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Recollection Bias and Its Underpinnings: Lessons from Terrorism Risk Assessments

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Recollection bias is the phenomenon whereby people who observe a highly unexpected event hold current risk beliefs about a similar event that are no higher than their recollection of their prior beliefs. This article replicates and extends the authors' previous study of recollection bias in relation to individuals' perceptions of the risks of terrorism attacks. Over 60% of respondents in a national U.S. sample of over 900 adults believe that the current risk of a future terrorist attack by either an airplane or in a public setting is no higher than they recall having believed, respectively, before the 9/11 attack and before the Boston Marathon bombing. By contrast, a rational Bayesian model would update to a higher currently assessed risk of these previously uncontemplated events. Recollection bias is a persistent trait: individuals who exhibited this bias for the 9/11 attack exhibited it for the Boston Marathon bombing. Only one-fifth of respondents are free of any type of recollection bias. Recollection bias is negatively correlated with absolute levels of risk belief. Recollection bias in relation to highly unexpected terrorist events—the belief that perceived risks did not increase after the surprise occurrence—dampens support for a variety of anti-terrorism measures, controlling for the level of risk beliefs and demographic factors. Persistent recollection bias for both 9/11 and the Boston Marathon bombing is especially influential in diminishing support for protective policy measures, such as surveillance cameras in public places. Given that public attitudes influence policy, educating the public about risk is critical.

KEY WORDS: Catastrophe; hindsight bias; recollection bias; risk perception; terrorism

1. INTRODUCTION

Catastrophic events that result from deliberate action pose well-established challenges for individuals' risk beliefs. Fortunately, such major catastrophes, which impose sudden harm on large numbers of victims, are rare events in our society. This infrequency implies that most Americans have little experience to draw on when forming risk beliefs regarding the potentially huge losses attendant on purposeful catastrophic events. This factor alone implies that there is the considerable likelihood that risk judgments will be seriously flawed. Public support for policies arrayed against terrorism will be affected.

Small probabilities often promote dramatic departures from rational decision; witness the vertical leap of the probability weighting function of prospect theory[1] at the bottom of the probability scale. Understandably, most decision experiments in the laboratory involve mechanical devices, such as pulling balls from urns. Though such devices can produce very small probabilities, those probabilities are much

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more easily grasped than equivalent-sized probabilities associated with natural disasters. And even with natural disasters, such as hurricanes, we have a reference class.

Terrorist events present several grave challenges for decision making. They involve very small probabilities. They tend to be *sui generis*, defeating efforts to identify a reference class. They are purposeful events, which makes them much harder to assess than even natural disasters. Significant behavioral biases should be anticipated when humans assess and respond to terrorist events.

In assessing a significant past event, it is valuable to reconstruct one's expectations before the event. This is particularly true when formulating future policies, when one has to estimate the probability that a similar event will occur. Was the past event a bolt from the blue, i.e., something impossible to anticipate, or was it an event a prudent person could have anticipated? The answer will guide estimated probabilities of similar future events, and/or enable us to prepare as best as possible for events that are not on our radar screen.

Our prime question is: How well can individuals assess how they viewed a past significant event before it happened? We focus on events with negative high consequences that public information reveals were either completely unanticipated, ignored, or assigned a very low probability before they occurred. Prime examples would be 9/11, the unanticipated rise of ISIS, and the 2008 financial meltdown. If people have a biased recall of how they viewed the likelihood of such events, it will impair our ability to anticipate major events in the future.

This article addresses two catastrophic attacks against the United States: the September 11, 2001, attack on four planes, the World Trade Center, and the Pentagon that killed 2,977 victims and shook the nation, and the April 15, 2013, bombing at the Boston Marathon that caused 3 deaths and 264 injuries. There were airplane hijackings prior to 9/11. By September 10, 2001, however, airport screening mechanisms were in place, and hijackings or attempted hijackings of planes from the United States had become extremely rare. Moreover, hijacked planes had never been used as weapons to target populated areas. In the three years before the 9/11 attack, the total annual number of deaths of U.S. citizens from anti-U.S. attacks by terrorists had ranged from 6 to 23, while the two years after 9/11, respectively, claimed 27 and 35 American lives.[2] These statistics include attacks outside the United States as well, so they overstate the domestic risks assessed in our survey.

The Boston Marathon bombing was a less distinctive phenomenon than 9/11, particularly since 9/11 had already occurred. Nevertheless, terrorist attacks in U.S. public places had been rare. The Oklahoma City bombing in 1995 had killed 168 people, but this was a domestic act unrelated to international conflicts. Thus, one would expect either of these unanticipated, shocking catastrophes to lead Americans to significantly update their risk beliefs regarding future catastrophes inspired by international terrorism, with 9/11 producing a more massive update. We examine whether actual updates reflect this expectation.

The particular phenomenon that we focus on in this article is what Viscusi and Zeckhauser[3] termed *recollection bias*. This term means that after the experience of a highly surprising adverse event, people recollect their risk beliefs prior to the event to have been no lower than what they currently believe about future risk levels. The initial article used convenience samples of student respondents and found evidence of recollection bias after the 9/11 attack. We take a similar survey approach to explore whether there is recollection bias with respect to both the 9/11 attack and the Boston Marathon bombing to examine the persistence of recollection bias and to examine the implications of this bias for risk assessments and policy preferences. Because this article uses a national adult sample rather than student samples, it is also possible to analyze the role of demographic characteristics in influencing recollection bias, risk beliefs, and policy preferences.

2. RECOLLECTION BIAS AND ITS UNDERPINNINGS

We test four principal hypotheses to explore the existence and ramifications of recollection bias:

Hypothesis 1: There will be recollection bias with respect to both 9/11 and the Boston Marathon bombing.

Hypothesis 2: Individuals who display recollection bias for one of these terrorist attacks will be significantly more likely to reflect it for the other event.

