The 1-in-*X* Effect on the Subjective Assessment of Medical Probabilities

Stefania Pighin, PhD, Lucia Savadori, PhD, Elisa Barilli, PhD, Laura Cremonesi, Maurizio Ferrari, Jean-François Bonnefon

Among numerical formats available to express probability, ratios are extensively used in risk communication, perhaps because of the health professional's intuitive sense of their clarity and simplicity. Moreover, health professionals, in the attempt to make the data more meaningful, tend to prefer proportions with a numerator of 1 and shifting denominators (e.g., 1 in 200) rather than equivalent rates of disease per unit of population exposed to the threat (e.g., 5 in 1000). However, in a series of 7 experiments, it is shown that individual subjective assessments of the same probability presented through proportions rather than rates vary significantly. A 1-in-X format (e.g., 1 in 200) is subjectively perceived as bigger and more alarming than an N-in-X*N *format (e.g., 5 in 1000). The 1-in-X effect generalizes to different populations, probabilities, and medical conditions. Further-more, the effect is not attenuated by a communicative intervention (verbal analogy), but it disappears with an icon array visual aid.* ***Key words:*** probability assessment; risk communication; numerical risk format ***(Med Decis Making XXXX;XX:xx-xx)***

Increasing emphasis has been placed on the way doctors communicate risk to patients.[1–5] Health communication research pointed out that, because of time constraints, much of the information that doctors have to communicate needs to be summarized and simplified, and doctors might frequently rely on raw numbers to communicate clinical risks.[6,7] Among numerical formats available to express probability, ratios are extensively used in risk communication, perhaps because of the practitioners' intuitive sense of their clarity and simplicity.[8] In particular, health practitioners tend to prefer proportions with a numerator of 1 and shifting denominators in the expression of risks (e.g., 1 in 200) rather than equivalent rates of disease per unit of population exposed to the threat, normally per 1000 people (e.g., 5 in 1000). Although this inclination seems to result from a spontaneous attempt to make the population size statistics more understandable to the public[9] and from the intuition that this format might be especially motivating,[10] experimental evidence nevertheless exists that laypeople understand proportions no better than rates.[9,11,12] No clear experimental evidence, however, exists to say whether the presentation of the same probability through proportions rather than rates varies patients' subjective probability assessment as well.

Starting in the 1990s, various empirical studies considered whether different ratio formats denoting the same objective probability (e.g., 1 in 10 v. 10 in 100 or, more generally, 1 in *X* vs. *N* in *X*N*) could vary choices and subjective evaluations. These studies delivered contrasting results. On one hand, Kirkpatrick and Epstein[13] suggested that people tend to neglect denominators, preferring for example a lottery with a 10-in-100 chance of winning to a lottery with a 1-in-10 chance of winning. That phenomenon was dubbed the ratio-bias effect by some authors,[14–16] whereas other authors simply explained it as a "denominator neglect."[17,18] On the other hand, Yamaguchi[19] suggested that when people are asked to evaluate a threat whose likelihood is kept constant,

---

Received 15 September 2010 from the Centre National de la Recherche Scientifique and Université de Toulouse, Toulouse, France (SP, J-FB); the Department of Cognitive Science and Education, University of Trento, Trento, Italy (LS, EB); and HSR–University Hospital of San Raffaele, Milan, Italy (LC, MF). This research was supported by the European Commission ("Special Advances in Foetal and Neonatal Evaluation Network" Project N:LSHB-CT-2004-503243) and by grant ANR-07-JCJC-0065-01. The authors thank Natascia Cont for her help in data collection. Revision accepted for publication 15 January 2011.

Address correspondence to Stefania Pighin, Department of Cognitive Science and Education, University of Trento, Corso Bettini, 31, 38068 Rovereto, Trento, Italy; e-mail: stefania.pighin@unitn.it.

DOI: 10.1177/0272989X11403490

they tend to rate the threat as more probable when it will affect 1 person in 10 than when it will affect 10 persons in 100. That phenomenon, dubbed the group-diffusion effect, suggests that people neglect numerators rather than denominators (for a comparison between ratio-bias and group-diffusion effect, see Price and Matthews[20]). A germane effect was observed in charitable donations.[10,21,22] In particular, Small and others[23] showed that donations to charities can actually decrease when moving from one recipient to multiple ones.

A general limitation of previous research is that it presented people with the same probability couched in 2 formats, and asked for a direct comparison between the 2 formulations.[*] This method might compromise the ecological validity of the results if we consider the domain of medical risk communication. Presumably, doctors rarely explain to patients that one treatment has a 1-in-10 chance to succeed, whereas the other has a 10-in-100 chance to succeed. Using different ratio formats for 2 probabilities that are trivially the same, besides being in principle not advisable because the employment of different denominators in the ratios does not favor a sound comprehension and comparison of likelihood magnitudes,[5,25] would surely be an odd communicative move.

