Chapter 4

The communication of probabilistic information

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4.1 INTRODUCTION

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In everyday communication people use many different words and symbols in connection with probabilities of events. 'Chance', 'risk', 'possibility' and 'likelihood' are among the most often used words. The multiplicity of terms used for probabilities can result in difficulties in interpreting a message. Therefore various studies have considered the problem of communicating probabilities, especially small values. However, according to the research review presented in the previous chapter (Idzikowska *et al.* this volume), people may either overweight or ignore information relating to small probabilities. As a consequence, communicating probability information to the general public in any domain, including that of natural hazards, is very difficult. At the same time, effective risk communication is very important as it can contribute to the taking of preventive action aimed at reducing the probability of an event associated with a risk occurring or diminishing the negative consequences of such an event if it does occur.

In the first part of this chapter we present different quantitative and qualitative methods of communicating probabilistic information that can be useful in the case of high impact, low probability (HILP) events. Our focus is on very low probability (below 1%) natural hazards such as floods, earthquakes, tornadoes, etc. Unfortunately, very few studies examine these types of risk (although see, e.g., the studies of natural hazards and traffic risk: Wu & Weseley, 2013; Hu *et al.* 2014; Henrich *et al.* 2015). Instead, the majority of studies are in the medical field and doctor-patient communication, where probability levels are higher than 1%. Researchers agree that conveying low-probability risk magnitudes is particularly difficult (Covello *et al.* 1986; Magat *et al.* 1987; Camerer & Kunreuther, 1989; Fisher *et al.* 1989; Roth *et al.* 1990; Fisher, 1991; Stone *et al.* 1997).

In the latter part of the chapter we present a new format of probabilistic information – sequential display – which seems to be an attractive method of communicating such information. The chapter ends with conclusions summarizing the main findings of the study and some recommendations regarding effective ways of communicating natural hazards with very low probabilities and serious consequences.

4.2 PROBABILITY FORMATS

Among the most frequently analyzed quantitative formats in the literature are numerical (e.g., frequencies, percentages, base rate, and proportions) and graphical (e.g., graphs, pictographs, population figures) ways of presenting probabilistic information (Timmermans *et al.* 2008; Visschers *et al.* 2009; Ancker *et al.* 2011; Hess *et al.* 2011). There have been a number of studies analyzing people's understanding of risk and the benefits of presenting probabilistic information in different formats. Results show that different risk formats have their advantages and disadvantages. Generally, no one format is suitable for all the different situations requiring communication of probabilistic information. The characteristics of the above probability formats and a literature review analyzing formats' impact on the process of communicating probabilistic information are presented below.

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4.2.1 Numerical probability formats

4.2.1.1 Percentages

Percentages (e.g., 0.1%) are the most common way to communicate risk and, according to many authors, also the most difficult to evaluate. They are used for hazard communication in many different areas; natural, medical and technical. Generally, research has shown that it is difficult for many laypeople to deal with numerical information (Gigerenzer *et al.* 2007; Peters *et al.* 2008) and to evaluate numerical probability information (Visschers *et al.* 2009), a format which requires cognitive effort to understand. Consequently, understanding of information is correlated with level of numeracy (Peters *et al.* 2006). In a study of health risk communication, Schapira *et al.* (2004) showed that high numeracy skills were correlated with more consistent risk judgments, this being manifest in the provision of identical responses for percentage and frequency scales for a given risk estimate.

Moreover, presenting probability information in a percentage format may have a lower impact on people's decisions due to its abstract nature (Slovic *et al.* 2005). According to Timmermans *et al.* (2008), information that is more concrete and easier to imagine has a greater impact on decisions. In these authors' study, participants evaluated risk information presented as percentages, frequencies and population figures. Results showed it was more difficult for people to understand and imagine probability information expressed in percentages (e.g., 10%) than in frequencies (1 out of 10) or with population figures. On the other hand, Schapira *et al.* (2004) compared the accuracy of breast cancer risk perceptions measured on both frequency and numeric (percentage) scales, and found that a frequency scale led to more accurate estimations of lifetime risk of breast cancer, while a percentage scale exhibited higher accuracy in estimating five-year risk.

Summarizing we can say that percentages:

- Are used the most often, but at the same time are the most difficult for people to evaluate,
- Are particularly inappropriate for less numerate people,
- Are abstract and therefore have low impact on people's decisions, and, in particular, may lead people to ignore small probabilities in the case of HILP events.

4.2.1.2 Frequencies

Frequencies (e.g., 1 in 10,000) according to the Cambridge Advanced Learner's Dictionary and Thesaurus are defined as 'the number of times something happens within a particular period' (CALDandT, 2016) and are often used in the communication of probabilities as they are easier to use and imagine than percentages (Timmermans *et al.* 2008). Unsurprisingly then, research has shown that frequencies have a greater impact on people's judgments (Slovic *et al.* 2005; Timmermans *et al.* 2008) and elicit greater emotional engagement (Food & Drug Administration

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[FDA], 2011) compared to percentage formats, which are relatively abstract. On the other hand, although frequencies are easier to understand than percentages, people may not regard frequencies as being personally important, Visschers *et al.* (2009) showing that a frequency might be positively interpreted (i.e., people associated themselves with one of the nine people not affected by a particular risk when the risk was presented as '1 out of 10'). However, greater emotional engagement can lead to higher risk evaluations, especially among respondents with low numeracy skills, when compared to information presented in a percentage format (Peters *et al.* 2006).

