**Numeric, Verbal, and Visual Formats of Conveying Health Risks: Suggested Best Practices and Future Recommendations**


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# Numeric, Verbal, and Visual Formats of Conveying Health Risks: Suggested Best Practices and Future Recommendations

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*Perception of health risk can affect medical decisions and health behavior change. Yet the concept of risk is a difficult one for the public to grasp. Whether perceptions of risk affect decisions and behaviors often relies on how messages of risk magnitudes (i.e., likelihood) are conveyed. Based on expert opinion, this article offers, when possible, best practices for conveying magnitude of health risks using numeric, verbal, and visual formats. This expert opinion is based on existing empirical evidence, review of papers and books, and consultations with experts in risk communication. This article also discusses formats to use pertaining to unique risk communication challenges (e.g., conveying small-probability events, interactions). Several recommendations are suggested for enhancing precision in perception of risk by presenting risk magnitudes numerically and visually. Overall, there are little data to suggest best practices for verbal communication of risk magnitudes. Across the 3 formats, few overall recommendations could be suggested because of 1) lack of consistency in testing formats using the same outcomes in the domain of interest, 2) lack of critical tests using randomized controlled studies pitting formats against one another, and 3) lack of theoretical progress detailing and testing mechanisms why one format should be more efficacious in a specific context to affect risk magnitudes than others. Areas of future research are provided that it is hoped will help illuminate future best practices.* **Key words:** *risk communication; methodology.* ***(Med Decis Making 2007;27:696–713)***

Risk communication, defined, for example, as the "communication with individuals (not necessarily face-to-face) which addresses knowledge, perceptions, attitudes, and behaviour related to risk"[1(p147)] is pervasive (see Table 1 for other definitions[2–4]). The media, medical personnel, and even our families and peers craft communications designed to warn us about the risk of disease and the dangers of poor lifestyle habits (e.g., smoking, drinking, not exercising, failing to vaccinate or screen for cancer). As patients, we are told about the benefits and side effects of medical procedures (e.g., surgery) and the risks associated with prescribed medications. At times, the intent of these messages is to increase a person's sense that something bad can happen to them (i.e., perceived risk) to motivate behavior change to either prevent or diminish the threat. At other times, the intent of these communications is to improve understanding of risk (e.g., improve calibrations via decisions aids or other means) to help achieve informed consent, which is itself viewed as a valued outcome in decision-making processes. Furthermore, some risk communications are crafted to allay people's fears and avoid overreactions to hazards that are rare and/or of little consequence (e.g., outrage at having a waste dump next door).[5]

Although a comprehensive understanding of risk requires knowledge of precursors (e.g., risk factors), likelihoods (probabilities), consequences, and the pros and cons of preventive actions necessary to control/avert the harm if possible,[6] this article focuses primarily on the probability dimension (i.e., likelihood of an event happening). The focus on this dimension is due to its central role in health communications as well as its being perhaps the

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**Table 1** Examples of Defining Risk Communication

| Definition | Source |
|---|---|
| "Risk communication is an interactive process of exchange of information and opinion among individuals, groups and institutions. It involves multiple messages about the nature of risk and other messages, not strictly about risk, the express concerns, opinions, or reactions to risk messages or to legal and institutionalized arrangements for risk management." | National Research Council[2] (p 21) |
| "The interactive exchange of information and opinions throughout the risk analysis process concerning risk, risk-related factors and risk perceptions, among risk assessors, risk managers, consumers, industry, the academic community and other interested parties, including the explanation of risk assessment findings and the basis of risk management decisions." | Codex Alimentarius Commission[3] |
| "Risk communication" can refer to "any public or private communication that informs individuals about the existence, nature, form, severity or acceptability of risks." | Plough and Krimsky[4] (p 6) |

Note: Although these definitions vary, key aspects of risk communication include such features as a source (e.g., expert or not), target audience(s) (e.g., public, patients, organizational group), domain (e.g., health or industrial), content (i.e., specific messages), channel of transmission (e.g., face-to-face, media), flow of transmission (e.g., one-sided from expert to the audience or interactive exchanges), with some intent or purpose (e.g., increase knowledge, action plan to curb or deal with a crisis).

most difficult facet of risk to convey and understand.[7] Probabilistic information is often communicated using numerical, verbal, and visual (e.g., graphical) formats. For example, a smoker can be told that compared with nonsmokers, his or her chance of getting a disease is 20% compared with 10% (numerical) or is twice as likely (verbal), or the smoker can be shown a histogram of the risk for smokers and nonsmokers (graphical).

In this article, I suggest some best practices, when possible, for using these 3 common formats of communicating probabilistic health information. These suggested best practices are based on my expert opinions after synthesizing the empirical studies in the domains of interest using such databases as Psychinfo and Medline (e.g., search terms *risk communication*, *risk perceptions*, *verbal/numerical communication of risk*, *visual/graphical displays*), bibliographic references on risk (National Cancer Institute's Risk Communication Bibliography, http://dccps.nci.nih.gov/DECC/riskcommbib/), review articles on risk communication practices, books on risk communication, and consultation with other experts in risk communication. The review encompassed the areas of health risk communication proper and, to a much lesser degree, environmental risk communication, bioinformatics, nursing, psychology of judgment and decision making in general and clinical/medical decision making specifically.

The outline of this article is as follows. First, I provide a general working definition of risk and issues surrounding the operationalizing of risk. This will be followed by a review of potential ways of evaluating the efficacy of risk communications. The focus will then turn to discussions of numerical, verbal, and graphical formats of conveying likelihood information. I then address formats that target specific risk communication challenges (e.g., communicating small probabilities, interactions, cumulative risk). This article concludes with suggested areas for future research.

## DEFINITION OF RISK

Most recent conceptualizations of risk view risk as a combined function, often multiplicative, of the probability of loss and consequence of loss (e.g., severity of loss in the physical, psychological, social, and economic realms).[8–12,a] For example, the risk of taking a medication can be defined by the total number of possible side effects (i.e., consequences) and their associated probabilities. Despite the apparent simplicity of this definition, several issues arise concerning the operationalizing of risk.[9] For example, should combining probability and severity be a multiplicative or some other function (e.g., additive)? What should the unit of assessing severity be (e.g., number of lives lost?). Should an event with a high probability of occurrence that has

[a]Some definitions of risk link probabilities with both positive and negative outcomes rather than negative outcomes only. In this article, risk will be discussed in terms of negative outcomes, which is consistent with most definitions of the construct.

consequences of lower severity be treated the same as an event with a lower probability of occurrence that has severe consequences (e.g., a cold versus a cancer)? One point of contention in the operationalization of risk that is central to what formats of communicating probabilistic information mean is the interpretation of probability.

