further, a main conclusion from our analysis is that task characteristics are pivotal in determining age-related difference in risky choice, and it remains to be studied which aspects of decisions from description and experience contribute to moderating age effects. For example, there may be different formats of decisions from experience that can increase or decrease task difficulty for those with declining capacity to learn.[59]

Conclusion

Increases in life expectancy pose challenges to modern societies that can be met partly by assuring that older adults can make sound health and financial decisions. We conducted a systematic literature search and quantified age-related differences in decisions under risk. In decisions involving learning from experience, age-related differences in risk taking were a function of decreased learning performance: older adults were more risk seeking compared to younger adults when learning resulted in risk-averse behavior, but proved more risk averse when learning resulted in risk-seeking behavior. In decisions from description, the majority of studies suggest negligible differences between younger and older adults' risky behavior, but there are exceptions as a function of the experimental paradigm used. Overall, our findings suggest both that the pattern of age-related differences in risk taking is complex but systematic as a function of task demands and that more work is needed to identify the task properties (in the laboratory and in the wild) as well as the proximal mechanisms that give rise to age-related differences in risky choice.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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Author	Year	N	g
Denburg	2005	80	2.72
Baena	2010	78	1.72
Zamarian	2008	85	0.76
Fein	2007	164	0.71
MacPherson	2002	60	0.61
Denburg	2009	152	0.48
Isella	2007	80	0.32
Wood	2005	155	0.10
Henninger	2010	112	0.05
Lamar	2004	43	−0.03
IGT			**0.28**
Samanez–Larkin	2010	77	0.50
Samanez–Larkin	2011	108	0.43
BIAS			**0.46**
Rolison	2011	84	−0.23
Henninger	2010	112	−0.71
BART			**−0.38**

−1   0   1   2   3

Figure 1.
Decisions from experience. Forest plot for studies using decisions from experience paradigms. The positions of the squares on the *x*-axis indicate the effect size for each study; the bars indicate the 95% CI of the effect sizes, and the sizes of the squares are inversely proportional to the respective standard errors (i.e., larger squares indicate smaller standard errors).

Author	Year	N	g
Kim	2005	80	0.95
Zamarian	2008	85	0.19
Kim	2005	106	0.09
Bruine	2007	119	0.07
Roennlund	2005	384	0.05
Lauriola	2001	49	0.03
Holliday	1988	48	−0.08
Weller	2010	419	−0.24
Mikels	2009	44	−0.39
Mayhorn	2002	116	−0.61
Lee	2007	21	−0.89
Sure/Risky			**−0.03**
Ashman	2003	32	0.06
Rafaely	2006	103	−0.03
Rafaely	2006	87	−0.13
Dror	1998	36	−0.45
Blackjack			**−0.07**
Henninger	2010	112	0.90
Deakin	2004	86	0.31
CGT			**0.47**

Figure 2.
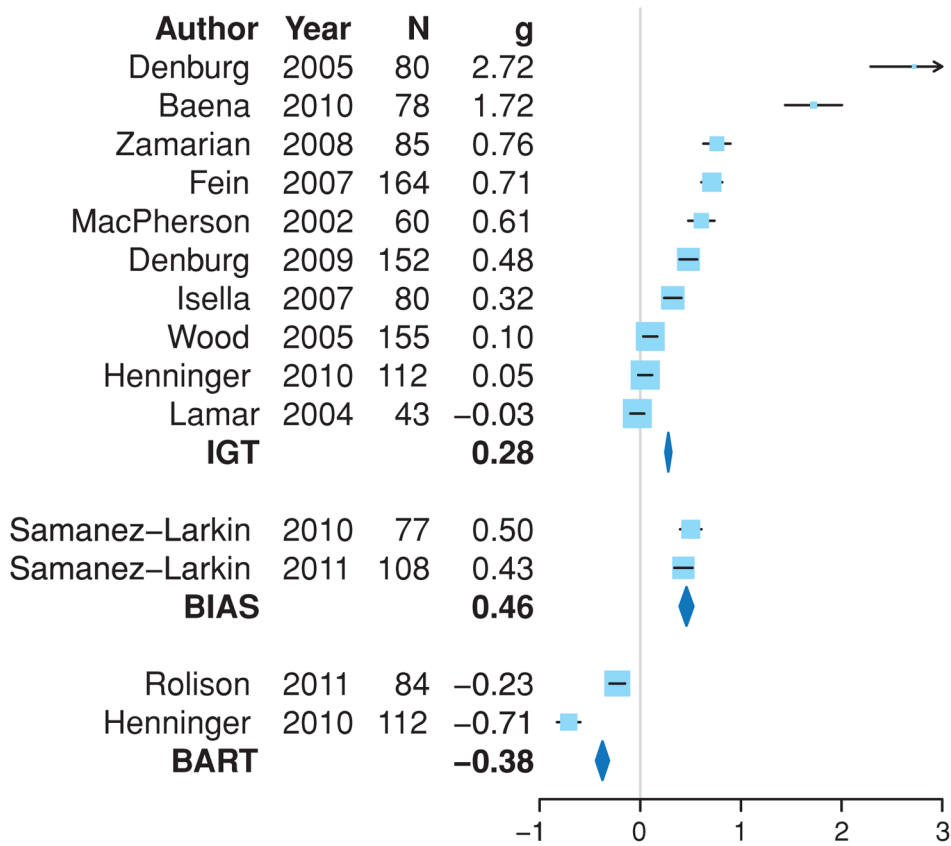Decisions from description. Forest plot for studies using decisions from description paradigms. The positions of the squares on the *x*-axis indicate the effect size for each study; the bars indicate the 95% confidence intervals of the effect sizes, and the sizes of the squares are inversely proportional to the respective standard errors (i.e., larger squares indicate smaller standard errors).