Studies of frequency formats have also revealed that this method of communicating probabilities has weaknesses that can influence the understanding of information. For example, the literature review by Visschers *et al.* (2009) indicated that frequency information often seems to be misinterpreted, especially when different denominators are used. Yamagishi (1997) analyzed what happens when the same frequency is presented as a fraction of various denominators. They described the effect of small versus large denominators (100 versus 10,000) and showed that respondents relied only on the numerator (the number of deaths caused by one factor from a list of causes) as an anchor to estimate risk and ignored the denominator (the sample size) when assessing risk in a population. Gigerenzer *et al.* (2007) showed that people understand frequencies better when risk is expressed as a natural frequency, which is a step-by-step description of a risk's probability reflecting the way people would learn its probability in real life (Visschers *et al.* 2009).

Along with frequencies, researchers have also investigated proportions, which are a special case of the frequency format. With frequencies, the number of people affected by a risk (numerator) changes, while the denominator remains a round, constant number (e.g., 3 per 1000 people). In proportions, the numerator is kept constant, and the denominator changes (e.g., 1 per 333 people). This method of presenting probability information is often used by health professionals, who change denominators to obtain a numerator of 1 (e.g., 1 in 3333). Pighin and his team (2011) conducted a series of experiments in this area and showed that proportions were subjectively perceived as larger and more alarming than the same values presented as frequencies. These results provide evidence that proportions may often be misinterpreted.

Summarizing we can say that frequencies:

- Are easier to use and imagine than percentages,
- Elicit emotional engagement, which leads to higher risk evaluations,
- May be misinterpreted, especially if denominators are not the same.

4.2.1.3 Base rates

Base rates are a statistic used to describe the percentage of a population that demonstrates a characteristic, and are often presented in percentages or frequencies, that is, the base rate of a particular hazard in a given population can be presented as 0.1% (1 in 1000), which means that 1 person will experience the particular outcome, while 999 will not. Research shows that probability information communicated

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in this format is often misunderstood or neglected (Fischhof, 1995), although the study by Visschers *et al.* (2009) provided evidence that base rates are better understood than proportions.

Some researchers have noted that conditional base rates (for specific conditions) can be more useful than general base rates (for a whole population). Greening *et al.* (2005) asked two groups of respondents to report their perceptions of risk of personal harm. One of these groups was provided with general, and the other with conditional, base rates. The conditional base rate group was divided into two subgroups: low- and high-risk (non-smokers versus smokers in relation to the risk of lung cancer). People in all groups tended to report that they were at lower risk of harm than the average for their cohort. However, providing conditional base rates for high- and low-risk groups decreased the number of people reporting this over-optimistic attitude. Thus, conditional base rates seem helpful for a proper estimation of risk.

Moreover, Klein and Stefanek (2007) discussed the relationship between the framing of probability information and the propensity to take preventive actions. Their review noted that people are more likely to engage in screening behaviors (mammography) when presented with loss-based messages than gain-framed messages, and they often ignore the base rate of a given disease when assessing their own risk of getting the disease.

Summarizing, it seems that, in the case of HILP events, base rates may be used when information about probabilities can be augmented by additional, tailored data or presented with loss-framed messages in order to increase the propensity to take preventive actions. However, research has revealed a low level of understanding of probability information when it is presented in a base rate format.

In conclusion, base rates are:

- Often misunderstood or neglected,
- Sometimes better understood than proportions,
- In need of additional information (e.g., framing) to be useful.

4.2.2 Graphical probability formats

4.2.2.1 Graphs

Graphical probabilistic information formats embrace graphs, pictographs (including population figures) and Paling Perspective Scales. Graphs present probability information in a visual way to communicate risk characteristics: risk magnitude (how large or small a risk is), relative risk (comparison of the level of two or more risks), cumulative risk (trends over time), uncertainty (estimations of variability and ranges of scores) and interactions among risk factors (Lipkus & Hollands, 1999). According to Lipkus and Hollands visual displays such as graphs can increase understanding of information about values of a particular risk. The authors claim that graphs help people to analyze information more effectively than when only numbers are provided. There are various ways of presenting probability information via graphs: histograms,

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line graphs, and pie charts. Figures 4.1 to 4.3 present examples of each of these for different types of natural disaster according to https://ourworldindata.org.

Figure 4.1 presents a histogram comparing the frequency of deaths from three different natural hazards (floods, earthquakes and droughts) worldwide over the last few decades according to https://ourworldindata.org.

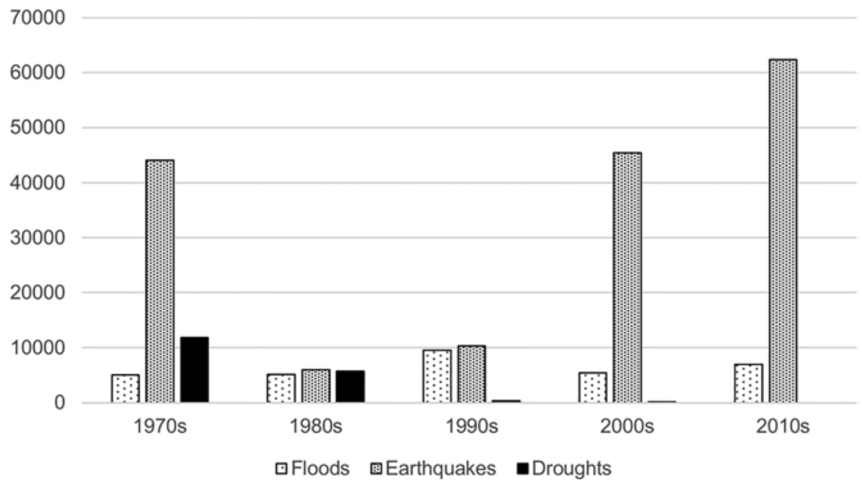

Figure 4.1 A histogram presenting data on the number of deaths caused by floods, earthquakes and droughts between 1971–2016 (https://ourworldindata.org).

