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Making Low Probabilities Useful*

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Abstract

This paper explores how people process information on low probability-high consequence negative events and what it will take to get individuals to be sensitive to the likelihood of these types of accidents or disasters. In a set of experiments, information is presented to individuals on the likelihood of serious accidents from a chemical facility. Comparisons are made with other risks, such as fatalities from automobile accidents, to see whether laypersons can determine the relative safety of different plants. We conclude that fairly rich context information must be available for people to be able to judge differences between low probabilities. In particular, it appears that one needs to present comparison scenarios that are located on the probability scale to evoke people's own feelings of risk. The concept of *evaluability* recently introduced by Hsee and his colleagues provides a useful explanation of these findings.

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JEL Classification: C93, D8, D18

1. Introduction

Disasters, such as the explosion at the Union Carbide plant in Bhopal, India in 1984, have sensitized the public to the potential dangers from chemical facilities even though the likelihood of such accidents is extremely small. This concern with the impact of major accidental chemical releases can be illustrated by Congressional passage of the Clean Air Act Amendments (CAAA) of 1990. In implementing one of the provisions of the CAAA (Section 112R), the U.S. Environmental Protection Agency (EPA) requires chemical facilities to develop and implement risk management programs for preventing the occurrence of such releases and sharing these prevention plans with the public (Er et al., 1998).

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This paper explores whether one can present information to people on the likelihood of serious accidents from a chemical facility so they can determine the relative safety of different plants. One possible way to do this is to vary the probabilities of an accident to see if this makes a difference in people's risk perception. Another way is to vary the insurance premium that the firm has to pay to protect itself against the event. One can present this information on just the chemical accident itself or compare this event with others.

If one can provide data in a form that enables people to comprehend the risks they face, then it may be possible to encourage firms to take preventive action through public pressure. One may also want to utilize economic incentives, such as lower insurance premiums to encourage firms to reduce their risk and/or impose standards through required third party inspections.

Insurance is often available to reduce financial losses from low probability-high consequence events. Consumers have experience in making decisions on their homeowners coverage as well as their automobile policies. They also face decisions as to whether to adopt protective measures ranging from dead-bolt locks to car alarms to product warranties. There is evidence that many people are not able to meaningfully use probability information in these contexts (Hogarth and Kunreuther, 1995). By making low probabilities meaningful to individuals, they can choose the appropriate level of protection for various risks.

The next section discusses related research in the area of low probability-high consequence events. Section 3 provides evidence from a set of experiments designed to examine risk perceptions regarding the safety of a chemical plant. In these studies changes in the likelihood of an accident are expressed through either differences in probability or insurance premiums. The concluding section discusses the policy implications of these findings and suggests directions for future research.

2. Earlier studies on low probability-high consequence events

A number of published studies reveal the difficulties people have in interpreting low probabilities when faced with personal risks (Camerer and Kunreuther, 1989; Magat, Viscusi, and Huber, 1987). In fact, there is evidence that people may not even want data on the likelihood of an event occurring. In a recent study of several hypothetical risky managerial decisions, Huber, Wider, and Huber (1997) find that when subjects are required to search out their own information, they rarely ask for any data on probabilities. One group was given a minimal description and the opportunity to ask questions. Only 22% of these respondents asked for probability information. Not one of these respondents asked for precise probabilities. Another group of respondents was given precise probability information, and less than 20% of these respondents mentioned the word "probability" or "likelihood" in their verbal protocols.

Hogarth and Kunreuther (1995) studied the decision process related to the purchase of warranties against the failure of durable consumer products such as stereos, computers, and VCRs. They asked individuals to specify the arguments they utilized to justify their choice and found that people rarely list *probability that the item needs repair* as a reason for purchasing this protection.

Other research has demonstrated that there are ways of reframing the probability of an event occurring that will cause people to use this information in deciding how much to pay for protection. Stone, Yates, and Parker (1994) find that people pay considerably more to reduce the risk of some adverse event if the likelihood is depicted as ratios of very small probabilities (e.g. the risk of an event occurring when one is protected is half of what it is when one is not protected) than if people are presented with two small probabilities (e.g. .000006 probability without protection and .000003 with protection). Slovic, Fischhoff, and Lichtenstein (1978) find more interest in wearing seatbelts if the chance of an accident is framed over a 50 year lifetime of driving (.33) rather than as a .00001 chance each trip. A recent study by Weinstein, Kolb, and Goldstein (1996) found that re-framing the probability of death as the time interval during which a single death is expected can affect risk perceptions.

