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# Do risk communication methods perform to generate rationality?

Marielle BRUNETTE

*Janvier 2012*

**Document de travail  
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# Do risk communication methods perform to generate rationality ? \*

Marielle BRUNETTE<sup>1,2</sup>

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## Abstract

In this paper, we present several methods of risk communication designed to improve the understanding of people during experience. We observe if these methods are able to generate empirical observations in accordance with rational choice theory. To do so, we concentrate on two well-known departures from rational choice theory: 'insensitivity to scope' and 'gain/loss asymmetry', and we observe in which extent these biases are lessened by risk communication methods. First, we show that some risk communication methods allow to reduce the 'insensitivity to scope' (logarithmic risk ladder, array of dots) while others not (verbal analogy, flexible risk ladder). In-between, some communication methods allow to display a weak scope sensitivity but not a strong one (table with squares, linear risk ladder, risk circles). Second, we observe that all the risk communication methods reported allow to reduce the 'gain/loss asymmetry', reconciling thus theory and practice. However, these results are sometimes controversial. The analysis of these disagreements underlines the lack of homogeneity between studies and shows that the risk context, the sample, the wording and the baseline risk can play a significant role in the choice of a risk communication method.

**Key words :** risk, communication, rational choice, insensitivity to scope, gain/loss asymmetry.

## Résumé

*Les méthodes de communication du risque parviennent-elle à générer des comportements rationnels ?*  
Dans cet article, nous présentons plusieurs méthodes de communication du risque dont l'objectif est d'améliorer la compréhension des sujets lors d'expériences. Nous regardons si ces méthodes sont capables de générer des résultats empiriques conformes à la théorie du choix rationnel. A cette fin, nous nous concentrons sur deux résultats empiriques allant à l'encontre de la théorie du choix rationnel : « l'insensibilité à la réduction de risque » et « l'asymétrie gain/perte », et nous observons dans quelle mesure ces écarts, entre théorie et observations empiriques, sont réduits par diverses méthodes de communication du risque. Nous montrons que certaines méthodes de communication du risque permettent de réduire « l'insensibilité à la réduction de risque » (échelle de risque logarithmique, tableau de points) alors que d'autres non (analogie verbale, échelle de risque flexible). Entre ces deux extrêmes, nous observons que certaines méthodes mettent en évidence une faible sensibilité à la réduction de risque mais pas une forte (tableau de carrés, échelle de risque linéaire, cercles de risque). Nous remarquons également que toutes les méthodes de communication du risque analysées permettent de réduire « l'asymétrie gain/perte », réconciliant ainsi résultats théoriques et empiriques. Toutefois, certains de nos résultats conduisent à des désaccords. L'étude de ces désaccords souligne le manque d'homogénéité entre les expériences et montre que le contexte, l'échantillon, la formulation et le risque de référence peuvent jouer un rôle lors du choix d'une méthode de communication du risque.

**Mots clés :** risque, communication, choix rationnel, insensibilité à la réduction de risque, asymétrie gain/perte.

**Classification JEL :** C91, D01, D81.

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# 1 Introduction

Since several years, non-market valuation methods, like experimental economics, choice experiment or contingent valuation approach, allow to collect data on individual behaviors in various risky situations. These methods are described as stated preference methods and allow to apprehend individual's behavior in domain such as environmental risk, health risk, transportation risk... They consist in implementing a controlled environment in order to artificially represent situations reflecting conditions of economic theory. They have in common to test theoretical assumptions of economic model. The risk is commonly represented by numerical probabilities. However, such probabilities are often misunderstood by individuals because this kind of information seems to be complex, technical and uncertain for respondents (Loomis and du Vair, [54]; Andersson and Svensson [2]). Moreover, data obtained from non-market valuation methods often exhibit behaviors incompatibles with theory leading to severe criticism (Diamond and Hausman, [23]). This opposition between on a side, subjects who potentially not well-understand risk and on the other side, empirical results different from theoretical ones, raising several questions: could the difference between theoretical results and empirical ones be due to the use of numerical probabilities to communicate about risk? Are the risk communication methods able to reconcile theory and practice ? We try to provide some responses to these questions.

Lots of paper concentrate on how different numerical expressions about risk affect the perception of people and their decision making process. Several numerical formats were tested and compared: time intervals (Weinstein et al. [76]), verbal probabilities (Brun and Tiegen [7]; Erev and Cohen [26]; Bruine de Bruin et al. [20]), relative risk versus incidence rate (Halpern et al. [33]; Stone and Yates [70]; Fischhoff and McGregor [28]), frequency (Siegrist [65]; Yamagishi [80]), ratio of smaller risk versus larger one (Denes-Raj and Epstein [21]; Denes-Raj et al. [22]), longer based period (Slovic et al. [66]). Visschers et al. [74] propose a survey on different numerical ways of providing probability risk information. The conclusion of this literature is that the way risk information is transmitted matters, in the sense that it impacts people' behaviors.

Other studies deal with the impact of graphs and pictures on individual's behavior. They test different risk communication methods such as computer program (Henrion and Granger Morgan [37]), graph (Cleveland and McGill [13]; Ibrekk and Granger Morgan [41]; Visschers et al. [74]), table (Jones-Lee et al. [43]), risk circles (Smith and Desvouges [67]; Loomis and du Vair [54]), risk ladders (Loomis and du Vair [54]; Corso et al. [15]; Sund [72]), array of dots (Corso et al. [15]; Sund [72]; Kaplan et al. [48]; Weinstein et al. [78]), pictographs (Hess et al. [38], Stone et al. [71]),

asterisks (Stone et al. [71]; Schirillo and Stone [64]), color photos (Carson et al. [10]; Lindhjem and Navrud [52]; Beer-Borst et al. [6]). Lipkus and Holland [53] propose a survey with some of these risk communication methods. The conclusion is unanimous: visual displays modify the individual's behavior compare to a situation with only numerical probabilities.

In this literature, the performance of risk communication methods is discussed according to several criteria. First, some papers look at the capacity of risk communication methods to improve the comprehension of people compared to simple numerical probabilities. Indeed, individuals can misinterpret numerical probabilities due to a low numeracy or difficulties to deal with probabilistic information (Gigerenzer and Edwards [31]; Visschers et al. [74]). In that case, it seems determinant to identify methods allowing to these people to correctly understand the information. Second, some papers determine objectives for risk communication methods and observe in which extent they reach these objectives. For instance, Covello et al. [16] identify four objectives for risk communication: i) information and education, ii) behavior change and protective action, iii) disaster warnings and emergency information, iv) joint problem solving and conflict resolution. They analyse each objective and underline the problems complicating each task. For example, a problem complicating the task of informing and educating people about risk is the fact that risk information is often complex<sup>1</sup>. Third, Jones-Lee et al. [43] propose to look at the capacity of a risk communication method (table with squares) to generate sensitivity to scope. Indeed, Jones-Lee [42] had showed theoretically that individuals should be sensitive to scope in case of risk change and thus, he want to test empirically this result. The third criteria of performance is then the compatibility between theoretical results and empirical ones. However, this criteria of performance is about the sensitivity to scope such that one theoretical result was concerned and one risk communication methods was tested.