Another example of graphs are line graphs, often used to show trends over time. Figure 4.2 presents a line graph of deaths caused by storms from the middle of the 20th century.

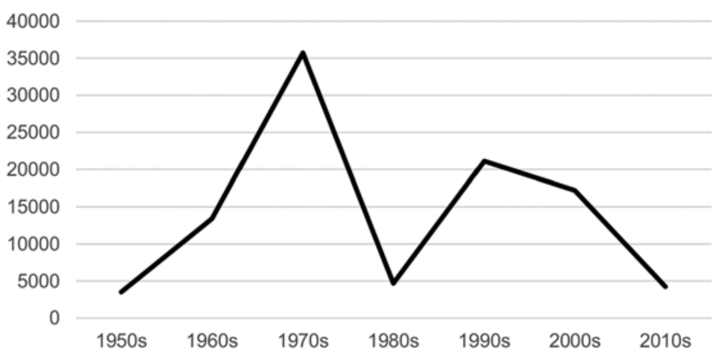

Figure 4.2 A line graph presenting a time trend of deaths from storms from the 1950s to the first decade of the 21st century (https://ourworldindata.org).

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Figure 4.3 shows proportions of deaths from wildfires, volcano eruptions and dry mass movement within the first decade of the 21st century.

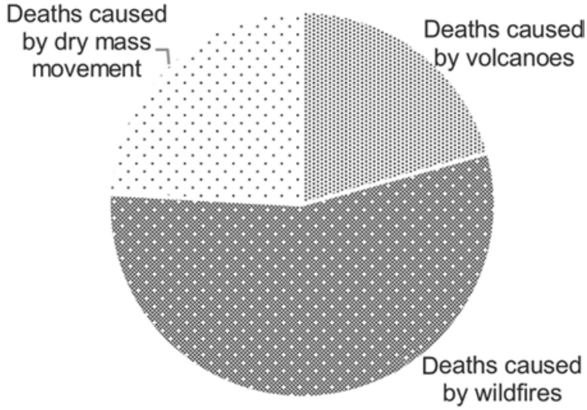

Figure 4.3 A pie chart illustrating proportions of deaths from volcano eruptions, dry mass movements and wildfires within the last decade of the twentieth century (https://ourworldindata.org).

Particular types of graphs serve specific purposes. Histograms are used for comparisons (presenting risks for different groups, seasons or areas), line graphs show trends over time and interactions among different risk factors, and pie charts are helpful for judging proportions.

Generally, graphical depictions capture attention more than numerical information (Chua *et al*. 2006). However, they do not lead to more accurate estimates of risks compared to numeric-only displays (Schapira *et al*. 2006). Moreover, graphs are difficult to use for very rare natural hazards. Many researchers have emphasized that graphs should be accompanied by clear, comprehensible explanations of their meaning (Armstrong *et al*. 2001; Parrot *et al*. 2005; Lipkus, 2007).

In conclusion, graphs:

- Help people to analyze information, but do not lead to more accurate estimates of risks,
- Are useful for showing trends and interactions,
- Are problematic for displaying probabilities below 1%.

4.2.2.2 Pictographs

Pictographs are symbols used to present proportions graphically. They help to communicate risk. Depending on the type of risk communicated, pictographs show the part of a population at risk. Figure 4.4 shows a pictograph depicting house

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fire risk. The number of houses reflects the number of elements in a population. A black house indicates a fire, a white house designates no fire.

Figure 4.4 A pictograph communicating the risk of a house fire.

Several studies have shown that, contrary to numerical formats, pictographs can be particularly useful for communicating risks to people with low numeracy skills (Zikmund-Fisher *et al.* 2008; Galesic *et al.* 2009; Hess *et al.* 2011). There are two basic ways of processing pictographs: focusing on the numbers of different elements or holistic processing. Highly numerate people pay more attention to the numerical information in a graph, while those with lower numeracy may have difficulty analyzing such information. Adding reference information to a pictograph can therefore help to communicate risks only when the receiver of information exhibits high numeracy (Paling, 2003; Lipkus, 2007; Hawley *et al.* 2008).

Figure 4.5 shows a special type of pictograph called a population figure pictograph. These are used in communicating probability information concerning risks related to humans. The number of figures represents the size of the population. The grey figure indicates a person at risk (e.g., of having a particular disease), while the black figures indicate people at no risk.

Figure 4.5 An example of a population figure pictograph.

Timmermans *et al.* (2008) showed that population figure pictographs have a great affective impact. Risk presented in this format was evaluated as significantly greater than the same risk presented in other formats. Again, as with the previously described graphical formats, pictographs and population figures are difficult to use in cases of very small probabilities.

In conclusion, both pictographs in general and population figure pictographs:

- Help to communicate risk, especially to people with low numeracy skills,
- May induce the greatest affective impact of all formats,
- Are problematic for probabilities below 1%.