Author	Year	N	g
Kim	2005	80	0.54
Bruine	2007	119	0.15
Holliday	1988	48	0.11
Watabene	2010	414	0.06
Sproten	2010	75	0.05
Roennlund	2005	384	0.00
Mikels	2009	44	−0.03
Weller	2010	419	−0.37
Lauriola	2001	49	−0.54
Kim	2005	106	−0.74
Mayhorn	2002	116	−0.84
Gains			**−0.05**
Kim	2005	80	1.35
Kim	2005	106	0.93
Lauriola	2001	49	0.39
Roennlund	2005	384	0.10
Bruine	2007	119	0.00
Weller	2010	419	−0.10
Holliday	1988	48	−0.21
Mayhorn	2002	116	−0.39
Mikels	2009	44	−0.69
Watabene	2010	415	−3.43
Losses			**−0.05**

−2   0   2

Figure 3.
Decisions from description: gains vs. losses. Forest plot for studies using decisions from description and that distinguish between gain and loss domains. The positions of the squares on the *x*-axis indicate the effect size for each study; the bars indicate the 95% confidence intervals of the effect sizes, and the sizes of the squares are inversely proportional to the respective standard errors (i.e., larger squares indicate smaller standard errors).
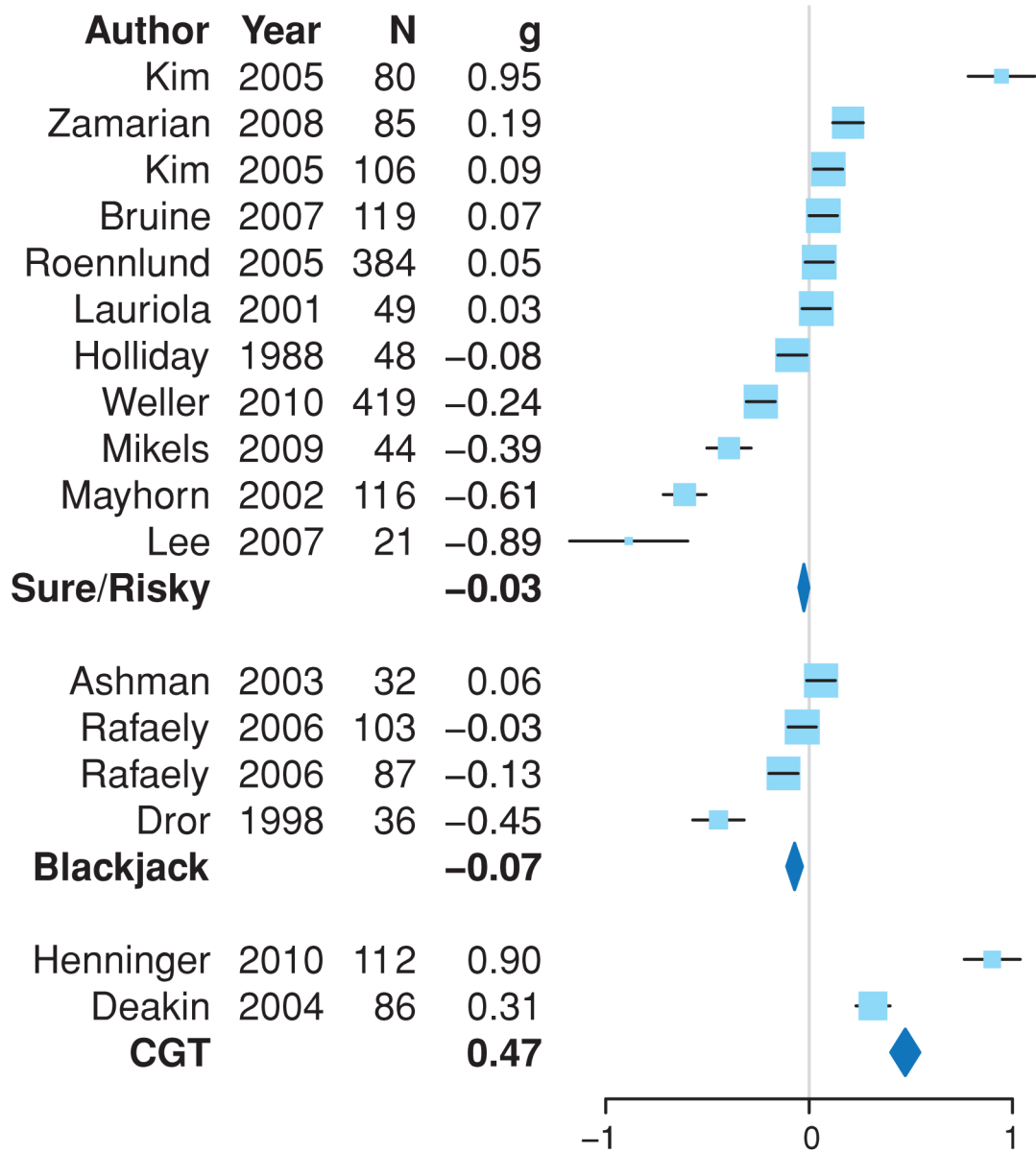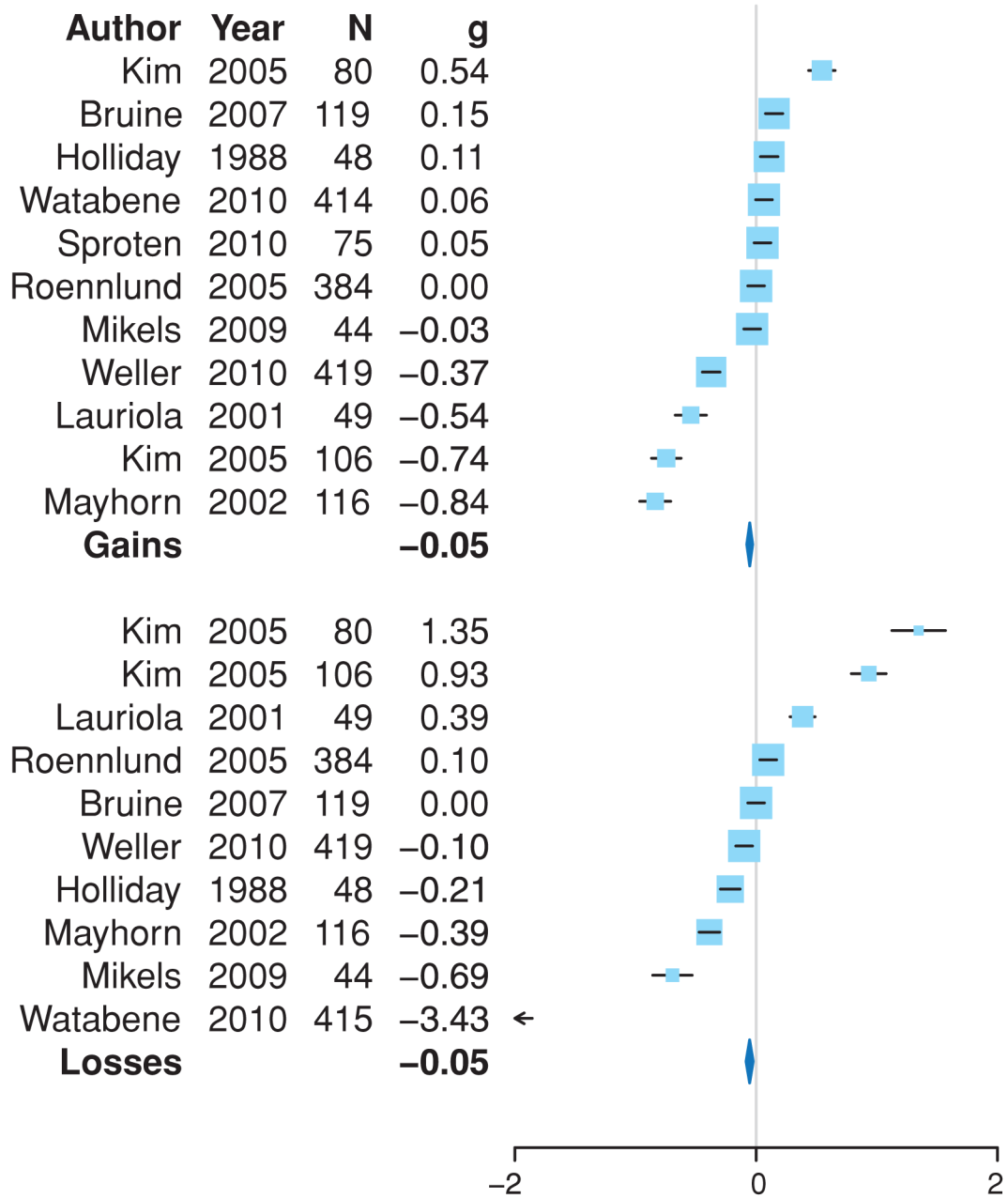
Table 1

