Making Numbers Matter: Present and Future Research in Risk Communication

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***Objective*: To summarize existing research on individual numeracy and methods for presenting risk information to patients. *Methods*: We selectively retrieved articles from MEDLINE and the *Social Sciences Citation Index*. *Results*: Many Americans have low numeracy skills, a deficit that impedes effective health care. Approaches to risk communication vary in current practice, but how risks are presented can significantly affect both patients' risk perceptions and their knowledge. *Conclusions*: Adhering to some basic principles for presenting risk information to patients can improve understanding. However, different risk-communication methods may be needed for individuals with high versus low levels of numeracy.**

***Key words*: numeracy, decision aids, graphs, visual displays, informed consent, shared decision making, patient education**

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Increasingly, decision aids are being developed to help patients learn about new diagnoses and their treatment options.[1] As a result, understanding the role of literacy in health communication is critical. If people cannot understand the written materials they turn to, it is unlikely that these communications will have any meaningful impact on patients' understanding of their health condition.[2] However, patients need to understand not only the text of a decision aid but also the risk statistics that are contained within. Just as people need sufficient literacy skills to understand prose contained in decision aids, people also need the analogous quantitative skills to understand the numerical information. Such skills, termed *numeracy*, include the ability to think about and interpret probabilities, fractions, and ratios.[3,4] Unfortunately, research has shown that many people, even those with a college education, have poor numeracy skills.[4]

In this paper we discuss how poor numeracy skills hinder many patients' decision making. We also argue that, just as literacy affects health behaviors and outcomes, numeracy has a significant impact on medical decision making and risk perceptions. Research has shown that having low numeracy skills negatively impacts important patient outcomes, and other research has shown that the ability to understand numerical information is limited in some individuals and can be further hindered by stress

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or advanced age. Given these findings, we discuss methods to improve patients' understanding of numerical information regarding the risks and benefits of treatment. Furthermore, we consider whether the methods that have been shown to improve understanding of risk/benefit information can be expected to have the same influence on low- versus high-numeracy individuals.

Review of Numeracy Literature

Below we review the numeracy literature and, specifically, how it relates to medical decision making. To retrieve relevant articles, we conducted a MEDLINE search for all articles that contained the word *numeracy* (in all categories, such as title, abstract, keywords). We reviewed each article and also examined the bibliography of particularly relevant articles as a secondary identification method. Finally, we used the *Social Sciences Citation Index* to find additional articles that had cited the articles found using the previously discussed methods. Not all findings are reported in the current article, as we limited our review to those we found most relevant.

Measuring Numeracy in Adults

Numeracy is typically measured using "objective" measures such as a list of mathematical problems that test understandings of frequency, probability, and percentages. Schwartz and colleagues first assessed numeracy with 3 questions which tested the ability to translate percentages into fractions and understandings of probability (eg, how often a fair coin would come up heads or a fair die would land on an even number).[3] Lipkus and colleagues expanded the Schwartz measure by adding 8 questions that focus more directly on participants' ability to understand disease risk.[4]

An alternate, more indirect, approach to measuring numeracy involves assessing people's self-perception of their own numeracy. We have developed an 8-item subjective numeracy scale (SNS) that asks participants to evaluate their numerical ability (eg, "How good are you at calculating a 15% tip?") and to indicate their preference for the presentation of numerical information (eg, "When people tell you the chance of something happening, do you prefer that they use words ['it rarely happens'] or numbers ('there's a 1% chance')?").[5] We developed the SNS because of concerns that many research participants find objective numeracy measures to be aversive and time-consuming. Our research in developing the SNS has shown that it is less time-consuming, frustrating, and stressful to complete than the Lipkus measure; is moderately correlated with objective numeracy; and predicts most of the behaviors that objective numeracy predicts, such as comprehension of survival curves.[5, 6]

Thus, researchers hoping to measure numeracy have 2 types of choices: objective measures and subjective measures. The best measure for any given study will depend on the time constraints of participants, the importance of retaining participants in follow-up studies, and the value of obtaining perfect versus imperfect measures of objective numeracy.