4.2.2.3 The Paling Perspective Scale

The Paling Perspective Scale is a type of graphical representation depicting risks of different orders of magnitude on a logarithmic scale. In contrast to other graphical formats, it presents not only the risk at issue but also information about other risks, which may help people evaluate the particular risk at issue (Keller & Siegrist, 2009).

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For instance, this format allows representation of flood risk in relation to risk of fire or other natural hazards. Figure 4.6 illustrates the use of the Paling Perspective Scale to present information about the probability of a selection of rare natural hazards causing death.

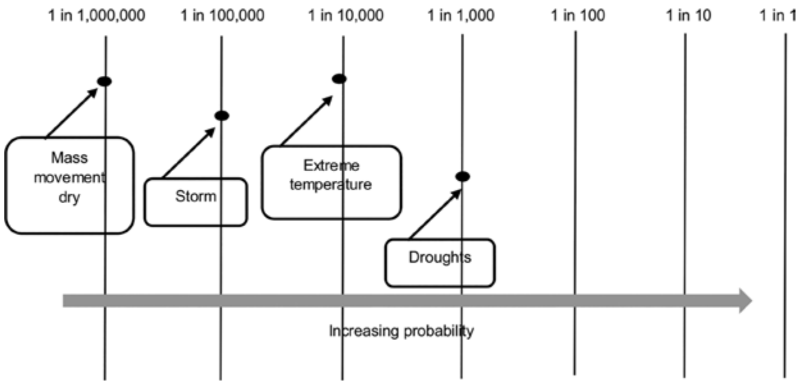

Figure 4.6 Frequency of natural hazards as causes of death presented using the Paling Perspective Scale.

The inclusion of information about the probability of other risky events is based on the assumption that people may not know whether the probability of the risk at issue is low or high. Therefore, additional information helps them to evaluate the risk. Keller and Siegrist (2009) noted that the comparative risks selected might substantially influence risk perceptions. In order to facilitate comparison between different risks, all risks should belong to the same category, for example, natural hazards, health problems, crime.

Keller and Siegrist also analyzed relationships between risk level, numeracy skills, and comprehension of probability information presented on a logarithmic scale. Results showed that only highly numerate people can understand information presented using the Paling Perspective Scale. Although this scale was developed to facilitate the comprehension of information about very low probability events, this finding limits its applicability.

Summarizing, the Paling Perspective Scale:

- Provides additional information to help to evaluate a risk,
- Is understandable only to highly numerate people.

4.2.3 Verbal probability information

Verbal probability terms (e.g., exceptionally unlikely, almost certain, almost impossible) are qualitative methods of communicating probabilities. They are intuitive since they are used in everyday life. Moreover, they imply an interpretation

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of risk probabilities that can induce affect (Visschers *et al.* 2011). Verbal probability expressions are predominantly used in the case of very frequent events, where a relatively large number of synonyms exist. The smaller number of terms available for describing very rare events increases the difficulty of precisely communicating probability information for such events.

Research shows that numerical correlates of verbal expressions differ greatly between individuals, and especially between experts (e.g., physicians) and the general public (Weber & Hilton, 1990; Visschers *et al.* 2009). Brun and Teigen (1988) showed that verbal information about probabilities was associated with lower numerical values in a medical treatment context than in a no-context condition. Therefore, to accommodate different interpretations of the same expressions, Visschers and colleagues (2009) claim that verbal expressions of probability information should be pretested for the specific contexts and target groups for which they are to be used. Some researchers suggest using both numerical and verbal probability information in risk communication, because people prefer numerical information for its accuracy but use verbal statements to relay probability information to others (Visschers *et al.* 2009).

Patt and Schrag (2003) asked participants to assign a numerical value to verbal probabilities and found that highly severe consequences decreased the numerical probabilities assigned to verbal probability expressions. Indeed, when participants were asked to assign numerical probabilities to the terms 'likely, perhaps likely', or 'unlikely, perhaps very unlikely', they ascribed lower numerical probabilities to a hurricane than to a snow flurry.

Summarizing: communicating probability information using a verbal format is:

- Very intuitive,
- Dependent on context.

4.3 DISPLAYING PROBABILITY INFORMATION IN A SEQUENTIAL FORMAT: AN EMPIRICAL VERIFICATION

The above literature review shows that the majority of existing formats for imparting probability information are difficult to use in the case of very low probability hazards, that is, very rare events. Therefore, we have attempted to develop a new format of probabilistic information designed to communicate very low probabilities. This new format is based on a combination of graphically displayed and experience-based probability information. Participants in an experiment were asked to observe a series of binary events which allowed them to learn the proportion of specified events occurring. Such a combination was tested by Tyszka and Sawicki (2011) who presented their participants with a sequence of 100 binary events represented by two photographs: one of a normal child and one of a child with Down's syndrome. When they compared the experience-based format with certain numerical and graphical formats they found that the experience-based probability format led to

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greater sensitivity to differences in probability magnitudes. However, the format used by Tyszka and Sawicki cannot be applied to very rare events.

Therefore our goal was to design a new format appropriate for presenting very small probabilities using a sequential display format. This is a series of screens, each of which presents the number of distinct objects (e.g., house fires in a particular area, HIV infected patients) in the context of the whole population at issue. Using a number of screens instead of one allows the representation of very rare events.