Behavioral measures of risk included in the meta-analysis

Category	Task	Task Description	*N*
Decisions from experience	Iowa Gambling Task (IGT)	Subjects choose one card per trial from four decks. Two of the decks are "advantageous" (positive expected value) and two decks are "disadvantageous" (negative expected value). Subjects learn about the decks' characteristics from the gains and losses associated with each card. Risk taking is measured as the average number of selections from advantageous minus disadvantageous decks (see Supporting Information).	10
	Behavioral Investment Allocation Strategy (BIAS)	Subjects allocate their money between two stocks and one bond. The bond's payoff stays constant over all trials. In each block of trials, there is a "good" stock leading to better outcomes than the "bad" stock and subjects can learn about the stocks' characteristics over trials from the gains and losses associated with each investment. Risk seeking is measured as the number of stock choices that deviate from those of a rational actor with the same experience with the task.	2
	Balloon Analogue Risk Task (BART)	Subjects pump a balloon for as many pumps as they want without knowing when it will explode. Each pump increases the amount of money won but also the chance of explosion. The subject can stop pumping to save the money earned before the balloon explodes, but if the balloon explodes the accumulated money for that balloon is lost. Subjects learn about the probability of a balloon exploding over trials. Risk taking is measured as the number of pumps in unexploded balloons.	2
Decisions from description	Sure thing vs. risky gamble	Subjects have to decide between a sure amount and a risky gamble involving points or money, with decisions being made in the gain or loss domain. Tasks differ regarding whether probabilities are presented numerically or as bowls or cups. Risk taking is measured as the number of choices of the sure amount.	12
	Blackjack	Subjects are given a two-card hand and decide whether they want to take a third card. Each card is worth a number of points and the aim is to collect as many points as possible without exceeding a total sum of 21 points. Risk taking is measured as the proportion of trials in which participants take a third card.	4
	Cambridge Gambling Task (CGT)	Subjects bet concerning the location of a token. A token is hidden behind one of six red or blue boxes varying in their ratio (5:1, 4:2, 3:3). On each trial, subjects bet where the token is and every choice is associated with a potential gain or loss. The higher probability color is associated with lower gains (losses) than lower probability color. Risk taking is measured as the proportion of trials in which participants choose the lower probability color.	2

Note: N, number of studies that used the respective task included in the meta-analysis.