There is also evidence that absolute probabilities seem to be edited to "a very small number" or zero for some individuals. In a laboratory experiment on purchasing insurance, McClelland, Schulze, and Coursey (1993) found that many individuals bid zero for coverage. This implies that these respondents viewed the probability of a loss as sufficiently small that they were not interested in protecting themselves against it. Studies associated with siting hazardous facilities arrive at a similar conclusion. For example, many homeowners residing in communities that are potential sites for nuclear waste facilities have a tendency to dismiss the risk as negligible (Oberholzer-Gee, 1998).

The notion of *evaluability* recently introduced by Hsee and his colleagues (Hsee, 1996; Hsee et al., 1999) offers some insight into why so many studies find that people have difficulty interpreting low probabilities. According to the evaluability hypothesis, if an attribute is hard to evaluate independently then a person does not know how good a given value of the attribute is without making comparisons that are meaningful to him or her.

People given low probabilities associated with some event may not know how to evaluate these likelihoods. It is difficult to gauge how concerned one should feel about a 1 in 100,000 probability of death without some comparison points. Most people just do not know whether 1 in 100,000 is a large risk or a small risk. As we will show below, individuals are much better able to evaluate probabilities when they are able to use specific comparison information.

3. Judging the safety of chemical facilities

We report on five studies that were undertaken to determine how people judge the safety of a chemical facility after learning either about the *probability of an accident* releasing a toxic chemical or the *actuarially fair insurance premium* for providing coverage to the chemical plant to cover the costs of a chemical release. In Study 1, we try to make low probability events more evaluable in two ways. First, we include a comparison point by telling respondents the probability of death from a car accident. Second, we provide some respondents with data on insurance premiums instead of probabilities. Our feeling was that people have a lot of experience with insurance premiums and are very familiar with the dollar scale. Therefore, we hypothesized that insurance premiums would be more evaluable than small probabilities. We were mistaken.

Study 1

In this study individuals were presented with either a probability or an insurance premium related to the discharge of a hypothetical toxic chemical, Syntox, which had the potential of causing fatalities to individuals living near the plant. The participants in the experiment were then asked a set of questions regarding their perception of the risk posed by the facility. The questionnaire was completed by 241 adult visitors to the San Francisco Exploratorium in July, 1998.

Each respondent saw the following scenario about a chemical plant:

> The ABC Chemicals Company is a large firm that has a plant in a community on the outskirts of an urban center in New Jersey. A chemical labeled Syntox, used in production at the plant, will be regulated under the Environmental Protection Agency's Clean Air Act Amendments. Syntox is the only toxic chemical used at the plant. As is required in the regulations, ABC Chemicals has determined that the worst conceivable accident at the plant would occur if its entire inventory of Syntox were accidentally released into the atmosphere in a very short time period. If this did occur, a plume of toxic vapors would form that could cover any home in the community, depending on how the wind blows. This vapor would only affect a few homes in the community.
>
> An insurance company has estimated the probability of a discharge of Syntox causing deaths in the community surrounding the plant. The insurance company made the risk assessment to determine what premium it should charge ABC Chemicals to provide $1 million coverage to each resident of the community against death from the discharge of Syntox. Insurance companies charge a higher premium to cover an individual if they believe the risk the individual faces is high; they charge a lower premium if they believe the risk is low.

Half of the respondents then read one of three scenarios as shown by the probability figures specified in brackets [ ] for a discharge of Syntox:

> As background for assessing the risks of Syntox, the probability of an individual dying in a car accident is 1 in 6,000 per year.
>
> The estimated probability of an individual in the community dying from a discharge of Syntox is [1 in 1 million per year or 1 in 100,000 or 1 in 10 million].
>
> A regulatory agency has determined that for both car accidents and Syntox discharges, these probability estimates are accurate.

Table 1. Probabilities and insurance premiums for Study 1

	High	Medium	Low
Probabilities	1 in 100,000	1 in 1 million	1 in 10 million
Premiums	$15.00	$1.50	15 cents

The other respondents read one of three scenarios as shown by the insurance premium figures specified in brackets [ ]:

> As background for assessing the risks of Syntox, a fair premium for providing $1 million coverage against each death in a car accident is $245 per year.
>
> A premium of [15 cents or $1.50 or $15.00] per year for each resident of the community is the fair and appropriate one to charge for providing $1 million coverage against each death from a discharge of Syntox.
>
> A regulatory agency has determined that for both car accidents and Syntox discharges, these premiums are fair and appropriate.