Hypothesis 3: Recollection bias will be associated with a failure to update beliefs, both recalled and future looking.

Hypothesis 4: Individuals displaying recollection bias will be less supportive of anti-terrorist measures.

To foreshadow our results, all four of our hypotheses are confirmed.

2.1. Relationship of Recollection Bias to Hindsight Bias

Recollection bias is quite different from but closely related to *hindsight bias*. Hindsight bias[4] promotes Monday morning quarterbacking on business and life decisions: "She shouldn't have made that investment; he shouldn't have married that woman." Hindsight bias has been studied in detail in relation to juror behavior in liability cases.[5–8] Kelman, Fallas, and Folger[9] examine different experimental reference points for hindsight bias and refer to after-the-fact judgments by external observers, such as jurors, as "third-party hindsight bias."

Both hindsight bias and recollection bias compare two assessments of the likelihood of a significant event from the past. They both ask current individuals to report what they believed about the likelihood of a salient event before it occurred. Call this the *retrospective assessment*. However, the two concepts differ completely in the comparator they employ for the retrospective assessment. Hindsight bias compares it to *prospective assessments* that were made before the event. Recollection bias compares an individual's retrospective assessment to that individual's prospective assessment of a similar event looking forward.

Hindsight bias usually compares prospective assessments by one group of subjects before an event with retrospective assessments by either the same or a different group of similar subjects after the event. Recollection bias, by contrast, makes all assessments after an event and asks each individual to make two assessments, what she believed before the event and what she believes now. It is intrinsically a within-subject phenomenon. If anything, the restriction to a within-subjects format creates a pressure against finding recollection bias. An individual, in theory, could compare her own two assessments and recognize that the information provided by the past event should increase her probability estimate for a future event.

Given hindsight bias, people will overestimate the extent to which a low-probability event had been predictable. In its extreme form, hindsight bias is reflected in the statement: "I knew it all along." In a more moderate version, it would be: "I always knew it was a real possibility." Thus, with hindsight bias, neither 9/11 nor the Boston Marathon bombing would be thought afterwards to have been a substantial surprise. Not infrequently, hindsight bias is exhibited by a third party who blames a decisionmaker for not taking adequate precautions. "Monday morning quarterbacking," where a sports fan explains why a player or manager made a different decision, exemplifies hindsight bias combined with blaming.

2.2. Fundamentals of Bayesian Learning about Terrorism Risks

To examine how a rational learning process works, consider the following stylized example involving drawing balls from a Bernoulli urn consisting of red and white balls. Let the matter of concern be the probability of drawing a red ball. The prior assessed probability is given by a beta distribution with parameters b and c, whereby the prior belief is equivalent to having drawn b red balls and c white balls. The initial perceived probability of drawing a red ball is $b/(b + c)$. If the person draws a ball from the urn and sees that it is red, the probability is updated to $(b + 1)/(b + c + 1)$; drawing a white ball reduces the assessed probability to $b/(b + c + 1)$. New draws change risk beliefs less as $(b + c)$ increases. In short, the less information initially, the more the draw of a single ball from the urn should change risk beliefs.

To illustrate, to deal with a highly unlikely situation where a single occurrence would lead the posterior probability to be massively greater than the prior probability, we might have $b = 0.01$ and $c = 10$, hence a prior probability of $1/1{,}001 = 0.001$. A single trial would consist of a year with or without an event. If the event did occur, the probability would jump to $1.01/11.01 = 0.092$, or by a multiple of more than 90.

If the probability and magnitude of an adverse event are positively correlated, a more extreme event will convey more information. Here are three examples where a positive correlation would seem plausible: (1) There is an extreme outbreak in a region of a mosquito-carried disease. Knowing nothing more, this would lead you to believe that infected mosquitoes are more prevalent in that region, hence the probability of any size outbreak is greater. (2) You do not know how stable or unstable a securities market is. You learn that it dropped 5% in a day last week, suggesting that it is more unstable than you thought. A 2% drop next week has become

more likely. (3) In November 2015, ISIS launched a terrorist attack in Paris that killed 130 people. This suggested that ISIS had greater capability to launch attacks in Europe than would have an ISIS-directed attack that killed four people. The likelihood of a successful future ISIS-directed attack in Europe was greater than would have been the case after a hypothetical four-death attack.

2.3. Risk, Uncertainty, Ambiguity, and Ignorance

When a low-probability event occurs, its likelihood of reoccurrence should be multiplied. In a rational Bayesian framework, greater variability in the prior estimate of the probability—its uncertainty or ambiguity[3]—will multiply the likelihood further. Thus, in the beta distribution example above, low values of b and c imply that prior beliefs are loosely held. Thus, the effect of a terrorist attack event on risk beliefs should be substantial.

The metaphor of drawing balls from an urn, when those balls are known to be red or white, dramatically underestimates the monumental surprise associated with some terrorist attacks, such as 9/11. A more appropriate analogy might be drawing a ball from an urn when the composition of their colors is completely unknown. The ball turns out to be checked with colors of chartreuse and magenta. Posit that one had been asked in advance about the likelihood of getting such a marble on a single draw when asked along with a vast number of other possibilities. The response might have been 1 in 100,000.[4] However, having drawn one such ball, a rational Bayesian assessor might assign the likelihood as 1 in 20 that the next ball would also be checked chartreuse and magenta. Note the synergy between the low likelihood and the massive ambiguity that enters once marbles need not be a solid single color.[5]

Very low probabilities allow for great ambiguity, hence massive updates in probabilities. With our checked chartreuse magenta example, a single ball draw made the outcome 5,000 times more likely.[6] By contrast, if one's prior probability estimate for an event is 2%, for example, its posterior likelihood can multiply by no more than 50.