Research to date has demonstrated that many Americans have poor numeracy skills. The 2003 National Adult Literacy Survey found that 22% of Americans demonstrated "below basic" quantitative literacy (numeracy) skills and an additional 33% merely had basic skills.[7] Only 13% of individuals were considered to be proficient in quantitative literacy skills. Lipkus et al found that that even highly educated (eg, college-educated) individuals often have poor numeracy skills.[4] For instance, only 55% of subjects were able to indicate how many times a die would come up even in 1000 rolls. Given that so many Americans have low numeracy skills, it is important to understand how numeracy impacts health behaviors, understanding, and decision making.

Research on Numeracy in Medical Decision Making

Risk perception. Individuals with low numerical ability have been found to differ from their higher numeracy counterparts in their perception of risk. For example, compared to women with high numeracy skills, women with lower numeracy skills are more likely to overestimate their own breast cancer risk and the average woman's lifetime risk of breast cancer.[8,9]

Numeracy is also related to patients' perceptions of the benefits of screening tests and treatment. For example, Schwartz and her colleagues surveyed 287 female veterans and tested their ability to calculate the risk reduction

achieved by undergoing annual mammograms.[3] The survey described how much women's 10-year risk of death due to breast cancer is reduced by having annual mammograms, and the risk reduction was presented in 1 of 4 ways: (1) 33% relative risk reduction, (2) 33% relative risk reduction plus baseline risk of death, (3) a 4 in 1000 absolute risk reduction, or (4) 4 in 1000 absolute risk reduction plus baseline risk of death. Regardless of how the statistic was communicated, most women were unable to accurately calculate the risk reduction from mammography, often overestimating the effectiveness of mammograms. However, inaccurate assessments were most prevalent among low-numerate women. Specifically, of women who were unable to answer any of 3 numeracy questions correctly, only 5.8% were able to accurately calculate risk reduction. Accuracy rates increased for women who were able to answer 1 (8.9%), 2 (23.7%), and all 3 (40.0%) of the numeracy questions correctly.

In another study, Weinfurt et al investigated cancer patients' perceptions of the benefits of participating in Phase I clinical trials.[10] Participants were 328 adult cancer patients with advanced malignancies and for whom standard therapies were either unavailable or ineffective. Patients who answered the single numeracy question incorrectly had significantly higher expectations of benefit from experimental therapy than did patients who answered the question correctly.

These results indicate that patients with low numeracy skills have significant difficulty calculating the benefit of a procedure. This has important implications for medical decision making. If people are unable to accurately interpret the risks and benefits of treatment, it increases the chance that patients will make uninformed decisions that may be at odds with their preferences.

Numeracy and medical outcomes. Low numerical ability has also been shown to influence medical outcomes. Individuals with low numeric ability may be especially vulnerable to having difficulty with following a complicated dosing regimen. In fact, 1 study showed that lower numeracy individuals had worse medical outcomes, when their health condition was dependent on the ability to follow complicated medication instructions.[11]

Utility elicitation. Utility elicitations are often used to help clarify patient values and to help develop public policy. However, several studies have shown that lower numerate individuals are less able to accurately complete utility elicitation tasks (eg, standard gamble [SG] and time trade-off [TTO]). For instance, Woloshin et al found that within lower numeracy patients, there was a negative correlation between TTO and SG responses and ratings of patients' self-reported health.[12] Similar results were found in a small study of patients with head and neck cancer who rated their quality of life.[13] These results suggest that utility elicitation tasks are ineffective for low-numerate individuals and could have negative consequences in regard to the development of public policy or in values clarification exercises.

Summary

The above research reveals that low numeracy plagues many Americans, including highly educated individuals. This low numeracy has significant implications on people's health care. For instance, people with low numeracy often err in their understanding of the risks and benefits of treatment, often times overestimating the benefits of treatment.

Although we may not easily change people's numeric ability, it may be possible to create health materials that help patients with low numeracy skills better understand the risks and benefits of treatment.

Why Developing Effective Health Materials for Patients Is Critical

Imagine someone who has been diagnosed with early stage prostate cancer. Not only does he have to deal with the stress and emotions of a new cancer diagnosis, but he is also encouraged (and sometimes required) to make a complicated treatment decision. He may need to choose between radical prostatectomy (surgery), 2 different types of radiation therapy, or engaging in watchful waiting. In making his decision, he must not only understand any statistical differences in outcomes between these different approaches, but also consider each alternative's chance of causing various complications or side effects (eg, urinary incontinence or impotence).