In this paper, we follow the argument of Jones-Lee et al. [43] and decide on the performance of risk communication methods by observing their ability to improve compatibility between empirical observations and theoretical results. Indeed, differences between theoretical results and their empirical tests could be an artefact due to inadequate risk communication tool. However, we broaden the analysis in two ways: i) we present all the different risk communication methods used, to our knowledge, to counter the empirical insensitivity to scope (seven methods) and their associated results; ii) we test in addition to sensitivity to scope, the capacity of risk communication methods to counter an other empirical result, the 'gain/loss asymmetry'.

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<sup>1</sup>For similar approaches see Rohrmann [60], Weinstein and Sandman [77] and Keeney and von Winterfeldt [49].

The present survey is restricted in two ways. First, non-market valuation methods display lots of empirical behaviors not in accordance with theory and it is impossible to analyse all of them, so that we concentrate on two well-documented and well-known departures from theory (two 'biases') : 'insensitivity to scope' and 'gain/loss asymmetry'. Doing so, we restricted our analysis by concentrating on rational choice theory. However, the rational choice theory is currently the main theoretical paradigm in microeconomics. In the same way, rationality is an assumption widely used to represent individual's behavior in microeconomic models and largely employed to analyse human decision-making. Thus, in this paper, we present some risk communication methods and we analyse if they generate rational choices. Second, we concentrate our survey on non-market valuation studies, neglecting qualitative approaches.

Our results prove that risk communication methods could perform to reconcile theoretical results and empirical ones. On the one hand, we show that some risk communication methods allow to reduce the 'insensitivity to scope' (logarithmic risk ladder, array of dots) while others not (verbal analogy, flexible risk ladder). In-between, some communication methods allow to display a weak scope sensitivity but not a strong one (table with squares, linear risk ladder, risk circles). On the other hand, we observe that all the risk communication methods studied allow to reduce the 'gain/loss asymmetry', reconciling thus theory and practice. However, these results are sometimes controversial. The analysis of these disagreements underlines the lack of homogeneity between studies and shows that the risk context, the sample, the wording and the baseline risk can play a significant role in the choice of a risk communication method.

The rest of the paper is organized as follows. First, we describe the rational choice theory and the two biases we concentrate on (Section 2). Second, we analyse the performance of some risk communication methods to reduce each bias, 'insensitivity to scope' (Section 3) and 'gain/loss asymmetry' (Section 4) respectively. In Section 5, we summarize and discuss the results. Finally, Section 6 concludes.

## 2 Rational Choice Theory

The rational choice theory is a framework designed to understand and represent social and economic behavior. This theory rests on the expected utility model based on a set of axioms: completeness, transitivity, independence and continuity (von Neumann and Morgenstern [56]). These axioms provide criteria for the rationality of choices. Borrowing the description of Kahneman and Tversky

[47], we can said that: *“The choices of an individual who conforms to these axioms can be described in terms of the utilities of various outcomes for that individual. The utility of a risky prospect is equal to the expected utility of its outcome, obtained by weighting the utility of each possible outcome by its probability. When face with a choice, a rational decision-maker will prefer the prospect that offers the highest expected utility (Von Neumann and Morgenstern [56]; Savage [63])”*. However, this rational choice theory is often inconsistent with empirical observation. Indeed, some experiences show that individuals exhibit patterns of preference which are incompatibles with rational choice theory such as 'insensitivity to scope' and 'gain/loss asymmetry'.

First, in the theory of rational choice the decision-maker has the capacities to perfectly understand and treat the information, especially relative to risk and its potential change. Jones-Lee [42] proposed an expected utility model which objective is to develop a qualitative analysis of compensating variations for changes in the probability of an individual's own fatal accident. In other words, the author observes how the willingness-to-pay (WTP) of an individual varies with a change in the level of risk. The conclusion is that for reduction in small probabilities of death, the decrease in WTP should be nearly proportional to the change in probability, displaying a scope sensitivity. As indicated by Hammitt and Graham [35], this means that if a reduction in annual mortality risk from 20 in 100 000 to 18 in 100 000 is valued at 20\$ then a larger reduction from 20 to 16 in 100 000 should be valued at about 40\$. Goldberg and Roosen [32] extend the work of Jones-Lee [42] by differentiating the 'weak scope sensitivity' and the 'strong scope sensitivity'. The first one suggests that WTP for a reduction in risk should increase with the amount of risk reduction (assuming that a risk reduction is a desired good) and the second one indicates that, for small changes in risk, WTP should be quasi-proportional to the risk reduction. However, empirical works reveal the difficulty of individuals to perceive the magnitude of the risk change. Thus, several empirical studies conclude to an 'insensitivity to scope': Jones-Lee [42], Eom [25], Lin and Milon [51], Baron [4], [5], Hammitt and Graham [35], Corso et al. [15] and Goldberg and Roosen [32], among others. This literature shows that the individuals' WTP for a risk reduction is less than proportionnal to the risk reduction<sup>2</sup>.

Second, in the rational choice theory, individuals ought to value gains and losses in the same manner, so that a 'gain/loss symmetry' appears. In other words, if an individual is risk-averse in gain domain then s/he must be risk-averse in the loss one. Nevertheless, empirical works reveal

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<sup>2</sup>At the other extrem, we find the works of Kahneman and Tversky [46], [47] who noted excessive sensitivity to magnitude when a risk is entirely eliminated. This sort of 'oversensitivity to scope' is called 'certainty effect' by the authors, but in this paper we are not interested in the elimination of risk but only in the relative risk changes.

that individuals value losses more highly than gains. This tendency of individuals to be risk-averse in the gain domain and risk-taking in the loss domain is called ‘reflection effect’ and was displayed by Kahneman and Tversky [47] through the following simple experiences :

Imagine that the U.S. is preparing for the outbreak of an unusual Asian disease, which is expected to kill 600 people. Two alternative programs to combat the disease have been proposed. Assume that the exact scientific estimate of the consequences of the programs are as follows:

Experience 1:

- If Program A is adopted, 200 people will be saved.
- If Program B is adopted, there is 1/3 probability that 600 people will be saved, and 2/3 probability that no people will be saved.

Which of the two programs would you favor?

Experience 2:

- If Program C is adopted 400 people will die.
- If Program D is adopted there is 1/3 probability that nobody will die, and 2/3 probability that 600 people will die.

Which of the two programs would you favor?

152 subjects participated to the first experience and 155 to the second one. They indicate to prefer program A (72%) to program B (28%) exhibiting risk aversion in the gain domain while they indicate to prefer program D (78%) to program C (22%) exhibiting risk-taking behavior in the domain of losses. These experiences allow Kahneman and Tversky to display the ‘gain/loss asymmetry’ in a risky context. Such an asymmetry is also exhibited in an uncertain framework (Curley and Yates [17], [18]; Cohen et al. [14]; Wehrung [75]; Di Mauro and Maffioletti [55]; Chakravarty and Roy [11]).