Patients are more often confronted with a single prospect whose likelihood is conveyed through either one format or the other (or with 2 equally likely options whose likelihood is conveyed through the same format).

Moreover, patients are frequently required to evaluate clinical risks without having the contextual knowledge that would support consistent risk perceptions. Very often, risks cannot be compared against each other, and they have to be evaluated on an absolute scale (for an exhaustive review concerning the differences between joint and separate evaluations and on how these 2 evaluation modes differently affect preferences, see Lichtenstein and Slovic[26]). The present research focuses on a relatively less evaluable context where only separate evaluations are possible.

In experiment 1, we show that the likelihood of a clinical condition is subjectively perceived as bigger and more alarming when expressed as 1 in *X* (e.g., 1 in 200) rather than when expressed as *N* in *X*N* (e.g., 5 in 1000). In experiment 2 (2a, 2b, 2c, and 2d), we generalize this effect to different populations, probabilities, and medical conditions, ruling out some possible explanations. Finally, in experiments 3 and 4, we investigate the effectiveness of 2 communicative interventions (frequently used in medical practice) to attenuate or even eliminate the 1-in-*X* effect.

EXPERIMENT 1

Experiment 1 was intended to investigate whether the ratio format (1 in *X* v. *N* in *X*N*) used to convey a medical message affects patients' subjective probability assessment of a clinical risk and, in case an effect is found, the direction of such influence.

Method

A total of 63 women (mean [*s*] age 33.6 [4.7]), patients of the maternity ward of an Italian hospital, volunteered to take part in a study on risk communication and completed a questionnaire.[†] Most of the participants had concluded high school (53%) or had already one university degree (34%), and only few participants (13%) had achieved the lowest education level in Italy. A single independent variable (ratio format: 1 in 200 v. 5 in 1000) was manipulated in a between-subjects design. In this experiment and all that follow, participants were randomly assigned to the experimental conditions. All experiments were conducted in Italian, and all the material presented here is an English translation of the Italian original version. Participants read the following scenario:

> Imagine that you have bought a trip to Kenya and you have just read that the risk of being affected by malaria while traveling to Kenya is [1 in 200; 5 in 1000].

---

[*] Yamagishi's study[17] is an exception with respect to the use of a direct comparison paradigm. In his study, participants were asked to judge the riskiness of various causes of death when the death rates were presented as ratios using either large or small denominators according to the experimental session and with a 7-day interval between the consecutive sessions. Participants' judgments appeared to be associated to the numerators more than the denominators. As claimed by Price and Matthews, this result could be ascribed to the small amount of "attention drawn to the denominator versus the numerator of the relevant ratio."[20(p445)] Indeed, it has to be noted that in Yamagishi's study, participants were informed about the denominator (or base rate) at the beginning of the session only. The information regarding the denominator was not repeated for each judgment in Yamagishi's study, and this absence may have affected participants' judgments, giving rise to the denominator neglect effect. The same objection can be raised with respect to the study by Zickmund-Fisher and others,[24] which partially supported Yamagishi's findings.

[†] All participants of the 7 experiments of this research were volunteers and did not receive any reward or incentive to participate. They all answered a single questionnaire.

Three dependent variables were measured: the subjective probability assessment, the perceived severity of contracting malaria, and the degree to which this information would be worrisome. Specifically, 3 questions were asked: "In your opinion, the probability of being affected by malaria while traveling to Kenya is . . ." (7-point scale anchored at *extremely low* and *extremely high*); "Malaria is a disease that is . . ." (5-point scale anchored at *not severe at all* and *extremely severe*); and "How worried would you be about the probability of [1 in 200; 5 in 1000] of being affected by malaria while traveling to Kenya?" (7-point scale anchored at *not worried at all* and *extremely worried*). Responses were analyzed using multivariate analysis of variance. Two-tailed statistical tests and a critical alpha of .05 were used in all data analyses in this study, except when noted.

Results

Figure 1 displays the mean values of the 3 dependent measures as a function of the ratio format used to communicate the risk in the 2 experimental conditions of experiment 1.

The visual inspection of Figure 1 immediately suggests that changing the ratio format changed patients' subjective assessments of probability, as well as the degree they find the risk worrisome, while not affecting the subjective severity of malaria.

Ratio format had a global impact on our set of dependent measures, F (3, 59) = 2.8, $P < 0.05$, partial $\eta^2 = .13$. This global impact, though, was the result of a localized impact on the probability and worry measures, rather than on the severity measure. The mean (s) subjective probability assessment was 3.8 (1.0) when it was phrased as "1 in 200" and only 3.1 (1.2) when it was phrased as "5 in 1000," a significant difference, F (1, 61) = 6.3, $P = 0.01$, partial $\eta^2 = .09$. Similarly, mean (s) worry about the risk was 5.2 (1.2) when the probability was phrased as "1 in 200" and only 4.2 (1.5) when it was phrased as "5 in 1000," a significant difference, F (1, 61) = 7.3, $P < 0.01$, partial $\eta^2 = .11$. However, the mean (s) perceived severity of malaria was the same in the 2 conditions (3.6 [.8] v. 3.5 [.7]), F (1, 61) = 0.5, $P = .47$, partial $\eta^2 < .01$.