Each respondent saw only one value, either a premium or a probability for the chemical plant. Table 1 summarizes the values for the low, medium and high probabilities and premiums for this study.

Following the scenario subjects were asked a set of questions on how risky the chemical plant appeared to be and its relationship to other risks that individuals face such as car accidents, home fires and food disease. (The questions appear in the Appendix.) Four questions were asked about the perceived risk of the chemical facility: (1) whether the plant posed a serious health and safety risk to those living in the community, (2) whether the plant could operate in a manner that was safe for the community, (3) how serious is the risk of death posed by the plant, and (4) how close to the plant respondents would be willing to live.

Results. Since the responses to these four questions were highly intercorrelated ($\alpha = .81$), they were combined into a single scale. The score for each respondent represents his or her overall perception of the risk of the chemical plant. This score was scaled to range between 1 (lowest risk) to 5 (highest risk). Two one-way ANOVAs were performed on the scaled scores, one for the three groups of probability responses and a separate analysis for the responses to the three insurance premiums. As shown in Table 2 neither the means for the three probability conditions nor the means of the insurance premiums were significantly different from each other [Probability conditions ($F(2,119) =$

Table 2. Mean perception of risk of chemical plant for different probabilities and insurance premiums associated with chemical accident (Study 1)

	High	Medium	Low
Probabilities	3.03	2.93	3.01
Premiums	2.81	2.74	3.12

.153, ns); Insurance premium conditions: ($F(2,116) = 1.58$, ns)]. In fact, the premiums are not even monotonic as one would expect them to be.

Conclusions. The two main findings from Study 1 can be summarized as follows. First, people seem unresponsive to changes in the order of magnitude of a low probability. This occurred despite the comparison point they were given for automobile accidents. One explanation for this insensitivity is that the absolute numbers for the release of Syntox may have been too far from the comparison point for automobile accidents. All conditions used probabilities less than one tenth the value for automobiles, so respondents may have seen the risks from the chemical plant as "much lower than car travel."

The second key finding is that people do not respond to insurance premiums as a signal for the risk associated with a chemical plant. This is somewhat more surprising since most people are familiar with insurance policies and should know that premiums tend to reflect risk. Many people are required to purchase automobile insurance and are aware that premiums fluctuate with the age of drivers and with accidents and traffic tickets. People are also very familiar with the dollar scale. While they may not be able to think meaningfully about what a 1 in 100,000 chance of death means, they certainly know what $15.00 means. However, the premiums for the chemical plant are all less than one tenth of the premiums given for automobile accidents. People may think that any risk smaller than the risk associated with driving in a car is safe enough, and thus they do not distinguish between small premiums.

Study 2

To test whether the values used in Study 1 are all too small relative to the comparison point, all the values associated with the release of Syntox are increased in Study 2. The highest value is now approximately one order of magnitude above the comparison point, the middle value is around the comparison point and the lowest value is an order of magnitude below the comparison point. In other words, some respondents would see the risk of a Syntox release as being more probable than car accidents, others would see the risk as similar to car accidents and a third group would see the risk as less probable than car accidents. Our expectation was that these differences would sensitize respondents to the risk differences associated with the release of Syntox. This study was embedded in a short set of studies completed by 175 adult visitors to the San Francisco Exploratorium. The values utilized in the study are shown in Table 3. There were six different groups, with each respondent seeing only one value for the chemical plant.

Table 3. Probabilities and insurance premiums for Study 2

	High	Medium	Low	Comparison value for car accidents
Probabilities	1 in 650	1 in 6300	1 in 68,000	1 in 6000
Premiums	$2170	$241	$23	$245

Table 4. Mean perception of risk of chemical plant for different probabilities and insurance premiums associated with chemical accident (Study 2)

	High	Medium	Low
Premiums	3.52	3.65	3.05
Probabilities	3.61	3.47	3.07

Results. As in Study 1, the four risk questions were combined into a single scale ($\alpha = .76$). The results are shown in Table 4. Two separate one-way ANOVAs were performed on the scaled scores, one for responses in the probability conditions and one for responses in the premium conditions. The premium conditions yielded findings that to our surprise were similar to those of Study 1, with the means not differing significantly between high, medium and low conditions. ($F(2,58) = 2.07$, ns). Furthermore, these means do not decrease monotonically with the premium. In the probability conditions the mean scores decrease monotonically from high to medium to low probabilities but the differences are not statistically significant ($F(2,49) = 2.82$, $p = .069$).