The response of the scientific community to these departures from rational choice theory are twofold. First, some authors think that empirical observations are correct and thus, that rational choice theory does not allow to represent reasonably the individual behaviors. Then, they propose alternative theoretical models, the non-expected utility models for example with, among others, the ‘Prospect Theory’ (Kahneman and Tversky [46], Tversky and Kahneman [73]), the ‘Rank Dependent Expected Utility’ (Quiggin [59]) or the ‘Dual Theory’ (Yaari [79]). Second, some authors assume that people fails to interpret risk probabilities and thus that empirical observations are not accurate. Consequently, they try to improve the comprehension of the subjects during experience. In this paper, we focus on this second approach. We present risk communication tools designed to facilitate the understanding of individuals and we look at their capacity to generate human behaviors compatibles with the rational choice theory.

### 3 ‘Insensitivity to scope’

The ‘insensitivity to scope’ refers to the difficulty of individuals to perceive the magnitude of the risk changes. In this section, we present some methodologies, encountered in the literature, aiming at improve the cognitive abilities of individuals and we look at their capacity to transfer information about the magnitude of the risk change. We analyse these methodologies function of their order of appearance in the literature, from tables with squares in the middle of 80’s to risk ladders and array of dots in 2000’s.

#### 3.1 Table with squares

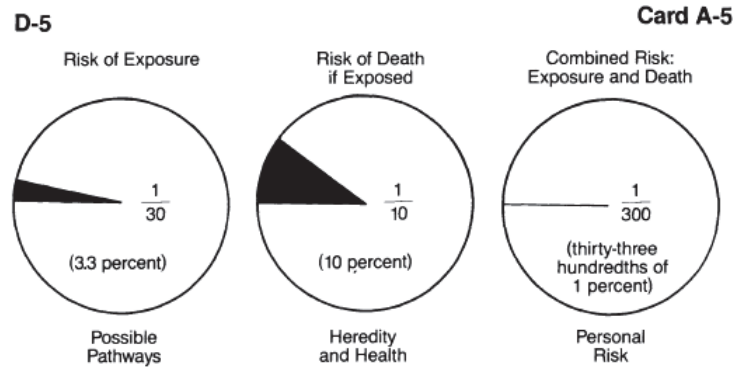
Jones-Lee et al. [43] were among the first in 1985 to propose the use of a graphic representation to facilitate the risk comprehension of the subjects. The experience consists in asking participants to indicate their WTP in return of a modification in their death probability or serious injury for a coming period. These probabilities are presented as ‘ $x$  on 100 000’. For example, a question asked to the subjects is: *“If you had to choose between them, which one of these risks would you rather face: a risk of 10 in 100 000 of being killed; or a risk of 1 000 in 100 000 of serious injury?”*. Each probability is associated to visual representation in which the appropriate number of squares had been blacked out on a piece of graph paper containing 100 000 squares. The authors analyze the effect of this new visual methodology to represent risky situation on the individual’s behavior. They show that the people’s WTP decreases when the probability decreases (weak scope sensitivity) but that the theoretical proportionality between reduction in WTP and reduction in risk does not appeared (no strong scope sensitivity).

This methodology was also used by Persson and Cedervall [57] and Jones-Lee et al. [44] who obtained similar results. A colored extension of this method was also proposed by Alberini et al. [1]. The baseline risk is represented through red squares on a white grid containing 1000 squares and the reduction in risk is represented by turning the appropriate number of red squares to blue. The result obtained was identical, weak scope sensitivity appeared but not strong one.

#### 3.2 Risk circles

Smith and Desvousges [67] in 1987 apprehend the valuation of people for reduction in the risk of exposure and premature death from hazardous wastes. To do so, they ask individuals about their WTP for different scenarios of risk reduction. To facilitate the comprehension of individuals, they used risk circles to represent the probabilities, as indicated in Figure 1. The risk circles allow to represent proportions.

Figure 1: Risk circles



These circles correspond to the individual risk of exposure from hazardous waste ( $1/30$ ), the death risk for a given dose of hazardous waste ( $1/10$ ) and last one indicates the combined result of the two first. The authors propose to individuals several sets of such risk circles with modifications on the individual level of risk ( $1/30$ ,  $1/60$ ,  $1/150$ ). They show that using risk circles to transfer information about risk changes do not allow to improve the abilities of subjects to understand magnitude in risk reduction. Indeed, they prove that WTP is not sensitive to the reduction of risk (neither weak scope sensitivity nor strong one).

### 3.3 Verbal analogy

Hammit and Graham [35] ask subject to indicate their WTP for risk reduction in two domains: transportation and food. For each numerical probability used, they associate verbal analogies concerning distance (inches in a mile), time (minutes in a year), population (size of particular cities, football stadium attendance) and games of chance (coin flipping, card dealing). For example, an annual risk of  $20/100\,000$  corresponds to 105 minutes in a year. The authors show that the use of such verbal analogies has a low effect on the sensitivity of WTP to risk reduction. Results indicate that verbal analogy having the higher effect is in terms of capacity of football stadium while the one having the lower effect is the number of minutes in a year, but none of these analogies has a significant impact.

### 3.4 Risk ladders

A risk ladder is a visual display presenting risk such that increasing risk is represented higher up on the ladder<sup>3</sup>. Sometimes, the considered risk is compared with other, especially more common<sup>4</sup>.

<sup>3</sup>Sandman et al. [62] show that the perception of risk is influenced by the location of the risk on the ladder; people perceiving threat as greater at the top of the ladder.

<sup>4</sup>Such comparisons have led to two major criticisms: comparisons reduce risks to loss of life expectancy while risks could be multidimensional, comparisons inform subjects about the risk but also about what the risk should be (see

In this case, the risk ladder is usually called ‘community risk scale’. Calman and Royston [9] proposed such a ‘community risk scale’ (see Figure 3 in Appendix A). The risk ladder can represent magnitude but also probabilities. It has been used most extensively to describe environmental risks (Sandman et al. [62]; Smith et al. [68], [69]) or health risks (Gerking et al. [30]; Hammitt [34]; Dickie et al. [24]; Buzby et al. [8]; Lanoie et al. [50]). However, only three articles are interested in the effect of such a visual display on the ‘insensitivity to scope’ of individuals, the articles of Loomis and du Vair [54] which compare risk ladders with risk circles and the papers of Corso, Hammitt and Graham [15] and Sund [72], both comparing risk ladders with an array of dots.

### 3.4.1 Risk ladders *versus* risk circles

Loomis and du Vair [54] are interested in the individual’s WTP to finance an American public program aiming at minimizing the hazardous wastes. They compare two visual displays to facilitate the understanding of individuals for the same type of risk and the same level of risk. They compare risk circles (similar to Smith and Desvousges [67]) and they propose a linear risk ladder, as represented in Figure 4 of Appendix B. The risk ladder represents risk magnitude and associates probabilities of other risks. Subjects face three scenarios representing by three programs corresponding to different risk reductions: 25% for program B, 50% for C and 75% for D. In this last case (program D), the risk of death from exposure to heavy metals would be similar to the risk of death due to air pollution. Subjects must indicate their WTP for each program. The authors show that with risk circles, the subject’s WTP is lower than with risk ladder. This last methodology would then be associated to a perception of more important risk, which leads the authors to say “*the ladder does a better job providing information on relative risk, i.e. how the risk under study compares with other, often time, more familiar risks*”. Loomis and du Vair [54] demonstrate that both methodologies allow to display a reduction in WTP resulting from a risk reduction, but that none of them allow to obtain a proportionnal relationship between WTP reduction and risk reduction. Again, the weak scope sensitivity appeared but not the strong one.