To further establish that the increased worry expressed by the participants in the 1-in-200 condition was mediated by an increase in subjective probability, we conducted a path analysis by means of a series of regressions analyses. The ratio format (dummy coded, 0 standing for "5 in 1000") was a significant predictor of how much the risk was worrisome (standardized regression coefficient $\beta = .33$, $t = 2.7$, $P < 0.01$) and a significant predictor of subjective probability ($\beta = .31$, $t = 2.5$, $P = 0.01$). Subjective probability also was a significant predictor of how worrisome the risk was ($\beta = .61$, $t = 6.1$, $P < 0.001$). When ratio format and subjective probability were simultaneously entered as predictors of how worrisome the risk was, subjective probability remained a significant predictor ($\beta = .57$, $t = 5.4$, $P < 0.001$), but ratio format did not ($\beta = .15$, $t = 1.5$, $P = 0.15$). A Sobel test (whose value was 2.3, $P = 0.02$) confirmed that the contribution of the ratio format dropped significantly when subjective probability was entered into the regression.

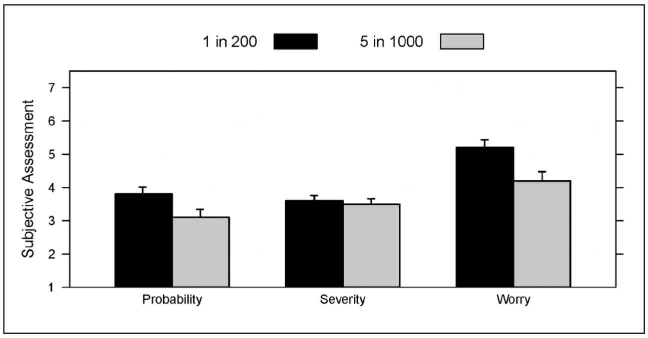

Figure 1 Subjective ratings of probability (1–7 scale), severity (1–5 scale), and worrisomeness (1–7 scale), as a function of ratio format. Error bars show 1 standard error of the mean.

Discussion

A 1-in-200 chance of contracting a disease (here, malaria) seemed larger and more worrying than a 5-in-1000 chance of contracting the same disease, a tendency that we could dub the 1-in-X effect. Furthermore, the risk was judged more worrying because it was judged more probable. Accordingly, we focus on subjective assessments of probability in the following experiments.

The results of our first experiment are clearly inconsistent with the idea of denominator neglect. Patients who would neglect denominators when assessing probability ratios would perceive 5 in 1000 as bigger than 1 in 200 and not the opposite. The purpose of experiments 2a to 2d is to rule out possible explanations of the effect observed in experiment 1 and to generalize it to different ratios, outcomes, and populations.

EXPERIMENTS 2A–2D

Participants of experiment 2 (a, b, c, and d) were recruited among the employees of local offices and companies. Participants' educational level in 4 parts of experiment 2 did not differ significantly and was as follows: 45% of participants had a university degree, 43% completed high school, and only 12% had the lowest education level in Italy.

Experiment 2a

Experiment 2a aims at replicating the main result of experiment 1, extending it to another medical condition and to the general adult population. Eighty adults (48% men, 52% women; mean [*s*] age 35 [11]) volunteered to take part in the research and completed a questionnaire. The experiment used the same design and scenario as in experiment 1, but the medical condition that participants were asked to evaluate was hepatitis A instead of malaria. Participants were asked to provide their subjective probability assessment on a 7-point scale anchored at *extremely low* and *extremely high*. Exactly as in experiment 1, ratings were greater for the format 1 in 200 ($\bar{x}$ [s], 3.9 [1.1]) than with the format 5 in 1000 ($\bar{x}$ [s], 2.9 [1.1]), $t(1, 78) = 4.2$, $P < 0.001$.

Experiment 2b

There is a superficial difference between the 2 ratios that we have used so far, in terms of the number of digits that appear in the numerator and in the denominator. The ratio 1 in 200 has a 1-digit numerator and a 3-digit denominator, whereas the ratio 5 in 1000 has a 1-digit numerator and a 4-digit denominator. It could be the case that participants were sensitive to the relative number of digits in the numerator and in the denominator and accordingly perceived 5 in 1000 as smaller than 1 in 200, independently of the fact that this second ratio had the 1-in-*X* format. Experiment 2b aims at ruling out this possible explanation.

