# 7 Using visual aids to help people with low numeracy make better decisions

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To effectively participate in decision making, patients and healthcare professionals need to understand the risks and benefits of different medical treatments, screenings, and lifestyle choices (Garcia-Retamero & Galesic, 2013). Unfortunately, research indicates that people often struggle to grasp numerical concepts that are essential for understanding and communicating health-relevant information (Reyna et al., 2009; Peters, 2012; Garcia-Retamero & Galesic, 2013; Chapters 2 and 4 in this volume). Even highly educated individuals tend to have difficulties understanding and manipulating a host of elementary probability expressions (Ancker & Kaufman, 2007). In short, the general public lacks basic numeracy, which limits their risk literacy (i.e., the ability to accurately interpret and make good decisions based on information about risk; Galesic & Garcia-Retamero, 2010; Cokely et al., 2012). (For major assessments of risk literacy in large adult and student samples see Kutner et al., 2006 and OECD, 2012.)

Over the past 20 years, numerical reasoning skills have become increasingly necessary for navigating the modern healthcare environment (Fagerlin et al., 2007; Apter et al., 2008; Keller & Siegrist, 2009). For example, people with low numeracy have less accurate perceptions of the risks and benefits of screenings and medical treatments (Schwartz et al., 1997; Davids et al., 2004; Donelle et al., 2008), which reduces their medication compliance and impairs risk communication (Reyna et al., 2009). People with low numerical ability are also especially vulnerable to having difficulty with following a complicated dosing regimen (Estrada et al., 2004), they have more hospitalizations (Apter et al., 2006), they have more deficits in understanding nutrition labels necessary

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to following dietary recommendations (Rothman et al., 2006), and they are more susceptible to being influenced by the way the health information is framed in problems involving probabilities (Peters et al., 2006). Moreover, people with low numeracy are generally less willing to participate in decision making about their health (Galesic & Garcia-Retamero, 2011a; Garcia-Retamero et al., in press).

Visual aids are simple graphical representations of numerical expressions of probability and include bar and line charts and icon arrays, among others (Paling, 2003; Spiegelhalter et al., 2011). Visual aids have long been known to confer benefits when communicating risk information. However, not all visual aids are equally effective. Visual aids tend to provide an effective means of risk communication when they are *transparent* (Garcia-Retamero & Cokely, 2013) – that is, when their elements are well defined and they accurately and clearly represent the relevant risk information by making part-to-whole relationships in the data visually available (Ancker et al., 2006; Reyna & Brainerd, 2008). (For good practices for designing transparent visual aids, see the guidelines of the Human Factors and Ergonomics Society; Gillan et al., 1998). For example, appropriately designed visual aids improve comprehension of risks associated with different medical treatments, screenings, and lifestyles, and they promote consideration of beneficial treatments despite side effects (Paling, 2003; Lipkus, 2007; Waters et al., 2007; Zikmund-Fisher et al., 2008a). Visual aids also increase appropriate risk-avoidance behaviors, they promote healthy behaviors, they reduce errors induced by anecdotal narratives (Fagerlin et al., 2005; Schirillo & Stone, 2005; Cox et al., 2010), and they can aid comprehension of complex concepts such as incremental risk (Zikmund-Fisher et al., 2008b). Risk information presented visually is also judged as easier to understand and recall, and requires less viewing time than the same information presented numerically (Feldman-Stewart et al., 2007b; Goodyear-Smith et al., 2008; Gaissmaier et al., 2012). Nevertheless, the benefits of visual aids are different for different people. Our hypothesis is that visual aids might be especially useful for people with low numeracy. In the following sections, we describe the results of a series of studies supporting this hypothesis and provide some guidelines for transparent risk communication by using visual aids.