Conclusions. Study 2 replicates the insensitivity found in Study 1. Clearly respondents are not feeling much safer when they see a probability or insurance premium ten times below the value for car travel than when they see a value ten times higher than car travel. It is possible that people do not think probabilities or premiums are relevant to the risk posed by a chemical plant. Perhaps the fact that someone may die from a Syntox release is the only information that people feel is relevant for evaluating this risk. It appears that no attention is paid to the likelihood of this event occurring whether expressed in terms of probabilities or insurance premiums.

Study 3

In the first two studies respondents considered one chemical plant with a single probability or premium. Study 3 gives people the opportunity to compare either the three probabilities or the three insurance premiums. We did this for two reasons: (1) to examine whether respondents think probabilities and/or insurance premiums *should* affect their risk perception and (2) to make sure people are able to differentiate between the values we are using. Each respondent was presented with either three probabilities or three insurance premiums associated with three different chemical plants and asked to judge the risks for each of the plants. This study was embedded in a short set of studies completed by 57 adult visitors to the San Francisco Exploratorium.

Respondents saw the same scenarios used in Studies 1 and 2, but this time were told that there are three chemical plants that use the Syntox chemical. The communities in which each plant is located are similar to each other. The probabilities and premiums were identical to the ones used in Study 2. In other words, the values used in Study 3 correspond to those displayed in Table 3.[1]

Table 5. Mean perception of risk of chemical plant for different probabilities and insurance premiums associated with chemical accidents (Study 3)

	High	Medium	Low
Probabilities	4.64	3.84	2.78
Premiums	4.50	3.82	2.97

Since respondents were asked questions about all three chemical plants, we only used a subset of our previous questions to limit the length of the questionnaire. More specifically, respondents were asked (1) whether the plant posed a serious health and safety risk to those living in the community, (2) how serious is the risk of death posed by the plant, and (3) how close to the plant respondents would be willing to live.

Results. Each set of three questions was combined into a scale, yielding one score for each plant for each respondent. (The reliability (α) ranged from .51 to .72, for the three plants.) Table 5 shows the mean scores for each level of probability and premium. A repeated-measures ANOVA reveals that the effect of probability is highly significant ($F(2,34) = 32.0$, $p < .001$). A separate repeated-measures ANOVA revealed that insurance premiums also had a highly significant effect ($F(2,62) = 42.9$, $p < .001$).

The differences found in this within-respondent sample can be compared to the earlier studies by examining Figure 1. The mean differences in Study 3 dwarf any differences found in Studies 1 and 2.

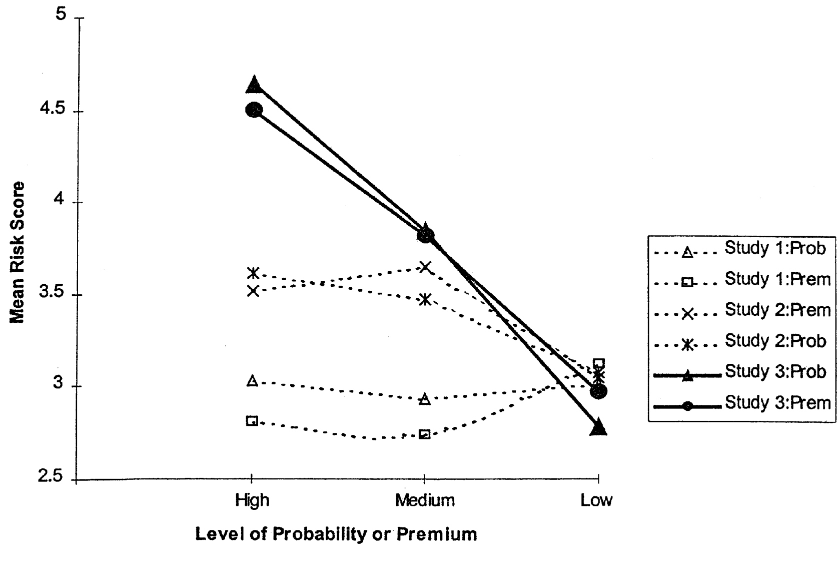

Figure 1. Differences in mean risk score for different probabilities and premiums (Studies 1–3).

Conclusions. The results of Study 3 confirm that people find both insurance premiums and probabilities relevant to risk evaluations. If people thought these objective measures of likelihood should *not* matter, they would have responded with similar risk perceptions for all three plants. Study 3 also shows that the values we chose are sufficiently different from each other for our scale to measure the resulting differences in risk perception.