Neither the general public nor many risk experts foresaw a homeland attack of the level and character of the 9/11 event. It differed in both damage and fatalities by many orders of magnitude from any prior terrorist incident on American soil. It also had many more perpetrators than any prior incident, it used a weapon hardly contemplated by authorities (an airplane as a bomb), and the attackers came from overseas. Outliers of course are possible. One estimate is that the probability of observing a terrorist event of 9/11 size or larger somewhere in the world over the 45-year period 1968–2013 was 11–35%.[12] However, U.S. vulnerability was presumably much lower, both because the United States has less than 5% of the world population and the widespread belief before 9/11 that the United States was less vulnerable than other targets, such as the Middle East or even Europe. That estimate stretched over four-and-a-half decades, whereas the implicit (sometimes explicit) time period for our questions was just a year. Risk projections for the United States surely should have multiplied after 9/11, as the novel mode of the attack undermines such models' premise of a stationary event generation process.

Given that 9/11 had already happened, the Boston Marathon bombing was much less startling, particularly because of its more conventional mode of attack and less monumental consequences. Nevertheless, both events represented instances of uncertainty, not risk—their probabilities were both unknown and highly ambiguous. More appropriately, we believe that they should be thought of as situations of ignorance, where even the possible states of the world are not known.[13] Indeed, these events reflect a much deeper level of ignorance than simply having imprecise priors. Few people even contemplated the possibility of such attacks. At the 2013 Boston Marathon, for example, security was slight.

This raises the question as to what events should be classified together as a reference class. For example, 9/11 dramatically raised the likelihood for the

[3]Knight[10] distinguished between risk, where probabilities are known, and uncertainty, where they are unknown. Decision theorists, including the authors, usually treat uncertainty by positing a prior probability distribution, often subjectively determined, on the underlying probability. Ellsberg[11] employed the term ambiguity to apply to uncertainty situations.

[4]Of course, asking about a specific pattern and color combination would lead the subject to raise that probability. That is why it is important to ask about a "vast number of other possibilities."

[5]This example adds layers of ambiguity above the one described by Ellsberg,[11] since the possible colors are not known, there is the possibility of mixed colors, and the colors can be in varying patterns, or indeed nonpatterns.

[6]This would be consistent with a beta prior with b representing a checked chartreuse magenta marble and c representing all other color marbles. Here, b would be 0.0002 and c would be 20. Technically, the posterior would really be 1.0002/21.0002, or slightly above 1/21.

use of airplanes as weapons, but its occurrence also increases the likelihood of another major terrorist event inspired by Islamic extremism. In the latter category, it should alert us that our enemies are more capable and more eager to attack us than we thought.

The marathon bombing as well as the 2015 San Bernadino massacre are better characterized as lone-wolf attacks. Leaving aside any copycat effects, it is tempting to conclude that since we have seen a number of such events, one more should not be a surprise. However, even if we think of such events as coming from a Poisson distribution, given that the numbers are small, one more attack should notably increase our assessment of the mean λ of that distribution. Furthermore, if we believe that the mean has a trend, e.g., terrorist events may be becoming more common, the occurrence of an event would also require updating the estimate of the slope of the trend.

Terrorist attacks can differ greatly in their motivation, locale, mode of attack, and the organization involved, suggesting that they are much more differentiated than natural disasters, such as floods or hurricanes. They fit less well into a single reference class. Thus, there should be more updating when two young men educated in an American high school get radicalized and use a crude bomb to kill 3 and injure 250+ others than when there is a major flood or category 5 hurricane. Major lone-wolf, jihadi terrorist attacks have been revealed to be much more of a threat.

2.4. The Better Protection Rationale

Before proceeding, we should mention one conceivable justification for why individuals' assessments after a severe adverse event might dampen the updated probability, indeed possibly make it lower than the prior probability: protective measures could be taken. Thus, burglar alarms are installed after one's home is robbed. After 9/11, al Qaeda leaders and adherents are killed, and airline security is considerably tightened.

No 9/11-type incident has occurred over many intervening years. Does that imply that protection is now better? Unfortunately, a very low probability updates massively and quickly when it occurs, but slowly when it does not.[14] Suppose that after the 9/11 attack, the person's beliefs for subsequent annual attack risk were characterized by a beta distribution where $b = 10$ and $c = 90$. Thus, the person believes that the annual risk of attack is $b/(b + c) = 0.10$. After 15 years with no incident, the value of the denominator rises to 115, while the numerator remains the same, and the assessed probability falls to $10/(115) = 0.087$. That represents substantial updating, but hardly to the extent of what should have happened in the opposite direction from pre-9/11 to immediate post-9/11.

We do not believe that increased protective measures, plus the deterrence to perpetrators they promoted, or other recent developments have been nearly sufficient to swamp the sizeable updating in probability that should have accompanied the 9/11 or Boston Marathon attacks.

2.5. Weak Updating

Posit that individuals recall their assessed probability of a salient low-probability event before it happened as being too large relative to their current assessment of the risk, as judged from the standpoint of rational decision theory. Such a bias could arise from weak updating, meaning that they updated too little from their prior to their posterior probability. This might happen, for example, because they *anchored*[15] too heavily on their initial probability, the likelihood ratio they employed for updating was too low, or because they did not employ the tools of decision theory, even informally, to update their probability.

2.6. Retrospective Adjustment of Prior Probabilities (RAPP)

The RAPP phenomenon arises because present beliefs affect what we recall ourselves believing in the past, a form of backward anchoring. At a deep level, we believe that the RAPP phenomenon is related to cognitive dissonance: "It is hard for me to believe now that such a consequential phenomenon that I now fear greatly was of so little concern to me before its first occurrence." In fact, we believe that few citizens consciously contemplated any probabilistic possibility for something like 9/11 or the Boston Marathon bombing before it occurred. Thus, their actual probability estimate went from "not on the radar screen" to "strongly on the radar screen" at whatever is their current probability estimate. Our surveys made no attempt to parse the relative contributions of weak updating, leading to too low a posterior, and RAPP, promoting too high a prior.