## Using visual aids to improve risk understanding in people with limited numeracy

People with high numeracy can often understand health risks even if visual aids are not provided (Galesic et al., 2009; Keller & Siegrist, 2009). The challenge is to reach vulnerable people with low numeracy as they are likely to make errors or avoid decision making altogether (Hawley et al., 2008; Peters et al., 2009). Recently, Galesic and Garcia-Retamero (2011b) revealed that people, regardless of their numeracy skills, differ substantially in their ability to understand graphically presented quantitative information. The authors developed a graph literacy scale and investigated the distribution of graph literacy in probabilistic national samples in the USA and Germany. The graph literacy scale consists of 13 items and measures several abilities of graph comprehension (Friel et al., 2001); covers four frequently used graph types – line plots, bar charts, pies, and icon arrays; and includes items dealing with the communication of medical risks, treatment efficiency, and prevalence of diseases.

In a related study, Garcia-Retamero and Galesic (2010b) showed that well designed visual aids can improve risk understanding in people with limited numerical skills to the level of those who are more skilled in understanding risks as long as they have relatively high graph literacy. In particular, the authors investigated whether numeracy and graph literacy affect the efficacy of visual aids reporting information about treatment risk reduction. Participants were probabilistic national samples in the USA and Germany, and completed the graph literacy scale of Galesic and Garcia-Retamero (2011b) and a numeracy scale consisting of nine items selected from Schwartz et al. (1997) and Lipkus et al. (2001). Participants were classified in four groups depending on whether their numerical and graph literacy skills were above or below the median scores of their group. The authors compared the efficacy of different types of visual aids (i.e., icon arrays and bar graphs), representing either affected individuals only or the entire population at risk (see Figure 7.1). In addition, they tested the efficacy of visual aids when the numerical information added to the visual aids was presented either as absolute or relative risk reduction. When the information was presented in absolute terms, participants were told: "Of the patients who took a placebo, 20 had a stroke. Compared to the group that took a placebo, 5 fewer patients had a stroke in the group that took Vitarilen." When the information was presented in relative terms, participants were told: "Compared to the group that took a placebo, the relative reduction in risk of having a stroke in the group that took Vitarilen was 25%."

Results were clear: Garcia-Retamero and Galesic (2010b) observed similar increases in accuracy with icon arrays and bar graphs; visual aids were useful additions when the numerical information was presented both in terms of absolute and relative risk reductions; and they were especially useful when they represented the entire population at risk. Importantly, results showed that visual aids were most beneficial for individuals who

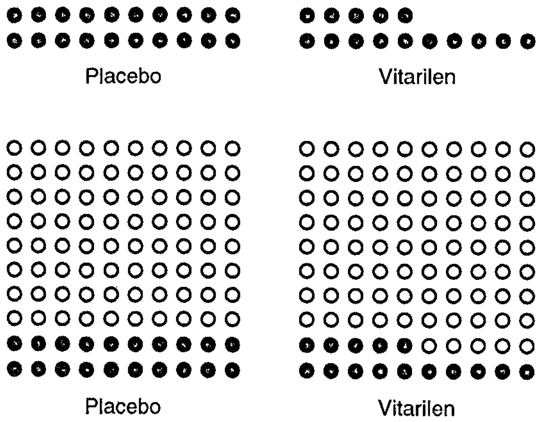


Figure 7.1. Icon arrays presented in addition to numerical information about risk reduction when they represent affected individuals only (top) or the entire population at risk (bottom). (Reprinted from *Social Science & Medicine*, 70(7), April 2010, "Who profits from visual aids: Overcoming challenges in people's understanding of risks" by Rocio Garcia-Retamero and Mirta Galesic, with permission from Elsevier.)

had low numeracy but relatively moderate-to-high graph literacy, especially when the visual aids presented the entire population at risk (see Figure 7.2). Among this group of people, accuracy increased from less than 20% to nearly 80% when visual aids were used. In fact, providing visual aids about the effectiveness of medical treatments eliminated the differences between these people and those with high numeracy. Unfortunately, people with both low numeracy and low graph literacy did not benefit from visual aids (see also Gaissmaier et al., 2012).

