

Age and adaptation

1 **IN PRESS: RISK ANALYSIS**

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3 Age and adaptation: Stronger decision updating about real world risks in older age

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**ABSTRACT**

In later life, people are faced with a multitude of risky decisions that concern their health, finance, and personal security. Older adults often exercise caution in situations that involve risk. In this research, we asked whether older adults are also more responsive to warnings about potential risk. An answer to this question could reveal a factor underlying increased cautiousness in older age. In Study 1, participants decided whether they would engage in risky activities (e.g., using an ATM machine in the street) in four realistic scenarios about which, participants could be expected to have relevant knowledge or experience. They then made posterior decisions after listening to audio extracts of real reports relevant to each activity. In Study 2, we explored the role that emotions play in decision updating. As in Study 1, participants made prior and posterior decisions, with the exception that for each scenario the reports were presented in their original audio format (high emotive) or in a written transcript format (low emotive). Following each posterior decision, participants indicated their emotional valence and arousal responses to the reports. In both studies, older adults engaged in fewer risky activities than younger adults, indicative of increased cautiousness in older age, and exhibited stronger decision updating in response to the reports. Older adults also showed stronger emotional responses to the reports, even though emotional responses did not differ for audio and written transcript formats. Finally, age differences in emotional responses to the reports accounted for age differences in decision updating.

51 **1. INTRODUCTION**

52 In later life, people face a multitude of important decisions about their health, finance,  
53 and personal security. The outcomes of poor health choices are likely to be most apparent in  
54 older age as negative health outcomes, such as diabetes and heart disease, are more prevalent  
55 in later life.<sup>(1)</sup> Older adults are commonly exposed to warnings and advice about their health  
56 and are encouraged by health authorities to undergo regular health assessments.<sup>(2,3)</sup> Older  
57 adults also face numerous financial decisions, some of which are designed specifically to  
58 harm them. Financial fraud in the guise of sweepstakes and bogus lotteries is often targeted  
59 specifically at the elderly whom fraudsters perceive as vulnerable and gullible.<sup>(4,5)</sup> Many  
60 older adults must also decide whether to surrender their driving privileges and compromise  
61 their mobility on the basis of doctors' recommendations and the advice of friends and  
62 family.<sup>(6)</sup> Psychological literature has often reported that older adults exercise caution in  
63 situations that involve risk,<sup>(7-9)</sup> particularly in health, recreational, and financial contexts.<sup>(10)</sup>  
64 Yet, are older adults also more responsive to warnings about potential risk? Answering this  
65 question could cast new light on a factor underlying increased cautiousness in older age.

66 One method of assessing how people update their risky decision making has been to  
67 use behavioral tasks, in which individuals are provided feedback about the outcomes of their  
68 decisions across multiple trials.<sup>(11-13)</sup> Behavioral tasks simulate real world experience-based  
69 learning in situations that afford multiple learning opportunities. However, behavioral tasks  
70 have yielded mixed findings about age differences in experience-based learning. Older adults  
71 respond like younger adults to the negative outcomes of their decisions on some tasks<sup>(14,15)</sup>  
72 and are less responsive than younger adults on other tasks,<sup>(16,17)</sup> which is indicative of risk  
73 seeking behavior. This is the case on the widely used Iowa Gambling Task—a card game in  
74 which individuals must learn to avoid choosing cards from decks that yield large potential  
75 monetary wins but higher losses in favor of decks that yield smaller potential wins, but higher

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76 average gain.<sup>(12,16)</sup> Differences in risk taking on this and similar tasks have commonly been  
77 attributed to impaired learning in older age.<sup>(14,16,17)</sup>

78 Behavioral tasks that impose heavy demands on memory can impair the learning  
79 abilities of older adults. As in the Iowa Gambling Task, when individuals must learn to avoid  
80 a disadvantageous option in favor of an alternative that offers a higher gain in the long run,  
81 the decision options and their outcomes must be tracked across multiple trials.<sup>(18-19)</sup> Multi-  
82 play decision tasks for which the decision maker has a long-run aspiration also elicit greater  
83 search,<sup>(20)</sup> which further burdens working memory resources.<sup>(21)</sup> The number of choice  
84 options also imposes additional demands on memory that impair decision making abilities in  
85 older adults. For example, older adults have been shown to make similar choices to younger  
86 adults when choosing between two risky options after first learning about their potential  
87 outcomes.<sup>(22)</sup> When the number of options is increased from two to four or eight options,  
88 raising the demands on memory, age differences in risky choice behavior emerge.<sup>(22)</sup>

89 In real world situations rewards and losses are inversely related to their probabilities  
90 as large rewards (or losses) typically have small probabilities.<sup>(23)</sup> Severe events, such as car  
91 crashes, are rare<sup>(24)</sup>—and an individual may never experience the consequences of not  
92 wearing a seat belt. Other consequences of risk taking have a long time horizon, such as in  
93 the case of lung cancer and heart disease linked to smoking. Thus, many risky decisions may  
94 be made in everyday life without experiencing negative outcomes. Further, when experience  
95 is sampled over a period of time, such as months or even years, rare events (e.g., a car crash)  
96 are likely to be under-sampled, leading people to underestimate the probability of rare, but  
97 highly consequential events.<sup>(25,26)</sup>