How probability is interpreted is controversial.[13–15] Two classic orientations are whether probabilities refer to an objective likelihood of an event occurrence, as espoused by actuarial and epidemiological as well as frequentist approaches (e.g., what is the actual likelihood of experiencing dizziness by taking a medication based on what is observed in the population?), versus whether probabilities represent beliefs about an event occurrence, as espoused, for example, by the Bayesian perspective (e.g., what do I believe is the likelihood of experiencing dizziness by taking a medication?). Similar arguments pertain to consequences (e.g., what are the measurable losses versus the perceived severity of the losses?). Note that a person may acknowledge the population likelihood yet believe his or her individual probability is different.

Although no attempt is made here to reconcile these approaches (for integrative and alternative perspectives, see Gillies[16] and Hackings[17]), these opposing views have implications for understanding the intent and reactions to formats of communicating risk. For example, are the data from the source intended to represent objective probabilities and/or beliefs? Similarly, are people's reactions to risk information expressions of objective facts, beliefs, or both? Because probabilistic information can represent both objective facts and opinions, it is good practice to clarify the intended meaning of the probability. In this review, the focus is on the probability rather than the consequence (i.e., severity) dimension. This is due to the greater abundance of studies that focus on communicating probabilistic rather than severity information. Communication that focuses primarily on probabilistic information is unfortunate given that perceptions of severity may dictate decisions at a fixed level of probability.[18]

## ASSESSING EFFICACY OF RISK COMMUNICATIONS

Relatively few guidelines exist on evaluating the efficacy of risk communications,[19–22] and these guidelines vary by whether communications are focused on education, persuasion, crisis management, or conflict management. Below is a summary, not meant to be exhaustive, of outcomes used to evaluate the efficacy of risk communication processes.

*Engagement in recommended behavior(s).* A risk communication is deemed effective if the resulting perceptions of risk lead to the recommended health-protective or disease-prevention behavior. A risk communication would be judged ineffective or even detrimental if it causes the person to act inappropriately (e.g., failing to get a mammogram because one judges one's personal risk as low). At times, there may not be consensus as to what actions a person should take (e.g., the benefits and risks are approximately equal, or no consistent clear evidence of benefit exists). In these situations, the focal outcomes may be whether the person truly understands the risks versus the benefits, makes a decision that is consistent with his or her values, is satisfied with the decision reached, and decreases possible feelings of regret should the decision lead to poor outcomes.[19] For example, does a person who wishes not to suffer nausea as a result of cancer treatment choose a treatment that is consistent with these wishes?

*Paying attention to the message.* A key factor in any communication is whether the target audience pays attention to the message. Risk messages that are attended to, as reflected in such outcomes as amount of information processed and reviewed, recall, use, and dissemination to others, can be considered effective in some situations. Thematically related, there is increasing attention to understanding the factors that influence a person's motivation to process risk messages (e.g., confidence in his or her own knowledge, gender, time limitations) and the consequences of such processing.[23–27] In general, it is argued that greater elaboration of risk messages increases the likelihood that the resulting perceptions of risk will influence decisions and behaviors.

*Acquisition of factual knowledge.* Did the risk communication result in greater understanding of the phenomenon in question, especially in relation to the dimensions of understanding risk previously discussed (e.g., knowledge of personal risk factors, understanding what actions to take to reduce or prevent the negative outcome, understanding the nature of the disease/event, understanding probabilities of an event occurring)?

*Effects on emotions.* Risk communications can cause undue positive or negative emotional reactions. For example, after receipt of risk information, do individuals express undue anxiety, stress, or anger? Conversely, do they express unexpectedly high levels of positive affect in light of highly likely negative outcome(s)? Emotional responses can have important consequences in terms of decision-making processes, behavioral outcomes, and perhaps psychological well-being (e.g., do the resulting negative emotions from the risk communications, if sustained, lead to depression?). Indeed, newer models of risk and decision making, such as risk as feelings[28] and the affect heuristic,[29] suggest that emotions play an important role in decision making. Studies may assess how the format of the risk communication affects emotional reactions, which in turn may have effects on decisions and behaviors.

*Judging perceived risks/benefits.* Assuming individuals are aware that actions can be taken to reduce their risk, they may not fully understand the benefits and costs of such actions (e.g., mastectomy to reduce breast cancer risk) or at times inaction. They may not fully appreciate the risks and benefits or be unable to balance them (e.g., how much is my risk reduced in light of the possible side effects?). Interestingly, whereas risks and benefits are usually positively related in nature, the public perceives risks and benefits to be inversely related (e.g., as risks increases, perceived benefit decreases).[30]

*Evaluation of the messages.* To what extent does the audience find the information credible, accurate, useful, relevant, comprehensive, trustful, clear, and easy to understand?

Numerical, verbal, and graphical formats that convey risk likelihood may affect one or more of these outcomes (e.g., poorly communicated numerical probabilities may have little effect on decisions and behaviors, lead to no gain in knowledge, and may cause frustration). Thus, it is useful to assess several of these dimensions to obtain a better understanding of the mechanisms (i.e., mediators) through which formats of communicating risk achieve their desired goal(s). Unfortunately, such comprehensive assessments are rarely done. I now turn to a discussion of the various formats of communicating risk magnitudes.

## NUMERIC COMMUNICATION OF RISK

Numbers are often used to describe the likelihood of an adverse event occurring. Individuals may be told they have a 5% chance of getting a disease, or, similarly, a 5 in 100 chance. Numbers have several appealing qualities: they 1) are precise and as such lead to more accurate perceptions of risk than the use of probability phrases and graphical displays, 2) convey an aura of scientific credibility, 3) can be converted from one metric to another (e.g., 10% = 1 out of 10), 4) can be verified for accuracy (assuming enough observations), and 5) can be computed using algorithms, often based on epidemiological and/or clinical data, to provide a summary score (e.g., Gail score for breast cancer).[31] Furthermore, it is assumed that many people appreciate numbers because of having received mathematical training in school and/or professionally and often use them in daily life (e.g., financial transactions). Of import, when it comes to making important health decisions, individuals often prefer numeric information relative to other formats (e.g., verbal probabilities).[32–35] Potential weaknesses of using numbers include their lack of sensitivity for adequately tapping into and expressing gut-level reactions and intuitions and problems people have understanding and applying mathematical concepts (i.e., people's level of numeracy).[36,37] Furthermore, algorithms used to derive numbers may be incorrect, untestable, or result in wide confidence intervals (i.e., uncertainty) that may affect the public's trust[38] (see Politi and others in this issue[39]).