### 3.4.2 Risk ladders *versus* array of dots

Corso et al. [15] ask subjects to indicate their WTP to reduce the risk of dying in a motor vehicle crash from 2.5/10 000 or 2.0/10 000 to 1.5/10 000. They test different methodologies to provide information about risk: a community risk scale and an array of dots. In particular, they consider two community risk scales, a logarithmic community risk scale and a linear one. These risk ladders  


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 Fischhoff et al. [29]; Roth et al. [61]). Such considerations are out of our work.

are represented in Figure 5 and Figure 6 of Appendix C and communicate about risk probabilities. For the array of dots, the risk of death is represented through a  $11 \times 17$  black and white display of 25 000 dots divided into 10 by 10 groups. They found that the median WTP ranges from 253\$ (no aid) to 362\$ (linear risk ladder) for those presented with the larger risk reduction, and from 159\$ (array of dots) to 293\$ (linear risk ladder) for those presented with the smaller risk reduction. Three main results are thus displayed: 1/ individual's WTP are not sensitive to risk reduction when no visual display is used; 2/ the logarithmic scale and the array of dots perform to induce sensitivity to scope because they display a reduction in WTP when the variation of risk decrease and a quasi-proportionality between risk reduction and WTP reduction; 3/ the results are in-between for the linear scale. Corso et al. [15] conclude that the reason why previous studies prove a reduction in WTP less than proportionnal to the risk reduction, is the use of inappropriate methodologies of provision of information about risk. The performance of an array of dots to generate weak and strong scope sensitivity was also found by Hammitt and Haninger [36] proposing a colored version of an array of dots for online survey.

Another comparison between risk ladder and array of dots is presented by Sund [72]. He realizes a comparison between a flexible community risk scale and an array of dots (similar to Corso et al. [15]). He uses the following terms to define a flexible community risk scale: *"It uses the characteristics of the community risk scale (Calman and Royston [9]) and also tries to generalise it in a way that is 'community specific' without having to assume that a certain community is representative for a larger society"*. The author investigates the capacity of these two visual displays in valuing mortality risk reductions for sudden out-of-hospital cardiac arrest. More precisely, Sund [72] questions participants about WTP for a public program allowing to increase the survival rate from cardiac arrest from 5% to 10% or 15%. The risk of suffering from an out-of-hospital cardiac arrest over a 10 years period is 67 per 10 000 individuals. A survival rate of 5% means that 3 persons will survive while a rate of 10% implies that 7 persons will survive. The author shows that, contrary to Corso et al. [15], an array of dots do not allow to verify the sensitivity to scope, neither weak nor strong. In the same way, the flexible community risk scale tested also fails to generate adequate sensitivity to scope.

In conclusion, it seems that, in some cases, the logarithmic scale and the array of dots proposed by Corso et al. [15] could be able to reconcile empirical behaviors and the traditional model of rational choice. However, this ability of array of dots is critically discussed by Sund [72]. We analyse this disagreement in section 5.

## 4 ‘Gain/loss asymmetry’

The ‘gain/loss asymmetry’ corresponds to a situation where individuals value losses more highly than gains. In this section, we present some means of communication displayed to allow a better comprehension of the subjects. We analyse these methodologies and observe their capacity to reduce the ‘gain/loss asymmetry’. We present them function of their order of appearance in time. Thus, we begin with array of dots in the middle of 80’s.

### 4.1 Array of dots

This method is presented in the previous section about ‘insensitivity to scope’. Here, it is used to counter the ‘gain/loss asymmetry’. Kaplan et al. [48] inform students about their probability of dying of influenza if unvaccinated (1 chance of 1 000) and of contracting a syndrome as a side effect of the vaccination (1/1 000, 1/10 000 or 1/100 000). 120 students were submitted to the experience with only numerical representation of the risk while 120 others have received numerical expression plus a visual display in terms of an array of dots. The participants exposed to the visual display were told that the probability to have a side effect was one against the number of dots represented on pages. Thus, a probability of 1/1 000 corresponds to a 1/10 of a page covered with dots, probability of 1/10 000 is represented by an entire page of dots and the 1/100 000 information is associated to ten entire pages of dots. The authors ask the subject how likely they are to get vaccinated. More precisely, participants must indicate on a scale the probability that they would take the vaccine. The scale goes from 0 meaning “I absolutely would not take the vaccine” to 100 meaning “I am certain that I would take the vaccine”. The experience shows that, whatever the probability of the side effect, the array of dots increases the likelihood that subjects would take the vaccine compared to a situation with only numerical information. In other words, this graphical representation allows to reduce the risk-taking behavior of the subjects in the domain of loss and thus to reduce the ‘gain/loss asymmetry’.

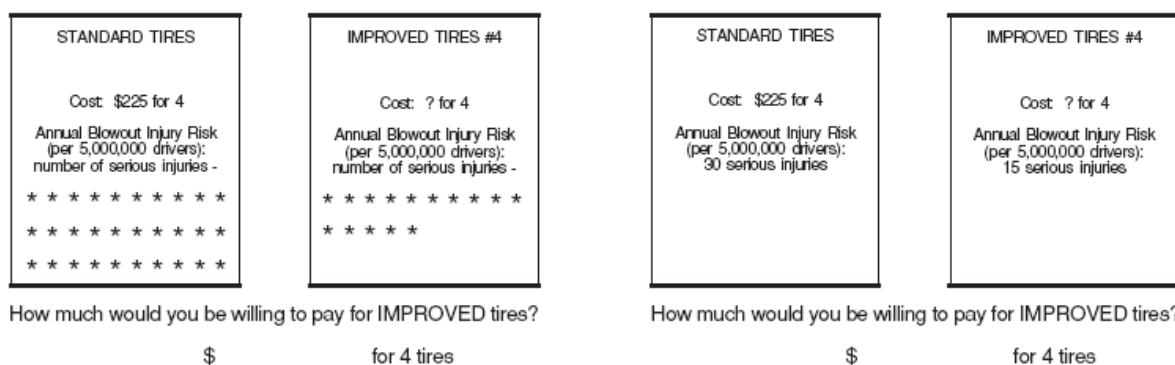
Weinstein et al. [78] try to verify and extend the work of Kaplan et al. [48]. They consider two different risk dilemmas (nerve damage from vaccine or from pesticides), two levels of risk (1 in 50 and 1 in 10 000) and four formats: 1) numerical probability; 2) numerical probability plus a page with dots (for a risk of 1 in 10 000, a page with 10 000 dots); 3) probability plus array of dots of two pages (for a risk of 1 in 10 000, a page with 1 dot and another one with 10 000 dots); 4) numerical probability plus an array of dots of one page but the dilemma, format and questionnaire assessing risk and intention to act are presented one page at a time. The experience was conducted on 896

college students. The analysis of variance allow to observe a significant effects of risk level and dilemma but no effect of risk communication format. Consequently, as this extended experience fails to met the result of Kaplan et al. [48], Weinstein et al. [78] conduct a second experience repeating exactly the study of Kaplan et al. [48]: only nerve damage from vaccine dilemma (with a probability of 1/1 000) and a risk of side effect of 1/10 000. In this context, Weinstein et al. [78] test the four formats presented above with the third one corresponding to the exact replication of Kaplan et al. [48]. The participants were 287 college students. One more time, they do not observe any effect of format on intention to get vaccinated. In other words, the result of Weinstein et al. [78] fails to replicate the conclusion of Kaplan et al. [48]. From the point of view of Weinstein et al. [78], an array of dots is not able to reduce the ‘gain/loss asymmetry’.