98 Expert advice, government campaigns, and media reports are intended to inform  
99 people's decision making about serious risks.<sup>(27)</sup> For example, following an outbreak of the  
100 Zika virus in South America in 2015, the Centres for Disease Control and Prevention issued a

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101 website to inform the public about the symptoms, diagnosis, and treatment of the Zika virus  
102 and preventive measures against infection.<sup>(28)</sup> The website was specifically aimed at women,  
103 warning of the risk that the Zika virus can be transmitted to the foetus of pregnant women.  
104 The introduction of pictorial health warnings to cigarette packaging is a further example of  
105 how government campaigns are designed to inform people's decisions about health risks.<sup>(29)</sup>  
106 Some campaigns and awareness-raising strategies are targeted specifically at elderly people  
107 who may be vulnerable to injury as road users and to financial fraud.<sup>(4,6)</sup> When people base  
108 their decisions on expert advice or statistical risks reported in government campaigns and the  
109 media, they are making decisions from description.<sup>(30)</sup>

110         Can descriptive information delivered by government campaigns and media reports  
111 overcome personal experience? In one study, Yechiam, Barron, and Erev<sup>(31)</sup> recorded visits  
112 made to Israeli hotels before and after a series of terrorist attacks in Israel. Hotel visits among  
113 foreign tourists decreased by 80% following the attacks, indicating that media reports of the  
114 attacks strongly influenced the travel choices of foreign tourists. Yet, hotel visits among  
115 domestic tourists actually increased by 20% during the same period. Unlike the foreign  
116 tourists, the Israeli tourists had accrued a vast amount of personal experience about the rarity  
117 of such terrorist attacks, many of whom may never have experienced of a terrorist attack.  
118 Thus, media reports may have little impact on decision making in situations that people have  
119 accrued personal experience. Even statistical risks, such as those used in government  
120 campaigns, may have less impact than the influence of personal experience. For example,  
121 Betsch, Haase, Renkewitz, and Schmid<sup>(32)</sup> asked participants to assess the riskiness of a  
122 vaccine used to prevent a fictitious severe disease. To help inform their judgment, they were  
123 also told about the statistical likelihood of adverse effects of the vaccine. Participants were  
124 then asked to imagine finding on an internet bulletin board, information about instances of  
125 positive and negative effects of taking the vaccine. Crucially, even though the participants

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126 knew the objective risk of the vaccine, they were strongly influenced by their exposure to the  
127 individual instances in which the vaccine had led to positive and negative outcomes. This  
128 finding suggests that experiencing a single event (e.g., a positive or negative outcome of a  
129 vaccine) can overpower the influence of a statistical report that summarises many such  
130 events. When a negative outcome is rare (e.g., a car crash) an individual may experience a  
131 vast number occasions in which the negative outcome does not occur (i.e., a crash-free  
132 journey). Consequently, the provision of a statistical report, such as in the form of a road  
133 safety campaign, could have very little impact on risk perception and decision making.

134         If personal experience weighs heavily on people's decision making about risks that  
135 have rare consequences, then older adults may actually be less responsive than younger adults  
136 to warnings about potential risk. For rare, but highly consequential events, older adults will  
137 have encountered many more instances than younger adults, in which their decision making  
138 (e.g., not wearing a seatbelt) did not lead to a negative event (e.g., a road traffic injury). In  
139 some contexts, an older adult may never have experienced negative consequences of their  
140 risky choices. Similar to the domestic tourists in Israel, warnings delivered in media reports  
141 and government campaigns may have relatively little impact on the decision making of older  
142 adults in contexts that are highly familiar to them.

143         On the other hand, developmental research indicates that a tendency to update beliefs  
144 about familiar risks (e.g., likelihood of a home burglary) in response to undesirable news  
145 increases from adolescence to young adulthood.<sup>(33)</sup> In this task, participants first estimated the  
146 likelihood of adverse life events. They were then informed about the actual numerical risk of  
147 each event that was either desirable (i.e., the actual likelihood was lower than their own  
148 estimate) or undesirable (i.e., the likelihood was higher than their estimate) and were asked to  
149 make a second re-estimate of the likelihood of each event. Belief updating following  
150 desirable news was independent of age. Conversely, a tendency to update beliefs in the

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151 direction of the true likelihood of an adverse event following undesirable news was found to  
152 increase from age 9 years to age 26 years. If the tendency to update beliefs in response to  
153 undesirable news extends to decision making in later life, older adults may show a stronger  
154 tendency to update their risky decision making in response to warnings about risk.