4.4 EXPERIMENTS 1 AND 2: COMPARING A SEQUENTIAL DISPLAY FORMAT WITH OTHER PROBABILITY FORMATS

4.4.1 The research goal

The main goal of our research was to test whether the new sequential display format for communicating probabilities is better than the alternatives. In doing this, we took account of Sjoberg's (1979) observation that small probabilities are especially difficult to judge because it is hard to discern meaningful subjective differences between, for example, a probability of 0.001 and a probability of 0.0001. Therefore, we were interested in whether, relative to other formats, the new format improves sensitivity to differences between small probabilities. We hypothesized that sensitivity to differences in probability magnitudes would be the highest for the sequential display probability format.

4.4.2 Method

4.4.2.1 Participants

We recruited 139 students for Experiment 1 and 150 students for Experiment 2 from Kozminski University, Warsaw. For Experiment 1 participants' mean age was 24 years ($SD = 5.9$), and 59% were women, while in Experiment 2 participants' mean age was 23 years ($SD = 4.5$) and 61% were women. Participants were given course credits for their participation.

4.4.2.2 Design

Both experiments consisted of one computerized session (performed using the labsee.com online platform). To test the hypothesis, we chose two scenarios involving different rare risks: a house fire risk connected with high material losses and risk of HIV infection.

The first of these, used in Experiment 1, is an example of a rare natural hazard. Levels of probability used in the study were obtained from an analysis of fire service headquarters statistics and reflected the real incidence of house fires.

In Experiment 2 we used medical risk as the majority of studies in the extant literature on the effects of probability format on comprehension of information and

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decision-making concern medical risk, and people do indeed frequently have to face probabilistic information in the context of the medical treatment of diseases. Risk of HIV infection was selected since World Health Organization statistics show that its frequency is similar to that of a house fire.

Participants were randomly assigned to one of three experimental conditions. Each condition used one of three probability formats. Probabilities of a serious house fire (or people infected with HIV) were presented as frequencies (e.g., 10 in 10,000), as percentages (e.g., 0.1%) or as sequential displays (the novel format).

4.4.2.3 The sequential display probability format

In our experiments we applied the sequential display probability format and two other probability formats: percentages and frequencies. In Experiment 1 the risky event was a house fire, observed by the participant on 20 sequentially presented screens (Figure 4.7). In Experiment 2 the risky event was HIV infection during blood transfusion, observed in the same manner as for Experiment 1. On those screens a series of figures (houses or people) were presented, where the red figures (indicating the occurrence of the risky event) were distributed randomly. In both experiments the total presentation of events lasted less than one minute.

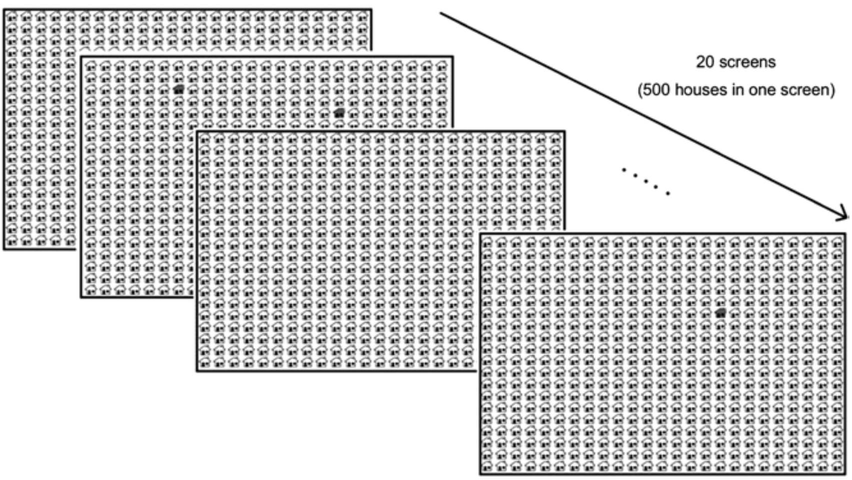

Figure 4.7 An example of boards in the sequential display format.

The Experiment 1 scenario was as follows:

Please imagine that you are going to change your place of residence. In a moment, you will be shown the frequency of house fires in one year in your new

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location according to the statistics of the local fire service. You will see a series of houses in two colors: white and red. Red indicates houses having suffered a fire and white indicates houses experiencing no fire. Fires were serious enough to cause significant material damage.

(The red houses were distributed randomly. The total presentation of events lasted less than one minute.)

The Experiment 2 scenario was as follows:

Please imagine that you are going on vacation to an exotic country. During your stay you fall ill with a disease, the treatment of which requires a blood transfusion. In a moment you will see a display of World Health Organization statistics relating to the annual frequency of HIV infection during blood transfusions in this country. The display consists of a series of people in two colors: black and red. A red person indicates an HIV infection and a black person indicates no infection during a blood transfusion in this country.

(The red people were distributed randomly, and the total presentation of events lasted less than one minute.)

4.4.2.4 Procedure

Each participant was presented with three different levels of the probability of a house fire (or HIV infection; a within-subjects factor) in random order: 10, 32, or 50 in 10,000. There were breaks of five seconds between presentations of each screen

After each presentation at a given probability level, participants were asked to evaluate the risk of a house fire in Experiment 1 and HIV infection risk in Experiment 2 on a visual analog risk affect scale (0–100) consisting of three items:

- Risk – (ranging from ‘complete lack of risk’ to ‘extremely high risk’),
- Danger – how dangerous the risky situation was (from ‘complete lack of danger’ to ‘extremely high danger’),
- Worry – being worried about the risk (from ‘extremely calm’ to ‘extremely anxious’).

Cronbach’s α for the scale was 0.94.