## 4.2 Stick figures, asterisks, bar graph and faces of people

Stone et al. [71] analyse the difference, in terms of risk avoidance, between numerical and graphical representations of risk. They focus on four graphical representations: stick figures, asterisks, bar graph and faces of people. They consider two types of serious injuries, those resulting from automobile tire blowouts (annual injury risk is 30 out of 5 000 000 Michigan drivers) and those coming from serious gum disease (annual injury risk is 30 out of 5 000 toothpaste users). They ask subjects to indicate their WTP for reducing the risk by 50%, i.e. their WTP to buy a safer product reducing the risk by half. Some subjects face the numerical representation while others are exposed to graphical one. For example, Figure 2 presents the experiment in case of numerical versus asterisks representation.

Figure 2: Asterisks



The authors indicate that the cost of 4 standard tires is 225 dollars with a blowout risk of 30/5 000 000 and question subjects about their WTP for 4 improved tires reducing the risk by

half (15/5 000 000). The two boxes at the right hand side of Figure 2 expressed this dilemma in a numerical way while the two boxes at the left hand side used asterisks. The same design is used for stick figures, bar graph or faces of people with each of these representations replacing asterisks (see Figure 7 in Appendix D for stick figures and faces of people).

The authors show that each graphical representation allows to decrease the risk-taking behavior of the subjects compare to a situation with numerical information both for tire and toothpaste. For instance, with a numerical representation, the subjects are willing to pay 34% more for the safer tires (76 dollars more than the standard tires price of 225 dollars) than for the standard ones and with asterisks, this figure is 48% (107 dollars more than the standard tires price of 225 dollars). Consequently, Stone et al. [71] prove that graphical representation of risk allows to decrease the risk-taking behavior of the subjects and at the the same time to reduce the ‘gain/loss asymmetry’, when the reduction of risk is of 50%. Chua et al. [12] confirm this result for the bar graph format.

Schirillo and Stone [64] propose an extension of this previous work with only asterisks representation but with several percentages of risk reduction, from 30 serious injuries to 29, 25, 20, 15, 10, 5 and 1, i.e. reductions of risk from 96.7% to 3.3% via 50%. Schirillo and Stone [64] report that, for a risk reduction of 50%, the subjects are willing to pay 52 dollars more than the standard tires price of 225 dollars with numerical representation and 60 dollars more with asterisks, confirming the result of Stone et al. [71]. Moreover, they show that this result is true for all the risk reductions except for a reduction from 30 serious injuries to 29, where the WTP for safer tires, although higher, is not significantly different from the WTP for standard tires. Consequently, this article shows that graphical representation of the risk in the form of asterisks is more effective than its numerical counterpart in inducing risk-avoidance, whatever the relative risk ratio of serious injuries.

## 5 Discussion

In this paper, we present several risk communication methods designed to improve the understanding of risk information. Their capacity to generate observations in accordance with rational choice theory is discussed according to two well-known biases ‘insensitivity to scope’ and ‘gain/loss asymmetry’. Table 1 summarizes the results obtained in this survey. Several comments can be made on the basis of this table.

Table 1: Summary of the results

Representation of risk	Authors	Efficiency
<b>‘Insensitivity to scope’</b>		
Table with squares	Jones-Lee et al. [43], [44] Persson and Cedervall [57] Alberini et al. [1]	Weak ss* No strong ss
Risk circles	Smith and Desvougues [67]  Loomis and duVair [54]	No weak ss No strong ss Weak ss No strong ss
Verbal analogy	Hammit and Graham [35]	No weak ss No strong ss
Risk ladders	Loomis and duVair [54]  Corso et al. [15]	Weak ss No strong ss Weak ss No strong ss
• Linear	Corso et al. [15]	Weak ss Strong ss
• Logarithmic	Corso et al. [15]	Weak ss Strong ss
• Flexible	Sund [72]	No weak ss No strong ss
Array of dots	Corso et al. [15] Hammitt and Haninger [36] Sund [72]	Weak ss Strong ss No weak ss No strong ss
<b>‘Gain/loss asymmetry’</b>		
Array of dots	Kaplan et al. [48] Weinstein et al. [78]	↘ Asymmetry No effect
Stick figures	Stone et al. [71]	↘ Asymmetry
Asterisks	Stone et al. [71] Schirillo and Stone [64]	↘ Asymmetry ↘ Asymmetry
Bar graph	Stone et al. [71] Chua et al. [12]	↘ Asymmetry ↘ Asymmetry
Faces of people	Stone et al. [71]	↘ Asymmetry

\* ss: scope sensitivity.

First, it seems that each risk communication method is tested by very few studies, making difficult the elaboration of recommendations. Then, the results must be considered carefully.

Second, it seems that risk communication methods is bias specific. Indeed, we observe that in Table 1, different methods are used to counter each bias. Then, the risk communication methods employed to generate sensitivity to scope are not the same that methods used to obtain ‘gain/loss symmetry’, except for array of dots which performance is discussed as regard to the two biases.

Third, it seems that some risk communication methods could perform to reconcile theory and

practice but sometimes it is controversial. On the one hand, a logarithmic risk ladders and an array of dots seem to be able to generate sensitivity to scope because they allow to observe weak and strong scope sensitivity. However, a controverse appears between, on one side Corso et al. [15] and Hammitt and Haninger [36] and on the other side, Sund [72] concerning the array of dots. On the other hand, all the risk communication methods tested seem to be able to counter the ‘gain/loss asymmetry’, even if the ability of array of dots is discussed by Kaplan et al. [48] and Weinstein et al. [78]. Let us remark that it is the same risk communication method, an array of dots, which lead to disagreement between the authors. We try to explain these disagreements by analysing potential difference in terms of design between these studies. We first analyse the difference between on one side Corso et al. [15] and Hammitt and Haninger [36] and on the other side Sund [72] and second, between Kaplan et al. [48] and Weinstein et al. [78]. Note that the first comparison is about contingent valuation studies while the second one deals with experiments.

### 5.1 Does an array of dots perform to induce sensitivity to scope?

We propose to answer to this question by comparing the characteristics of the studies of Corso et al. [15] and Hammitt and Haninger [36] to the study of Sund [72]. These characteristics are presented in the following table.