155         Why might belief updating about negative events increase with age? One possibility is  
156 that age-related dopaminergic decline motivates avoidance of negative outcomes. Previous  
157 research has found that lower levels of dopamine are related to an increased likelihood of  
158 avoiding negative outcomes, and that increased dopamine levels are related to increased  
159 sensitivity to positive outcomes. In general, dopamine levels decline with age. Using a  
160 probabilistic selection task, Frank and Kong<sup>(34)</sup> reported that older adults showed an enhanced  
161 tendency to learn from negative compared to positive consequences of their decisions.  
162 Moreover, negative mood, which is associated with depleted dopamine levels,<sup>(35)</sup> is linked to  
163 heightened risk perceptions in older age. For example, Chou, Lee, and Ho<sup>(36)</sup> found that a  
164 negative mood-inducing manipulation, in the form of a mood-arousing video clip, reduced  
165 risk taking among older adults for hypothetical real life dilemmas, but had no such effect on  
166 younger adults. Conversely, Carpenter, Peters, Västfjäll, and Isen<sup>(37)</sup> found that inducing  
167 positive feelings in older adults increased their frequency of card choices from “gain” decks  
168 that yielded monetary wins over “loss” decks that yielded monetary losses. Hence, despite  
169 older adults’ lifetime of accrued experience, the above findings suggest that they may exhibit  
170 stronger decision updating tendencies than younger adults in response to warnings about risk,  
171 perhaps due to negative mood-inducing effects of warnings.

172         In the current research, we studied risky decision making in younger and healthy older  
173 adults in the local community. In contrast with previous approaches that have used monetary  
174 gambles<sup>(9,17)</sup> or examples of extreme activities (e.g., bungee jumping),<sup>(38)</sup> we designed four  
175 everyday scenarios about which people of all ages would have some relevant knowledge or

176 experience. Scenarios described visiting a family member in a local hospital despite poor  
177 weather (weather scenario), using an ATM machine in the street (fraud scenario), ordering a  
178 high-salt meal at a restaurant (health scenario), and accepting a car ride without access to a  
179 seat belt (safety scenario). Participants made initial (prior) decisions about whether to engage  
180 in each activity. They then listened to audio extracts of real reports relevant to each scenario;  
181 either a forecast of severe weather (weather scenario), a report on ATM fraud (fraud  
182 scenario), a report on salt consumption (health scenario), or a report on seat belt use (safety  
183 scenario). Decision updating was assessed by asking participants to make posterior decisions  
184 following each audio report.

## 185 **STUDY 1**

### 186 **2. METHOD**

#### 187 **2.1. Participants**

188 The research was approved by the appropriate IRB committee. All participants  
189 provided informed consent. Thirty nine younger (18-35 years of age; mean age=23.18 years;  
190 54% male) and 39 older (65-82 years of age; mean age=72.58 years; 39% male) volunteers  
191 participated. The target sample size was based on previous studies. The mini-mental state  
192 examination was used to screen for cognitive impairment with scores greater than 25  
193 indicative of intact cognition. All participants passed the screen.

#### 194 **2.2. Materials and Procedure**

195 For each of four scenarios, participants were asked to make an initial (prior) decision  
196 about whether they would engage in an activity described in the scenario. A weather scenario  
197 read:

198 *“A member of your family who you are very close to is unwell and requires*  
199 *surgery at the Royal Victoria Hospital in Belfast. Tomorrow is your only*  
200 *opportunity to visit them at the hospital before their surgery. On the other hand,*  
201 *you hear on the radio and see on television that there is a weather warning of*  
202 *heavy rain and strong winds for tomorrow.”*



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203 For which participants were asked to make a decision about whether or not they would visit  
204 their family member despite the potential bad weather. A fraud scenario read:

205 *“You are late for an appointment in town and need to withdraw some money*  
206 *on your way. You pass by a bank.”*

207 For which they were asked whether or not they would use the ATM machine outside the bank  
208 rather than use a machine inside the bank. A health scenario read:

209 *“You visit a restaurant that offers a choice of meal options. Among the*  
210 *options is your favourite dish, but which you know to be typically high in salt.*  
211 *Other meal options are also appealing.”*

212 For which they were asked whether or not they would order their favorite meal at the  
213 restaurant. And a safety scenario read:

214 *“You visit a friend who lives a short walk from your home. It is late and your*  
215 *friend offers you a lift home. Your friend is safety conscious, but has been*  
216 *reupholstering the seats in their car, which means that the seatbelts are currently*  
217 *not attached.”*

218 For which they were asked whether or not they would accept a short ride home from their  
219 friend.

220 Following their initial (prior) decisions, participants listened to an audio report  
221 relevant to each scenario that indicated a significant domain relevant risk. A report of severe  
222 weather in the local area was heard for the weather scenario (duration 1 min 24 sec; see  
223 supplementary material for transcript); a crime report on ATM fraud was heard for the fraud  
224 scenario (duration 2 min 20 sec); a health report on the dangers of a high sodium diet was  
225 heard for the health scenario (duration 1 min 43 sec); and a government road safety campaign  
226 on seat belt use was heard for the safety scenario (duration 28 sec). Following each report,  
227 participants were asked: “Please describe what you just heard in the report in a way that could  
228 inform someone else’s decision making who has not heard the report”. This was done in  
229 order to encourage participants to reflect on the information provided in the audio reports.  
230 They were then asked to make a second (posterior) decision about whether to engage in each  
231 activity having heard the report. Prior and posterior decisions were made before moving onto

232 the next scenario and scenarios were completed in a randomly generated order for each  
233 participant.