Experiment 2b involved 100 adult volunteers (mean [*s*] age 38 [12]) who completed a questionnaire. Forty-two of those participants were men, and 58 were women. The design was the same as in experiments 1 and 2a, except that the probability ratios were 1 in 12 and 10 in 120. The first ratio has a 1-digit numerator and a 2-digit denominator, whereas the second ratio has a 2-digit numerator and a 3-digit denominator. If participants' responses reflect the relative number of digits in the numerator and in the denominator, the second ratio should be perceived as larger than the first. Conversely, if participants' responses are sensitive to the 1-in-*X* effect, then the first ratio should be perceived as larger than the second. Participants read the following scenario:

> Anna is a 48-year-old woman married since when she was 29. Despite the fact she and her husband had always desired a child, some fertility problems had impeded it. Once the situation had been accepted, Anna discovers she is pregnant. During a visit, Anna's gynecologist informs her that, due to her age, the risk of having a child with Down syndrome is approximately [1 in 12; 10 in 120].

As in the previous experiments, participants were asked to provide their subjective probability assessment. They responded using an 11-point scale anchored at *extremely low* and *extremely high*. In line with the 1-in-*X* effect, ratings were greater for the format 1 in 12 ($\bar{x}$ [s], 7.5 [0.4]) than for 10 in 120 ($\bar{x}$ [s], 6.2 [0.4]), $t(1, 98) = 2.4$, $P = 0.02$.

Experiment 2c

So far, results seem to converge on a specific effect of the 1-in-*X* format. One last possibility, though, has to be ruled out. In our experiments, the 1-in-*X* format always (and trivially so) featured a smaller denominator than the *N*-in-*X*N* format. The fact that participants perceived 1 in *X* as larger than *N* in *X*N* might thus reflect a general focus on the denominator of the ratio rather than a specific effect of the 1-in-*X* format and on people's tendency to provide lower probability assessments as the number of people exposed to a threat increases,[19] that is, when the denominator increases. Given that our interest is on subjective assessments of the same probability presented through different formats, it is not possible to disentangle the magnitude of the denominator from the magnitude of the numerator. Thus, experiment 2c aims at ruling out the numerator neglect explanation by comparing 2 equivalent ratios with different denominators, none of which are in the 1-in-*X* format.

A total of 66 adult volunteers (mean [*s*] age 32 [12]), 33 men and 33 women, completed a questionnaire. The design of the experiment was similar to other experiments in the series, except that the 2 ratios were 3 in 48 and 10 in 160. Participants read the following scenario:

> Anna is a 45-year-old pregnant woman. During a visit, her gynecologist informs her that due to her age, the risk of having a child with Down syndrome is approximately [3 in 48; 10 in 160].

Participants rated their subjective probability assessment on a 7-point scale anchored at *extremely low* and *extremely high*. These ratings were similar when the probability was expressed as 3 in 48 ($\bar{x}$ [s], 3.9 [1.8]) and 10 in 160 ($\bar{x}$ [s], 3.7 [1.7]), $t(1, 64) = .48$, $P = 0.63$.

Experiment 2d

Experiment 2d aims at replicating the null effect observed in experiment 2c, using a different scenario and different ratios. A total of 87 adult volunteers (23 men, 64 women; mean [s] age 30.1 [11.5]) completed a questionnaire. The design of the experiment was similar to other experiments in the series, except that the 2 ratios were 2 in 5 and 40 in 100. Participants read the following scenario:

> You are informed by a new study of the WHO (World Health Organization) that, in Peru, the risk for a woman to be a victim of domestic violence by her partner is [2 in 5; 40 in 100].

Participants rated the magnitude of the probability on a 7-point scale anchored at *extremely low* and *extremely high*. These ratings were similar when the probability was expressed as 2 in 5 ($\bar{x}$ [s], 5.0 [1.6]) and 40 in 100 ($\bar{x}$ [s], 4.9 [1.4]), $t(1, 85) = .28$, $P = 0.77$.

Overcoming the 1-in-*X* Effect

Experiments 2a to 2d replicated, generalized, and triangulated the effect observed in experiment 1: When the probability of a medical risk is expressed as 1 in X, this probability looms bigger (and the risk more alarming) than when it is expressed by the equivalent ratio N in X^*N. The effect seems to happen independently from the specific health outcome at stake, as the applicative context of the studies were all different.

Doctors must thus be warned that their choice of a ratio format might influence the subjective impression they make on their patients. Ideally, a given doctor should arguably stick to one ratio format when communicating with a given patient, in order not to bias the patient's assessment of the various probabilities attached to different outcomes. There is no guarantee, however, that the patient will not be given probabilities using a different ratio format when interacting with another health professional.

As a consequence, and to avoid biased interpretations[11,12] and suboptimal decisions, it is necessary to explore possible communicative interventions that would attenuate or eliminate the 1-in-*X* effect. In the rest of this article, we test 2 such interventions, comparing their effectiveness.