At such moments, patients often turn to the Internet or other written materials (eg, decision aids) to learn about the risks and benefits of available treatment options. For this information to play a significant role in patients' decision making, it must be useful to people of all numeracy levels. A vast literature has attempted to determine optimal methods for presenting risk information to patients. Below we briefly discuss a number of these methods. We also discuss opportunities for further research to clarify the role of numeracy in risk communication.

Presenting Risks/Benefit Information Using Multiple Formats

What we know. Statistical information regarding the risks and benefits of treatment can be presented in many formats: verbally (eg, the risk of incontinence following radical prostatectomy is "moderate"), numerically (eg, 60 in 100) or graphically (eg, in a pictograph).

Many studies have identified serious criticisms of presenting risk/benefit information in verbal terms only.[14] One common criticism focuses on the lack of consensus regarding how numerical figures map to verbal labels (eg, what percent risk is equated to a "rare" risk?). People vary in the numerical probabilities they assign to verbal labels. For example, although 1 individual may equate a low risk of a side effect with a 10% risk, another individual may view a low risk as a 1% risk. Given this variability, developers of patient education materials are advised to avoid using verbal descriptions of risks/benefits and instead to provide specific statistical information.

Although it is possible to present statistics using solely numbers (eg, a table), previous research has shown that presenting information in graphical formats results in increased understanding[15] and changes in decision making.[16] Graphs provide a second way for people to process the information (pictorial as well as verbal).[17] Recent psychological research has supported the concept that people utilize 2 parallel systems for learning: a rational or rule-based system and a more intuitive and experiential one.[18,19] Although tabular presentations require cognitive processing that likely only results in analytical learning, graphical displays may facilitate more experiential processing that enables people to learn the gist of the graph without interpreting the details.

However, not all graphical formats are equally effective in communicating risk information.[20-22] Two excellent reviews of graphical communication have explored the strengths, weaknesses, and overall effectiveness of a vast variety of graphs.[21,23] These reviews highlight the importance of understanding the goals of risk communication and choosing graphs that achieve those goals. Is the goal to present single risk numbers or to compare treatments or multiple risks? Alternately, is the goal to show how risk changes over time or the incremental risk that might be caused by a treatment? For instance, line graphs highlight trends (eg, effectiveness of a drug over time), whereas bar graphs allow viewers to compare multiple options. A graph to show the differential rates of impotence following prostate cancer treatment across treatments, therefore, would be better structured as a bar graph than a line graph.

Another consideration in determining which graphical format to use is patients' preferences. When surveyed, adults vary in their preference for graphical format. For instance, Brundage and Feldman-Stewart found that people had a preference for line graphs over bar graphs or text only.[22] In a qualitative study, Schapira et al found that participants preferred pictographs for single probabilities, whereas bar graphs were preferred when multiple risks were presented.[20] However, previous research has also shown that people prefer 3-dimensional bar graphs, but are better at interpreting 2-dimensional bar graphs.[24,25] Thus, designers of risk communication tools need to be aware that giving people their preferred format may not be the most effective way to communicate the risks and benefits of treatment.

What we need to learn. Unfortunately, little research has examined whether patients' ability to understand graphics is affected by numeracy. It is possible that certain types of graphics are more appropriate for low-numeracy individuals, whereas others are more effective for those with high numeracy skills. Furthermore, low- and high- numeracy individuals may differ in their preference for how information is presented. For instance, lower numeracy individuals may prefer pictographs (due to their simplicity) whereas high-numeracy individuals

may prefer bar graphs (because they are more comfortable with analytical representation). Research on graphical presentation of risk needs to include numeracy measures (either objective or subjective) so that we can better understand how numeracy and graphical format interact to affect comprehension and treatment decision making.