When faced with a single chemical plant to evaluate, respondents may not have paid any attention to the probabilities and insurance premiums we gave them. Study 3 highlights these values by asking each person to evaluate several plants that vary only in this measure of risk. When respondents ask themselves what is the difference between the three plants, their attention is likely to be focused on the numerical value of probability or insurance premium. The results of this study will be treated as an upper bound on the sensitivity that we can expect from evaluations of a single plant.

Study 4

One reason that individuals may have a difficult time responding to probabilities or insurance premiums in Studies 1 and 2 is that the comparison point was not meaningful enough to help respondents map probabilities and premiums onto feelings of riskiness. For example, when respondents are given a single probability (or premium) for the chemical plant that is ten times better than car travel, they may still ask themselves, "How safe is car travel?" Providing people with a comparison point that is easier to interpret may help them evaluate the meaning of the chemical plant value.

Study 4 was designed to address this issue by giving respondents a single chemical plant to evaluate, and providing a qualitative description to associate with the probability or premium comparison value being considered. Respondents in this study read a few sentences describing driving conditions in Colorado that sound as if the roads were somewhat unsafe. This level of risk is then linked to a probability (or premium, depending on the group). Furthermore, a safer set of driving conditions in Arizona is described and linked to a different probability (or premium) value. After reading this information, respondents should have a better understanding of how probabilities or premiums can signal risk.

Our interest was in seeing whether providing respondents with a description of high and low probability automobile accident scenarios would enable them to distinguish between the risks associated with a Syntox release as one varied either the probability of such a chemical accident or the insurance premiums that the ABC chemicals plant had to pay. This study sampled 216 adult visitors to the San Francisco Exploratorium.

Each respondent saw the same scenario used in Studies 1 and 2. Three probabilities and three premiums were used resulting in six different groups of respondents. The probabilities and premiums are displayed in Table 6. One change was made to the auto accident scenario; the single sentence describing the risk of car accidents was replaced with the following paragraph in the probability condition:

> For comparison purposes, consider a small town in the mountains of Colorado where there is snow cover for a few months every year and the mountain roads have sharp

Table 6. Probability and insurance premium values used in Study 4

	High	Medium	Low	Comparison values for car accidents
Probabilities	1 in 650	1 in 6300	1 in 68,000	1 in 5900, Colorado 1 in 66,000, Arizona
Premiums	$2170	$241	$23	$280, Colorado $36, Arizona

curves. For a driver in this town, the estimated probability of his or her death from a car accident is 1 in 5900 per year. For a driver in a similar size town in Arizona where it rarely rains, never snows and the roads have very few sharp curves, the estimated probability of his or her death from a car accident is 1 in 66,000 per year.

Those in the premium condition saw the same paragraph with probabilities replaced by annual premiums of $280 for drivers in Colorado and $36 for drivers in Arizona.

Results. The four questions measuring risk were again combined into one scale ($\alpha = .81$). The means are shown in Table 7. Again, separate one-way ANOVAs were performed on the probability and premium conditions. The effects of probability ($F(2,101) = 26.2$, $p < .001$) and premium ($F(2,103) = 7.30$, $p = .001$) are highly significant. Looking at Figure 2, we can see that the sizes of the differences in this study are only slightly smaller than those found in Study 3.

Conclusions. Study 4 provides evidence that people's difficulty in evaluating the probability and premium numbers in Study 2 lead to the insensitivity to those values. When respondents are shown how qualitative feelings of risk are associated with different numerical values on a quantitative scale, they are willing and able to respond to a specific value on that scale. Respondents saw a single probability or a single insurance premium for the chemical plant and were able to associate that number with a measure of perceived risk.

Study 5

Study 4 still leaves one with some ambiguity. Are people more sensitive to the scales simply because we gave them a description that evoked a sense of risk? Or is it because they were shown two comparison points on the scale instead of just one? Hsee et al.

