Numeracy and the Perception and Communication of Risk

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In the present paper, I focus on a small but important piece of the risk communication/perception puzzle, namely how individuals who differ in number ability comprehend and use numeric information about risks differently. Highly numerate individuals appear to pay more attention to numbers, better comprehend them, translate them into meaningful information, and ultimately use them in decisions. Decisions of the less numerate are informed less by numbers and more by other non-numeric sources of information, such as their emotions, mood states, and trust or distrust in science, the government, and experts. Careful attention to information presentation, however, allows the less numerate to understand and use numbers more effectively in decisions. As a result, the challenge is not merely to communicate accurate information to the public but to understand how to present that information so that it is used in risky decisions.

Key words: **risk communication; risk perception; numeracy; dual process model**

Risk communication often involves highly technical information at the same time as it is rife with important issues of perceived fairness, trust, and emotion.[1] In the present paper, I focus on a small but important piece of the risk communication/perception puzzle, namely how individuals who differ in number ability comprehend and use numeric information about risks differently. The purpose of this paper is not to suggest that the public is irrational because some of them do not understand numbers as well as scientists. Instead, I suggest an additional challenge to the scientific community to understand how number ability interacts with how numbers are presented in order to influence the comprehension and use of numbers. As a result, the challenge is not merely to communicate accurate information to the public but to understand how to present that information so that it can be used in risky decisions.

Making decisions about hazards and other risks involves the use of complex data about physical, social, and economic systems (e.g., risk reduction efforts in a large populated area known for seismic activity). The success of current risk communication efforts aimed at increasing stakeholder participation and improving the quality of risky decisions across diverse stakeholder groups (scientists, engineers, doctors, policy makers, interested members of the public) rests on the ability of experts and stakeholders to make informed choices guided by the data and the knowledge and values of all groups. When there is confusion about risk data and its interpretation, however, involved stakeholders will have difficulty understanding its implications for their concerns and the concerns of others. Effective decision making in these types of situations requires all participants to have access to information and its meaning so that the entire group can interpret the information, incorporate it into their decision making, and support a group decision (if necessary) to the outside world.

High-quality risk data (e.g., complex data concerning natural hazards and weather) are increasingly available to experts and the public. To a degree never before possible, individuals are in a position to understand risks, such as natural disasters, and their likelihood of occurrence, and, in the process, increase control over their lives. However, it is not clear whether all stakeholders have the skills to use this risk information when it is provided using the usual methods of risk communication. Risk communicators tend to assume that simply providing information will result in a level playing field for everyone. However, individuals may lack the skills, knowledge, or motivation to access credible sources, process information, and make informed choices. As a result, the same data may not be understood or used in the same way by all users.

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Dual Process Modes in Decision Making

Information in decision making appears to be processed using two different modes of thinking: deliberative and affective/experiential.[2,3] The deliberative mode is conscious, analytical, reason-based, verbal, and relatively slow. It is the deliberative, "high reason" view of decision making that we tend to consider in our attempts to inform choices (e.g., provide more information for better choices). The problem with this view, however, is that laypeople and scientists alike have limited capacity to process information,[4] and that capacity declines with age.[5] As a result, individuals tend to rely on mental shortcuts to deal with such complexity.[6] The use of mental shortcuts is frequently adaptive (because they are efficient and the resulting judgments or decisions are generally good enough), but it can also be maladaptive (resulting in poorer decisions).[7,8]

Processing in the experiential mode, on the other hand, is intuitive, automatic, associative, and fast. It is based on affective (or emotional) feelings, and one of its primary functions is to highlight information important enough to warrant further consideration. As shown in a number of studies, these affective feelings provide meaning, motivation, and information to choice processes and can influence decisions without conscious deliberative input.[9–11] Judgments that laypeople and scientists make about risks are often influenced by affect and emotion in ways that are both simple and sophisticated.[1,12–15]

Both modes of thinking are important to risk perceptions and communication, and good choices are most likely to emerge when both affective and deliberative modes work in concert and decision makers think as well as feel their way through judgments and decisions.[10,16] Consumers need to consider information carefully, but they also need to be able to understand and be motivated by the meaning that underlies that information.

These multiple needs suggest that the simple provision of information may not be enough to ensure good decisions. The state of Nebraska found this out the hard way in their pension plan designs. For 30 years they allowed workers to choose either a traditional pension plan or a 401(k) plan that was managed by the individual worker. Workers who chose the 401(k) plan earned average annual returns that were far less than the traditional pension plan, even though Nebraska provided not only information but plenty of education (see FIG. 1).[17] In 2003, Nebraska eliminated employee choice from its 401(k) plan, even though Nebraska provided not only information but plenty of education about their options.