Several numeric formats exist to express probabilistic information, for example, percentages (0% to 100%), odds (e.g., 50 to 1), natural frequencies (e.g., 20 events observed out of 100), and classical probabilities (0 to 1). These formats can be used to relay specific types of risk information, such as absolute risk, relative risk, attributable risk, and, more recently, numbers needed to treat or harm.[40] The number needed to treat refers to the number of people who need to be treated for 1 person to benefit (e.g., 60 people need to be treated with a drug for 1 person to experience a benefit). Numbers needed to harm is similar to the above, except it refers to how many people can undergo an intervention for 1 person to be harmed.

Among these numeric formats, the one that facilitates understanding and solving of probabilistic computations (e.g., Bayesian problems[41,42,b]) is natural frequencies, which corresponds to the results of

[b]There are several findings that show that natural frequencies may not necessarily be superior to other numerical formats (e.g., percentages in the context of solving conditional probabilities using word problems). The reader is referred to the excellent review by Reyna and Brainerd[43] discussing these findings and conditions that enhance numerical meaning to promote improved judgments of risk and probability.

observing outcomes in the environment that are not normalized (i.e., that contain base rate information).[44] Natural frequencies may reduce misinterpretations significantly because they identify the reference class in question; that is, the group of people being targeted.[45] The reader is referred to the article by Hoffrage and others[44] containing both an explanation of natural frequencies and a review of studies that have challenged the use of natural frequencies as an optimal method of presenting statistical information. General discussions of the use and processing of frequencies can be found in the text by Sedlmeier and Betsch.[46]

A critical issue is whether providing a person with a numeric probability is understood sufficiently, especially in the context of unfamiliar health outcomes. Often, a single number is provided, as, for example, the chance of getting a disease (e.g., absolute risk of getting lung cancer: "Your lifetime risk of getting lung cancer is 3%.").[47] However, a single number may not be enough to convey sufficient meaning. For example, how clearly does a single number convey the magnitude of risk? Does the same number possess the same meaning across different disease states (e.g., does someone interpret a 3 out of 100 chance of getting heart disease the same as a 3 out of 100 chance of getting diabetes)?

To facilitate understanding of risk magnitude, a person can be given 1 or more numeric comparisons. (Note that without a numeric or other standard of reference, individuals may resort to their own internal reference point [i.e., anchor] to judge the risk as high or low, e.g., "you told me my risk was 5% when I thought it was 30%, so my risk is really low.") Common reference points used in risk communications are how the person's risk compares to 1) those who are missing the risk factor(s) (e.g., risk of having a heart attack comparing individuals with or without elevated cholesterol) and/or 2) the likelihood of occurrence of other, more familiar, events (e.g., risk of heart attack compared to being in a car accident, plane crash).[48–52] The reader is referred to Covello and others and related research for describing different methods of making risk comparisons and their presumed efficacy.[48,51,53] The use of these risk factor profiles provides comparative standards that can influence risk magnitudes; indeed, they are often expressed statistically as absolute risk differences, relative risks, and odds ratios.[54] The following are suggested guidelines for enhancing the meaning of providing a single numerical estimate of risk, numeric comparisons, and the use of numbers to represent risk more generally.

- Be consistent in the use of numeric formats. For example, do not compare percentages with odds or frequencies. Make comparisons among similar rather than different objects. Compare apples with apples rather than to oranges.
- Use the same numeric denominator (e.g., compare 5 out of 100 with 15 out of 100).[50] This facilitates comparisons and reduces cognitive effort. For example, Johnson and others found that in the domain of preference reversals, people invested more cognitive effort processing ratios with unusual-looking denominators than common ones.[55] Overall, individuals more readily comprehend denominators of base 10 (e.g., 10, 100, 1,000).
- Round numbers and avoid the use of decimals.[53] Psychologically, individuals understand more readily wholes than wholes plus parts (e.g., it is easier to grasp 30 than 29.6).[56]
- Risk perceptions vary based on whether communications using ratios emphasize differentially or equally the numerator, which often represents the number of individuals affected, or the denominator, which often represents the total population at potential harm. In general, the literature is inconsistent with respect to whether individuals pay more attention to the numerator versus the denominator.[57,58,c] At times, individuals base a decision on the magnitude of the numerator. What may decide the aspect attended to most is whether emphasis is placed on the numerator, denominator, or both equally. The resulting impression of risk is likely to be influenced by what information is being emphasized.[59,60] Related to the above, expression of mathematically equivalent ratios may result in varying perceptions of risk. For example, according to the ratio-bias phenomenon,[61–64] expressing a ratio as 2 smaller numbers (e.g., 1 out of 10) leads to lower perceptions of event likelihood than the same ratio incorporating larger numbers (e.g., 10 out of 100). Conveying a ratio using the latter format may increase the perceived magnitude of risk.
- Numbers close to zero (e.g., 1% or less) will at times be dismissed as representing no risk. Events that are perceived as well understood (e.g., familiar) and as less severe may be more readily dismissed than events that are more poorly understood and viewed as more consequential.[65–67] If the idea is to stress some level of risk, regardless of how small, a message to this effect is in order (e.g., even though the risk is extremely low, it may still happen). Indeed, going

[c]As a passing note, when individuals are presented with a ratio/fraction without any instruction, it is not always clear whether individuals view the numerator as representing the number of persons harmed and the denominator as the total in the population who can be harmed. Whether this approach of "humanizing" the statistics ultimately affects risk perceptions merits further research.

from no risk to some risk has important psychological consequences.[68]

- Communications of relative risk that state the risk is *X* times higher than another (e.g., "if you are a smoker, your chance of getting a disease is 10 times higher than that of a nonsmoker") often result in an overestimation in perceived risk.[69–72] This format is useful if persuasion is the goal, although this may raise ethical questions. If the aim is to achieve a more accurate assessment of risk, it is best to both specify the relative risk and include the baseline value (e.g., "the chance of nonsmokers getting a disease is 1%, while the chance of smokers is 10%; therefore, smokers have a 10 times greater chance of getting a disease than do nonsmokers"). In general, including base rate information reduces the perceived risk,[72,73] and including it along with relative risk has been recommended for conveying risk data.[54,74] For the general issue as to when base rates are attended to, the reader is referred to the excellent review by Koehler.[75]

Related to the above, many communications use percentages to convey relative risk. Informing individuals they have a certain percentage of greater or lesser risk is vague (e.g., "those who took the medication reduced their cholesterol 14% compared with those who did not take the drug"). To make the comparative percentage more meaningful, specify the baseline risk value (e.g., "on average, the risk is 5%. Your risk may be 10% higher, that is, 5.5%," or, to simplify, around 6%). As a general guideline, when encountering a message that provides a percentage to convey a greater or lesser relative risk, include the base rate. Indeed, a 10% relative increase in risk when the base rate is 1% is much different than when the base rate is 10%. Without the base rate information, it is unclear what a 10% relative increase means.