2.7. The Basic Question

The prime issue being addressed here is not whether individuals' risk beliefs have in fact increased or decreased, and if so, moved too much or too little. The survey questions with respect to the 9/11 attack and the Boston Marathon bombing are explicitly *not* longitudinal in nature. Thus, they do not track the level of people's actual previous risk assessments and compare them to their current risk beliefs. Neither do they represent a between-subjects analysis of beliefs expressed by one group before the event and by another group after.

Our prime question is whether respondents believe that the risks going forward are higher, lower, or the same as their current recollection of what their own risk beliefs were before the attack. This comparison may or may not reflect how beliefs have actually shifted. Rather, the focus is on whether respondents, recollecting what they believed before, perceive that risks have increased.

Given the analysis above, if an individual's risk beliefs did not increase from before the attack to now—or worse, the risk beliefs declined—a strong recollection bias must be at play. Interestingly, the policy implications of recollection bias may be quite the opposite of the influence of the availability heuristic. Whereas the availability heuristic phenomenon produces exaggerated responses to risk,[16] recollection bias may dampen people's response to a significant increase in risk.

A world of biases is a world of the second best. Once you suffer one bias, say availability bias, you might be better not worse off from suffering another, i.e., recollection bias, if the two to some extent counterbalance.

2.8. Updating by Experts versus Updating by the Public[7]

Experts may update much more effectively than the public for two reasons. First, experts have much more data to employ in formulating judgments. They are better equipped to know the frequency or infrequency of similar or relevant events in the past and to determine whether underlying forces have changed the likelihood of events. Trends in terrorist events could emerge from the rise and fall of overseas groups; trends in weather-related catastrophes could result from climate change. Second, experts are familiar with Bayesian methods. Thus, they intuitively understand concepts such as likelihood ratios and the updating of priors to posteriors based on the information seen. A major finding of the behavioral decision movement is that even when dealing with mechanical processes, such as drawing marbles from an urn, members of the general public have little intuitive grasp of Bayesian methods. Most relevant to this analysis, as pointed out above, they anchor on their original probability estimates too strongly: they update too little on the basis of new information.

When bolts from the blue arrive, how should updating ideally be done? To answer that question is beyond the scope of this analysis, but we will make four observations to aid future investigations. First, even experts may not be skilled in such processes. Therefore, any investigation should have a strong empirical component to see what likelihood ratios were assigned in various cases and whether posteriors were updated appropriately, too little, or too much. With feedback, experts might improve their performance significantly. Second, it should try to define reference classes in advance in a sufficiently broad manner to incorporate almost any occurrence. Thus, when considering terrorism, the classification might merely depend on the number of deaths and magnitudes of morbidity. Note that such a classification allows for terrorist attacks that cause illness or otherwise harm human health, not merely bombs or bullets. (Nevertheless, even that classification would miss a cyber-attack that merely severely inconvenienced American society and dragged down its economy.) Third, given that the analysis is dealing with low-probability events, no class of outcomes, such as terrorist events or weather events, will provide sufficient data in a reasonable timeframe. Thus, an aggregate or meta-analysis looking across different types of outcomes would be required to see how effective individuals are in formulating likelihood ratios and thus moving from priors to posteriors. Fourth, any definitive study would take years to complete. In the interim, attention to the methods that experts currently employ would be valuable.

None of this should suggest that expert assessment should trump public opinion in defining policy, and even less that it could do so. A critical question then becomes: How can the public best be involved in assessing the risks that effective policies are expected to confront? A 2008 National Academy of Sciences study[17] addressed this question for environmental problems dealt with by federal agencies. It

[7]We are indebted to area editor Warner North and a referee for encouraging us to include much more information on how updating should be conducted.

concluded that appropriately elicited public input not only aided legitimacy, but also increased the quality of decisions. This makes it all the more important to find ways to confront the biases that members of the public suffer when they assess low-probability risks. Public perceptions generate political pressures that in turn influence policies. Effective education about societal risks to overcome perceptional biases is critical.

3. RISK BELIEFS: SURVEY DESIGN AND SAMPLE DESCRIPTION

3.1. The Risk Belief Survey Questions

The empirical approach to assessing whether respondents are subject to recollection bias utilized the following questions for the 9/11 attack and the Boston Marathon bombing:

> Take yourself back to the World Trade Center disaster. Do you believe that the risk of a terrorist attack is higher or lower than what you thought it was before the September 11 disaster? Higher_____, The Same_____, Lower_____.
>
> Take yourself back to the Boston Marathon bombing. Do you believe that the risk of a terrorist attack is higher or lower than you thought it was before the Boston Marathon bombing? Higher_____, The Same_____, Lower_____.

The first of these questions follows the wording used in the surveys reported in Viscusi and Zeckhauser.[3] The Boston Marathon question employs a broadly based public-event risk context for the assessment. As stressed above, rational decision-makers would significantly raise their risk beliefs after they have experienced a totally unanticipated adverse event. Even if they had never heard of Bayesian analysis, they should raise them. For any given event, the extent of the revision should be greater when the prior beliefs were held less strongly. Similarly, for any given set of prior risk beliefs, events conveying more information, such as attacks leading to large numbers of casualties, should boost risk beliefs more than would smaller-scale attacks. For an equivalent example, you just moved to a new southern locale and encountered a hail storm in summer, something you never anticipated. Half-inch hail stones should raise your probability of a future hail storm more than 1/16-inch hail stones. Sunstein[18] finds that people tend to have "excessive reactions" to terrorist events because they respond more to the "badness of events" than to their probabilities. We are only seeking "appropriate responses" to the badness of events.

Our hypotheses, however, posit inappropriate responses. To reiterate, Hypothesis 1 is that people will tend to exhibit recollection bias for each of these two events. Hypothesis 2 is that this tendency will persist across these two classes of terrorism risks. Beyond examining the presence of recollection bias, it is also instructive to ascertain the level of respondents' risk beliefs. Hypothesis 3 posits that these risk beliefs will be lower in the presence of recollection bias.