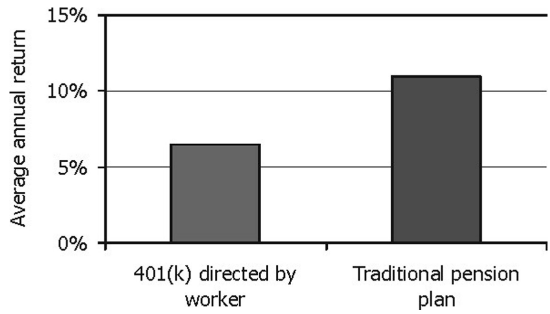

FIGURE 1. Average annual returns in Nebraska retirement plans.[17]

At least three reasons exist for why simple provision of information may not be effective in retirement and other risky choices.[18] First, information can be insufficient, uncertain, and changeable; for example, a city planner faces uncertainty about the probability of flooding near a proposed school site. Second, decision makers may not comprehend information even when it is sufficient. Results from health plan choice studies support this lack of comprehension and suggest that some people do not always comprehend even fairly simple information. Hibbard *et al.*[19] presented employed-aged adults (18–64 years old; $n = 239$) and older adults (65–94 years old; $n = 253$) with 33 decision tasks that involved interpretation of numbers from tables and graphs. For example, participants were asked to identify the Health Maintenance Organization (HMO) with the lowest copayment from a table that included four HMOs with information about monthly premiums and copayments. A comprehension index reflected the total number of errors made across the 33 tasks. The youngest participants (aged 18–35) averaged 8% errors; the oldest participants (aged 85–94) averaged 40% errors; the correlation between age and the number of errors was 0.31 ($P < 0.001$).

A third barrier to using information effectively is that decision makers may comprehend numerical information without understanding what it means to the decision at hand. Bateman *et al.*[20] examined how people evaluate the attractiveness of a simple gamble. One group rated a bet that gives a small chance to win \$9.00 (7/36, win \$9.00; otherwise, win \$0.00) on a 0–20 scale; a second group rated a similar gamble with a small loss (7/36, win \$9.00; 29/36, lose \$0.05) on the same scale. This second group had an objectively worse bet so that, normatively, they should rate the bet as worse. However, the data were anomalous from the perspective of economic theory. The mean response to the first gamble was 9.4. When a loss of $0.05 was added, the mean attractiveness jumped to 14.9 and there was almost no overlap between the distribution of responses around this mean and the responses for the group judging the gamble that had no loss.

Bateman and colleagues hypothesized that these curious findings can be explained by affect and affective precision. According to this view, a probability maps relatively precisely onto the attractiveness scale because it has an upper and lower bound and people know where a given value falls within that range. In contrast, the mapping of a dollar outcome (e.g., $9.00) onto the scale is diffuse, reflecting a failure to know whether $9.00 is good or bad, attractive or unattractive. Thus, the impression formed by the gamble offering $9.00 to win with no losing payoff is dominated by the rather unattractive impression produced by the 7/36 probability of winning. However, adding a very small loss to the payoff dimension puts the $9.00 payoff in perspective (i.e., makes it more affectively precise) and thus gives it meaning. The combination of a possible $9.00 gain and a $0.05 loss is a very attractive win/lose ratio, leading to a relatively precise mapping onto the upper part of the scale. Whereas the imprecise mapping of the $9.00 carries little weight in the averaging process, the more precise and favorable impression of a $9.00 gain compared to a $0.05 loss carries more weight, thus leading to an increase in the overall favorability of the gamble. Participants asked directly about their affect and precision of affect to the $9.00 had more clear and more positive feelings about the $9.00 in the $9.00 gain, $0.05 loss condition.[20] It is not that these decision makers did not comprehend the $9.00; many of them probably had $9.00 in their back pocket. However, the meaning of the $9.00 was clearer and more positive in the presence of the five cent loss.