Visual aids are also helpful to other vulnerable populations with limited numerical skills. Due to age-related cognitive decline and other cohort effects, older adults often struggle with numerical concepts (Finucane et al., 2002). Given that older adults more frequently suffer chronic diseases and confront health-related decision making, the challenges when dealing with health risks are magnified (Peters et al., 2000, 2007). A study by Garcia-Retamero et al. (2010) showed that visual aids can help less numerate, older adults make accurate assessments of the effectiveness of medical treatments. However, visual aids confused rather than helped some older adults. Again, those people who were both low in numeracy and low in graph literacy did not benefit from the visual aids (Ruiz et al., 2013). Garcia-Retamero and Dhami (2011) showed similar results in immigrants with limited language and numerical skills.

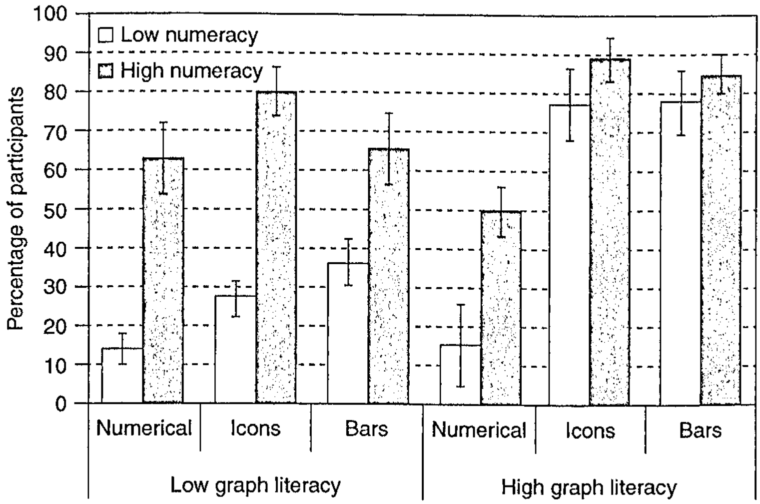


Figure 7.2. Percentage of participants with low and high graph literacy and numeracy who correctly inferred treatment risk reduction, by visual aids condition. In the visual aids conditions, icon arrays and bars reported the entire population at risk. Error bars represent one standard error.

## Using visual aids to reduce biases in people with limited numeracy

Visual aids can also reduce or eliminate several biases with important consequences for decision making. A prominent example is *denominator neglect* – the tendency to focus on the number of times a target event has happened (i.e., the numerator), while ignoring the overall number of opportunities for it to happen (i.e., the denominator; Reyna, 2004). To illustrate, in clinical trials the number of patients who receive a certain drug is often smaller than the number of those who do not. If people disregard denominators, neglecting the overall number of treated and non-treated patients (e.g., 100 and 800, respectively), they might perceive the drug to be more effective than it actually is. In other words, they might only compare absolute numbers of treated and non-treated patients who do not recover or die (e.g., 5 versus 80, respectively) rather than the proportion of treated and non-treated patients who do not recover or die (e.g., 5 of 100 and 80 of 800 for a treatment risk reduction of 50%; see Figure 7.3).

Past laboratory research examining perceptions of treatment risk reduction has often employed samples of treated and non-treated patients of the same size. However, this research is not representative of the type of

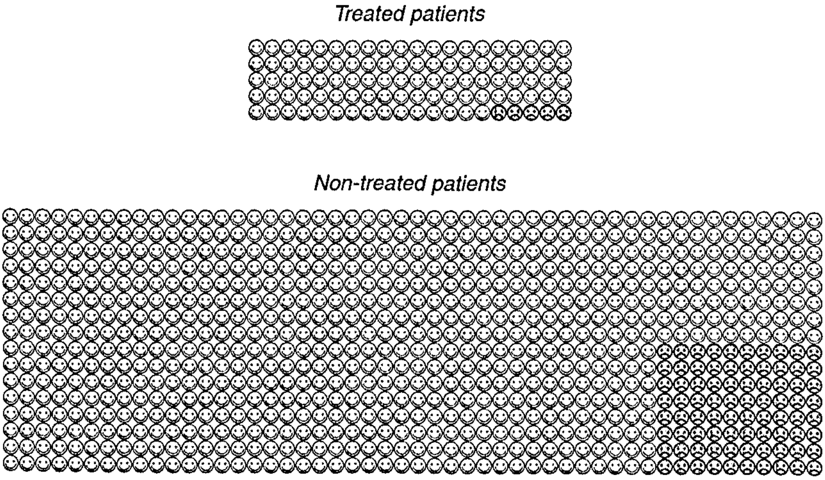


Figure 7.3. Icon arrays representing a treatment risk reduction of 50% with unequal samples of treated and non-treated patients (i.e., 100 and 800, respectively). Patients who died are represented in dark gray; healthy patients are represented in light gray.