To explore the range of uncertainty reflected in respondents' beliefs, we conducted a survey to elicit the overall level and the distribution of the respondents' current risk beliefs. In particular, the survey asked people for the 5th percentile, the 95th percentile, and their best estimate of the number of American terrorism deaths due to attacks on airplanes over the next 12 months. The survey question read as follows:

> Based on some estimates, the September 11, 2001, disaster led to 266 deaths in the planes and 2,717 deaths at the World Trade Center. The total number of deaths was consequently 2,983, or about 3,000. Below is a series of questions about the number of people who you believe will be killed in the next 12 months because of attacks by foreign terrorists on airplanes:
>
> (a) Think of the best-case outcome in which the number of terrorism deaths could be low. Suppose there is only one chance in 20 that the number of terrorism deaths could be at this low level or below. What is your estimate of this low-end death toll? _____
> (b) Now think of the worst-case outcome. Suppose there is only one chance in 20 that the number of terrorism deaths could be this high. What is your estimate of this high-end death toll? _____
> (c) Your best estimate of the actual death toll will be somewhere between your estimate of the low-end death toll and your estimate of the high-end death toll. What is your best estimate of the expected number of terrorism deaths in the next 12 months? _____

The survey also included a series of questions directed at policies that might be affected by risk beliefs regarding terrorist attacks. Recollection bias takes on potentially powerful policy importance if it is changes in self-perceived risk levels that drive behavior more than the perceived absolute level. Hypothesis 4 is that the presence of recollection bias will be associated with less support of anti-terrorism policies. An overreaction to the risk change may result if people who believe that the risk has escalated differentially favor aggressive policy.

Table I. Current Risk Assessments Relative to Recollected Assessments before Disasters

	2013 Sample		2002–2004 Samples
Risk Relative to before Disaster/Bombing	Airplane Risk	Public-Event Risk	Airplane Risk
Higher	33	39	43
Same	40	53	26
Lower	28	8	31
Recollection bias	68	61	57

Note: The 2002–2004 sample is 333, reported in Viscusi and Zeckhauser,[3] Table I. $N = 910$ for the 2013 sample.

Recollection bias and risk beliefs may alter the tradeoff people are willing to make between terrorism risk reduction through airport screening and civil liberties. The survey question directed at this tradeoff read as follows:

> One way of reducing terrorism risks to plane flights is better screening of passengers. The FBI has developed a profile of the chances that a passenger is a terrorist, taking into account the person's age, race, gender, national origin, appearance, and baggage. Airlines either could screen all passengers, leading to additional delays in line, or they could screen passengers based on the terrorist risk profiling. Targeted screening that would reduce the terrorist risk by as much as random searches would involve lesser time delays for passengers… Would you favor terrorist risk profiling if the alternative was for you to wait in line an extra 30 minutes so that all passengers could be screened randomly? Yes _____ No _____

The survey included two types of questions regarding surveillance cameras: "(1) Is installing surveillance cameras in public places a good idea (good idea, no opinion, bad idea)? (2) How many surveillance cameras should there be in public places (we need more, current amount is just right, we need fewer)?" We tallied responses to these two questions coding positive support as 1, neutrality as 0, and opposition as −1.

3.2. Sample Description

Viscusi and Zeckhauser[3,19] relied solely on several student samples. We expand on that analysis with a survey of a national sample of adults undertaken in the autumn of 2013, after the Boston Marathon bombing. That survey examined perceptual shifts associated with both airplane attacks and public-event attacks.

Our adult sample comprised 910 members of Vanderbilt University's e-Lab panel. The respondents completed the survey in the autumn of 2013. The Appendix summarizes the sample characteristics. The sample is 37% male, 11% nonwhite, 27% Republican, 38% Democrat, averages 15 years of education, has a mean age of 51, and a mean household income of $67,000 (with a median value of $52,500, which is 1% higher than the 2013 U.S. national median of $51,939).

The empirical analysis below employs a detailed set of demographic variables as controls. These variables are often of independent interest, as risk beliefs and preferences with respect to anti-terrorism policies vary with personal characteristics. Previous studies have found that support for anti-terrorism policies is greater among Republicans, the better educated, and those with higher risk beliefs, as found in Viscusi.[20] Thus, this analysis explores the effect of demographic characteristics on recollection bias, risk beliefs, and policy preferences.

4. DATA ANALYSIS

4.1. Summary of Risk Belief Responses

The first two columns of Table I summarize the risk belief responses to the airplane risk and public-event risk questions. For comparison, the third column provides results from Viscusi and Zeckhauser.[3] Individuals whose current risk estimates are the same or lower than their recalled estimates before the terrorist event suffer recollection bias. Consistent with Hypothesis 1, more than three-fifths of the sample exhibited recollection bias, 68% for the airplane risk and 61% for the public-event risk, slightly greater percentages than the 57% (among students) reported in Viscusi and Zeckhauser.[3] The distribution of public-event risk responses was more concentrated in the middle category, with only 8% who believed that their previous risk assessments were lower. The

Table II. Number of Respondents in Risk Belief Categories

		Airplane Risk Rating			
		Higher	Same	Lower	Total
Public-Event Risk Rating	Higher	196	87	73	356
	Same	95	265	122	482
	Lower	5	8	59	72
	Total	296	360	254	910

Note: Statistics indicate the number of respondents with current risk beliefs for airplane risks and public-event risks relative to their preattack values.

cross, tabulations in Table II show a strong concentration of responses on the diagonal, consistent with Hypothesis 2; thus, large numbers of respondents indicated that both risks are below or the same as they recall that they had believed before. The strongest persistence is for those who believe that the public-event risks are lower than before, as 82% of this group believe that the airplane risks are also lower. The empirical analysis below distinguishes three different recollection bias measures: airplane risk bias, public-event risk bias, and persistent bias for individuals who consider both risks to be the same or lower than before. Only 21.5% (i.e., 196/910) of individuals avoid both types of biases. Consistent updating merely in a rational direction is the exception.