Table 7. Mean perception of risk of chemical plant for different probabilities and insurance premiums associated with chemical accidents (Study 4)

	High	Medium	Low
Probability	4.19	3.27	2.78
Premium	3.47	3.10	2.75

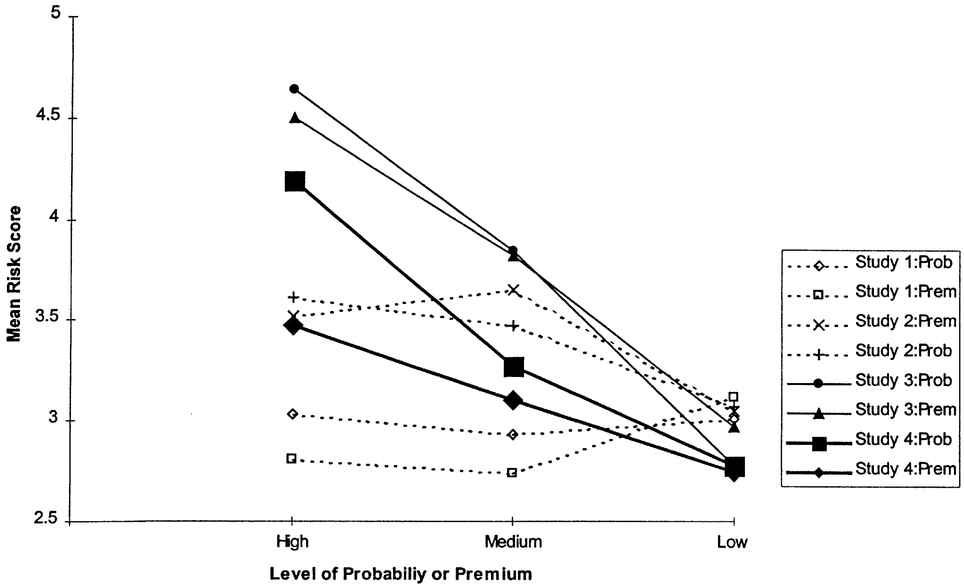

Figure 2. Differences in mean risk score for different probabilities and premiums (Studies 1–4).

(1999) suggest that knowing about two points on a scale leads to greater evaluability than knowing just a single point. Is it essential that the two comparison points be similar risks?

Study 5 examines these issues. Some respondents see a qualitative description for a single comparison point and others see two points with descriptions. The respondents who see two comparison points are further divided. For some respondents the two comparison points describe similar risks and for other respondents the two comparison points describe dissimilar risks. Respondents in Study 5 were 405 students at a large university in the northwest.

The same scenarios used in Study 4 were used in Study 5 with new comparison information on the probability of an accident. Study 5 was a 3 (probability for plant) $\times 3$ (comparison story) design with nine groups corresponding to the cells of Table 8. There were 3 types of comparison information given to three different groups of respondents. One group of respondents saw:

> For comparison purposes, consider a small town in the mountains of Colorado where there is snow cover for a few months every year and the mountain roads have sharp

Table 8. Design of Study 5

Comparison story	High probability	Medium probability	Low probability
1 car	1 in 650	1 in 6300	1 in 68,000
1 car/1 fish	1 in 650	1 in 6300	1 in 68,000
2 fish	1 in 650	1 in 6300	1 in 68,000

curves. For a driver in this town, the estimated probability of his or her death from a car accident is 1 in 5900 per year.

A second group of respondents saw the following comparison:

> For comparison purposes, consider a small town in the mountains of Colorado where there is snow cover for a few months every year and the mountain roads have sharp curves. For a driver in this town, the estimated probability of his or her death from a car accident is 1 in 5900 per year. For someone who eats well cooked, but not raw shellfish once a week at a reputable restaurant, the estimated probability of death from food poisoning is 1 in 66,000 per year.

The third group saw:

> For comparison purposes, consider someone in a small fishing town who eats raw shellfish every week that are purchased directly from small unlicensed fishing boats before the fish have been inspected. This person's estimated probability of death from food poisoning is approximately 1 in 5900 per year. For someone who eats well cooked, but not raw shellfish once a week at a reputable restaurant, the estimated probability of death from food poisoning is 1 in 66,000 per year.

Results. The means of the perceived risk are displayed in Table 9. Three separate one-way ANOVAs were performed, one for each comparison story. Respondents who saw the 1 car comparison story showed a significant effect of probability on perceived risk ($F(2,129) = 7.48$, $p = .001$). The 1 car/l fish comparison produced non-significant effects of probability on perceived risk ($F(2,124) = 1.74$, ns). The 2 fish comparison produced the largest effects in this study ($F(2,137) = 16.0$, $p < .001$).

Conclusions. Table 10 shows the effects of different comparison points on respondents' ability to use the probability value associated with chemical plant accidents. Respondents who saw a comparison point of car travel without any story to induce a feeling of riskiness (Study 2) did not appear to use the probability value associated with the chemical plant in judging the risk posed by the plant. A comparison point in Study 5 of car travel with a story that produced a feeling of riskiness in respondents produced a larger response to the probability scale (1 Car/Story).