information that people normally encounter when they assess the effectiveness of medical treatments (Garcia-Retamero et al., 2012). To address this concern of ecological validity, Garcia-Retamero and Galesic (2009) conducted a study reporting numerical information about the effectiveness of medical treatments using unequal samples of treated and non-treated patients. In particular, the overall numbers of treated and non-treated patients (i.e., the sizes of the denominators) were manipulated to be either 800 or 100 (see Table 7.1). To keep treatment risk reduction constant (i.e., 50%), the sizes of the numerators (i.e., the number of treated and non-treated patients who died) varied within conditions depending on the sizes of the denominators. Independently of this manipulation, half of the participants received – in addition to the numerical information about risk reduction – two icon arrays presenting such information (Figure 7.3 shows the icon arrays of the 100–800 condition). Again, participants were probabilistic national samples in the USA and Germany, and completed a numeracy scale consisting of nine items selected from Schwartz et al. (1997) and Lipkus et al. (2001). They were then classified in two groups depending on whether their numerical skills were above or below the median scores of their group.

Garcia-Retamero and Galesic (2009) showed that participants exhibited denominator neglect when the information about the medical treatment

Table 7.1. *Number of treated and non-treated patients who died in the scenarios with different denominator sizes.*

| | Treated patients | | Non-treated patients | |
|---|---|---|---|---|
| Sizes of denominators[a] | Dead patients | Population size | Dead patients | Population size |
| 800–800 | 40 | 800 | 80 | 800 |
| 100–800 | 5 | 100 | 80 | 800 |
| 800–100 | 40 | 800 | 10 | 100 |
| 100–100 | 5 | 100 | 10 | 100 |

Treatment risk reduction is 50% in all conditions.
[a] Treated and untreated patients, respectively.

was provided only numerically. That was especially the case in participants with relatively low numeracy. In particular, 71% of these participants *over-estimated* treatment risk reduction when the overall number of treated patients was lower than the overall number of patients who did not receive the treatment (i.e., in the 100–800 condition), whereas only 25% of the participants with high numeracy provided a lower estimate than the exact value in that condition (see Figure 7.4). Note that in such a case, the number of patients who received the treatment and died (N = 5) is much lower than the number of patients who did not receive the treatment and died (N = 80; see Table 7.1). It seems likely that many participants – especially those with low numeracy – did not take proportions into account but only absolute numbers in the numerators, which would have led them to believe that the treatment had a larger effect than it actually did.

In contrast, 67% of the participants with low numeracy *underestimated* risk reduction when the number of treated patients was higher than the number of patients who did not receive treatment (i.e., in the 800–100 condition), whereas only 19% of the participants with high numeracy provided a higher estimate than the exact value in that condition. In such a case, the number of patients who received the treatment and died (N = 40) is higher than the number of patients who did not receive the treatment and died (N = 10; see Table 7.1). This might have led participants – especially those with low numeracy – to believe that the treatment had a smaller effect than it actually did.

Finally, results showed that denominator neglect was effectively eliminated by using visual aids representing the risk information. This was particularly the case among participants who were less skilled in using numerical information. When the sizes of the denominators were different