It seems natural to turn to classic interventions aimed at coping with the poor understanding people have of probabilities and numbers.[3,27–31] In the domain of risk communication, it is common practice to use verbal analogies[32] or visual aids (graphical representations) whose vividness is assumed to help people visualize uncertainty. Concerning visual aids in particular, many authors have claimed that icon arrays facilitate numerical risk understanding (e.g., Ancker and others,[33] Feldman-Stewart and others,[34] and Hawley and others[35]) and could debias people into properly considering both the numerator and the denominator of the ratio.[36–38] Icon arrays consist of circles or other icons that depict individuals and whose color differentiates between affected and healthy individuals.

Experiments 3 and 4 tested the resistance of the 1-in-*X* effect to these 2 interventions.

EXPERIMENT 3

A total of 81 patients of the maternity ward of an Italian hospital (mean [s] age 33.6 [4.8]) volunteered to complete a questionnaire. Most of participants had a high school degree (51%) or a university degree (33%), whereas 16% of them had the lowest level of education in Italy. The ratio format (1 in 200 v. 5 in 1000) was manipulated in a between-subjects design. Participants read the following scenario:

> Imagine that you have bought a trip to Kenya and you have just read that the risk of being affected by malaria traveling to Kenya is [1 in 200; 5 in 1000]. *To better understand this probability, imagine a jar with [199; 995] white balls and [1; 5] red ball[s]. Imagine that you draw a ball from the jar. The probability of contracting malaria while traveling to Kenya is the probability that the ball you pick will be red.*

Participants rated on a 7-point scale (anchored at *extremely low* and *extremely high*) the subjective magnitude of this probability.

The classic 1-in-*X* effect was observed, even with the inclusion of a verbal analogy. Patients provided greater probability assessments in the 1-in-200

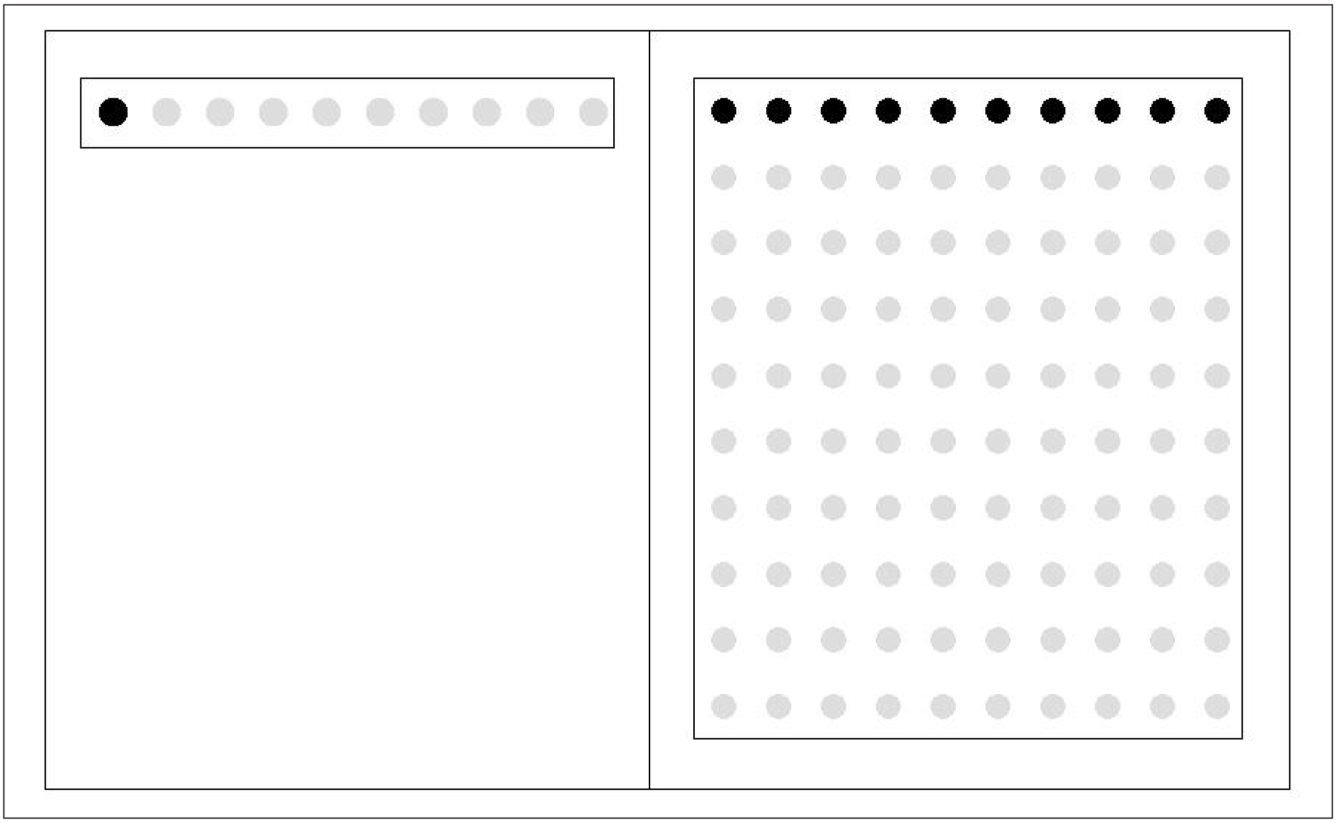

Figure 2 *Visual aids used in experiment 4, in the 1-in-10 and 10-in-100 conditions.*