4.4.3 Experiment 1 – results

4.4.3.1 Evaluation of house fire risk on the risk affect scale for three probability formats

Figure 4.8 depicts average evaluations of the three probability levels on the risk affect scale for the three probability display formats. Data were analyzed using a mixed-design analysis of variance (ANOVA) with probability level (0.0010, 0.0032, 0.0050) as a within-subjects factor and probability format (sequential display, frequencies, percentages) as a between-subjects factor. We found a significant

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main effect of probability level, $F(2,272) = 78.088$, $p < 0.001$, $\eta_p^2 = 0.365$, and a significant main effect of probability format, $F(2,136) = 4.158$, $p = 0.018$, $\eta_p^2 = 0.058$. Additionally, there was a significant probability level by probability format interaction, $F(4,272) = 2.892$, $p = 0.023$, $\eta_p^2 = 0.041$. Planned contrast showed that probability format had significant impact on evaluation of risk on the affect scale for probability 0.0010, $F(2,136) = 3.187$, $p = 0.044$, $\eta_p^2 = 0.045$ and for probability 0.0050, $F(2,136) = 4.981$, $p = 0.008$, $\eta_p^2 = 0.068$ but was insignificant for probability 0.0032, $F(2,136) = 2.956$, $p > .05$.

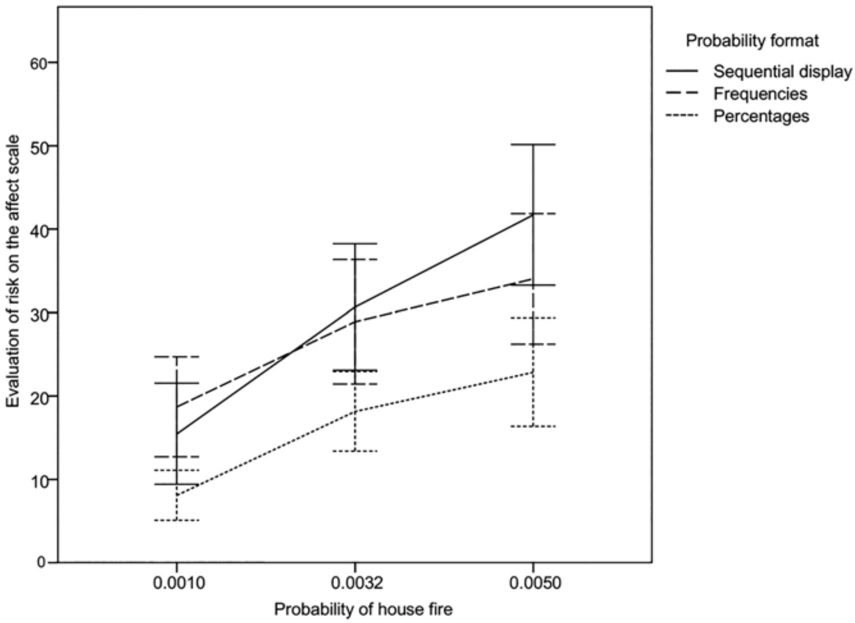

Figure 4.8 Average evaluation of house fire risk information on the risk affect scale for three probability levels in the three probability formats. Error bars represent 95% confidence intervals.

Evaluations of house fire risk were the highest for the sequential display probability format and lowest for the percentage probability format for two probability levels: 0.0032 and 0.0050. Previous studies have found that people tend to ignore information about probabilities of very rare events, and the tendency to ignore this information was lowest for the sequential display format. Moreover, the interaction between probability level and probability format indicated that participants had differing sensitivities to probability variations across the three probability formats.

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4.4.3.2 Sensitivity to differences in probability magnitudes

We measured sensitivity to differences in probability magnitudes as the difference between evaluations of house fire risk for the highest (0.0050) and lowest (0.0010) probability levels on the risk affect scale (see Figure 4.9).

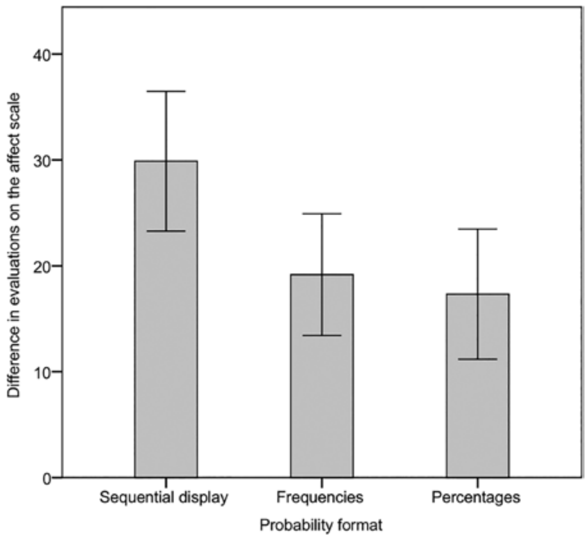

Figure 4.9 The difference between evaluations of the highest (0.0050) and the lowest (0.0010) probability levels on the risk affect scale for three probability formats. Error bars represent 95% confidence intervals.

For the results presented in Figure 4.9 the mean difference between the highest (0.0050) and lowest (0.0010) evaluations of house fire risk on the risk affect scale was 29.88 ($SD = 18.20$) for the sequential display format, 19.17 ($SD = 18.20$) for the frequency format, and 17.33 ($SD = 19.74$) for the percentage format. A one-way ANOVA performed on the differences between evaluations revealed a significant effect of format on risk affect scale responses, $F(2,122) = 4.935$; $p = 0.009$. The Tukey post hoc test revealed that the sensitivity to differences in probability magnitudes was significantly greater when sequential displays probability format was used than when both frequencies and percentages were used (each $p < 0.05$). The sensitivity to differences in probability magnitudes was not significantly different when frequencies and percentages were used.