Table III summarizes the patterns of risk assessments for the expected number of U.S. terrorism-related deaths both for the current sample as well as previous estimates from 2003 to 2004. This analysis excluded four outliers who believed the death toll would exceed 1 million. The mean and median values of the best estimate for the 2013 sample are, respectively, 1,383 and 100 deaths. The median of the lower- and upper-bound values are 15 and 600, respectively. Given the highly skewed nature of the risk-belief responses, the empirical analysis focuses on the log of the best estimate, which has a mean of 4.5.

Individuals' characteristics, such as age or political affiliation, may influence their risk beliefs. For example, Republicans might believe risks to be higher, or more likely to have increased, conceivably with causality flowing in either or both directions. Table IV conducts probit regression analyses to examine the factors related to our three recollection biases. The two most consistent and significant findings are that older and higher-income respondents are less subject to bias. Republicans are less subject to event bias. Males are more prone to airplane bias (0.05 significance level) and event bias (0.10 significance level). The result for males echoes previous findings by Mumpower *et al.*[21] that white males have lower risk beliefs regarding terrorist attacks on airplanes. It would not be surprising if respondents'

Table III. Terrorism Risk Estimates of Fatalities for the Next 12 Months

	Median	Mean	Std. Error of Mean
2013 Sample			
Lower bound (5th percentile)	15	203.15	56.79
Best estimate (50th percentile)	100	1,382.77	572.11
Upper bound (95th percentile)	600	8,977.04	2,252.80
2003–2004 Sample			
Lower bound (5th percentile)	1.5	95.95	33.71
Best estimate (50th percentile)	100	451.59	99.98
Upper bound (95th percentile)	2,000	23,768.35	12,658.61

Note: The 2003–2004 sample estimates are from Viscusi and Zeckhauser,[3] Table II. Reported statistics for both surveys omit estimates of over 1 million deaths, leading to 8 observations being dropped for the 2003–2004 sample and 4 observations being dropped for the 2013 sample.

Table IV. Probit Regressions for Different Forms of Recollection Bias

Variable	Airplane Bias	Public-Event Bias	Persistent Bias
Age	−0.003**	−0.005***	−0.004***
	(0.001)	(0.001)	(0.001)
Male	0.084**	0.064*	0.047
	(0.032)	(0.034)	(0.036)
Education	−0.005	1.8E−4	−0.002
	(0.007)	(78.9E−4)	(0.008)
Income/1,000	−0.795E−3**	−0.642E−3*	−0.911E−3**
	(0.345E−3)	(0.366E−3)	(0.381E−3)
Republican	−0.063	−0.104**	−0.093**
	(0.042)	(0.044)	(0.044)
City	−0.034	−0.011	−0.052
	(0.052)	(0.054)	(0.056)
Pseudo R^2	0.02	0.04	0.03

Note: $N = 910$. Other variables included in the regressions are nonwhite, suburb, small town, West, Midwest, South, New York City, Democrat, and missing income. All coefficients have been transformed to correspond to marginal effects. Significance levels *0.10, **0.05, and ***0.01.

Table V. Tobit Regressions for Log Best Estimate of Terrorism Deaths in the Next 12 Months

	Airplane Bias	Public-Event Bias	Persistent Bias
Recollection Bias	−0.643***	−0.747***	−0.585***
	(0.177)	(0.171)	(0.166)
Age	0.011*	0.009	0.010*
	(0.006)	(0.006)	(0.006)
Male	−0.309*	−0.315*	−0.333*
	(0.174)	(0.173)	(0.174)
Education	−0.070*	−0.066*	−0.067*
	(0.039)	(0.039)	(0.039)
Income/1,000	−0.004**	−0.004*	−0.004*
	(0.002)	(0.002)	(0.002)
Republican	0.302	0.267	0.289
	(0.214)	(0.214)	(0.215)
City	−0.630**	−0.614**	−0.644**
	(0.269)	(0.268)	(0.269)
Pseudo R^2	0.01	0.01	0.01

Note: $N = 906$. Respondents indicating an upper bound on terrorism deaths in excess of 1 million are excluded. Other variables included in the regression are nonwhite, suburb, small town, West, Midwest, South, Democrat, and missing income. Significance levels *0.10, **0.05, and ***0.01.

risk assessment levels related to recollection bias. That would be expected if weak updating were the prime source of the bias.

4.2. Factors Affecting Best Estimates

Table V presents double-bounded Tobit regressions assessing how the log value of the level of individuals' best estimates of the number of terrorism deaths relate to their demographic characteristics and any recollection biases they suffer. Given the log formulation, a value of 1 is assigned to predictions of zero terrorism deaths. The distribution of log responses is censored from below at zero and above as well, since outliers exceeding 1 million expected deaths were excluded.

All three recollection bias measures exhibit negative and statistically significant coefficients consistent with Hypothesis 3. Thus, in addition to possible direct effects of recollection bias on policy preferences, an indirect effect is exerted through the lower absolute level of risk beliefs. Males and better- educated and higher- income individuals have systematically lower risk beliefs. The most puzzling result is that city dwellers have lower risk beliefs compared to the omitted category of rural respondents. The surprising puzzle arises because the two most prominent attacks involved major urban areas, and previous research found that proximity to the 9/11 attack related positively to risk beliefs.[22]

4.3. Policy Preferences

We now turn to examine how recollection bias affects preferences for policies in dealing with terrorism. Recollection bias represents an amalgam of the change in perceptions of risk and the current level of beliefs. If the change in perceptions is influential alongside current beliefs in affecting preferences, recollection bias would have a powerful effect. Changes in perceptions often are important. For example, an incumbent president might have a greater chance of being reelected if unemployment went from 5.5% to 5.25% in the election year than if it increased from 4.5% to 4.75%. Similarly, an individual might be more likely to go to the doctor if pain progressed from mild to moderate, but not if it declined from severe to strong. Numerous causal models could make such behavior completely rational. However, behavioral factors could also be crucial contributors. In accord with prospect theory,[1] humans are attuned to noticing changes from a reference point. The potential for a strong response is what one might expect given the results in Gigerenzer,[23] who found that the alarmist private behavioral responses to terrorism risks on balance was counterproductive.