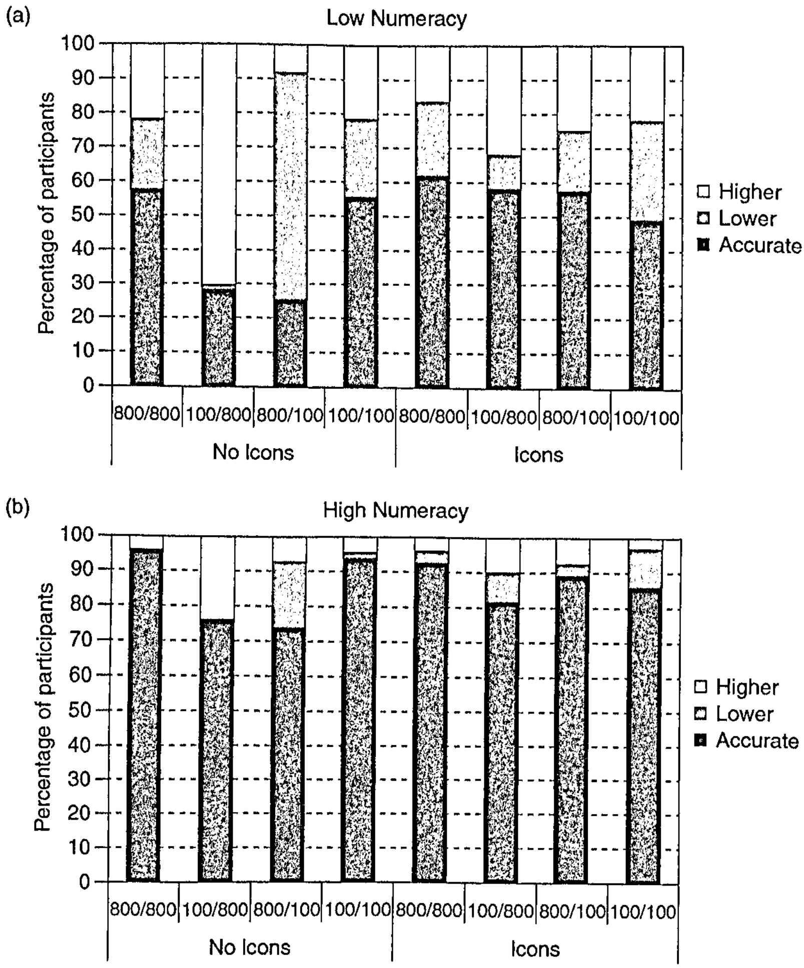


Figure 7.4. Percentage of participants with low (a) and high (b) numeracy whose estimates of risk reduction were either accurate or lower or higher than the exact value as a function of the sizes of the denominators and icon arrays. (Reprinted from *American Journal of Public Health*, 99(12), December 2009, "Communicating treatment risk reduction to people with low numeracy skills: A cross-cultural comparison" by Rocio Garcia-Retamero and Mirta Galesic, with permission from The Sheridan Press on behalf of The American Public Health Association.)

and icon arrays were added to the numerical information, the percentage of low numeracy participants who estimated the treatment risk reduction incorrectly decreased from 74 to 42%, and from 26 to 15% in participants with high numeracy. These percentages (i.e., 42 and 15%) are similar to those when the sizes of the denominators were equal (i.e., 45 and 22% for high and low numeracy participants). Thus, participants' estimates of risk reduction were not influenced by the sizes of the denominators when icon arrays were provided. Okan et al. (2012a) conducted a similar study in a large sample of undergraduate students in Spain. Participants completed the graph literacy scale of Galesic and Garcia-Retamero (2011b) and were classified in two groups depending on whether their graph literacy skills were above or below the median scores of their group. The authors showed that visual aids were effective for reducing denominator neglect in participants with relatively high – but not low – graph literacy.

Visual aids also reduce the influence of other errors and biases in populations with limited numerical skills, including the effect of message framing. Garcia-Retamero and Galesic (2010a) examined the effect of framed messages in perceptions of the effectiveness of medical surgery. The surgery was described in positive (i.e., "991 in 1000 people survive this surgery") or negative (i.e., "9 in 1000 people die from this surgery") terms. As in some of the studies described above, participants were probabilistic national samples in the United States and Germany, and completed a numeracy scale consisting of nine items selected from Schwartz et al. (1997) and Lipkus et al. (2001). They were classified in two groups depending on whether their numerical skills were above or below the median scores of their group. All participants answered a question about the effectiveness of the surgery. Half of the participants answered the question when the surgery was described in negative terms first, while the remaining participants answered the question when the surgery was described in positive terms first. Between the two questions, all participants answered a set of unrelated problems. The provision of visual aids – in addition to the numerical information about the effectiveness of the surgery – was manipulated between subjects across five conditions. In the four visual aids conditions, the number of patients who died and survived from surgery was represented using an icon array, a horizontal bar graph, a vertical bar graph, or a pie chart (see Figure 7.5). Participants in the numerical condition did not receive visual aids but received only the numerical information.