Table 2: Comparison between Corso et al. [15], Sund [72] and Hammitt and Haninger [36]

	Corso et al. [15]	Sund [72]	Hammitt and Haninger [36]
Number of methods tested	3	2	1
Risk context	Car accident	Cardiac arrest	Pesticid
Sample	1104	602	2018
Valued good	Side-impact airbag	Public program	Food
Wording	WTP to $\searrow$ the risk of death annual risk	WTP to $\nearrow$ the survival rate 10 years period risk	WTP to $\searrow$ the risk of death annual risk
Baseline risk	2.5/10 000 or 2/10 000	67/10 000	3/10 000 or 4/10 000
Magnitude of risk	$\searrow$ of death risk of 40% and 25%	$\nearrow$ in survival rate of 5% and 10%	$\searrow$ of death risk of 25%, 33%, 50%, 66%

*Number of methods tested.* Corso et al. [15] tested in the same study the effect of three different risk communication methods on the individual’s behavior, Sund [72] tested two of them and Hammitt and Haninger [36] just one of them. However, in Corso et al. [15] and Sund [72], the methods are between-subjects variables meaning that each participant is submitted only to one communication method. Consequently, the results of the three papers are comparable and this difference can not explain the disagreement between the authors.

*Risk context.* Corso et al. [15] deal with car accident, Hammitt and Haninger [36] with pesticide on a food and Sund [72] is interested in cardiac arrest. It seems that the potential victims of each risk are not the same, which leads Rohrmann [60] to indicate that “*A particular risk communication strategy might not work (or perhaps only works) for certain kinds of risk, certain institutions and communicators, certain types of audiences, certain political circumstances, etc*”. In the same way, the difference in terms of context leads Sund [72] to indicate “*The risk context of the valuation survey seems to be important for the performance of the array of dots and it may not be possible to generalise between different health and safety areas*”. Consequently, it seems that array of dots could be able to induce sensitivity to scope in the context of car accident or ingestion of food containing pesticide and not in the context of cardiac arrest. This suggest that performance of an array of dots is context dependent.

*Sample.* Corso et al. [15] recruit subjects of their contingent valuation study by phone and they are mailed the visual display. 1456 persons are contacted with a response rate of 75.8%, so that the study is based on 1104 WTP. Sund [72] adopts a mail contingent valuation survey on 602 subjects (1400 persons are contacted with a response rate of 43%). Hammitt and Haninger [36] contacted 2747 subjects through digital dial with a response rate of 74%. We remark that the methodology to recruit subjects is different and the response rate also but more interesting is that the number of participants in Sund [72] is around half of the number of participants in Corso et al. [15] and a quarter of Hammitt and Haninger [36]. Now, it is commonly accepted that a large sample leads to more precise estimations.

*Valued good.* We observe that in Corso et al. [15] and Hammitt and Haninger [36] the valued good is a private good (airbag and food, respectively). Inversely, in Sund [72] the valued good is a public program, allowing to reduce the risk exposure of each participant individually but also collectively. However, empirically, no consensus emerge concerning the differences between WTP for a private and a public risk reduction. On one side, some studies (de Blaeij et al. [19]; Hultkrantz and Andersson [40]) revealed that, for a similar risk reduction, the WTP is higher for private good than for a public one. On the other side, Araña and León [3] find an inverse relation: higher WTP for public good than for private one. Consequently, the mean by which the valued good can explain the difference between the results of the two studies is not clear.

*Wording.* Two differences appeared between on one side Corso et al. [15] and Hammitt and Haninger [36] and the other side Sund [72] concerning wording. First, Corso et al. [15] and Hammitt and Haninger [36] refer to WTP to reduce the risk of death while Sund [72] refers to WTP to increase the survival rate. This difference is really important because lots of papers show that the wording has a significant effect on individual's behavior. Especially, well-known experiences of Kahneman and Tversky [47] prove that dealing with survival rate or death rate leads subjects to inverse their preferences. This could explain why Sund [72] find systematically inverse results of Corso et al. [15] and Hammitt and Haninger [36]. Second, Corso et al. [15] and Hammitt and Haninger [36] present an annual risk of death while Sund [72] opts for a 10 years period risk. Slovic et al. [66] show that increasing the length of the period considered (50 years rather than one vehicle trip) may increase the perceived probabilities of injury and death and, therefore, induce higher WTP.

*Baseline risk.* Corso et al. [15] and Hammitt and Haninger [36] have small baseline risk compared to Sund [72]. Zeckhauser and Viscusi [81] in a game of Russian Roulette conclude that it makes sense to have higher WTP to reduce the number of bullets in a six-chamber revolver from 5 to 4 than from 2 to 1, underlying the role of the baseline risk. Indeed, in relative terms, the change from 2 to 1 corresponds to a reduction of 50% while the movement from 5 to 4 represents a 20% reduction. However, these two changes are associated to an absolute risk reduction of 1/6. To conclude, Hammitt and Graham [35] indicated that “*When the baseline risk is small, as is typically the case in CV studies of health risk reduction, the effect of baseline level of risk on WTP should be negligible*”. But, here, the baseline risk of Sund [72] is high, potentially explaining the disagreements in terms of the results.

*Magnitude of risk reduction.* Corso et al. [15] deal with risk reduction of 40% (from 2.5/10 000 to 1.5/10 000) and 25% (from 2.0/10 000 to 1.5/10 000), Hammitt and Haninger [36] with reduction from 33% to 66% (from 3/10 000 or 4/10 000 with reduction of 1/10 000 or 2/10 000) Sund [72] deals with increase in the survival rate of 5% (from 5% to 10%) and 10% (from 5% to 15%). In the literature, the effect of magnitude of risk reduction is not really tackled. Some papers (Bruine de Bruin et al. [20], [27]) show that 50% is treated differently than other percentages by the participants. Other, like Kahneman and Tversky [46], [47] prove an ‘oversensitivity to scope’, called certainty effect. Finally, Schirillo and Stone [64] conclude that the reaction of the subjects is the same whatever the risk reduction, 50% or other ones suggesting that the magnitude of the risk reduction can not explain why the effect of an array of dots on ‘insensitivity to scope’ is so

controversial.

To sum up, the studies of Corso et al. [15] and Hammitt and Haninger [36] on one side and Sund [72] on the other side present differences, some of them can clearly explain their disagreement in terms of performance of an array of dots to generate sensitivity to scope (risk context, sample, wording, baseline risk) and for others, the link is not so easy to establish (valued good and magnitude of risk reduction).

## 5.2 Does an array of dots perform to reduce ‘gain/loss asymmetry’?

The following table compares the studies of Kaplan et al. [48] and Weinstein [78]. It appears that few characteristics are different between the two studies. Indeed, as Weinstein et al. [78] try to replicate the experience of Kaplan et al. [48], some precautions were taken. Then, the risk context, the valued good and the wording are the same. We concentrate our analysis on the differences between the two studies.

Table 3: Comparison between Kaplan et al. [48] and Weinstein [78]

	Kaplan et al. [48]	Weinstein [78]
Number of methods tested	2	4
Risk context	Influenza if unvaccinated Side-effect of the vaccination	Influenza if unvaccinated Side-effect of the vaccination
Sample	240	287
Valued good	Vaccine	Vaccine
Wording	Probability to take the vaccine	Probability to take the vaccine
Support	Scale	?