Numeracy Matters for Comprehension and Use of Numeric Information

Numeracy refers to the ability to understand and use mathematical and probabilistic concepts. Based on the National Adult Literacy Survey,[38] almost half of the general population has difficulty with relatively simple numeric tasks, such as calculating the difference between a regular price and sale price using a calculator or estimating the cost per ounce of a grocery item. These individuals do not necessarily perceive themselves as "at risk" in their lives because of limited skills; however, research shows that having inadequate numeric skills is associated with lower comprehension and use of numeric information in important domains, such as health. For example, Lipkus *et al.*[21] found that 16% of highly educated individuals incorrectly answered straightforward questions about risk magnitudes (e.g., Which represents the larger risk: 1%, 5%, or 10%?). In our studies, scores on a simple, 11-item, numeracy test decrease significantly with age and education (see FIG. 2). Controlling for age and education, women also tend to score lower than men. Inadequate numeracy may be an important barrier to individuals' understanding of environmental, health, financial, and other risks.

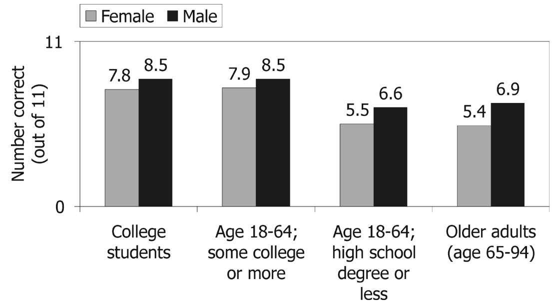

FIGURE 2. Numeracy scores across age, education, and gender.

Not surprisingly, greater ability with numbers leads to more comprehension of numeric information in important decisions (e.g., mammograms).[22] Numeracy relates in somewhat less intuitive ways to a variety of cognitive and affective biases in decision making.[23] For example, Dehaene[24] suggests that while children spend a lot of time learning the mechanics of math, they may not really understand how to apply those mechanics even in adulthood. We propose that adults high in numeracy will be more likely to do so. As a result, the high numerate should, for example, find alternative frames of the same number more accessible and more influential in decisions.

Slovic *et al.*[25] conducted a series of studies in which experienced forensic psychologists and psychiatrists were asked to judge the likelihood that a mental patient would commit an act of violence within 6 months of being discharged from the hospital. An important finding was that when clinicians were told that "20 out of every 100 patients similar to Mr. Jones are estimated to commit an act of violence," 41% refused to discharge the patient. But when another group of clinicians was given the risk as "patients similar to Mr. Jones are estimated to have a 20% chance of committing an act of violence," only 21% refused to discharge the patient. Similar results have been found by Yamagishi,[26] whose judges rated a disease that kills 1286 people out of every 10,000 as more dangerous than one that kills 24.14% of the population.

Unpublished follow-up studies by Slovic showed that representations of risk in the form of individual probabilities of 10% or 20% led to relatively benign images of the patient (e.g., unlikely to harm anyone), whereas the "equivalent" frequentistic representations created frightening images of violent patients (e.g., "some guy going crazy and killing someone"). These affect-laden images likely induced greater perceptions of risk in response to the frequency frame. [See Kurz-Milcke *et al.*[39] for more on natural frequencies; see Wang,[40] for a discussion of the impact of reference group size on risk perception.]

Peters *et al.*[23] extended this study by giving low- and high-numerate subjects information about the risk posed by a mental patient. Half of the subjects were given a percentage format—"Of every 100 patients similar to Mr. Jones, 10% are estimated to commit an act of violence to others"—whereas the other subjects were given the identical wording without the % sign—a frequency format. Individuals high in numeracy perceived the patient as posing a similar risk regardless of the format in which the information was provided. Low-numerate decision makers, however, who may be less able or less likely to transform probabilistic information from one format to another, perceived significantly lower risk when the danger was posed in a probabilistic rather than frequentistic format. Neither of these perceptions is necessarily more accurate, and the usefulness of each perception depends on your view. If you believe, for example, that scientists overweight some risk, then the more abstract percentage format is likely more useful. However, if you believe that the public underweights the risk, then the frequency format is more likely to increase that perception of risk and be useful in that sense.

Peters *et al.*[23] also presented participants with the exam scores of five psychology students and asked them to rate the performance of each student on a seven-point scale from −3 (very poor) to +3 (very good). The framing of the exam scores was manipulated as either percent correct or percent incorrect so that "Emily," for example, was described as having received either 74% correct on her exam or 26% incorrect. In a repeated measures analysis of variance of the rated performance, the usual framing effect was shown such that the more positive frame elicited more positive ratings. The interaction of numeracy with the frame, however, was also significant with the less numerate participants showing a stronger framing effect. These findings are consistent with our hypothesis that high-numerate participants are more likely to retrieve and use appropriate numerical principles and transform numbers presented in one frame into a different frame, whereas the less numerate respond more to the affect communicated by the single given frame of the information. We believe that less numerate decision makers are left with information that is less complete and lacks the complexity and richness available to the more numerate. Controlling for a proxy measure of intelligence (self-reported SAT scores) did not alter the results. Actual number ability appears to matter to judgments and decisions in important ways not captured by other measures of achievement or ability.