The protective policies considered in the survey include profiling of airline passengers, the use of more cameras in public places, and surveillance of mail, e-mails, and phones. Presumably, results for these policy preferences would carry over to decisions about Insuring against terror,[24] or going against terrorism's sources overseas.[25] The explanatory variables in the regressions include one of the three recollection bias measures indicated by the column heading, the absolute risk estimate as reflected in the log of the best estimate of the number of deaths, and a series of demographic variables. The best estimate value in turn is lower for those exhibiting recollection bias. Thus, the potential role of recollection bias includes both its direct negative effect on support for anti-terrorism policies and its indirect effect linked to lower values of the best estimates of the risk. Consistent with our Hypothesis 4, respondents' attitudes toward different anti-terrorism policies relate strongly to their risk beliefs for all policies except risk profiling.

The policy analyzed in Table VI reports the probit regression results for the 0–1 responses for

Table VI. Probit Regressions for Support of Profiling If a 30-Minute Waiting Time

	Airplane Bias	Public-Event Bias	Persistent Bias
Recollection bias	−0.046	−0.060*	−0.096***
	(0.036)	(0.035)	(0.034)
Log best estimate	0.012*	0.012	0.011
	(0.007)	(0.007)	(0.007)
Age	0.006***	0.006***	0.006***
	(0.001)	(0.001)	(0.001)
Male	0.004	0.003	0.004
	(0.036)	(0.036)	(0.036)
Education	−0.019**	−0.019**	−0.019**
	(0.008)	(0.008)	(0.008)
Income/1,000	0.227E−3	0.231E−3	0.184E−3
	(0.378E−3)	(0.377E−3)	(0.378E−3)
Republican	0.123***	0.119***	0.117***
	(0.042)	(0.042)	(0.043)
City	−0.012	−0.011	−0.016
	(0.056)	(0.056)	(0.056)
Pseudo R^2	0.06	0.06	0.06

Note: $N = 906$. Respondents indicating an upper bound on terrorism deaths in excess of 1 million are excluded. Other variables included in the regression are nonwhite, suburb, small town, West, Midwest, South, Democrat, and missing income. Significance levels *0.10, **0.05, and ***0.01.

whether subjects were willing to support racial and demographic profiling of passengers if the alternative was to wait in line for an extra 30 minutes.

The strongest negative effects are found for those exhibiting persistent recollection bias; they have a 0.1 lower probability of supporting profiling, an effect that is strongly significant at the 0.01 level. Older respondents and Republicans exhibit consistent positive support for demographic profiling; better-educated respondents are less supportive, consistent with the finding by Mumpower *et al.*[21] that better-educated respondents have lower willingness to pay to prevent attacks on airplanes.

Table VII reports the ordered probit results for whether respondents support surveillance cameras in public places using each of the three recollection bias variables indicated by the column headings. Table VIII reports analogous results for whether respondents support more surveillance cameras in public places. The coefficient for each recollection bias variable is negative and significant, indicating a dampening effect for both questions. When risks are perceived not to be increasing, support for expensive and intrusive protective measures falls.

Older respondents support cameras more; better-educated respondents support them less,

Table VII. Ordered Probit Regressions for Support of Surveillance Cameras in Public Places

	Airplane Bias	Public-Event Bias	Persistent Bias
Recollection bias	−0.343***	−0.197*	−0.315***
	(0.109)	(0.102)	(0.096)
Log best estimate	0.045**	0.045**	0.044**
	(0.020)	(0.020)	(0.020)
Age	0.019***	0.019***	0.019***
	(0.004)	(0.004)	(0.004)
Male	−0.192**	−0.205**	−0.208**
	(0.098)	(0.098)	(0.098)
Education	−0.042*	−0.040*	−0.041*
	(0.022)	(0.022)	(0.022)
Income/1,000	1.118E−3	1.252E−3	1.109E−3
	(1.093E−3)	(1.088E−3)	(1.094E−3)
Republican	0.450***	0.452***	0.445***
	(0.125)	(0.125)	(0.125)
Democrat	0.450***	0.446***	0.448***
	(0.111)	(0.110)	(0.111)
City	0.191	0.198	0.193
	(0.155)	(0.155)	(0.155)
Pseudo R^2	0.08	0.07	0.08

Note: $N = 906$. Respondents indicating an upper bound on terrorism deaths in excess of 1 million are excluded. Other variables included in the regression are nonwhite, suburb, small town, West, Midwest, South, and missing income. Significance levels *0.10, **0.05, and ***0.01.

Table VIII. Ordered Probit for Support of More Surveillance Cameras in Public Places

	Airplane Bias	Public-Event Bias	Persistent Bias
Recollection bias	−0.207**	−0.199**	−0.204**
	(0.086)	(0.084)	(0.080)
Log best estimate	0.044**	0.043**	0.044**
	(0.017)	(0.017)	(0.017)
Age	0.016***	0.015***	0.016***
	(0.003)	(0.003)	(0.003)
Male	−0.077	−0.082	−0.084
	(0.083)	(0.083)	(0.083)
Education	−0.055***	−0.054***	−0.055***
	(0.019)	(0.019)	(0.019)
Income/1,000	1.435E−3	1.498E−3*	1.430E−3
	(0.892E−3)	(0.890E−3)	(0.892E−3)
Republican	0.195*	0.188*	0.189*
	(0.102)	(0.102)	(0.102)
Democrat	0.365***	0.363***	0.361***
	(0.095)	(0.095)	(0.094)
City	0.046	0.052	0.045
	(0.130)	(0.130)	(0.130)
Pseudo R^2	0.05	0.05	0.05

Note: $N = 906$. Respondents indicating an upper bound on terrorism deaths in excess of 1 million are excluded. Other variables included in the regression are nonwhite, suburb, small town, West, Midwest, South, and missing income. Significance levels *0.10, **0.05, and ***0.01.