condition ($\bar{x}$ [*s*], 3.7 [1.3]) than in the 5-in-1000 condition ($\bar{x}$ [*s*], 3.1 [1.0]), $t(1, 79) = 2.3$, $P = 0.02$. The 1-in-*X* effect thus appears to be resistant to the introduction of a verbal analogy.

EXPERIMENT 4

A total of 192 adult volunteers (mean [*s*] age 25.8 [9.7]) completed a questionnaire. They were randomly assigned in 1 group of a 2 × 2 between-subject design, manipulating the ratio format (1 in 10 v. 10 in 100) and the presence or absence of a visual aid. Participants read the following scenario:

> Anna is a 45-year-old pregnant woman. During a visit, her gynecologist informs her that due to her age, the risk of having a child affected by Down syndrome is [1 in 10; 10 in 100].

Half of the participants were provided with a visual aid depicting this probability. These simple visual aids are reproduced in Figure 2.

The subjective magnitude of the probability was measured as in the previous studies, but on an 11-point scale anchored at *extremely low* and *extremely high*.

Figure 3 displays the mean values of subjective probability in the 4 experimental conditions of experiment 4. Participants in the control condition (without visual aid) showed the classic 1-in-*X* effect, but this effect completely disappeared for participants who were provided with a visual aid.

A 2 × 2 analysis of variance detected a (1-tailed) significant interaction effect, $F(1, 188) = 2.8$, $P < 0.05$, partial $\eta^2 = .015$. Subsequent contrast analyses confirmed that participants in the control condition provided greater ratings for the 1-in-10 ratio ($\bar{x}$ [*s*], 7.4 [3.0]) than for the 10-in-100 ratio ($\bar{x}$ [*s*], 5.6 [2.6]), $t(1, 94) = 2.4$, $P = 0.02$. However, participants who were given a visual aid provided remarkably similar ratings for the 1-in-10 ratio ($\bar{x}$ [*s*], 5.9 [3.0]) and for the 10-in-100 ratio ($\bar{x}$ [*s*], 6.0 [2.9]), $t(1, 94) = -0.03$, $P = 0.97$.

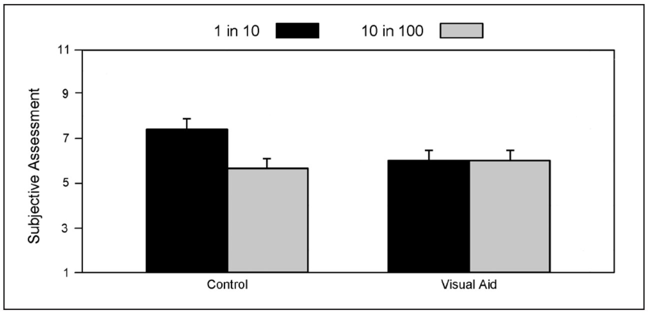

Figure 3 Subjective ratings of probability, with and without visual aid, for the 1-in-10 and the 10-in-100 format. The error bars show 1 standard error of the mean.

CONCLUSIONS

The way a probability ratio is expressed makes a difference to how big the probability sounds. A 1-in-*X* chance of contracting a disease sounds larger and more worrying than an *N*-in-*X*N* chance. Our 7 experiments replicated this effect across populations, probabilities, and conditions while triangulating the source of the effect to the 1-in-*X* format.

Even if some criticisms are possible concerning the limitations of a between-subjects design when the dependent variable is a judgment (see Birnbaum[39]), the decision to avoid a within-subjects design in the present research was supported by practical reasons. First, intuitive judgments are better studied using between-subjects than within-subjects designs because the latter encourage participants "to search for consistent strategies to deal with the task."[40] Second, our main interest focused on particular medical contexts, when little contextual information is available and only separate evaluations are possible. In such circumstances, a within-subjects design would be inappropriate, providing participants with information that could be used for comparison purposes. The current findings might not replicate in a within-subject design where participants could readily recognize that the probability communicated using 2 different formats is the same.

We believe that our research has robustly established the 1-in-*X* effect, but we are also aware that further research will have to pinpoint the cognitive processes that are responsible for the effect, specifically investigating, for example, whether the 1-in-*X* effect could be due to the increased ability to see oneself or others as that affected. Even before we attain this cognitive level of explanation, though, we can identify the practical implications of our findings for health care professionals.