Even if individuals do not consciously "run the numbers" to make choices, they still have to form perceptions and make judgments in situations that involve numeric information. The highly numerate appear to draw more precise affective meaning (i.e., their secondary affective reactions are more clear) from numbers and numerical comparisons.[23] In one study, subjects were offered a prize if they drew a colored jellybean from their choice of bowls. Bowl A contained nine colored and 91 white beans; Bowl B contained one colored and nine white beans, so the odds of success were objectively better in Bowl B. Nevertheless, subjects low in numeracy often chose Bowl A (33% and 5% of low and high numerate, respectively, chose from Bowl A) because it "gives more chances to win." Compared to the less numerate, high-numerate subjects reported more precise negative affect to the lower probability of winning in Bowl A. This secondary affect (likely produced through a comparison of the objective probabilities in the two bowls) appeared to drive their choices. The less numerate were influenced more by competing, less relevant, affective considerations from the number of winning beans.

Although this ability to generate secondary affect from numbers is generally helpful, it can lead to worse judgments. As described earlier, Bateman *et al.*[20] observed that the attractiveness of playing a simple gamble (7/36 to win \$9.00; otherwise win nothing) is greatly enhanced by introducing a small loss (7/36 win \$9.00; otherwise lose \$0.05). This "less rational" response, however, is shown only by the high numerate.[23] All participants responding to the "no-loss" gamble reported lacking precise feelings for how good \$9.00 is (they rated their feelings for the \$9.00 as about neutral), and they gave it little weight in their judgment of the first gamble. In the second gamble, only high-numerate evaluators appeared to compare the \$9.00 with the small loss, making the \$9.00 "come alive with feeling" (they rated their feelings about the \$9.00 as highly positive), and the \$9.00 became weighted in the judgment, thus increasing the gamble's attractiveness. The low numerate rated the two bets about the same. These results demonstrate the importance of contextual factors in determining affect and preference for simple opportunities. They show that the meaning, utility, and weighting of even a very familiar monetary outcome such as $9.00 is not fixed but depends greatly on contextual factors as well as individual proclivities. It also implies that individuals high in number ability may, in some cases, make judgments with an over-reliance on available numeric information.

Careful Presentation of Information Can Facilitate Informed Decision Making

Making decisions in the real world requires some numerical ability, and individuals with less ability may make worse decisions in some cases if nothing is done to assist them. Decisions can be supported through various means, however, including how they are presented. Thaler and Sunstein,[27] for example, discuss default options in retirement plans. If workers are automatically out of the plan (and must choose to be in it; this is the norm), about half initially enroll (49%). However, if the default is that workers are in the plan (but of course they can freely choose not to be), substantially more workers initially enroll (86%).[28] Automatic enrollment has particularly powerful effects in increasing retirement savings among low-income and younger workers.[29] Normatively equivalent formats of information can also matter a great deal. In a recent pilot study with undergraduates that I conducted with Ketti Mazzocco and Isaac Lipkus, lower numeracy scores were associated with less comprehension of information in a breast cancer decision aid called "Adjuvant," used by oncologists at Duke University, and with more recommendations of no treatment (the course of action with the lowest survival rate). Simple changes to how the information was presented, however, facilitated comprehension of the information among both low- and high-numerate decision makers and led to equivalent comprehension regardless of numeracy and more recommendations of the treatment leading to the highest survival rate.

Risk communicators will likely find that careful attention to how numbers are presented will best help individuals lower in numeracy. Some preliminary research has focused on how comprehension and quality of decisions vary as a function of the interaction between numeracy and the format of provided information.