- Avoid having the target audience undergo complex calculations.[76] Simplify the calculations (e.g., be explicit about how to conduct the calculation) or provide a summary of the result(s) with some discussion of what the result means (e.g., "when we add your 2 risk factors, poor diet and lack of physical activity, considering your age, your risk is 2 out of 100; that is, among 100 people like you, we expect that on average, 2 will get heart disease in the next 5 years"). Indeed, one reason natural frequencies may be effective at helping solve probabilistic calculations is that they present the information is a way that is more readily transparent for reaching the solution.[77]
- If a specific action or interpretative standard/threshold exists in relationship to a numeric risk value, provide it. For example, if the average risk represents a value of 1 out of 10,000, inform the target audience that values above this threshold involve greater than average risk, along with any recommendation for action. Good examples of such communications exist for environmental risks (e.g., radon).[78,79] Of import, this recommendation does not suggest communications should highlight only whether a person is above or below a threshold at the expense of discussing the degree of threat. For example, radon exposure levels of both 4.5 pCi/L and 25 pCi/L require remedial action; however, the latter poses a significantly higher health hazard. Thus, communications should be clear about action standards and the meaning of the absolute risk magnitudes (e.g., you need to engage in some action and understand the threat[s] imposed by the risk level).
- If possible, avoid using logarithmic scales. These are poorly understood by the populace. For example, it is difficult for most to fathom how a risk of 1 in 1,000,000 is that much different from a risk of 1 in 100,000—most do not experience these events. However, there have been suggestions to use logarithmic scales, such as the Pauling Perspective Scale.[80,81] A study on blood transfusion risk comparing this scale with a written numerical form using a 1 in *X* format revealed no differences in knowledge about or in perceptions of transfusion risk.[82] Clearly more work is needed to determine the utility of this scale to convey risk magnitudes.

## VERBAL COMMUNICATION OF RISK

Probabilities can be communicated verbally using a variety of terms, such as *unlikely*, *possible*, *almost certain*, *rare*, and so forth. The strength of using verbal terms to denote risk is that they allow for fluidity in communication (i.e., they are easy and natural to use); express the level, source, and imprecision of uncertainty; encourage one to think of reasons why an event will or will not occur (i.e., directionality); and, unlike numbers, may better capture a person's emotions and intuitions.[31,83–85] However, a potential weakness of probability phrases, especially if the goal is to achieve precision in risk estimates, is the high degree of variability in interpretation. A term used by one individual to represent risk may not be interpreted similarly by another (e.g., although some may interpret the term *likely* as representing 60%, other people may view it as meaning 80%). Variability in interpretation can be affected by such factors as event base rates and severity; the perceiver's knowledge, experience, and expectations; and the goals of the communication.[86–90]

Although progress continues to be made toward achieving greater homogeneity in the understanding and use of probability phrases between individuals,[91,92] at this time, no best practices can be offered based on the existing evidence for communicating probability using verbal phrases, especially if the goal is to permit precise interpretation of numerical estimates. However, one possibility if probability is to be conveyed using phrases is to use a common word stem with varying modifiers (K. Wallsten, personal communication, 2006).[50] For example, *likely* can be the stem, with several modifiers such as *very unlikely*, *somewhat unlikely*, *equally likely*, *very likely*, and so forth. Admittedly, this is not a new concept, and attempts to address potential weaknesses to this approach have been examined.[93] Potential obstacles to the successful implementation of standardized probability phrases include overcoming some of the factors alluded to above (e.g., having the same meaning across context, individual differences in knowledge, expectations, event severity, and so forth).

## VISUAL COMMUNICATION OF RISK

Graphics and other visual displays (e.g., film, cartoons) are being recommended and used more frequently as adjuncts to numeric and verbal communications of risk; the reader is referred to excellent resources on recommended practices for creating graphs.[94,95] The advantages of graphical displays include their ability to summarize a great deal of data and reveal patterns in these data that would otherwise go undetected (e.g., a regression line amid a scatter plot) using other methods.[96] Graphical displays are also useful for priming automatic mathematical operations (e.g., subtraction in comparing the heights between 2 bars of a histogram) and are able to attract and hold people's attention because they display data in concrete, visual terms.[97] Furthermore, graphs may be especially useful to help visualize part-to-whole relationships, as, for example, in conditional probability reasoning (e.g., pie chart showing a slice out of the whole, pictographs showing number afflicted in a population, Venn diagrams showing degree of overlap among nested events).[43] The disadvantages of graphics or other visual displays include the following: 1) data patterns may discourage people from attending to details (e.g., numbers); 2) some graphs are not well understood because they are poorly designed, complex, and/or unfamiliar to the general public (e.g., box and whiskers plot); 3) individuals may lack the skills or the educational resources to learn how to use and interpret graphs[98]; 4) they require technical programs to create, which may not be readily available in certain parts of the world; and 5) they are more challenging at times to prepare and use given the time and spatial constraints of clinical encounters. A further and perhaps the most serious concern is that graphs can mislead by calling attention to certain elements and away from others (e.g., graphs that present the numerator but not the denominator graphically may call undue attention to the numerator). The part of the graph that is attended to may unduly influence interpretation and subsequent decisions/actions.[99]

It must be noted that knowledge of how graphical displays affect risk perceptions is still in its infancy and remains, with few exceptions, a largely atheoretical research area. In general, graphical displays that promote accuracy in judgments do not necessarily lead to behavior change and vice versa.[100] To date, there have been 2 comprehensive reviews on the use of graphic elements to communicate risk.[97,100] Below is a summary of tentative recommended practices based on these reviews.

- Certain graphs are well suited for specific tasks. For example, bar charts (i.e., histograms) are good for making comparisons, especially as a function of subgroups (e.g., comparing magnitude of risk by race or sex); line graphs (e.g., survival and mortality curves) are good for showing trends over time and perhaps interactions among risk factors; and pie charts are good for judging proportions, although pie charts do have some biases.[101]
- If the goal is to promote accurate judgments of magnitude, then elements of the graphic displays should be proportional to the quantities depicted, as, for example, the part-to-whole relationship between the numerator and denominator. Graphs that differentially emphasize the numerator (foreground or number of people harmed) or denominator (background or total number that can be harmed out of a population) can affect risk behavior (e.g., willingness to pay to avoid the risk)[60,102,103] by affecting risk perceptions. Graphically emphasizing only the numerator of a risk (e.g., showing only those affected) increases risk-avoidant behaviors, whereas attending to both the numerator and denominator decreases risk-avoidant behaviors (see Figure 1a, respectively). For a related study showing when graphs (e.g., stick figures) reduce aversion to side effects of preventive medical treatment, the reader is referred to the study of Waters and others.[104] Displays that call attention to the number of people harmed (i.e., the foreground) increase the perceived size of the risk; displays that