### 234 **3. RESULTS**

235 First, we assessed age and scenario differences in participants' prior decisions. In  
236 order to take account of the clustering within our data, we conducted a random effects logistic  
237 regression analysis on prior decisions and included age group (older vs. younger) and  
238 scenario (weather, fraud, health, safety) as factors. This analysis revealed that older adults  
239 decided in favor of engaging in significantly fewer activities (76%) than their younger  
240 counterparts (94%; OR = 0.15,  $t = 3.90$ ,  $p < .001$ ), which is indicative of increased  
241 cautiousness in older age. The analysis also revealed scenario differences in risky decision  
242 making. Decisions in favor of engaging in the activities described in the reports were most  
243 frequent in the weather scenario (94%), followed by the health (90%; vs. weather, OR = 0.56,  
244  $t = 0.92$ ,  $p = .360$ ), fraud (87%; vs. weather, OR = 0.42,  $t = 1.42$ ,  $p = .155$ ), and safety  
245 scenarios (71%; vs. weather, OR = 0.11,  $t = 3.66$ ,  $p < .001$ ).

246 Crucially, if older adults are more responsive to warnings than younger adults, they  
247 should alter their decision making more than younger adults in response to the reports. To  
248 assess posterior decision making, we conducted a random effects logistic regression analysis  
249 on participants' posterior decisions, including age and scenario as factors, and controlling for  
250 prior decisions. This analysis revealed that older adults were significantly less likely  
251 (48%<sub>posterior</sub> vs. 76%<sub>prior</sub>) than their younger counterparts (88%<sub>posterior</sub> vs. 94%<sub>prior</sub>) to decide in  
252 favor of engaging in the activities described in the reports (OR = 0.09,  $t = 5.39$ ,  $p < .001$ ).  
253 Inspection of Figure 1 confirms that in all four scenarios older adults were more responsive to  
254 the reports than younger adults in their posterior decision making.

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## STUDY 2

In Study 1, older adults were more cautious than younger adults in their initial risk taking. Older adults were also more responsive to descriptive information about risk delivered in the audio reports. One possibility is that age-related differences in emotion processing partly explain the stronger tendency to update decisions about risk in older age. Depleted dopamine levels are associated with negative mood<sup>(35)</sup> which, in turn, is associated with avoidance behavior<sup>(34)</sup> and reduced risk taking<sup>(36)</sup> in older age. Perhaps older adults are more responsive to the negative mood-inducing effects of warnings about potential risk, which leads them to engage in greater decision updating to avoid negative potential outcomes. We explored this possibility in Study 2 by measuring participants' emotional valence and arousal responses to the reports. Specifically, we were interested in whether (a) negative emotional responses are associated with a stronger tendency to update posterior decision making, and whether (b) stronger negative emotional responses in older adults relate to age differences in decision updating.

The audio reports used in Study 1 may have been intensely mood-arousing, not only because of the descriptive information they provide about severe negative events (e.g., ATM fraud), but also because of their auditory format. For example, participants listened to a government road safety campaign on seat belt use in the safety scenario, which included realistic sounds of a car crash. Indeed, such campaigns are intentionally designed to induce intense-emotional responses in the listener. In Study 2, we further explored whether the auditory format of the reports, in addition to their descriptive content, influences decision updating tendencies. To do so, each participant received audio reports presented in the same format used in Study 1 for two of the four scenarios and received written transcripts of the audio reports for the remaining two scenarios. We hypothesized that if the auditory format of the reports added to their emotional intensity then delivering them in a written transcript

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282 format should reduce their emotional intensity and thus reduce age differences in decision  
283 updating.

## 284 **4. METHOD**

### 285 **4.1. Participants**

286 The research was approved by the appropriate IRB committee and all participants  
287 provided informed consent. Forty younger (18-35 years of age; mean age = 21.80 years; 45%  
288 male) and 40 older (65-90 years of age; mean age = 73.93; 40% male) volunteers participated  
289 in the study. A score of greater than 25 on the mini-mental state examination was used to  
290 indicate intact cognition in our screening of older adults. All participants passed the screen.

### 291 **4.2. Materials and Procedure**

292 Participants were shown the same four scenarios used in Study 1. For each scenario,  
293 they were asked to make an initial (prior) decision about whether they would engage in the  
294 activity described in the scenario. Participants were then provided the same four reports used  
295 in Study 1 on which to base their second (posterior) decision. For two of the four scenarios  
296 participants received the corresponding audio report presented in the same format used in  
297 Study 1. For the two remaining scenarios, they instead received a written transcript of the  
298 audio report, rather than listen to the report directly (see supplementary material for  
299 transcript). Using a mixed design, participants were pseudo-randomly assigned to receive two  
300 of the four reports in the audio format and the remaining two in the written transcript format.  
301 Hence, 10 participants received audio reports for the weather and fraud scenarios and written  
302 transcripts for the health and safety scenarios, 10 participants received audio reports for the  
303 weather and health scenarios and written transcripts for the fraud and safety scenarios, and so  
304 on, to ensure balanced participant numbers across all four combinations of scenario and  
305 report format.