For example, individuals tend to comprehend more and make more informed decisions when the presentation format makes only the most important information easier to evaluate and when it reduces the cognitive effort required.[30] Results from three experiments support the idea that "less is more" when presenting consumers with comparative performance information to make hospital choices. In one study, respondents given only the most relevant information about hospital quality (e.g., the percent of patients receiving recommended care) were better able to comprehend that information and were more likely to choose a higher quality hospital compared to respondents who received the same quality information plus less relevant information (e.g., the number of general-care beds). In a second study, making only a more important quality measure easier to evaluate rather than making all indicators easier to evaluate led to more choices of higher quality hospitals. In a third study, less cognitive effort was "more": presenting quality information in a format in which a higher number means better quality (the number of registered nurses per 100 patients) compared to a format where a lower number means better quality (the number of patients per registered nurse) facilitated comprehension and helped respondents make better choices.

If risky decisions are to be informed by numeric information, it appears that information providers need to show only the most important information (or at least highlight it), make that information easier to evaluate (for example, by using well-tested symbols), and present data in accordance with cognitive expectations (i.e., higher numbers mean better performance). For those with poor numeracy skills, the effect of information presentation on comprehension and choice is even more marked. Taking steps to present information in accordance with these recommendations will reduce disparities in the ability to use numeric information effectively in decisions and may assist risk communication efforts.

Other options for reducing cognitive effort have not been tested with numeracy but are likely to be effective. For example, with small probabilities it is tempting to present them as one chance out of a larger number (1 of 50, 1 of 1000); keeping the denominator constant, however, will reduce effort and increase comprehension and use of the information (20 of 1000, 1 of 1000. The use of visual cues, such as stars, to highlight the meaning of information is also likely to help, as is ordering and summarizing information.

Research on presenting numeric information about risks and benefits is still relatively new, but some general themes have emerged. Visual displays, for example, can

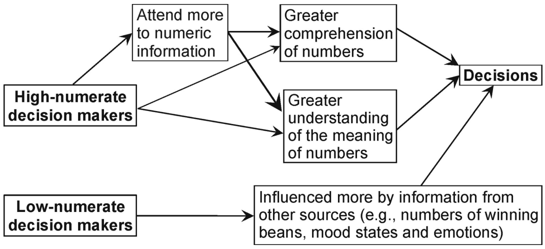

FIGURE 3. Numeracy and the comprehension and use of numeric risk information.

enhance understanding and risk perceptions. Chua *et al.*[31] demonstrated that visual displays of gum disease influenced cognitive and affective representations of risky options and increased willingness to pay to decrease risk. The affective influence, in particular, may be critical to risk perceptions and behaviors. Presenting absolute risks (e.g., 3 out of 1000 will have a stroke) enhances comprehension over the use of relative risks (50% higher chance of stroke).[32] Results are mixed as to whether percentage (13%) or frequency (13 out of 100) formats promote greatest understanding.[23,33,34] There is general agreement that decimals (0.03) should not be used. Finally, individualized risk estimates rather than general population figures may increase efforts to reduce risks but may not be evidence of more informed decisions.[35]

Conclusions

Highly numerate individuals are likely to pay more attention to numbers associated with a risk, to better comprehend them, to translate them into meaningful information, and to ultimately use them in decisions (see FIG. 3). Decisions of the less numerate are likely to be informed less by these numbers and more by other non-numeric sources of information, such as their emotions, mood states, and trust or distrust in science, the government, and experts.[23,30] Careful attention to information presentation should allow the less numerate to attend more to important numbers and use them more effectively in decisions. Risk communication efforts across diverse stakeholder groups are likely to improve as a result.

Numerical ability serves as a mediator of decision performance (helping performance in some situations and hurting performance in others). Most proposals for improving people's decision-making abilities[36,37] are based primarily on research results thought common to all individuals. It may be, however, that individuals will differ in the type of assistance they need. [See Finkel,[41] this volume, for more discussion of the importance of individual variability in risk estimation.] Those low in numerical ability may need different decision aids than those high in numerical ability. In some decisions that involve very complex numbers, we may all need assistance. We are increasingly being asked to make our own decisions about vital life issues. No longer are health and financial decisions left entirely to specialists, such as the family doctor. Instead, all decision makers are faced with more choices and more information than in previous generations. Thus, research-based advice is essential to help decision makers who differ in processing preferences and abilities and who face decisions that differ in numerical complexity.

A better understanding of how humans process information relevant to risk should substantially improve the communication of risk to the public. Numeracy research demonstrates that risk communicators cannot present "just the facts" because different people will understand and react to the same numbers differently and how those numbers are presented will influence the choices people make. A major challenge for risk communication is to explore how people who differ in ability process information about risks and benefits when that information is sufficiently nuanced to be a useful guide to decision making.

Conflicts of Interest

The author declares no conflicts of interest.

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