Choosing a Denominator for Communicating Risks

What we know. Using a consistent denominator when presenting multiple risks is recommended.[1,14] Thus, when presenting multiple probabilities, it is critical to determine the denominator (10 vs 100 vs 1000 vs 10,000) that will best facilitate consistent comparisons. If only 1 risk is being presented, then there is more latitude in the denominator chosen. Nevertheless, in a qualitative study, participants were suspicious when a numerator of 10 was used, because they were concerned about the sample size from which the data came from, whereas "graphics with larger denominators were perceived as depicting risk of lower magnitude."[20] Furthermore, participants consistently indicated that frequency graphics that used small denominators were viewed as being simple, direct, and easy to interpret.

What we need to learn. Because highly numerate individuals are better able to equate risk statistics presented with different denominators, it is possible that high-numeracy patients will have less need for consistent denominators than would low-numeracy patients. Furthermore, low- and high-numeracy individuals may differ in their preference for the size of the denominator. Further research should explore the role of numeracy in determining the size and consistent use of denominators.

Choosing the Time Span Used to Communicate Risk Statistics

What we know. The choice of time span used to present risks is based on several factors, including the best statistics that are available, the time frame over which events occur, as well as the time frame that is most useful for patients.[26] Often, lifetime frames are chosen. However, Woloshin et al argue that narrower time frames (eg, 10 years) are more appropriate.[27]

When women were asked how they wanted to see their risk of breast cancer presented, women of all ages were least interested in receiving annual risk information. Women aged 40-49 had a preference for receiving risk information in a 10-year time frame because they perceived a decade to be a time frame in which one commonly makes life plans. In contrast, older women preferred lifetime risk information. Similarly, women who perceived their risk of breast cancer as high also preferred to receive lifetime risk data.[20]

The choice of time span has an important impact on people's risk perceptions as well. Evidence suggests that people fail to adjust their risk perceptions to account for longer time spans. For example, telling people they have a 33% risk of serious injury if they fail to use seat belts in a lifetime of car trips yields greater seat belt use than communicating the much smaller risk of injury in a single trip.[28] Even when people receive risk information in survival graph format (which explicitly shows how risk changes with time), they often fail to adjust their risk perceptions to account for the time span displayed, eg, by seeing more risk in 15-year graphs than in equivalent 5-year ones.[29]

What we need to learn. No research has yet demonstrated an effect of numeracy on interpretation of different time spans. However, it is possible that if high-numeracy individuals are better able to perform the computations that provide them with their risk judgments at multiple time points, the choice of time span will not influence those people as much as it does low-numeracy patients, who cannot easily make these computations. High-numeracy patients might, for example, be allowed the flexibility to receive risk data in the time period most salient to their decision making without biasing their perceptions. Clearly, our understanding of how to communicate information across different time spans would be improved by research that includes measures of numerical ability.

Absolute vs Relative Risk Presentation

What we know. When patients are told that a drug decreases the likelihood of a side effect from 3.0% to 1.5%, the information is being presented using an absolute risk presentation. The same reduc-

Table 1
Recommendations for Effective Risk Communication When the Goal Is To Educate Patients About the Risks and Benefits of Treatment

Use multiple format for presenting risk (eg, numbers and graphs). Do not rely only on verbal descriptions of risk.
Use a consistent denominator to facilitate comparisons between multiple risks/benefits.
Present risks in as narrow time span as possible (eg, 10-year rather than life time). Emphasize the time span, as readers often ignore this information if it is not especially salient.
Never only present risk information using relative risk framing. Always provide the absolute risks (and/or absolute change in risk).
Present risk number using frequencies (eg, 1 in 100) instead of (or in addition to) percentage (eg, 1%).
In general, avoid presenting data in exclusively in either a gain or loss frame. Instead use both frames.

tion in risk can also be described using a relative risk format. In a relative risk presentation, patients would be told that the drug cuts their likelihood of experiencing a side effect by 50%.

There is a significant discordance between how patients want to receive risk information and what format has been found to be most accurate. Patients consistently indicate that they would prefer to receive risk information in terms of a relative risk reduction format.[30,31] However, one of the most well documented biases in risk communication is the fact that changes in risk (eg, an increase from 6% to 8%) are perceived as much larger when described in relative risk terms (33% more risk) rather than the absolute risk change (an increase of 2%). This inconsistency is well documented in both psychological and medical decision contexts (particularly when discussing risk reductions where the absolute risk is low).[32-34]

What we need to learn. Although relative risk biases are quite robust, the type of presentation may not have as significant of an impact on high-numeracy patients as for those with low numeracy skills. High-numeracy individuals have the mathematical ability to compute and equate both the relative and absolute risks, regardless of the how the information was presented. However, it is unlikely that low-numeracy individuals would have this same ability. Future research needs to examine how low- and high-numeracy individuals differ in their ability to understand and perform computations for absolute and relative risk information.