Table 2

Studies included in the meta-analysis

Study	Task(s)	N Older	N Younger	Mean (SD) or range of age Older	Mean (SD) or range of age Younger	Mean (SD) of education Older	Mean (SD) of education Younger
Ashman, Dror, Houlette & Levy[42]	Blackjack	16	16	75.0 (6.8)	25.0 (4.4)	–	–
Baena, Allen, Kaut & Hall[43]	IGT	39	39	60–90	18–35	–	–
Bruine de Bruin, Parker & Fischhoff[29]	Sure/risky	56	63	76.7 (5.8)	24.9 (5.6)	–	–
Deakin, Aitken, Robbins & Sahakian[44]	CGT	45	41	53–79	17–27		
Denburg, Tranel & Bechara[45]	IGT	40	40	56–85	26–55	–	–
Denburg et al.[46]	IGT	79	73	48.6 (11.9)	74.0 (5.6)	15.8 (2.6)	15.8 (2.0)
Dror, Katona & Mungur[16]	Blackjack	18	18	59–91	18–22	–	–
Fein, McGillivray & Finn[47]	IGT	52	112	73.3 (7.4)	37.8 (10.7)	16.1 (2.1)	16.4 (1.8)
Henninger, Madden & Huettel[48]	IGT, CGT, BART	54	58	70.7 (4.4)	23.4 (3.0)	15.9 (2.7)	15.0 (1.9)
Holliday[49]	Sure/risky	24	24	69.4 (3.8)	24.2 (2.3)	12.6 (2.3)	14.9 (2.3)
Isella, Mapelli, Morielli, Franceschi & Ildebrando[50]	IGT	40	40	65.4 (8.6)	27.9 (4.7)	8.7 (3.6)	13.1 (2.1)
Kim, Goldstein, Hasher & Zacks[51]	Sure/risky	186	186	58–78	17–28	–	–
Lamar & Resnick[52]	IGT	20	23	69.1 (5.0)	28.4 (5.9)	15.5 (3.4)	15.7 (2.6)
Lauriola & Levin[53]	Sure/risky	23	26	61–80	21–40	–	–
Lee, Leung, Fox, Gao & Chan[54]	Sure/risky	9	12	65.2 (4.2)	29.2 (6.2)	16.2 (1.2)	17.2 (1.8)
MacPherson, Phillips & Della Sala[55]	IGT	30	30	69.9 (5.5)	28.8 (6.0)	12.4 (3.2)	14.0 (3.2)
Mayhorn, Fisk & Whittle[56]	Sure/risky	58	58	70.3 (4.8)	20.3 (3.2)	–	–
Mikels & Reed[15]	Sure/risky	22	22	71.6 (4.5)	19.8 (1.2)	15.8 (3.5)	14.6 (1.2)
Rafaely, Dror & Remington (Experiment 1)[57]	Blackjack	45	42	70.5 (5.5)	20.9 (3.2)	13.3 (2.5)	14.6 (1.4)
Rafaely, Dror & Remington (Experiment 2)[57]	Blackjack	53	50	71.0 (5.2)	21.0 (4.4)	–	–
Rolison, Hanoch & Wood[58]	BART	44	40	76.6 (5.9)	19.3 (1.8)	16.5 (–)	13.4 (–)
Rönnlund, Karlsson, Laggnäs & Lindström[59]	Sure/risky	192	192	69.1 (7.4)	23.9 (3.5)	9.9 (3.9)	14.4 (2.2)
Samanez-Larkin, Kuhnen, Yoo & Knutson[32]	BIAS	42	35	72.5 (5.0)	25.7 (4.4)	16.1 (2.6)	16.2 (2.1)
Samanez-Larkin, Wagner & Knutson[60]	BIAS	59	49	70.6 (4.3)	27.3 (4.6)	–	–
Sproten, Diener, Fiebach & Schwieren[61]	Sure/risky	24	51	68.0 (7.3)	25.0 (3.5)	12.2 (1.4)	12.6 (1.3)
Watebene & Shibutani[62]	Sure/risky	168	661	72.5 (4.1)	44.8 (11.5)	–	–

Study	Task(s)	N		Mean (SD) or range of age		Mean (SD) of education	
		Older	Younger	Older	Younger	Older	Younger
Weller, Levin & Denburg[17]	Sure/risky	61	358	65–85	18–22	–	–
Wood, Busemeyer, Koling, Cox & Davis[63]	IGT	63	87	77.0 (5.2)	23.0 (5.9)	14.7 (2.3)	14.2 (1.2)
Zamarian, Sinz, Bonatti, Gamboz & Delazer[64]	IGT, Sure/risky	52	33	69.3 (7.0)	36.1 (13.7)	10.4 (2.5)	10.7 (1.3)
Total N		1614	2479				
Average age[a]				69	28		
Average education						13	15

Note: IGT, Iowa Gambling Task; CGT, Cambridge Gambling Task; BART, balloon analogue risk task; BIAS, behavioral investment allocation strategy.

[a]We used the midpoint for studies reporting age ranges only.