*Number of methods tested.* Kaplan et al. [48] compare two risk communication methods, numerical probabilities and an array of dots. Weinstein et al. [78] deal with four different methods, two of them are similar to the formats tested by Kaplan et al. [48] while the two others are news. However, in these studies, the format or risk communication method is a between-subject variable implying that each participant is submitted to only one format. The task for each participant is thus the same in the two experiences, so that the number of methods tested can not explain the difference between the two studies.

*Sample.* Kaplan et al. [48] test the performance of an array of dots on a sample of 240 college students with two risk communication methods, so that 120 of them are submitted to numerical

probabilities and 120 others to numerical probabilities plus the visual display. Weinstein et al. [78] replicate this study with a sample of 287 college students with four formats without saying how much of them are submitted to each treatment. In a factorial design, as used by Weinstein et al. [78], it is common to divide the sample in parts of equal size. Thus, one can think that around 70 students are exposed to each of the four formats, which is relatively lower than in the study of Kaplan et al. [48]. However, it is commonly accepted that a large sample leads to more precise estimations.

*Support.* Kaplan et al. [48] used a scale as support to collect the probability that the subjects adopt the vaccine, while Weinstein et al. [78] do not give information about the data collection. This visual display may influence the subject's choice.

Weinstein et al. [78], talking about the potential difference between the study of Kaplan et al. [48] and their own, indicate that “*No plausible reason appears to explain the discrepancy between our results and theirs*”. It seems that this assertion may be true even if Kaplan et al. [48] have a higher sample size.

To conclude, this section underlines the lack of homogeneity between the studies and thus the difficulty to compare them. In our comparison, it is impossible to conclude on the more robust study due many differences. However, it seems that the risk context, the sample, the wording and the baseline risk could be determinant to decide if a risk communication method is able to reconcile theory and practice or not.

## 6 Conclusion

In this paper, we concentrate on some risk communication methods aiming at reducing the departures of individual's behavior from rational choice theory. We focus on two well-known biases, the ‘insensitivity to scope’ and the ‘gain/loss asymmetry’. Our survey seems to indicate that some communication methods could allow to reconcile theory and practice. However, few studies test each risk communication method so that it is difficult to conclude on the more robust method. Even if several studies test some risk communication methods, the difference between studies in terms of risk context, sample, wording and baseline risk make difficult the comparison. Moreover, even when a study try to replicate an another one, some differences emerge and reduce the comparability of the results. This highlights the need of a comparative non-market valuation studies considering all the

risk communication methods presented in this paper in the same experience. Such a work would allow to inform practitioners about the efficient way to represent risk in non-market valuation studies.

However, this survey presents some limitations. First, the focus on two biases leads us to concentrate on some risk communication methods and to ignore other existing ones. For example, color photos are often used in contingent valuation to improve the comprehension of the attributes of the good. Thus, Carson et al. [10] use photos to represent the damages due to oil spill, the photos of Beer-Borst et al. [6] indicate the characteristics of some food products while Lindhjem and Navrud [52] opt for photos of endangered species and forest habitats to illustrate biodiversity concepts. Such a risk communication method is however not analysed in our study. Second, we concentrate on two well-documented and well-known biases but others should be analysed. For instance, the analysis of ‘Willingness-to-accept (WTA)/Willingness-to-pay (WTP) disparity’ could be interesting. The literature has shown that WTA is usually substantially larger than WTP, leading to a WTA/WTP ratio which is much higher than their economic intuition would predict (Kahneman et al. [45]). Horowitz and McConnell [39] propose a survey of this literature and conclude that the ‘WTA/WTP disparity’ is not an experimental artefact. Moreover, Plott and Zeiler [58] report that several methods were tested to try to explain and counter this disparity: samples of students and others, experiment in the lab and out the lab, several elicitation mechanisms, several commodities, introduction of learning... but they do not report the use of a visual display. Then, such a use to try to generate empirical results in accordance with theoretical ones could be a potential explanation and open a new area of research.

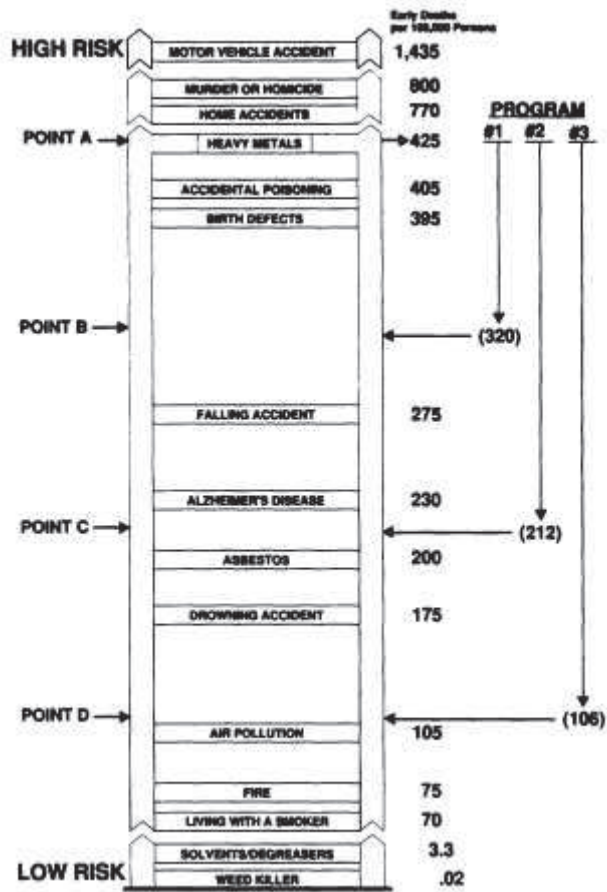
## A Community risk scale of Calman and Royston [9]

Figure 3: Community risk scale

<i>Risk</i>	<i>Risk magnitude</i>	<i>Risk description (unit in which one adverse event would be expected)</i>	<i>Example (based on no. of deaths in Britain per year)</i>
1 in 1	10	Person	
1 in 10	9	Family	
1 in 100	8	Street	Any cause
1 in 1000	7	Village	Any cause, age 40
1 in 10 000	6	Small town	Road accident
1 in 100 000	5	Large town	Murder
1 in 1 000 000	4	City	Oral contraceptives
1 in 10 000 000	3	Province or country	Lightning
1 in 100 000 000	2	Large country	Measles
1 in 1 000 000 000	1	Continent	
1 in 10 000 000 000	0	World	

## B Risk ladder of Loomis and duVair [54]

Figure 4: Linear risk ladder



C Risk ladders of Corso, Hammitt and Graham [15]