Health care professionals who routinely communicate probabilistic information must be warned that a probability phrased as "1 in *X*" sounds bigger than the same probability expressed as "*N* in *X*N*." This is all the more necessary because they might themselves be de-sensitized to this bias through their daily use of probabilistic ratio and thus not aware that patients might understand ratios differently than the way they are meant.[‡]

Ideally, one would like to provide health care professionals with a clear-cut prescriptive message about which ratio format they should use. This is difficult because it is not clear whether "1 in X" yields an overestimation of the probability or whether "N in X*N" yields an underestimation of the probability. As emphasized in Sunstein and Thaler's "libertarian paternalism"[41] perspective, when contextual influences (such as framing effects or status quo bias) render patients' preferences unclear, the physician should be free to self-consciously employ the format that is likely to steer patients' preferences in the direction of their well-being. Nevertheless, to provide a general communication guideline, it has to be noted that in our study, participants who were provided with a visual aid gave similar assessments of 1 in 10 and 10 in 100. These assessments were significantly lower than that provided for 1 in 10 by participants in the control condition and broadly similar to that provided for 10 in 100 by participants in the control condition. If we assume that the assessments given with a visual aid were better calibrated, then the results of experiment 4 suggest that the 1-in-*X* ratio leads to an overestimate of the probability it expresses. This finding, along with the harmful effect of proportions with a numerator of 1 and shifting denominators on people's comprehension,[12,30] speaks against the 1-in-*X* format.

Is the 1-in-*X* effect resistant to classic communicative interventions? Verbal analogies based on jars and balls did not help participants to overcome the 1-in-*X* effect, but a simple visual aid made the effect disappear. Although further research will be needed to identify the boundary conditions of this intervention, its effectiveness might be due to the way it

---

[‡] To explore this possibility, experiment 1 was replicated using a sample of 56 doctors of an Italian hospital. In this sample, 1 in 200 was not interpreted differently than 5 in 1000 ($\bar{x} = 4.5$ in both cases; the 95% confidence interval for the differences between the 2 means was –0.7 to +0.7).

transformed probability ratios into readily identifiable, visualized natural frequencies.[42–44]

Questions thus remain that future research will have to address. Our series of experiments have established this robust effect and identified a practical intervention that might eliminate it when needed. Further work can now target the cognitive mechanisms underlying the 1-in-*X* effect, as well as its boundary conditions. We look forward to these developments and to their practical implications for risk communication.

REFERENCES

1. Alaszewski A, Horlick-Jones T. How can doctors communicate information about risk more effectively? BMJ. 2003;327:728–31.

2. Calman KC, Bennett PG, Coles DG. Risks to health: some key issues in management, regulation and communication. Health Risk Soc. 1999;1:107–16.

3. Gigerenzer G, Edwards A. Simple tools for understanding risks: from innumeracy to insight. BMJ. 2003;327:741–4.

4. Gigerenzer G, Gaissmaier W, Kurz-Milcke E, Schwartz LM, Wolosin S. Helping doctors and patients make sense of health statistics. Psychol Sci Publ Interest. 2007;8:53–96.

5. Paling J. Strategies to help patients understand risks. BMJ. 2003;327:745–8.

6. Edwards A, Elwyn G, Gwyn R. General practice registrar responses to the use of different risk communication tools in simulated consultations: a focus group study. BMJ. 1999;319:749–52.

7. Schwartz LM, Woloshin S, Welch HG. Risk communication in clinical practice: putting cancer in context. J Natl Canc Inst Monogr. 1999;25:124–33.

8. Brase GL. Which statistical formats facilitate what decisions? The perception and influence of different statistical information formats. J Behav Decis Making. 2002;15:381–401.

9. Grimes DA, Snively GR. Patients' understanding of medical risks: implications for genetic counselling. Am J Obstet Gynecol. 1999;93:910–4.

10. Slovic P. If I look at the mass I will never act: psychic numbing and genocide. In: Roese S, ed. Emotions and Risky Technologies. Berlin: Springer; 2010. p 37–59.

11. van Vliet AAM, Grimes DA, Popkin B, Smith U. Lay persons' understanding of the risk of Down's syndrome in genetic counseling. Br J Obstet Gynaecol. 2001;108:649–50.

12. Cuite CL, Weinstein ND, Emmons K, Colditz G. A test of numeric formats for communicating risk probabilities. Med Decis Making. 2008;28:377–84.

13. Kirkpatrick LA, Epstein S. Cognitive-experiential self-theory and subjective probability: further evidence for two conceptual systems. J Pers Soc Psychol. 1992;63:534–44.

14. Dale D, Rudski J, Schwarz A, Smith E. Innumeracy and incentives: a ratio bias experiment. Judgm Decis Making. 2007; 2:243–50.

15. Denes-Raj V, Epstein S. Conflict between intuitive and rational processing: when people behave against their better judgment. J Pers Soc Psychol. 1994;66:819–29.