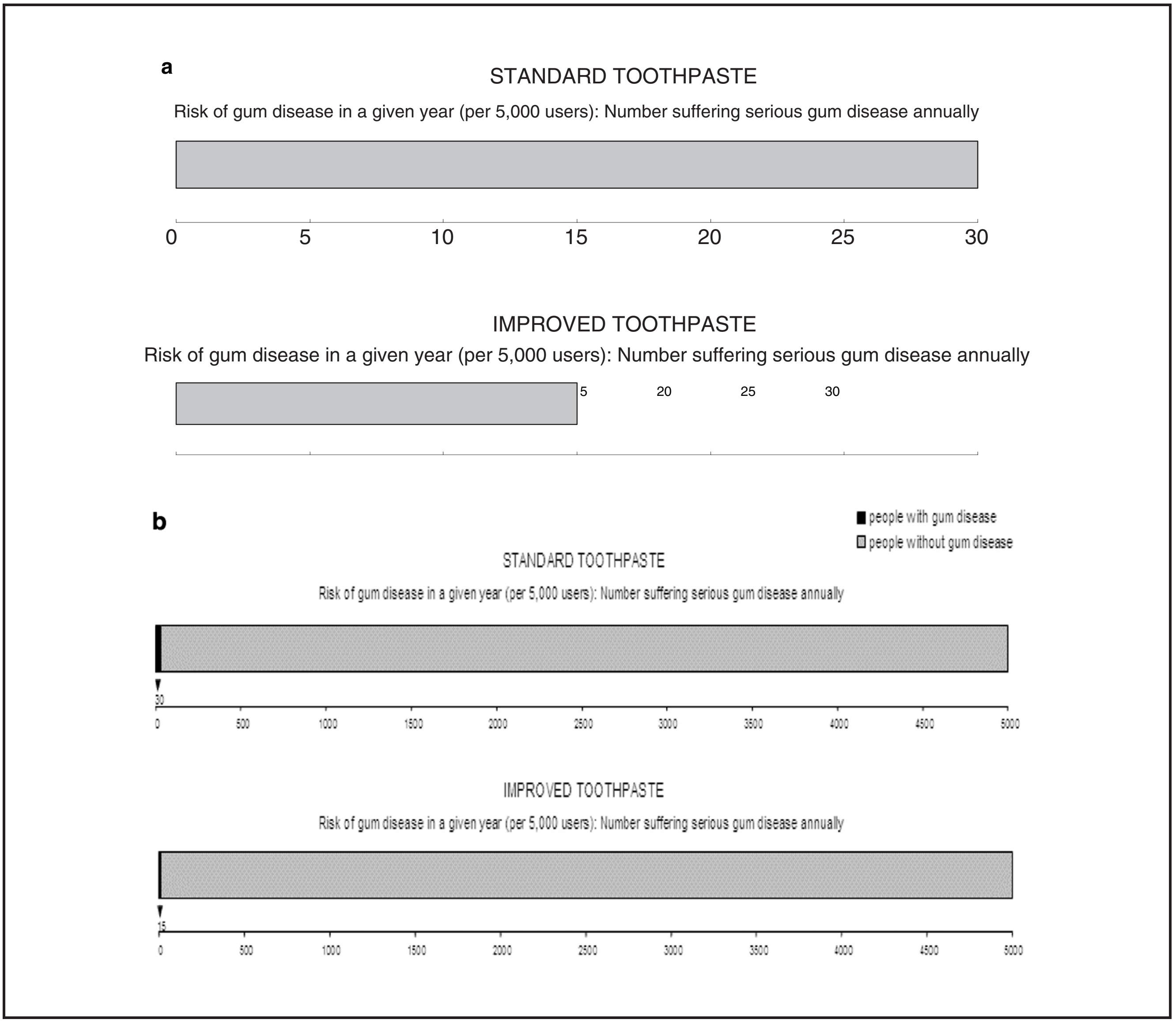


*Figure 1 (a) Bar graph display. This display emphasizes foreground information only, emphasizing the number of individuals who stand to benefit from the improved toothpaste relative to the standard toothpaste. Such displays lead to risk-avoidant behaviors (e.g., greater willingness to pay). (b) Stacked bar graph display. This display emphasizes both the foreground and background information, emphasizing both the number of individuals who stand to benefit from the improved toothpaste relative to the standard toothpaste out of a total population. Such displays lead to less risk-avoidant behaviors (e.g., less willingness to pay for the improved toothpaste). Reprinted from Stone and others[59] with permission from the first author.*

call attention to the number at risk (i.e., the background) decrease the perceived size of the risk. The former approach should be more effective at persuasion and thus potentially better able to induce behavior change. Note that graphical displays that differentially emphasize the foreground and background do not necessarily lead to more accurate estimates of the risks, at least in relation to numeric-only displays.[103]

- Individuals are sensitized to graphs that use height to signify risk likelihood or to make risk comparisons among events, such as bar graphs and risk ladders. For example, individuals easily comprehend that events located higher on a risk ladder—or vertical graphs more generally—convey greater risk than events located toward the bottom.[78,104]
- Icons, such as human figures, are a common method of displaying the number of individuals affected

within a population. At times, icons displaying the number affected will be distributed throughout the array to show randomness (e.g., in a $10 \times 10$ matrix, those afflicted are randomly shown in the array figure); they can also be grouped together. Assuming that accuracy in numeric estimates and speed of processing are key outcomes, grouping the affected individuals together will achieve these goals.

- Provide clear, comprehensible explanations of the meaning of each graph and any specific conclusions drawn: Auditory explanations are likely to be especially helpful for those who are visually impaired. For example, instructions were instrumental to the interpretation of survival graphs among people who had little or no experience with them.[105] Parrott and others[106] found that verbal explanations of the conclusions to be drawn from a complex graphic concerning genetic information made the graph more comprehensible and persuasive than one with only a caption. Work with risk ladders in the area of environmental risks has shown that providing recommended actions appropriate to levels of radon risk eased anxiety and promoted good decision making (see Figure 2).[79]

## SPECIAL RISK COMMUNICATION CHALLENGES AND ISSUES

### Personalizing Risks

With advances in evidence-based medicine, patients increasingly will be informed of their disease risks based on risk factor profiles (e.g., lifestyle and environmental factors, family history, genetics). Epidemiologically based algorithms exist for calculating risk for several cancers and heart disease.[47,107,108] These algorithms provide a summary statistic, often numeric, alerting a person to his or her chances of an event occurring over a certain time frame (i.e., a single-event probability). A critical assumption is that the characteristics of the person are represented in the population used to calculate the estimate.