Figure 5: Logarithmic scale

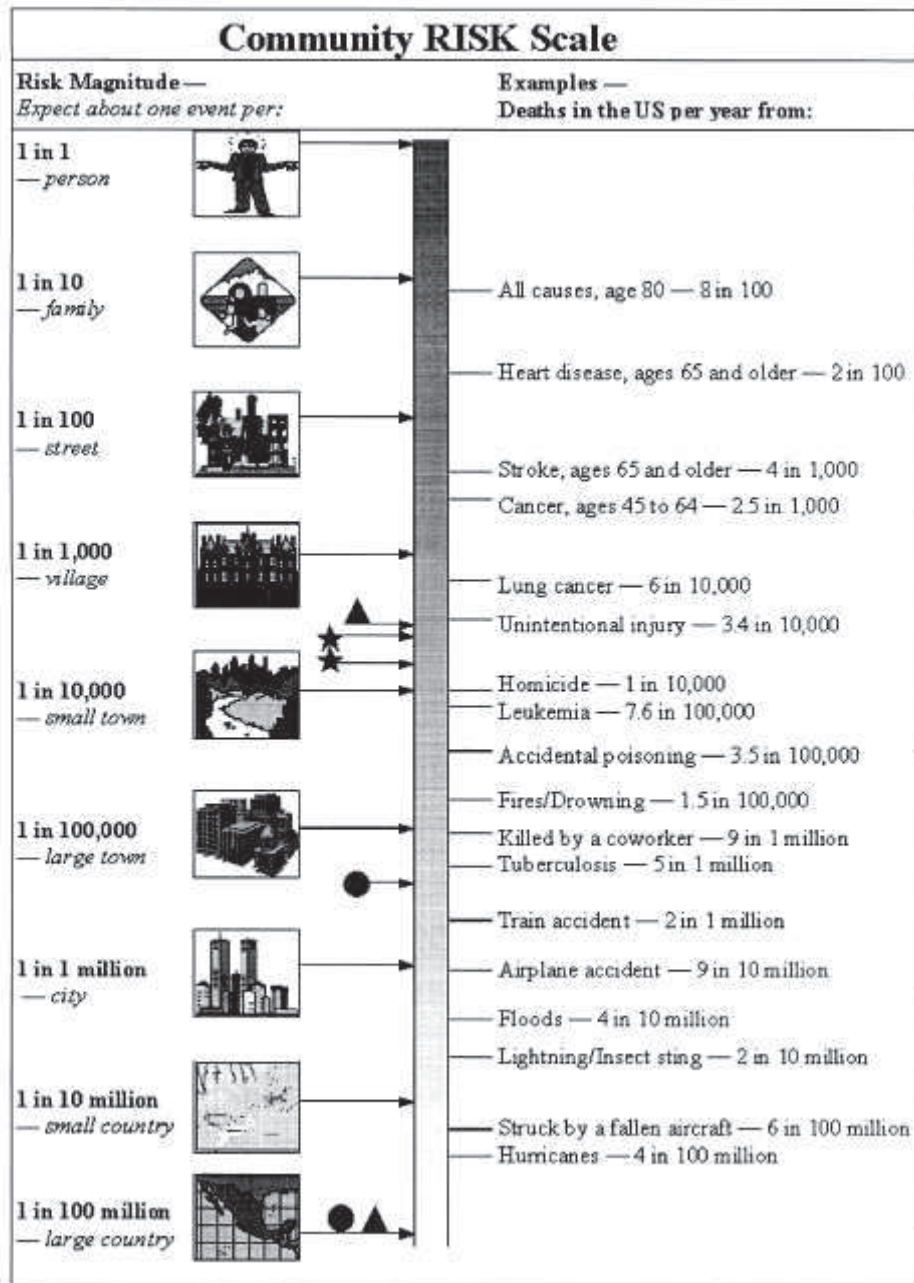
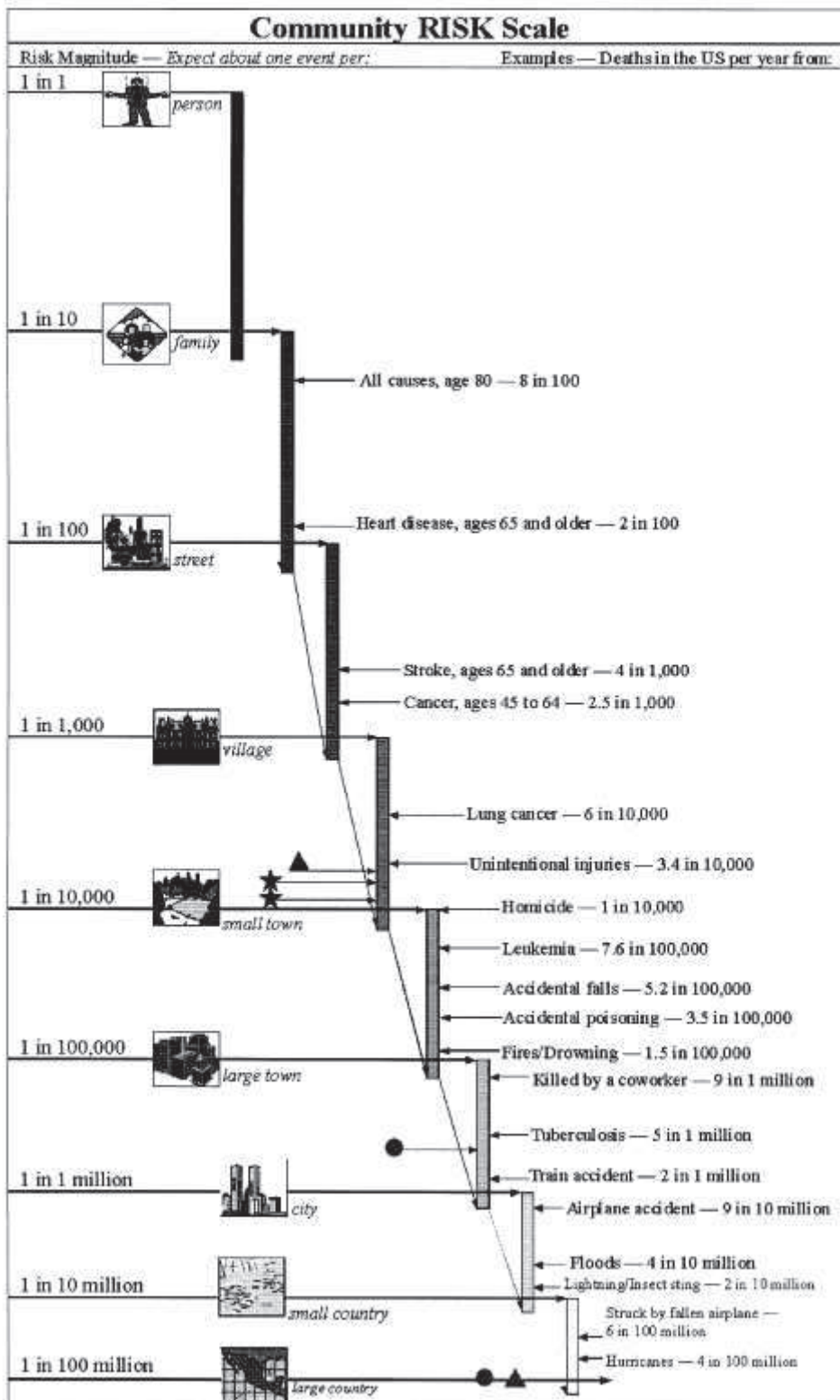


Figure 6: Linear scale



D Visual displays of Stone et al. [71]

Figure 7: Stick figures and faces of people



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