Respondents in Study 5 who saw two comparison points with risks and stories that were not readily comparable (1 Car/1 Fish), were not able to get a sense of how to map probability distances onto riskiness. However, when people in Study 4 were offered two

Table 9. Mean perception of risk of chemical plant for different comparison stories and different probabilities associated with chemical accidents (Study 5)

Comparison story	High probability	Medium probability	Low probability
1 car	3.75	3.42	3.00
1 car/1 fish	3.84	3.57	3.51
2 fish	3.52	3.24	2.64

Table 10. Results for different comparison values

Chemical plant value	Comparison	Difference in perceived risk between high and low probabilities
Study 2: One value	1 Car/No Story	.54
Study 5: One value	1 Car/Story	.75
Study 5: One value	1 Car 1 Fish/Story	.33
Study 5: One value	2 Fish/Story	.88
Study 4: One value	2 Cars/Story	1.41
Study 3: All three values	1 Car/No Story	1.86

comparison points that have distinctive feelings of risk that can be readily compared to each other (2 Cars/Story) their differences in perceived risk between high and low probabilities of a chemical accident was almost as large as when respondents were given all three probability values for the three different chemical plants (Study 3). These comparison points (2 Cars/Story) not only gave respondents an anchor point for the scale, but also a sense of how distance on the probability scale maps onto differences in feelings of riskiness.

There are a couple of possible reasons why the 2 Cars/Story comparisons evoked larger differences in perceived probability of chemical accidents than the 2 Fish/Story scenario. First, the car accident risk may be easier for respondents to visualize than the fish risk. We have lots of images of curvy roads, mangled cars, and people in stretchers next to the highway that we associate with car accidents. For the fish story it is less clear which images come to mind. Do respondents imagine discolored fish or a person looking nauseous after eating the fish? These images seem less accessible and less vivid. Comparison risks that have vivid images that easily come to mind may be the most effective way to sensitize people to varying levels of riskiness.

Another reason why the car comparison may have worked better than the fish comparison is the amount of experience respondents have with each type of risk. Most respondents have spent time riding in cars, seeing accidents on the side of the road, and viewing videos of accidents on TV or in a driver education class. Respondents most likely have limited if any experience with the risks associated with poisonous fish. What makes one comparison risk more effective than another is an important question for future research.

3.1. The psychology of low probability risks

The notion of *evaluability* recently introduced by Hsee and his colleagues (Hsee et al., 1999; Hsee, 1996) provides a theoretical basis for our results. In our experiments respondents were asked to use a small probability value as part of a judgment of riskiness. Using Hsee's framework, we would say that the small probabilities are not readily evaluable by respondents in the absence of context information. As individuals are provided with increasingly useful context information, the probabilities become more and more evaluable.

Consider people trying to evaluate the riskiness of a chemical plant in the absence of any context information. They are given a single low probability value as part of a description and asked to make a risk judgment. If they have no idea whether the probability represents a high or low risk, they will not be able to use that value in forming their risk judgment. Now consider the respondents in Study 2 who are given information about the probability of death for car travel. They are shown a probability for the chemical plant that is either above or below the probability for car travel. If respondents do not have a well-defined feeling of risk for car travel, this context information will not help them evaluate the chemical plant. Respondents will be left thinking, "The chemical plant may be safer than car travel, but exactly how safe is car travel?" The results of Study 2, in fact, show little effect of the probability of a chemical accident on its perceived safety when a car travel scenario is introduced.

Now, consider the respondents in Study 5 who are not only given the probability of death from car travel in Colorado but also a few sentences about driving in Colorado. The image of windy snow-covered roads is more likely to evoke a specific feeling of risk than reference to car travel in general. Some respondents see a probability of a chemical plant accident that is higher than the Colorado value and others see a probability that is lower. It is not surprising that these respondents had different feelings about the risk associated with the chemical plant.

While these respondents could judge less safe/more safe, they may not be very sensitive to the size of probability differences. Respondents could readily compare probabilities when given two scenarios, one involving a car accident in Colorado and the other a car accident in Arizona with a few sentences describing each event. This comparison can help them infer how distances along the probability dimension map onto distances along the riskiness scale. The two-car scenarios allow them to deduce that an order of magnitude change in probability corresponds roughly to the difference between driving on windy snowy mountain roads and driving on straight clear roads. When they see a chemical plant that is an order of magnitude less safe than driving in Colorado, they have a sense of how much less safe that really is. This results in even more sensitivity to probability.