At issue is the exact meaning of single-event probabilities and whether they should be used at all.[13,45] As discussed earlier, a single-event probability can refer to beliefs and/or the objective likelihood of any event's occurrence. With respect to the latter perspective, with rare exceptions (e.g., positive genetic test for Huntington disease), it is impossible to state an individual's risk with certainty. Rather, what can be computed with greater confidence is the number of individuals in a population with certain risk factor profiles who are estimated to be afflicted with a disease (i.e., a frequentist approach to estimating risk). From this view, communications would stress the likelihood of an event's occurring within a population. Admittedly, most individuals will not be interested in population-level risks but will want to know their own chances; potential exceptions might be individuals who identify strongly with a certain racial/social group, who have strong family histories, and so forth. A central communication challenge then is to help the person link individual risk with population-level risks, again assuming the characteristics of the individual match those of the population from which the estimate was derived.

How should communication of personal risks proceed? Regardless of the specific format of communicating likelihoods (e.g., numeric), whenever possible, individuals should be presented with population-level risks to represent risk likelihood. After being presented with this information, they should be informed that to the extent they resemble the population in question, the risk in the population may represent their own. For example, assuming that 10 individuals of 100 with the same risk factor profile as the patient in question are likely to be affected, the patient should be informed that he or she may be 1 of the 10 affected or 1 of the 90 not affected.

### Communicating Interactions

At times, it is necessary to explain to patients and/or the public how 2 or more risk factors contribute to a disease or health condition to affect risk magnitudes. A classic example is providing feedback from health risk appraisals.[109] Of import, 2 or more risk factors may work synergistically to achieve a greater risk than the sum of their individual risks (i.e., a multiplicative versus an additive model), or 2 factors may combine subadditively. For example, the multiplicative model can be used to show that the risk of lung cancer is a multiplicative combination of the individual risks of smoking and radon gas.[110]

Individuals have difficulties understanding interactions, especially those involving unfamiliar risk factors (e.g., radon).[110–114] The typical finding is that people underestimate multiplicative risk. Attempts to improve understanding have been met with limited success.[110] In part, this inability to find a successful communication strategy involving synergy between risk factors may stem from a lack of sensitivity of the rating scales used to capture perceptions of interactions.[113,114] Consequently, at this time, no clear recommendations can be given on how best to communicate the way risk factors interact to affect risk magnitudes. However, as a tentative suggestion, communications may first present how

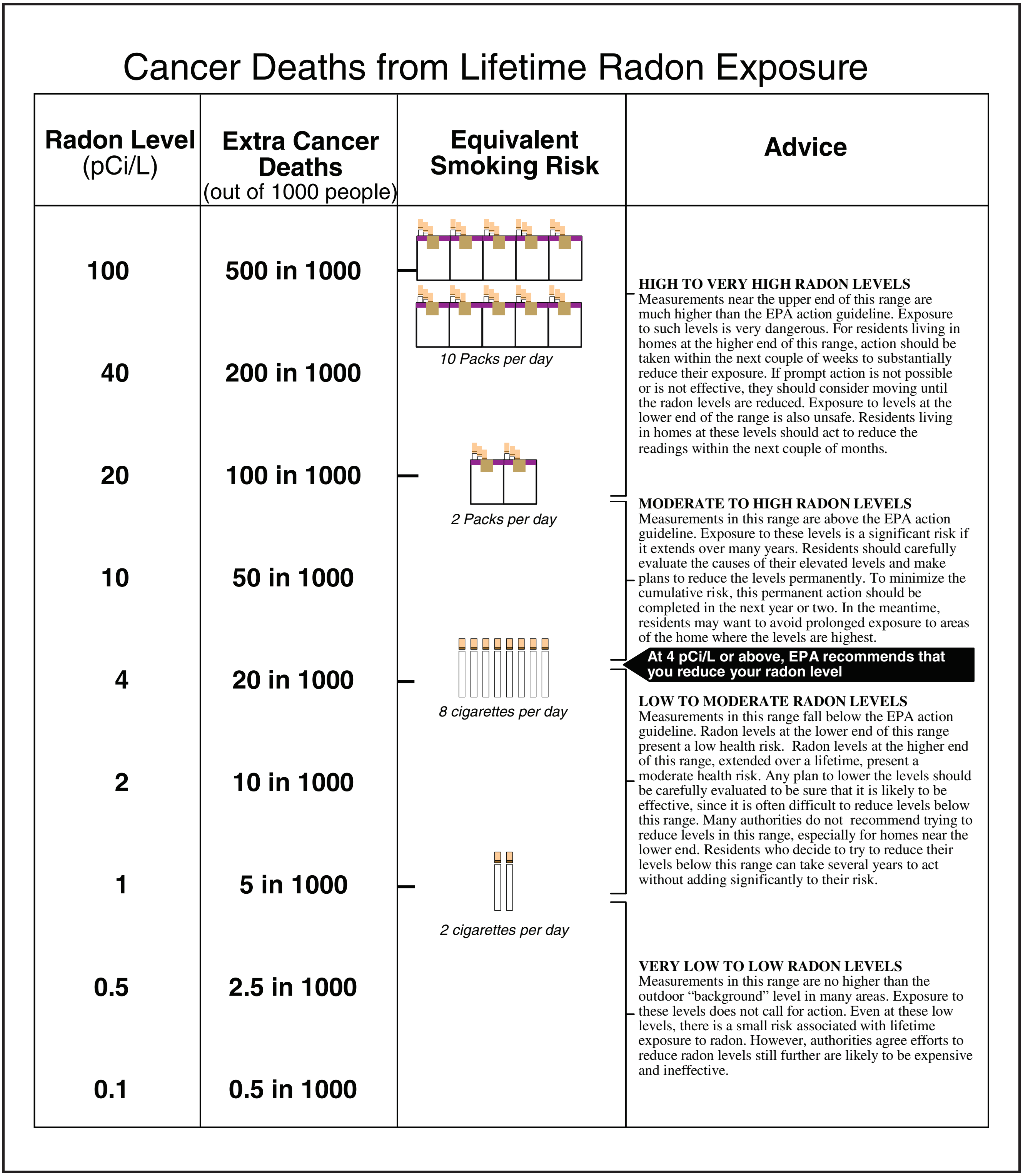


*Figure 2* Example of a risk ladder conveying risk of radon. Radon levels are being compared with the number of cigarettes smoked and the number of extra cancer deaths. On the right, the ladder displays an action standard (pointing arrow at 4 pCi/L), along with advice on how to interpret radon levels and the action that is required, if any. Reprinted from Lipkus and Hollands.[97]