16. Denes-Raj V, Epstein S, Cole J. The generality of the ratio-bias phenomenon. Pers Soc Psychol Bull. 1995;21:1083–92.

17. Yamagishi K. When a 12.86% mortality is more dangerous than 24.14%: implications for risk communication. Appl Cognit Psychol. 1997;11:495–506.

18. Reyna VF, Brainerd CJ. Numeracy, ratio bias, and denominator neglect in judgments of risk and probability. Learn Indiv Differ. 2008;18:89–107.

19. Yamaguchi S. Biased risk perceptions among Japanese: illusion of interdependence among risk companions. Asian J Soc Psychol. 1998;1:117–31.

20. Price PC, Matthews TV. From group diffusion to ratio-bias: effects of denominator and numerator salience on intuitive risk and likelihood judgments. Judgm Decis Making. 2009;4: 436–46.

21. Small D, Loewenstein G. Helping a victim or helping the victim: altruism and identifiability. J Risk Uncertainty. 2003;26: 5–16.

22. Kogut T, Ritov I. The "identified victim" effect: an identified group, or just a single individual? J Behav Decis Making. 2005; 18:157–67.

23. Small D, Loewenstein G, Slovic P. Sympathi and callousness: the impact of deliberative thought on donations to identifiable and statistical victims. Organ Behav Hum Decis Process. 2007; 102:143–53.

24. Zickmund-Fisher BJ, Fagerlin A, Roberts TR, Derry HA, Ubel PA. Alternate methods of framing information about medication side effects: incremental risk versus total risk of occurrence. J Health Comm. 2008;12:107–24.

25. Burkell J. What are the chances? Evaluating risk and benefit information in consumer health materials. J Med Libr Assoc. 2004;92:200–8.

26. Lichtenstein S, Slovic P. The Construction of Preference. New York: Cambridge University Press; 2006.

27. Gigerenzer G. Reckoning with Risk: Learning to Live with Uncertainty. London: Penguin; 2002.

28. Garcia-Retamero R, Galesic M. Communicating treatment risk reduction to people with low numeracy skills: a crosscultural comparison. Am J Publ Health. 2009;99:2196–202.

29. Peters E, Lipkus IM, Diefenback MA. The functions of affect in health communications and in the construction of health preferences. J Comm. 2006;56:S410–62.

30. Lipkus IM, Samsa G, Rimer BK. General performance on a numeracy scale among highly educated samples. Med Decis Making. 2001;21:37–44.

31. Peters E, Västfjäll D, Slovic P, Mertz CK, Mazzocco K, Dickert S. Numeracy and decision making. Psychol Sci. 2006;17:407–13.

32. Barilli E, Savadori L, Pighin S, et al. From chance to choice: the use of a verbal analogy in the communication of risk. Health Risk Soc. 2010;12:546–59.

33. Ancker JS, Senathirajaha Y, Kukafka R, Starren JB. Design features of graphs in health risk communication: a systematic review. J Am Med Informat Assoc. 2006;13:608–18.

34. Feldman-Stewart D, Brundage MD, Zotov V. Further insight into the perception of quantitative information: judgments of gist in treatment decisions. Med Decis Making. 2007;27:34–43.

35. Hawley ST, Zikmund-Fisher B, Ubel P, Jancovic A, Lucas T, Fagerlin A. The impact of the format of graphical presentation on

health-related knowledge and treatment choices. Patient Educ Counsel. 2008;73:448–55.

36. Galesic M, Garcia-Retamero R, Gigerenzer G. Using icon arrays to communicate medical risks to low-numeracy people. Health Psychol. 2009;28:210–6.

37. Garcia-Retamero R, Galesic M. Who profits from visual aids: overcoming challenges in people's understanding of risks. Soc Sci Med. 2010;70:1019–25.

38. Garcia-Retamero R, Galesic M, Gigerenzer G. Do icon arrays help reduce denominator neglect? Med Decis Making. 2010;30: 672–84.

39. Birnbaum MH. How to show that 9 > 221: collect judgments in a between-subjects design. Psychol Meth. 1999;1:243–9.

40. Kahneman D. A perspective on judgment and choice: mapping bounded rationality. Am Psychol. 2003;58:697–720.

41. Sunstein CR, Thaler RH. Libertarian paternalism is not an oxymoron. Univ Chicago Law Rev. 2003;20:1159–202.

42. Cosmides L, Tooby J. Are humans good intuitive statisticians after all? Rethinking some conclusions from the literature on judgment under uncertainty. Cognit. 1996;58:1–73.

43. Gigerenzer G. How to make cognitive illusions disappear: beyond heuristics and biases. Eur Rev Soc Psychol. 1991;2:83–115.

44. Gigerenzer G. The bounded rationality of probabilistic mental models. In: Manktelow KI, Over DE, eds. Rationality: Psychological and Philosophical Perspectives. London: Routledge; 1993. p 284–313.