306 We used the Self-Assessment Manikin (SAM)<sup>(39)</sup> to assess emotional valence and  
307 arousal responses to the reports. After making each posterior decision, participants were  
308 shown a row of nine basic drawings depicting a person (i.e., the manikin) ranging from very  
309 sad (value of -4), to neutral (value of 0), to very happy (value of 4) from the left to right side  
310 of the computer monitor. Participants were instructed that *“The faces below are arranged on  
311 a continuum from unhappy (left) through to happy (right).”* Participants were asked to  
312 indicate their emotional valence response to the report in an instruction that read: *“Please  
313 indicate how you felt whilst [listening to, reading] the report you just [heard, read]. To make  
314 your choice, select the corresponding option box located below the faces. If you felt  
315 completely neutral, neither happy nor sad, select the option box below the middle figure.”*  
316 Next, participants were shown a row of nine basic drawings depicting a person ranging from  
317 very calm (value of 1; left) to very anxious (value of 10; right) and were instructed that *“The  
318 faces below are arranged on a continuum from calm (left) through to anxious (right).”* They  
319 were asked to indicate their arousal response to the report in an instruction that read *“Please  
320 indicate how you felt whilst [listening to, reading] the report you just [heard, read]. To make  
321 your choice, select the corresponding option box located below the faces.”* Finally,  
322 participants were asked *“How informative did you find the report in your decision making  
323 about whether to [make the journey tomorrow, use the cash machine outside the bank, order  
324 your favourite meal at the restaurant, accept the short lift home from your friend]”* and  
325 provided their rating on a 100-point scale ranging from “Not at all informative” (value of 1)  
326 to “Extremely informative (value of 100).

## 327 **5. RESULTS**

328 First, we assessed age and scenario differences in participants’ prior decisions. We  
329 conducted a random effects logistic regression analysis on their prior decisions, including age  
330 group (older vs. younger) and scenario (weather, fraud, health, safety) as factors. This

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331 analysis confirmed that older adults engaged in fewer risky activities (70%) in their initial  
332 risk taking compared to younger adults (88%; OR = 0.19,  $t = 3.33$ ,  $p = .001$ ), indicating  
333 greater cautiousness in older age. The analysis also confirmed a trend in risky decision  
334 making across scenarios that was similar to the trend discovered in Study 1. Decisions in  
335 favor of engaging in the activities were most frequent in the weather scenario (95%),  
336 followed by the health (84%; vs. weather, OR = 0.20,  $t = 2.41$ ,  $p = .016$ ), fraud (81%; vs.  
337 weather, OR = 0.16,  $t = 2.77$ ,  $p = .006$ ), and safety scenarios (56% vs. weather, OR = 0.03,  $t$   
338 = 5.06,  $p < .001$ ).

339         Next, we assessed participants' posterior decisions on the basis of their age and the  
340 presentation format (transcript vs. audio) of the reports. Controlling for prior decisions in a  
341 random effects logistic regression analysis, older adults were significantly less likely than  
342 their younger counterparts to decide in favor of engaging in the activities described in the  
343 reports (Table 1; Model 1). However, the age differences between prior (88%<sub>younger</sub>; 70%<sub>older</sub>)  
344 and posterior decisions (76%<sub>younger</sub>; 53%<sub>older</sub>) were much smaller than those observed in Study  
345 1. In comparison to Study 1, younger adults were more responsive to the reports in their  
346 posterior decision making. Participants were not significantly more responsive to the audio  
347 format (79%<sub>initial</sub>; 66%<sub>posterior</sub>) than to the written transcript format (79%<sub>initial</sub>; 63%<sub>posterior</sub>) in  
348 making their posterior decisions (Table 1; Model 1). Including an interaction term between  
349 age and presentation format did not reveal that age differences in decision updating depended  
350 on the presentation format of the reports (OR = 1.38,  $t = 0.45$ ,  $p = .654$ ).

351         Did younger and older adults differ in their emotional responses to the reports? We  
352 conducted a random effects linear regression on participants' valence ratings, including age  
353 (older vs. younger), scenario (weather, fraud, health, safety), and report format (transcript vs.  
354 audio) as factors. This analysis revealed that older adults were significantly more negative in  
355 their valence response to the reports ( $M = -0.28$ ) than younger adults ( $M = 0.43$ ; Table 2).