Garcia-Retamero and Galesic (2010a) showed that participants with low numeracy were more susceptible to framing than those with high numeracy (see also Peters & Levin, 2008, and Peters et al., 2006 for similar results in other unrelated topics). When only numerical information was provided,

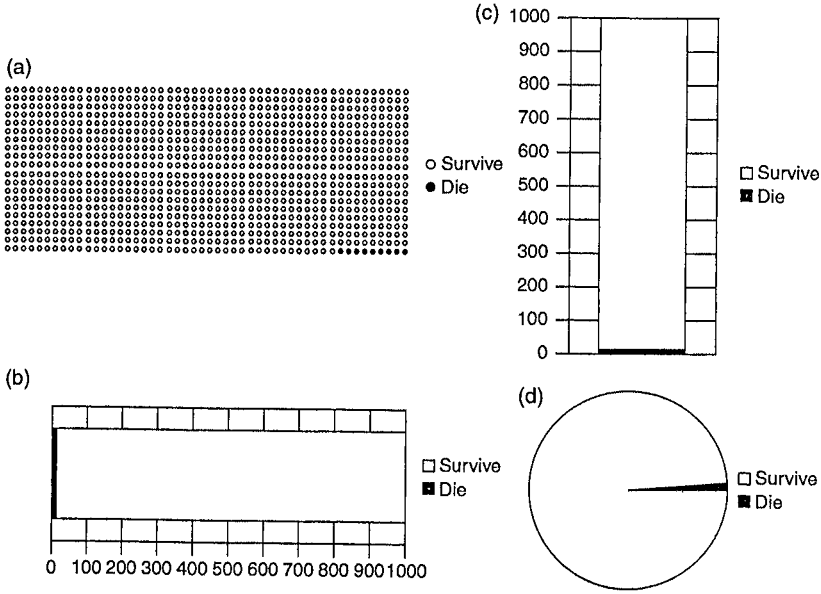


Figure 7.5. (a) Icon array presented in Condition 1; (b) horizontal bar graph presented in Condition 2; (c) vertical bar graph presented in Condition 3; and (d) pie chart presented in Condition 4. All figures represented the number of people who died (i.e., 9) and survived (i.e., 991) from the surgery. (Reprinted from *Journal of General Internal Medicine*, 25(12), January 1, 2010, "How to reduce the effect of framing on messages about health" by Rocio Garcia-Retamero and Mirta Galesic, with kind permission from Springer Science and Business Media.)

participants with low numeracy often perceived the surgical procedure as less risky when the associated risk was presented in positive terms (i.e., chances of surviving) than in negative terms (i.e., chances of dying). In contrast, participants with high numeracy often provided equal estimates when the risks were expressed in positive and negative terms. Accordingly, the average difference between perceptions of the risk of the surgery expressed in positive and negative terms in the numerical condition was 0.90 (SEM = 0.12) and 0.10 (SEM = 0.06) for participants with low and high numeracy, respectively. When visual aids were added to the numerical information, the effect of framing was reduced in low-numeracy participants. The average difference between perceptions of the risk of the surgery expressed in positive and negative terms in the visual conditions was 0.16 (SEM = 0.09) for participants with low numeracy. In contrast, participants more skilled in using quantitative information benefited less from visual aids. For these participants, the average difference between perceptions of the risk expressed in positive and negative terms was similar when they received (0.21; SEM = 0.08) and did not receive visual aids (0.10; SEM = 0.06). Recent behavioral interventions involving visual aids indicate that these aids can also reduce the effect of framed messages promoting health behaviors in patients with low numeracy.