Summarizing, the data supported the study's hypothesis that participants would be the most sensitive to probability variations when the sequential display probability format was used. Additionally, we found that the lowest sensitivity was observed for the percentage format.

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4.4.4 Experiment 2 – results

4.4.4.1 Evaluation of HIV infection risk on the risk affect scale for three probability formats

Figure 4.10 represents average evaluations of the three probability levels on the risk affect scale for the three probability formats. As in Experiment 1, data were analyzed using a mixed-design ANOVA with probability level (0.0010, 0.0032, 0.0050) as a within-subjects factor and probability format (sequential display, frequencies, percentages) as a between-subjects factor. There was a significant main effect for probability level, $F(2,294) = 72.783$, $p < 0.001$; $\eta_p^2 = 0.331$, and a significant main effect for probability format, $F(2,147) = 3.464$, $p = 0.034$, $\eta_p^2 = 0.045$. The interaction between probability level and probability format was marginally non-significant, $F(4,294) = 2.135$, $p = 0.076$, $\eta_p^2 = 0.028$.

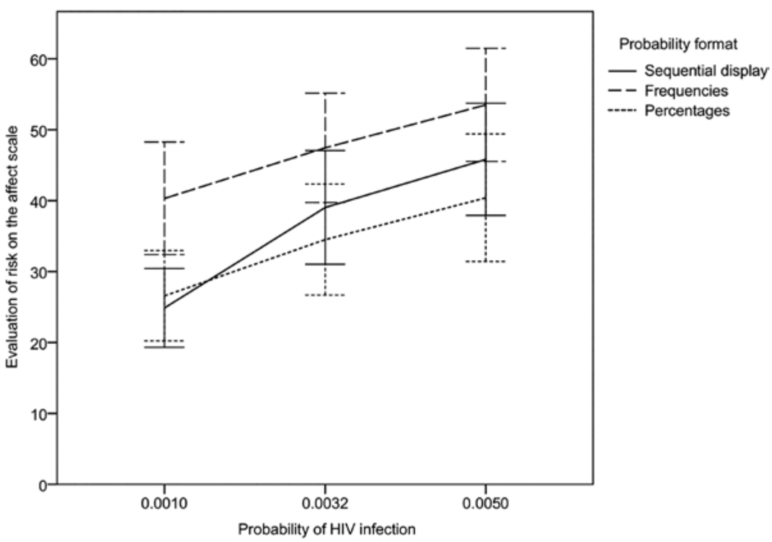

Figure 4.10 Average evaluation of HIV risk information on the risk affect scale for three probability levels in the three probability formats for communicating probabilistic information. Error bars represent 95% confidence intervals.

Unlike Experiment 1, evaluations of HIV risk were highest for the frequency probability format and (for two probability levels: 0.0032, 0.0050) lowest for the percentage probability format. However, for all three probability levels, the mean evaluations of HIV infection risk for the sequential display format were similar to those in Experiment 1 where the stimulus was house fire risk. This result suggests that, regardless of the type of risk, participants made similar evaluations of probability levels on the risk affect scale under the sequential display format.

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4.4.4.2 *Sensitivity to differences in probability magnitudes*

We measured sensitivity to variations in probability as the difference between evaluations of HIV infection risk for the highest (0.0050) and the lowest (0.0010) probability levels on the risk affect scale (see Figure 4.11).

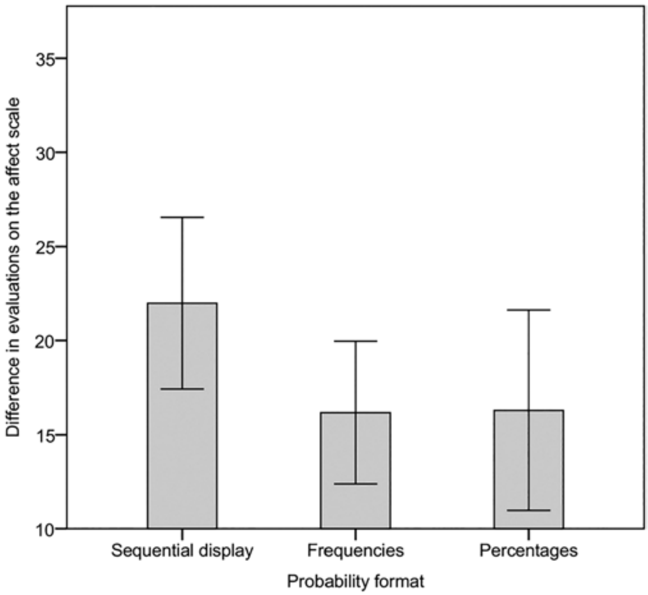

Figure 4.11 The difference between evaluations for the highest (0.0050) and the lowest (0.0010) probability level on the risk affect scale for three probability formats. Error bars represent 95% confidence intervals.

For the results presented in Figure 4.11 the mean difference between the highest (0.0050) and lowest (0.0010) evaluations of HIV infection risk on the risk affect scale was 21.99 ($SD = 15.56$) for the sequential display format, 16.17 ($SD = 12.47$) for the frequency format, and 16.3 ($SD = 17.93$) for the percentage format. A one-way ANOVA performed on the differences between the evaluations showed no significant effect of format on risk affect scale responses, $F(2,134) = 2.119$, $p = 0.124$.