Table IX. Probit Regressions for Support of Surveillance of Mail, E-Mails, and Phones

	Airplane Bias	Public-Event Bias	Persistent Bias
Recollection bias	−0.057	−0.035	−0.058*
	(0.037)	(0.035)	(0.034)
Log best estimate	0.026***	0.026***	0.025***
	(0.007)	(0.007)	(0.007)
Age	0.007***	0.007***	0.007***
	(0.001)	(0.001)	(0.001)
Male	−0.022	−0.025	−0.024
	(0.036)	(0.036)	(0.036)
Education	−0.015*	−0.015*	−0.015*
	(0.008)	(0.008)	(0.008)
Income/1,000	0.755E−3**	0.790E−3**	0.757E−3**
	(0.376E−3)	(0.375E−3)	(0.375E−3)
Missing income	−0.161*	−0.159*	−0.160*
	(0.075)	(0.075)	(0.075)
Republican	0.029	0.029	0.027
	(0.044)	(0.044)	(0.044)
City	0.086	0.087	0.084
	(0.056)	(0.056)	(0.056)
Midwest	−0.088*	−0.092*	−0.089*
	(0.048)	(0.048)	(0.048)
South	−0.079*	−0.079*	−0.077*
	(0.042)	(0.042)	(0.042)
Pseudo R^2	0.06	0.06	0.06

Note: $N = 906$. Respondents indicating an upper bound on terrorism deaths in excess of 1 million are excluded. Other variables included in the regression are nonwhite, suburb, small town, West, and Democrat. Significance levels *0.10, **0.05, and ***0.01.

though the effect is weaker in Table VII than for the enhanced surveillance policies in Table VIII. It is intriguing that both Democrats and Republicans strongly support these surveillance measures; the omitted category of respondents in groups such as Independents and Libertarians is less supportive.

Attitudes toward surveillance of mail, e-mails, and phones in Table IX are much less strongly linked to recollection bias. The negative coefficient on recollection bias is only marginally significant at the 0.10 level for the persistent bias variable. As expected, the presence of higher risk beliefs increases support for these efforts, so there continues to be a plausible relation to individual beliefs. Support for surveillance of mail, e-mail, and phones increases with the level of risk beliefs, age, and income; there is a weaker negative relation to education.

5. CONCLUSION

This article documented the presence of recollection bias, which is not restricted to the 9/11 attack, but is a more general phenomenon that has persisted more than a decade after the 9/11 attack and applies to public-event risk as well. Recollection bias proved to be widespread in a survey of 933 individuals asked to compare their risk assessments before the 9/11 and Boston Marathon attacks with their current assessments. Overall, 68% of the 9/11 risk beliefs and 61% of the public-event risk beliefs fell prey to the bias. This evidence in favor of our Hypothesis 1 had to overpower the implications of the availability bias, which would predict a significant increase in risk assessment after a dramatic, highly memorable event. Two possible explanations for recollection bias are that individuals anchored much too strongly on their original risk estimate, or that individuals "upgraded" their recollected prior estimate to accord with their current estimate, a phenomenon related to cognitive dissonance.

Recollection bias is of importance beyond its scientific interest because it is a persistent phenomenon that cuts across different terrorism risks (Hypothesis 2), it is associated with lower risk beliefs (Hypothesis 3), and it influences policy preferences both directly and indirectly on the level of perceived risks (Hypothesis 4). The public's attitude toward different anti-terrorism policies reflects people's overall terrorism risk beliefs, as one might hope. However, even taking the level of risk beliefs and an extensive set of demographic characteristics into account, there is also a profound influence of recollection bias on policy perspectives, particularly for respondents who are subject to persistent recollection bias.

These results surely have implications that extend beyond the particular risk context. People suffering recollection bias believe that their prospective risk levels are not higher than they recollect their previous risk beliefs to have been before a strongly surprising negative event. In many policy contexts, it is the change in the risk situation that promotes support of new initiatives rather than the risk level alone. Individuals with risk beliefs recollected as stable or possibly declining, even in the wake of a strongly adverse and unforeseen event, are poorly suited to adapt to changes in the decision environment. As a result, their well-being suffers, and their policy preferences are poorly informed.

Given that the beliefs and preferences of the public also affect policy decisions taken by government officials, recollection bias will also influence policy. A remaining challenge is to develop interventions that will succeed in overcoming these biases. Effective education of the public about the assessment

of risk could thus improve both its welfare and public policies.

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APPENDIX: SAMPLE CHARACTERISTICS

Table AI. Summary Statistics for All Variables

	Mean	*SD*
Recollection bias – plane	0.675	0.469
Recollection bias – public	0.609	0.488
Recollection bias – persistent	0.499	0.500
Best guess of terror fatalities	1,382.77	17,220.43
Log best guess of terror fatalities	4.521	2.333
Age	50.755	13.574
Male	0.368	0.483
Nonwhite	0.105	0.307
Education	14.875	2.336
Income/1,000	67.253	48.800
Missing income	0.043	0.203
Republican	0.269	0.444
Democrat	0.378	0.485
New York City	0.030	0.170
City	0.280	0.449
Suburb	0.387	0.487
Small town	0.179	0.384
West	0.213	0.410
Midwest	0.231	0.422
South	0.397	0.489

Note: $N = 910$. For best guess and log best guess, $N = 906$; respondents indicating an upper bound on terrorism deaths in excess of 1 million are excluded.

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