Frequencies vs Percentages

What we know. A consistent and robust literature has shown that both patients and physicians show better understanding of risk information (in terms of gross comparison and risk assessment tasks) if risks are presented in terms of frequencies (eg, 5 out of 100 people experience a side effect) rather than in percentages (5%).[35] Furthermore, people prefer to receive risk information in frequencies rather than proportions. Schapira found that people perceived frequencies as more "people-oriented."[20]

Peters and colleagues tested whether both low- and high-numeracy individuals perform better if risks are presented in frequencies rather than percentages.[36] In this study, some participants read the following scenario text: "Of every 100 patients similar to Mr Jones, 10% are estimated to commit an act of violence to others during the first several months after a discharge." A second group had the "%" deleted to create a frequency presentation. Participants then used a 1 (low) to 6 (high) scale to rate the level of risk that Mr Jones would harm someone. Ratings

Table 2
Example of a Poor and an Improved Risk Presentation

Poor risk presentation	Improved risk presentation
"Women who take tamoxifen experience a 50% risk reduction in their likelihood of getting breast cancer."	*"A woman who has a 6 in 100 chance (6%) of developing breast cancer in the next 5 years will have her risk of breast cancer reduced to 3 in 100 (3%) if she takes tamoxifen. This means that the woman would reduce her 5-year risk of developing breast cancer by half."*
Weaknesses: • Numerical information in percentage format only. • Includes relative risk only, no absolute risk information. • No time information.	Advantages: • Provides absolute risk statistics. • Risk data shown in frequencies and percentages. • Risk decrease shown in both absolute and relative risk terms. • Time frame clearly specified.
	In this example we only use loss frame, as gain framing would be both cumbersome and ineffective at enhancing women's understanding of their risk.

by high-numeracy individuals did not differ across conditions. In addition, both high-numeracy groups and the low-numeracy group given frequencies rated the risk of Mr Jones harming someone as medium. However, low-numeracy individuals given percentages rated the risk as lower.

What we need to learn. The results of Peters et al suggest that although low-numeracy individuals perceive risks as different when given frequencies vs percentages, the same is not true for higher numeracy individuals. Thus, future studies testing differences in heath risk perceptions or behavior should include numeracy measures to identify similar interaction effects.

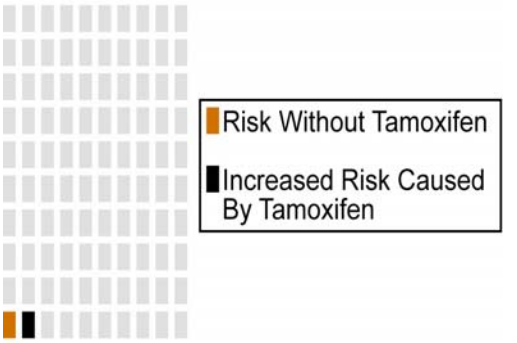
Gain and Loss Frames

What we know. The term *framing effect* refers to the finding that when people are told that a treatment has a 90% chance of survival (gain frame), most want it, whereas when the same treatment is presented as having a 10% chance of death (loss frame), most decline the treatment.[37] Research consistently finds that using gain versus loss frames can achieve different results. For instance, loss frames are more effective at encouraging individuals to engage in detection (eg, mammograms), whereas gain frames are more effective when promoting prevention behaviors (eg use of sunscreen).[38] These findings, however, are more applicable to instances in which the developer of education materials is trying to persuade the reader to take a particular action. When developing a decision aid for individuals who are attempting to make an informed treatment decision, presenting information in only one frame may result in biased decision making. Thus, decision aids may need to present risk statistics in both gain and loss frames.