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356 There were also significant scenario differences in participants' valence responses (Table 2).  
357 Participants were least negative in their response to the health report ( $M = 0.90$ ), followed by  
358 the weather ( $M = 0.29$ ), fraud ( $M = 0.03$ ), and safety reports ( $M = -0.90$ ). Valence responses  
359 were stronger for audio reports ( $M = 0.05$ ) than for written transcript reports ( $M = 0.11$ ), but  
360 this difference was not significant (Table 2).

361 Next, we tested for age, scenario, and report format differences in arousal responses  
362 using a random effects linear regression analysis. Older adults exhibited stronger arousal  
363 responses to the reports ( $M = 5.48$ ) than did younger adults ( $M = 4.68$ ; Table 2). The analysis  
364 also revealed scenario differences in arousal response (Table 2). Arousal was strongest in  
365 response the safety report ( $M = 6.01$ ), followed by the weather ( $M = 5.2$ ), fraud ( $M = 4.99$ ),  
366 and health reports ( $M = 4.11$ ). Finally, while arousal responses were stronger for audio  
367 reports ( $M = 5.19$ ) than for written transcripts ( $M = 4.96$ ), this difference was not significant  
368 (Table 2).

369 Did younger and older adults differ in how informative they perceived the reports? To  
370 test for age, scenario, and report format differences in informative ratings we conducted a  
371 random effects linear regression analysis. While older adults rated the reports as slightly less  
372 informative ( $M = 55.61$ ) than did their younger counterparts ( $M = 59.60$ ), our analysis  
373 indicated that this age difference was not significant (Table 2). Participants rated the weather  
374 report as most informative ( $M = 65.34$ ), followed by the safety ( $M = 59.55$ ), fraud ( $M =$   
375  $59.15$ ), and health reports ( $M = 46.39$ ). Finally, participants also rated audio reports as more  
376 informative ( $M = 60.04$ ) than written transcript ( $M = 55.18$ ), but this differences was not  
377 significant (Table 2).

378 Did emotional responses and informative ratings account for tendencies to update  
379 posterior decision making in response to the reports? Posterior decisions against engaging in  
380 the activities described in the scenarios were associated with a stronger negative valence

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381 response and higher informative ratings for the reports (Table 1: Model 2). In a third block,  
382 we included all possible interaction terms involving age group (older vs. younger), valence,  
383 arousal, and informative ratings (Table 1: Model 3). There were no significant interactions  
384 with age. However, valence interacted with arousal, such that arousal only influenced  
385 posterior decisions when the valence was negative. Indeed, valence was a strong negative  
386 predictor of arousal ( $b = -0.79, t = 12.11, p < .001$ ), which indicates that the reports were  
387 arousing when they were negative, leading to a stronger influence on decision making.

388 Finally, we tested whether valence and arousal responses and informative ratings  
389 accounted for age differences in posterior decisions. Recall that older adults showed stronger  
390 valence and arousal responses to the reports, but did not differ from younger adults in their  
391 informative ratings for the reports. We conducted a random effects logistic regression  
392 analysis on posterior decisions, including valence, arousal, and informative ratings in separate  
393 models, and in each model we controlled for prior decisions. Age differences in posterior  
394 decisions remained significant after partialing out informative ratings ( $OR = 0.32, t = 2.44, p$   
395  $= .015$ ), but not after partialing out valence ( $OR = 0.57, t = 0.96, p = .338$ ) or arousal  
396 responses ( $OR = 0.52, t = 1.40, p = .161$ ).

397 In sum, older adults made fewer risky decisions than their younger counterparts and  
398 were also more responsive to warnings about risk, albeit less so than in Study 1. Older adults  
399 also showed stronger emotional valence and arousal responses to the reports, even though  
400 emotional responses did not differ between audio and written transcript formats of the  
401 reports. Reports that were perceived as highly informative or that elicited a stronger  
402 emotional response were more influential on posterior decision making. Controlling for  
403 informative ratings, age differences in emotional valence and arousal partialled out age  
404 differences in decision updating.

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406 **6. DISCUSSION**

407 Older adults face many risky decisions, including ones about their health, finance, and  
408 personal security. In later life, people are exposed to numerous warnings and advice about  
409 their health and safety, such as whether to continue driving.<sup>(6)</sup> Government campaigns and  
410 awareness raising strategies often target the elderly who may be vulnerable to financial  
411 fraud.<sup>(4,5)</sup> In the current research, we investigated whether older adults are more responsive to  
412 warnings about potential risk with a view to uncovering an underlying cause of increased  
413 cautiousness in older age. Our studies revealed that older adults were less likely than their  
414 younger counterparts to engage in risky activities described in realistic scenarios and were  
415 also more responsive to warnings about potential risk delivered in reports taken from the  
416 media and government campaigns. This finding points to decision updating tendencies as a  
417 potential underlying cause of increased cautiousness in later life. We can expect that most  
418 individuals will have been exposed to similar such warnings (e.g., severe weather forecasts,  
419 health and dietary warnings) in their daily lives. Older adults may have exhibited greater  
420 caution in their initial decision making as a result of previous exposure to similar warnings  
421 experienced in their daily lives.