Summarizing, the data partially supported the study's hypothesis that participants would be the most sensitive to probability variations when the sequential display probability format was used, and that the lowest sensitivity would be observed for the percentage format.

In the two studies we demonstrated the effect of probability format on sensitivity to probability variations using a risk affect scale. In both studies the highest sensitivity was observed for the sequential display format. Differences

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in sensitivity to variations in probabilities across formats were significant in the experiment involving house fire risk but not in that involving HIV infection risk. Therefore, there was only partial confirmation of the hypothesis that the highest sensitivity to probability variations would be for the sequential display format. Nonetheless, we still suggest that, overall, the new presentation format is more effective for low probability events than the alternatives.

The studies also showed differences in comprehension of probability information for both house fire risk and risk of HIV infection during a blood transfusion. Perhaps this was due to the type of risk: to a physical asset in the case of house fire risk and to health in the case of HIV infection. Generally, we obtained higher values on the risk affect scale in the case of health risk (Experiment 2), which can be attributed to the nature of this risk inducing greater emotional arousal. Consequently, this could also have resulted in the lower differences in sensitivity to probability variations observed in Experiment 2. However, further research is required to confirm this. It is worth noting that, in addition to its sensitivity to probability variations being the highest and despite differences in the nature of risk, the mean measure for the sequential display format was relatively stable across both studies.

4.5 CONCLUSIONS

The proposed new format for communicating probabilities – sequentially displayed frequencies – had some advantages over other formats. One advantage was that the new probability format was less influenced by the type of risk being evaluated, which makes the probability evaluations it produces more reliable. The other advantage was that it had the highest sensitivity to variations in probabilities compared to the frequency and percentage formats. These advantages suggest that the sequential display format may be useful in communicating small probability risks and may contribute to more systematic and less heuristic-laden processing of risk messages (Visscher *et al.* 2009).

Where do the advantages of sequential displays of frequencies over the other formats of presenting probabilities come from? In the 1950s and 1960s there was a series of research studies on the perception of frequencies of everyday life events such as frequencies of the appearance of different letters in newspapers, of different words in spoken English, etc. (see, e.g., Attneave, 1953). The results of these experiments showed that subjective evaluations of the frequencies of such events were highly accurate. Further, Hasher and Zacks (1979) found that even pre-school children performed well on tasks in which they observed stimuli shown with different frequencies and had to evaluate their frequencies of occurrence. According to Tooby and Cosmides (1992), this amazing accuracy of perceptions of frequencies may be the result of human evolution. Historically, people needed to develop a mechanism for using information about the frequencies of various events. Human hunter-gatherers depended upon the resources they were able to find in nature. The ability to properly determine frequencies associated with the abundance of resources

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seems to be crucial for survival. Thus, the proposed sequential display method of communicating probabilities is based on evolutionarily adapted perceptions of frequencies of events. And this accounts for its high practical usability.

Still another advantage of the sequential display of frequencies format over the other formats of presenting probabilities is its relative insensitivity to affect-laden stimuli. This is a vital issue, since when dealing with affect-laden stimuli people become insensitive to values of probabilities. For example, Fox (2014) noted that more than a quarter of Americans were worried about being infected with Ebola despite expert opinion that the spread of this virus in the United States or any other developed country was very unlikely. In this case, intense emotions resulted in significantly overweighting the very low level of probability. On the other hand, people may underweight small probabilities of events which have not occurred recently (see Chapter 2 of this volume). The sequentially displayed frequencies method seems to reduce such tendencies.

How might this method be used for communicating probabilities of flooding? There are two major differences between the display used in our two experiments and the requirements for information about flooding. First, while frequencies of fires and infections can be represented by the proportions of their occurrence within a neighborhood or community during a given interval, frequencies of floods should be presented as a function of time (years). The frequencies of flood events should refer to the flooding of certain areas during different periods. Second, unlike fires and infections, which either happen or not, the degree of severity of a flood is highly relevant. Thus, in the case of floods it seems desirable to include at least three states: no flooding, a small flood and a large flood.

For example, in order to communicate the probabilities of flood events – 0.02 for a large flood, 0.2 for a small flood, and 0.78 for no flood – one could use a sequence of 50 screens randomly presenting the three events – no flood, small flood, and large flood (as shown in Figure 4.12), with corresponding frequencies: 1, 10, and 39. Each screen represents one year. For still smaller probabilities, one can use screens representing not 1 year but longer intervals such as 10 years.

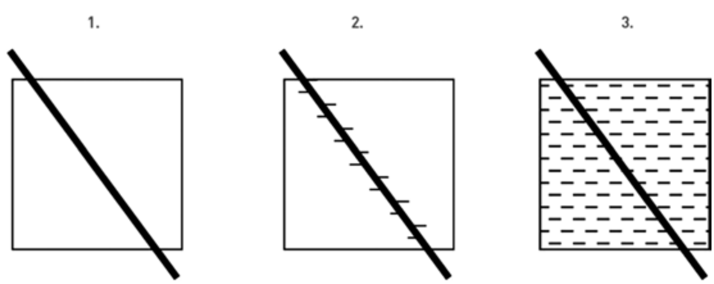

Figure 4.12 Communicating probabilities of flood events. Random presentation of screens relating to three events: (1) no flood; (2) small flood, and (3) large flood.

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