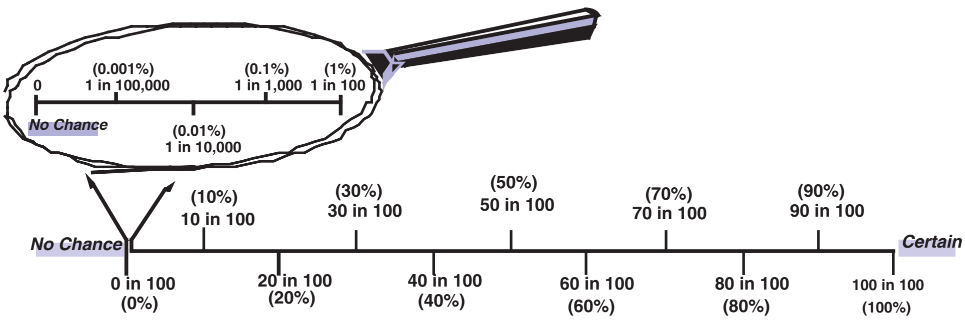


*Figure 3 Magnifier risk scale. This scale was used for eliciting risk perceptions. The magnifying lens at the low end allowed users to respond with smaller values for very low risks. Reprinted from Woloshin and others,[123] with permission of the first author.*

the individual risk factors affect the likelihood, then present their multiplicative effects, followed by a summary statement describing the interaction.[114] For example, describe the likelihood of lung cancer from smoking and radon alone and then discuss their synergistic effects, summarizing how the combined effect is significantly and multiplicatively higher than both of them added together.

### Communicating Small Probabilities

The public has difficulty understanding small probabilities (i.e., probabilities less than 1%). This difficulty may be due to the rarity with which people experience these events.[57] Understanding how these probabilities are encoded, represented, and interpreted continues to pose formidable challenges. For example, under some circumstances, small probabilities are given more weight than would normatively be expected, as argued, for example, by prospect theory.[68] Under other circumstances, people give small probabilities lower weights.[115] Furthermore, it remains uncertain at what point in the weighing function people truncate small probabilities to represent no risk.[116]

Several formats have been used to communicate small probabilities (e.g., less than 1%) to affect such outcomes as perceived risk magnitudes and decisions (e.g., willingness to pay for a safer alternative or to become vaccinated). Studies have compared 1) numeric formats,[57,116,117] 2) numeric formats with probability phrases,[118–120] and 3) numeric formats with visual displays.[121,122] Furthermore, although intended as a method of assessing perceptions of small probabilities rather than conveying them per se, Woloshin and others[123] have used a magnifying glass to clarify smaller probabilities (see Figure 3). This approach has been used, for example, to assess perceived risk for Barrett's esophageal cancer.[124]

There is inconclusive data about what methods of communicating small probabilities are most effective, in part because some studies fail to directly assess perceptions of risk—some assess the perception of threat, which includes risk magnitudes. The addition of graphic displays to numeric data has been shown to increase individuals' likelihood of making risk-averse decisions on some[122] but not on other occasions,[121] the assumption being that the presentation format influenced risk perceptions. Stone and others[116] found that expressing information in terms of verbal relative risks (e.g., for improved tires, annual blowout injury risk was half of that for standard tires) leads to greater risk aversion (e.g., more willingness to pay for improved product) than does presenting the information as 2 separate incidence rates (e.g., for standard and improved tires, incidence rates were 0.00000060 v. 0.00000030). In their pilot data, subjects who viewed incidence rates presented as frequencies tended to be more willing to pay for the improved product than did subjects who received incidence rates formatted as probabilities. In studies evaluating perceptions of medication side effects, numbers led to more precise estimates of risk (e.g., perceived risk more closely matched the numbers provided) than did verbal probability phrases.[118,119] The use of the magnifying glass to highlight smaller probabilities is associated with viewing small-probability events as less likely to occur; however, it also undermines the perceived likelihood of occurrence for higher probability events.[125] This is consistent with findings showing that graphs do not necessarily lead to more precise estimates of risk.[100]

The efficacy of communicating small risks rests on the aims of the communications. If the goal is to highlight small probabilities, available options include use of the magnifying glass, highlighting the numerator rather than the denominator, such as in graphical displays (i.e., foreground is prominent relative to background), comparing the probability level against a background level,[126] and using numeric frequencies. Furthermore, conveying a ratio that uses 2 larger numbers may increase the perceived magnitude of small risks, although this effect may be stronger when the information is presented visually rather than only numerically.[127]

Another method for increasing perceived likelihoods of rare events, if data exist, is to aggregate the small probabilities (e.g., cumulative risk).[67] For example, the probability per drive of being injured in a car accident is very low ($\sim$0.01%), but over the course of one's lifetime, it is about 33%.[128] However, this strategy may not be effective if the aggregated probabilities still remain extremely small over time.

### Communicating Cumulative Risks

The likelihood of an event's occurring may be very small at any given point yet add up over time. Individuals are poorly attuned for estimating cumulative risks.[129–132] Although more research is needed to learn how people think about and understand cumulative risk, simple graphical tools such as line graphs (e.g., survival or mortality curves) are useful for conveying decreasing or increasing risk over time, especially when graphs are accompanied by instructions.[89,105,133] Here, too, various factors affect the interpretation and use of survival/mortality curves, at least in clinical settings. For example, unlike physicians, patients seem to be most influenced by the starting and ending points of the curves, whereas physicians make more use of the middle portion of the graphs; a detailed verbal description of the graphs increases patients' attention to the midpoints of the scale and affects preference for treatment.[89,133] Furthermore, with survival curves, treatment efficacy is perceived as poorer when the data span is less rather than more years (e.g., 5 v. 15 years), even though the relative effectiveness of treatment remains constant across time; this temporal inconsistency bias is attenuated with the use of mortality curves.[134] An additional approach to help improve people's calibrations of cumulative risk is to perform the calculations for the intended audience, that is, to communicate what the risks are from the number of times the person has been exposed (e.g., think of number of exposures, present the risks of each, and demonstrate their combined effect; B. Fischhoff, personal communication, 2006).[129,130]

## RECOMMENDED AREAS OF FUTURE RESEARCH

Below, recommendations for future research are presented; it is hoped that these recommendations will benefit our understanding and application of the formats discussed above as well as the special challenges highlighted. These recommendations are not meant to be exhaustive.