422 Why are older adults more responsive to warnings about potential risk? One possible  
423 explanation is that warnings elicit stronger emotional responses in older adults, motivating  
424 them to avoid negative consequences of their decision making. Age-related decline in  
425 dopamine levels is associated with negative mood in older age<sup>(35)</sup> and avoidance of negative  
426 outcomes.<sup>(34)</sup> When negative mood is induced in older adults (e.g., using mood-arousing  
427 video clips), risk taking behavior further declines.<sup>(36)</sup> In our studies, we exposed participants  
428 to reports taken from real media and government campaigns, some of which were designed to  
429 elicit strong emotional responses. In the safety scenario, for example, participants listened to  
430 a government campaign designed to increase seat belt use that realistically portrayed a road

431 traffic accident. In Study 2, we found that when controlling for participants' ratings of how  
432 informative the reports were, stronger emotional responses were associated with greater  
433 decision updating in response to the reports. Additionally, older adults reported stronger  
434 negative mood and arousal in response to the reports and their emotional responses accounted  
435 for age differences in decision updating.

436         While older adults appear to experience more intense negative emotions in response  
437 to warnings about risk, emotional well-being and emotional stability have been shown to  
438 improve across adulthood.<sup>(40)</sup> Older adults review positive features of choice options for  
439 longer and attend less to negative features compared to younger adults.<sup>(41)</sup> They also report  
440 experiencing less negative emotional arousal than younger adults when evaluating loss cues  
441 in anticipation of monetary outcomes.<sup>(42)</sup> This prioritising of positive emotions in later life  
442 has been explained in terms of socio emotional selectivity theory.<sup>(43,44)</sup> The theory posits that  
443 as an individual's time horizon shortens positive emotional experiences are prioritised over  
444 negative emotional experiences. Despite prioritising positive emotions, older adults are more  
445 vulnerable to some negative consequences of their decision making than people in younger  
446 age ranges, especially in situations involving risk of physical harm and illness. Older drivers,  
447 passengers, and pedestrians, for example, are much more likely than younger road users to be  
448 fatally injured as a result of a road traffic collision, owing to their increased susceptibility to  
449 incur physical injury.<sup>(45)</sup> We can expect that individuals adapt to their own physical and social  
450 vulnerabilities in later life by heightening their emotional responses to harmful potential  
451 outcomes. Indeed, the scenarios we used in our studies all involved decisions that had severe  
452 negative consequences.

453         In the current research, we selected risk taking scenarios about which younger and  
454 older adults would have some prior knowledge or experience. For example, most people will  
455 have experienced using an ATM machine outside a bank (fraud scenario) or choosing among

## Age and adaptation

456 meal options at a restaurant (health scenario). Previous research has suggested that prior  
457 experience can overcome the influence of media reports<sup>(31)</sup> and statistical information<sup>(32)</sup> on  
458 risk perception and decision making. Even when experience is accrued over a long period of  
459 time, an individual may never experience severe negative outcomes of their decision making  
460 when the outcomes are rare (e.g., bank fraud as a result of using an ATM machine) or have a  
461 long time horizon (e.g., heart failure due to a diet rich in salt). This tendency can lead people  
462 to underestimate the probability of rare events and underweight the importance of descriptive  
463 information.<sup>(25,26,30)</sup> Our findings do not necessarily challenge this view. At least in Study 1,  
464 younger adults were relatively non-responsive to the reports (Figure 1). Although older adults  
465 were more responsive than younger adults to descriptive information, the results of Study 2  
466 suggest that when descriptive information is delivered in the form of warnings it can evoke  
467 stronger negative emotional responses in older adults that lead to greater decision updating in  
468 older age. An interesting direction for future research would be to explore age differences in  
469 decision updating in contexts that people have acquired less personal experience. For  
470 example, individuals who live in areas unaffected by the Ebola virus or Zika virus may be  
471 highly responsive to media reports and statistics issued in government reports.<sup>(27)</sup> In such  
472 situations, age differences in decision updating may even be stronger than those reported in  
473 our studies, as the greater personal experience accrued by older adults may have helped  
474 downplay the impact of descriptive information.

475         The influence of personal experience may help explain why people are far less  
476 responsive to advice than they should be,<sup>(46)</sup> a phenomenon known as ‘egocentric advice  
477 discounting’, which is proposed to result from strong beliefs in the importance of one’s own  
478 opinion.<sup>(47-49)</sup> In one study, Yaniv and Kleinberger<sup>(49)</sup> questioned participants about the dates  
479 of historical events. They then gave participants a second attempt at each question, this time  
480 presenting participants with their previous response and a response suggested by an advisor.

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481 Participants were shown to place considerably greater weight on their own responses than the  
482 suggestions of their advisor. However, participants were sensitive to the quality of their own  
483 responses in their uptake of the advice and were more receptive of good advice than they  
484 were of bad advice. Similarly, in Study 2, we found that participants were more responsive to  
485 warnings that they perceived as informative. Perceived informativeness may even be a  
486 necessary condition for responding to warnings that are highly emotive. We found that  
487 warnings that elicited intense emotional responses influenced decision updating when a  
488 warning was also perceived as highly informative.