The respondents who saw a few sentences about driving in Colorado and a few sentences about eating raw shellfish were given two risky scenarios, but these scenarios were harder to compare with each other. How much more dangerous is driving on snowy roads than eating raw shellfish in a reputable restaurant? Comparing driving risks to food risks may not leave respondents with a specific notion of relative risk. In fact, this comparison can even confuse respondents about how to map probabilities onto the risk scale and may lead to less use of probability information when evaluating the chemical plant.

We have seen that context information can have a large effect on people's ability to use small probabilities in forming risk judgments. We conclude that there needs to be fairly rich context information available for people to be able to judge differences between low probability events. In particular, people need comparison scenarios that are located on the probability scale and evoke people's own feelings of risk. It is also very useful for these contextual scenarios to be comparable to each other for people to get a sense of how differences in probability map onto differences in riskiness.

Finally we were surprised to find that insurance premium differentials did not enable respondents to differentiate between chemical accident risks better than differences in probabilities. We initially hypothesized that people's familiarity with insurance premiums would make it easier for them to differentiate between high and low dollar figures, so that this information would serve as a signal of the relative safety of the chemical plant. Even when context-scenarios are provided to the respondent as in Study 3, people appear to make better distinctions between the riskiness of the chemical plant when probability information is given to them than when insurance premiums are provided. Our results suggest that insurance premiums in isolation may not be the best communicators of risk. The potential role that insurance can play as a signal for safety is an area that needs further research.

4. Implications of findings

The studies highlight the need to give individuals enough context to draw on their own experiences and well-developed risk perceptions, if we are to ask them to evaluate an unfamiliar risk which has a small likelihood of occurring. A probability or insurance premium scale does not directly convey a feeling of riskiness. The feelings associated with different probabilities may be highly context dependent. In fact, if we had used different comparison points, we might have induced different perceptions of the chemical plant's risk.

Our findings have implications for risk management and policy. In the past, agencies such as the EPA have relied on command and control procedures for enforcing specific safety rules with only mixed success (Davies and Mazurek, 1998). More recently there has been an interest in market mechanisms such as third party inspections coupled with insurance as alternatives to these traditional procedures (Orts, 1995; Kunreuther, McNulty, and Kang, 2001). The fact that safer firms may be charged less for insurance could be a byproduct of such inspections. Perhaps by providing the public with these rate differentials or probability values in the context of an inspection process, one may be able to improve the risk communication process. As the above studies have shown, if one only gives individuals data on probabilities or insurance premiums this will not do the trick.

Our findings also have implications for consumers choosing protective measures for themselves and their property. If individuals are expected to distinguish different levels of risk posed by events with different probabilities of occurrence, they need more than to simply be made aware of the probability value, If perception is to accurately reflect the probability of relevant risks, the public needs substantial context information to allow appropriate evaluation of this risk. In our studies, this required giving individuals, not simply a comparison point or a dollar scale, but giving them scenarios that elicit their feelings of risk and linking them up with the probability scale.

Appendix

Please answer the following questions, after reading the scenario:

1. *Circle* how much you agree or disagree with each of the following statements:

   The ABC Chemicals plant poses serious health and safety risks for those currently living in the community.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

   It is possible for the plant to operate at its current location in a manner that is safe for the community.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

   Accidents are inevitable despite the best precautions, and the community just has to accept that some accidents will occur at the plant.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

2. **On a scale of 1 to 5, *circle* how serious do you think the risk of death is posed by each of the following items.** (1 = not serious, 5 = very serious)

Car accidents	1	2	3	4	5
Food poisoning	1	2	3	4	5
Accidents on the job	1	2	3	4	5
Heart disease	1	2	3	4	5
Homes fires	1	2	3	4	5
Syntox used at the ABC Chemicals plant	1	2	3	4	5
Airplane accidents	1	2	3	4	5

3. ***Circle* how close to the ABC Chemicals plant you would be willing to live.**

   Please base your decision *solely* on the safety of the plant, assuming that the plant is otherwise an ideal neighbor.

Adjacent to the plant	1
Not adjacent, but within 1/2 mile	2
Within 1/2 to 1 mile	3
Within 1 to 3 miles	4
Over 3 miles	5
Would not be willing to live in the community because of the plant	6

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Note

1. We did not vary the order of presentation of the three chemical plants in presenting the scenarios to individuals. We do not anticipate that order had any effect, since respondents were answering each question for plant 1 then plant 2 then plant 3 before moving on to the next question. In the questionnaire layout, we expect that individuals had all three plants in mind each time they provided a response.

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