## Behavioral interventions involving visual aids

Messages promoting a health behavior can be framed in terms of the benefits afforded by adopting the behavior (a gain-framed appeal) or in terms of the costs associated with failing to adopt the behavior (a loss-framed appeal; see Rothman et al., 1999). To illustrate, a message promoting condom use can emphasize the benefits of this practice (e.g., using condoms helps prevent sexually transmitted diseases or STDs) or the costs of avoiding this practice (e.g., failing to use condoms increases the risk of STDs – a loss-framed appeal; see Garcia-Retamero & Cokely, 2012 for a review). In a longitudinal study, Garcia-Retamero and Cokely (2011) examined the effects of a brief risk awareness intervention (i.e., a sexual health information brochure) in a large sample of sexually active young adults in Spain. These participants had very limited numerical skills according to the nine-item numeracy scale described above. Garcia-Retamero and Cokely (2011) showed that gain-framed messages induced greater adherence for a prevention behavior (e.g., condom use), whereas loss-framed messages were more effective for promoting an illness-detecting behavior (e.g., STD screening; see Figure 7.6). This was the case even if the two types of framed messages were comparable. However, when visual aids reporting numerical information about STDs were added to the health information, both the gain- and loss-framed messages became equally and highly effective (i.e., the framing bias was eliminated). Providing the same information in numbers did not reduce the effect of the framed messages.

Follow-up interventions conducted in large samples of sexually active young adults in Spain showed that well-constructed visual aids were as effective as an extensive 8–10 hour "best practices" educational program for promoting condom use (Garcia-Retamero & Cokely, in press a). Young adults disadvantaged by their lack of numerical skills benefitted more from the visual aids than those who had higher numeracy as long as they were moderately graph literate (Garcia-Retamero & Cokely, in press b).

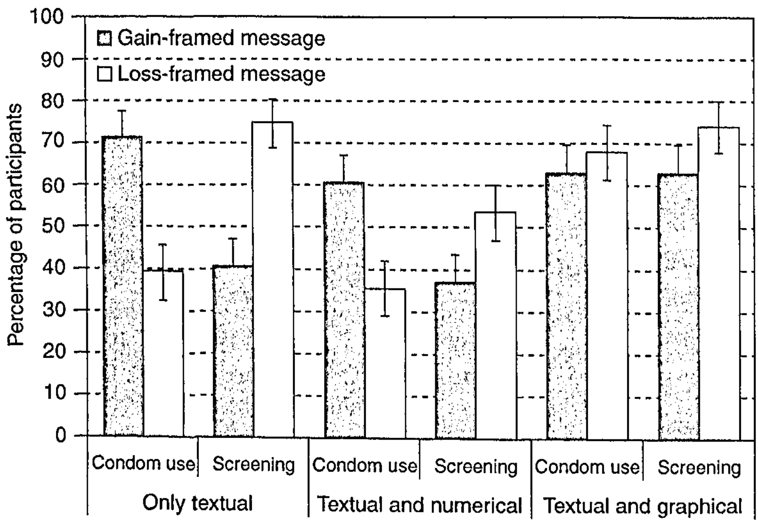


Figure 7.6. Percentage of participants who reported performing the promoted behavior (condom use or STD screening) when the health information brochure was framed as gains or losses as a function of message format (text only, text and numerical information, and text and graphical information). Error bars represent one standard error.

Ongoing research indicates that visual aids can also encourage patients' trust in their own physician and their willingness to participate in decision making about their health. Visual aids seem particularly beneficial for patients who have relatively low numeracy – a group that generally tends to be more passive in health decision making (Galesic & Garcia-Retamero, 2011a). Visual aids have also been found to boost accuracy above and beyond the effect of other transparent information formats. For instance, doctors and their patients often have difficulties inferring the predictive value of medical tests from information about the prevalence of diseases and the sensitivity and false-positive rate of the tests (Gigerenzer & Hoffrage, 1995; Hoffrage & Gigerenzer, 1998). Communicating information about the tests in natural frequencies as compared to conditional probabilities improves diagnostic inferences (Hoffrage et al., 2000a, 2000b). However, our research shows that visual aids improve these inferences in doctors and their patients beyond the effect of natural frequencies (Garcia-Retamero & Hoffrage, 2013). This research also indicates that doctors tend to be more accurate in their diagnostic inferences than their patients – a difference in accuracy that disappeared when differences in numerical skills were controlled for.