489         Research on advice taking in decision making has shown how characteristics of the  
490 advisor (e.g., their reputation) influence the uptake of advice.<sup>(49)</sup> Our studies show in a risky  
491 decision making context that the age of the individual receiving advice also determines its  
492 uptake. We used a similar experimental procedure to procedures used in advice taking  
493 studies; namely, participants first made an initial (prior) decision and then made a second  
494 (posterior) decision after receiving advice in the form of an audio warning. Our findings  
495 suggest that age differences in emotional processing underlie stronger decision updating in  
496 older age. An alternative possibility is that older adults are more compliant with requests in  
497 experimental settings. The experimental procedure, in which posterior decision making was  
498 assessed following the delivery of advice, is likely to have been salient to participants.  
499 However, social desirability, which underpins compliance, has not been found to differ with  
500 age.<sup>(50)</sup> Thus, it would seem unlikely that individual differences in compliance explain our  
501 current findings. Another possibility is that younger adults strive to be consistent in their  
502 behavior and as a result responded less to the warnings in their posterior decision making.  
503 However, conscientiousness, which promotes consistent behavior, actually increases with age  
504 across adulthood.<sup>(51)</sup> As such, greater conscientiousness in older age may even have  
505 dampened the size of the age effects we observed on decision updating.

## Age and adaptation

506           In conclusion, our findings demonstrate that older adults are more responsive than  
507 younger adults to warnings about potential risk, which may partly explain why older adults  
508 are often cautious in situations that involve risk. Our findings also contribute to a growing  
509 body of literature pointing to the importance of emotional factors in risk taking and possibly  
510 as a basis of cautiousness in older adults.

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**Table 1.** Experiment 2: Logistic regression models used to predict posterior decisions

Included	Model 1	Model 2	Model 3
	Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)
Constant	0.02 (0.00: 0.20)*	0.42 (0.02: 11.45)*	0.07 (0.00: 38.81)*
Prior decisions	632.53 (60.41: 6622.67)**	9,787.37 (349.59: 274,010.71)**	7,448.72 (270.07: 205,443.00)**
Age			
Older vs. younger	0.38 (0.16: 0.92)*	0.35 (0.10: 1.25)	0.28 (0.00: 23.60)
Scenario			
Weather	1.00	1.00	1.00
Fraud	0.43 (0.18: 1.06)	0.33 (0.10: 1.10)	0.47 (0.15: 1.50)
Health	3.41 (1.07: 10.93)*	1.19 (0.28: 5.05)	1.68 (0.40: 7.02)
Safety	0.56 (0.21: 1.53)	1.00 (0.26: 3.88)	2.14 (0.49: 9.45)
Report format			
Transcript vs. audio	0.74 (0.36: 1.51)	0.61 (0.24: 1.55)	0.72 (0.29: 1.80)
Valence		1.95 (1.15: 3.32)*	0.53 (0.10: 2.75)
Arousal		0.76 (0.57: 1.01)	0.97 (0.40: 2.38)
Informative		0.95 (0.92: 0.97)**	0.97 (0.91: 1.03)
Age x valence			0.83 (0.34: 2.01)
Age x arousal			1.04 (0.61: 1.78)
Age x informative			1.00 (0.95: 1.04)
Valence x arousal			1.41 (1.19: 1.66)**
Valence x informative			1.00 (0.98: 1.01)
Arousal x informative			1.00 (0.99: 1.01)

678 Note. \* $p \leq .05$ , \*\* $p \leq .001$ .

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**Table 2.** Experiment 2: Linear regression models used to predict valence, arousal, and informative ratings

Included	Valence	Arousal	Informative
	beta (95% CI)	beta (95% CI)	beta (95% CI)
Constant	1.23 (0.84: 1.61)**	5.73 (5.09: 6.37)**	69.76 (61.87: 77.65)**
Age			
Older vs. younger	-0.71 (-0.28: -1.13)*	0.79 (0.04: 1.55)*	-3.99 (-12.31: 4.33)
Scenario			
Weather	-0.61 (-0.27: -0.96)*	-0.81 (-0.31: -1.31)*	1.00
Fraud	-0.88 (-0.53: -1.22)**	-1.03 (-0.52: -1.53)**	-6.19 (-13.62: 1.24)
Health	1.00	-1.90 (-1.40: -2.40)	-18.95 (-11.52: -26.38)**
Safety	-1.80 (-1.45: -2.15)**	1.00	-5.79 (-13.22: 1.64)
Report format			
Transcript vs. audio	0.06 (-1.19: 0.30)	-0.23 (-0.59: 0.12)	-4.86 (-10.12: 0.39)

692 Note. \* $p \leq .05$ , \*\* $p \leq .001$ .

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713 **Figure 1.** Percentage of decisions in favor of engaging in each activity in the four scenarios

714 before (prior) and after (posterior) hearing each audio report. Vertical bars represent 1

715 standard error above and below the mean.

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