More research is needed to explore how individual differences in numeracy affect the processing, computation, interpretation, and use of numeric risk information[36] as well as how different formats affect these processes among the less numerate.[135] Preliminary research has focused on how comprehension and quality of decisions (e.g., choosing the best hospitals or insurance plans) vary as a function of the interaction between numeracy and 1) amount of data (less v. more), 2) the salience of the most critical information and the ease of evaluating it (promoted, e.g., by attaching affective evaluative labels or using symbols/icons), and 3) the amount of cognitive effort involved (e.g., reduced by judicious ordering of the information). Overall, compared with more numerate individuals, the least numerate are more likely to have improved comprehension and to make better quality decisions when the presentation format makes the most important information easier to evaluate and reduces the amount of cognitive effort involved (E. Peters and others, unpublished data).[136] Making the most critical data easier to evaluate may motivate the less numerate to use the information.[137] Although these findings admittedly are not focused on conveying risk magnitudes per se, they are still useful for strategizing risk communications targeted to those with varying levels of numeracy. Ultimately, if numbers are to be used, the goal is to select a format that is well understood by most of the target audience, including, it is hoped, those at the extremes of the numeracy continuum. The issue of attending to individual difference in numeracy is just one example of the importance of being sensitive to characteristics of the target population in crafting formats of communicating risk.[138,139]

More work is needed to test optimal numerical formats, such as the often suggested use of natural frequencies. For example, what are the boundary conditions of a format's efficacy? More tests of mechanisms are needed to capture more fully why a format such as natural frequencies may lead to fewer misinterpretations than other formats (see footnote b). An important issue is how well natural frequencies facilitate understanding of very low-probability events; for example, under what conditions do natural frequencies cause low-probability events to be given more or less weight in judgments? Do natural frequencies facilitate making the events more imaginable or help to envision more ways the event can occur?[64,140,141]

With respect to verbal probability phrases, if future research leads to a consensus to use a common word stem and stem modifiers, then additional work will be needed to discern what these may be. Selection may be based not only on the degree to which the word stem and modifiers encompass probability ranges (e.g., select verbal phrases that have narrow, hence more precise, numerical values as part of their meaning)[142] but also to what extent they are minimally affected by such factors as context, severity of consequences, and individual differences (e.g., cultural factors, preferences for numbers rather than words).[143] Should this occur, the next challenge would be to contextualize this terminology and have it used consistently without introducing other probabilistic phrasing (e.g., how do we get clinicians to use the same verbal terminology?).

More theoretical work is needed to understand how graphical displays affect risk perceptions through the consistent testing of graphic elements (e.g., use the same type of graphical comparisons across studies). Theoretical accounts have explored both the perceptual processes (e.g., how information is scanned, retrieved, integrated) and comprehension (how data are interpreted) of graphic elements (for review, see Shah and others[144]). Recent advances in interactive models of graph comprehension[145,146] explore "how characteristics of the visual display, a viewer's prior knowledge and expectations about the data, and his or her graphical literacy skills influence a viewer's interpretation of a data set."[144] Such elements have yet to be studied together to assess their effects on risk perceptions and their subsequent effects on decision making and behaviors; these represent fruitful areas of investigation.[100]

We may find that mechanisms that govern perceptual processes predict how people respond to basic risk communication tasks, such as comparing risk magnitudes in crude terms (e.g., which risk is bigger); however, tasks that require more precise estimates (e.g., quantifying differences in risk magnitudes, integrating multiple sources of information) may be found to be influenced more by processes of interpretation, which are themselves influenced by several contextual and individual difference factors.[147] What may determine whether these displays affect health and medical decisions and behaviors is the final meaning derived from the presentations and not necessarily the specific facts, as suggested, for example, by fuzzy-trace theory.[148] In this regard, much more work is needed to explore the gist (i.e., meaning) people derive from using graphs, visual displays, and other formats to communicate risk. Exciting new technological methods are emerging that can help display and capture gist representations.[149]

The majority of studies communicating risk magnitude have used a single format, primarily numeric or verbal, with increasing integration of graphs. Although studies should continue to explore the efficacy of formats within a domain, more work is needed to learn how the various risk communication formats interact with one another.[69] For example, how do probability phrases and numbers change risk perceptions and comprehension when accompanied by a graph? It is clear that interactions between formats affect understanding of risk magnitude and patients' medical decisions. For example, Fagerlin and others[150] found that decisions about which hypothetical treatment to chose for angina varied as a function of the type of anecdotal information presented (e.g., number of personal vignettes that matched the statistical information for success or failure) and the inclusion of a graphical display (pictographs). The provision of a pictograph reduced the influence of anecdotal information on treatment decisions.

Related to the above, a guiding assumption of using any format is that the information provided will be clear, useful, and personally relevant. However, there is increasing evidence to suggest that providing instructions (e.g., how to use mortality curves) or summary statements can influence how the information is perceived and used. More work is needed to explore how instructions or summary statements influence risk judgments. For example, does the provision of such statements modify meaning, preferences, and actions—perhaps through less elaboration of the information—compared to when these statements are missing? Does providing summary information result in paying less attention to details concerning the risks?

Most of the research reviewed here emphasizes how the provision of probabilistic information influences perceived risk magnitudes. As such, it represents a rather passive approach of engaging the audience with the messages. A potentially fruitful area to explore is how engaging that target audience in the active representation and reflection of probabilistic information influences risk perceptions (e.g., magnitude, understanding, accuracy). For example, in study 1 by Natter and Berry,[151] participants were asked to imagine they had a sore throat and as a result visited a doctor. They were given a fictitious drug called Epidoxin, with an accompanying letter that described 4 side effects that afflicted 2% of the population. Participants in the passive condition were presented with a bar graph representing the risk; participants in the active condition were presented with a bar graph and asked to indicate the proportion of people who would experience 1 or more side effects by shading the corresponding area of the graph. Those in the active group reported a lower likelihood of experiencing the side effects than participants in the passive group. Other studies in health and other arenas have shown that the active and deliberative processing of information can lead to better understanding and performance.[152–154] In sum, processes that engage the target audience in the translation of a mental to an external representation of risk may provide significant benefits in terms of accurate understanding (e.g., better calibration of risk estimates) and use of the information.

## CONCLUSION

The communication of risk will continue to play a critical role in health behavior. However, as Ghosh and Ghosh[155(p178)] stated, "despite the large body of evidence, there seems to be a lack of consensus concerning the most appropriate method with which to communicate medical risk." The current review provides suggested formats to help educate the public about probabilistic information and to broach consensus. Formats used for conveying risk information are critical because individuals often do not have a priori and stable opinions about risk magnitudes; as such, their beliefs and feelings about risk are likely to be influenced by format.[156] Although this review was about communicating probabilistic information because of its central role in most risk communications, it should be noted that probabilistic data may not be the most important dimension of risk people desire or use.[157] Furthermore, we must not lose sight of the fact that risk communications occur within a context with certain objectives; the approaches discussed here, and methods used to improve risk communication, should be judged in light of these.[138,158]

As this review has shown, the available evidence suggests few best practices. Contributing factors preventing putting forth more best practices include the 1) lack of consistency in testing formats using the same outcome measures in the domain of interest (e.g., testing perceptions of breast cancer risk), 2) lack of critical tests using randomized controlled studies pitting formats, and 3) lack of theoretical progress detailing and testing mechanisms why one format should be more efficacious than others in communicating risk magnitudes in a specific context. It is hoped that strides in testing risk presentation formats will help guide future best practices and either reinforce or modify the recommendations herein, taking into consideration the multiplicity and complexity of outcomes related to the field of risk communication.

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