## What have we learned so far?

The research reviewed in this chapter shows that well designed visual aids can be especially useful for people with limited numerical skills as long as they have moderate-to-high levels of graph literacy. Although less numerate people typically have problems understanding risks, visual aids confer benefits and can raise their performance to the level of those who are more skilled in using numerical information. In short, our research converges to suggest that well-constructed visual aids offer a highly effective, transparent, and ethically desirable means of risk communication.

Although our studies take center stage in the current chapter, it is important to note that this work contributes to a large, active interdisciplinary field (see Ancker et al., 2006; Lipkus, 2007; Zikmund-Fisher et al., 2008a, 2008b; Keller & Siegrist, 2009; Reyna et al., 2009; Peters, 2012). In addition, our conclusions are likely to be robust as they are based on a variety of studies conducted in the general public (e.g., large, probabilistic national samples) and in diverse groups of patients from a wide range of countries (e.g., the USA, Germany, Great Britain, and Spain). These studies examined risk communication in different ecologically valid tasks that accurately reproduce the problems that people commonly encounter when they face health decisions. These ecological studies covered diverse topics including estimates of risk and risk reduction; diagnostic inferences and perceptions of treatment effectiveness; confidence and accuracy; and changes in attitudes, behavioral intentions, actual behaviors, and decision making. In addition, the general findings hold across different types of visual aids (e.g., icon arrays, bar charts, and line plots, presenting either affected individuals only or these individuals and the entire population at risk); when visual aids differ in iconicity (i.e., when they are more or less abstract; see also Gaissmaier et al., 2012); when visual aids are provided either in addition to or instead of numerical information; and when the numerical information is presented using different information formats (e.g., absolute or relative risks; see Garcia-Retamero & Galesic, 2013 and Garcia-Retamero & Cokely, 2013).

Our research adds to the literature by showing that problems associated with risk illiteracy are not simply the result of limited capacities or inherent cognitive biases that prevent good decision making (see also Gigerenzer et al., 2007; Gigerenzer & Gray, 2011). Instead, errors occur because ineffective information formats can complicate and mislead adaptive technologies other than visual aids (see Estrada et al., 2004; Apter et al., 2006; Amalraj et al., 2009 for some preliminary results)? Research should also determine what healthcare system designs support the information needs of patients with different levels of numeracy (see Chapter 9 of this volume).

Looking forward, risk communication will increasingly be integrated with information technology. There are well established standards for the construction of decision aids (IPDAS; see Feldman-Stewart et al., 2007a; for more information see ipdas.ohri.ca/), and theories of risk literacy and graph literacy are now starting to be embodied in adaptive instruments and software. Some such programs provide free online tools allowing anyone to build better graphs (e.g., www.iconarray.com). Other online programs provide fast, free, validated assessments of risk literacy for use by researchers and the public alike (e.g., www.RiskLiteracy.org; see also GraphLiteracy.org available summer 2014). The use of similar instruments may eventually help healthcare professionals quickly assess individual differences in risk literacy, with only a couple of questions. Adaptive, internet-based tutoring programs and custom-tailored educational brochures are also under development. These interactive educational and decision aid technologies hold great promise for leveraging what we already know about communicating risk and supporting informed decision making.

## Conclusion

The ideal of informed and shared decision making requires that patients understand health risks. Unfortunately, most patients are not sufficiently risk literate and thus are easily biased by commonly used risk communication formats. In this chapter, we reviewed a collection of studies investigating the benefits of visual aids for communicating health risks to individuals with different levels of numeracy. Results indicate that well-constructed visual aids are often highly effective, transparent, fast, memorable, and ethically desirable risk communication tools.

## Recommended online resources

www.iconarray.com. Create tailored, embeddable icon-based risk graphics for use in risk communications, free of charge for all academic and non-commercial uses.

www.RiskLiteracy.org. With this adaptive test, in about 3 minutes, you can assess your ability to accurately interpret risk as compared to educated people from around the world.

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