Peters et al examined whether framing effects differ in low- and high-numeracy individuals.[36] In this study participants rated students' quality of work on a 7-point scale. Framing was manipulated by whether exam scores were described as "74% correct" or "26% incorrect". A framing X numeracy interaction was significant and showed that lower numeracy individuals demonstrated a stronger framing effect than did higher numeracy individuals.

What we need to learn. It is likely that higher numeracy individuals are able to transform the numbers back and forth across the different frames. This suggests that worries about the impact of framing may be limited to those with low

Table 3
Example #2 of a Poor and an Improved Risk Presentation

Poor risk presentation	Improved risk presentation
"Women who take tamoxifen have a small risk of getting cataracts sometime during their lifetime." *"Women who take tamoxifen have a 100% greater chance of developing cataracts in 5 years."*	*"A woman who does not take tamoxifen has a 5-year risk of getting cataracts of 1 in 100 (1%). Taking tamoxifen increases this risk to 2 in 100 (2%). This means that, out of 100 women who take tamoxifen, 98 (98%) will not get cataracts within 5 years."* 
Weaknesses: • Only uses verbal terms to communicate the size of the risk. • Single format: no visual display. • Risk increase described only in relative risk terms. • Uses varying time frames (lifetime and 5-year risk) • Presented only in loss frame.	Advantages: • Includes both numeric and visual formats. • Uses consistent denominator. • Uses a narrow and consistent time span. • Risks shown as frequencies and percentages rather than just percentages. • Increased risk shown in absolute risk terms. • Presents both gain and loss frames.

numeracy. Future research needs to evaluate whether framing impacts both low- and high-numeracy individuals equally.

Summary

Anyone seeking to communicate risk information to patients clearly needs to consider many different factors in order to ensure that the information provided will be effective in helping patients make their medical decisions. Table 1 summarizes our recommendations for communicating information about the risks and benefits of treatments. It is important to note that these recommendations are limited to a decision-making paradigm. If the communicator's goal is to persuade a patient (eg, convince a patient to stop smoking) rather than to inform careful consideration of risk/benefit trade-offs, other risk communication methods might be more appropriate. Tables 2 and 3 present examples of how to (and how not to) communicate the risks and benefits of treatment.

Discussion and Future Directions for Research

The research summarized above shows that risk perceptions and medical decision making can often be significantly influenced by risk communication methods. For example, presenting information in terms of relative risk rather than absolute risk can change people's decisions. Although rationally these differences should not affect decision making—after

all, it is still the same numbers and the same risks— they often do.

What is not yet known is whether numeracy interacts with these communication methods. Are higher numeracy individuals immune to differences in risk presentation? Is their numerical ability sufficiently strong that their risk perceptions are stable across multiple ways of presentation? Future research on risk communication must include measures of numeracy (either objective or subjective) so that we can better understand whether the impact of risk communication differs among people with low and high numeracy abilities.

Another potential area for research is testing whether there is a preferred way to present information to patients with low numeracy and a different way to present information to high-numeracy individuals. If so, then it may be necessary to tailor risk communications to meet the requirements of patients with differing numeracy levels. For instance, it may be that low-numeracy individuals do not benefit from survival curves (and survival curves may actually hinder understanding), but that high-numeracy individuals benefit from the information. In this case it may be necessary to tailor the use of survival curves. Numerous studies have consistently shown that tailoring improves patient behaviors such as smoking cessation, mammography screening, and improving dietary habits.[39,40] This research has also suggested that tailoring might be more effective in low-socioeconomic patients. Tailoring risk communication methods could be an additional effective way to improve patients', and especially low-numeracy patients', understanding of the risks and benefits of treatment. Future research should examine whether tailoring risk communication methods impacts risk perceptions and medical decision making.

As patients rely more and more on written materials (eg, the Internet and decision aids) to learn about their new diagnoses and treatment options, it becomes critical that we better understand how to communicate the risks and benefits of treatment in a way that people can understand and can integrate into their medical decision making. Risk communication research needs to determine how different presentation methods affect people who differ in numeracy or other individual characteristics such as need for cognition. If we do discover that different risk-communication methods work better in low- (or high-) numeracy individuals, future communications should use this information to tailor materials based on the needs of the patient.

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