Department for Environment Food and Rural Affairs

Environment Agency

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How the public and professional partners make sense of information about risk and uncertainty – literature review

Science project SC070060/SR1

Flood and Coastal Erosion Risk Management Research and Development Programme

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Steve Killeen

Head of Science

Executive summary

Drawing from literature and other relevant sources of information, this report aims to determine how public and professional partners make sense of information about risk and uncertainty.

The scope of the review focussed on the understanding and use of **information about likelihood, chance or probability**. This narrowed the review to exclude research about information on consequences alone, or information just on what to do in an emergency situation where likelihood is not also being conveyed. However, it proved impossible to neatly disentangle risk from uncertainty, given that the two terms are often used interchangeably or given different meanings.

The review was not restricted to the UK as there was an evident need to pick up on risk information initiatives and experiences in other countries. However, caution needs to be exercised in making use of research undertaken in sometimes very different risk, cultural and political contexts.

The main findings of the literature review can be summarised as follows:

- Broad societal debates about public understanding of risk and uncertainty have moved in the direction of arguing that it is a good thing and that government institutions are more explicit and open about risk and uncertainty, promoting greater social trust and understanding. Counterarguments, however, point to the misunderstandings and undermining of expertise which might arise.

- Neither ‘the public’ nor ‘professional partners’ are a homogenous group. For example, a large number of members of the public may have issues with literacy and numeracy. Age, gender, ethnic, cultural and socioeconomic differences can all also be important in affecting how information is received and interpreted. In addition, the various professional partners might have quite different information needs.

- Research does not point to one single effective means of communicating probabilistic and uncertainty information. It is clear that communications are **interpreted** within personal, social or institutional contexts, and according to individual personality predispositions. Providing additional information may not lead to different decisions, as new information is merely one factor in the process of decision-making in the real world. Trust in the source of information can be particularly important.

- There is limited research to draw on to understand how probabilistic information on the likelihood of imminent hazard events is understood and used. This is the case for ‘the public’ and even more so for professional partners, where there is very little work on risk communication in general. Research on probabilistic information in hurricane warnings provides the only limited examples.

- There is a more substantial body of research on the use of probabilistic information in the fields of health and medicine, and weather forecasting. These fields can both provide some useful insights. However, it is important to remember the differences between these communication contexts. These include the types of information involved, who is communicating, the context of communication and the implications of actions taken.

- Literature from health and medicine suggests that how people assess and process risk information depends on their circumstances, medical condition at the time, and their emotional response. Research has tested many different formats for presenting probabilistic risk information. Numerical formats such as percentages can suggest precision but are in practice interpreted in different ways. Expressing probabilities in terms of relative risk and using reference classes have been recommended as more effective in some circumstances. Verbal qualitative formats might be easy to understand and suggest uncertainty. Guidelines have been developed, but some studies urge caution with assuming that these are clearly understood. Visual methods can hold people's attention and communicate summaries of data. The exact formats used appear important to understanding, but it is not necessarily the case that formats that are better understood lead to a greater degree of desired behaviour change.

- Research on weather forecasts tends to suggest that the public do understand basic probability information when it is presented clearly (e.g. 'there is a 30 per cent chance of rain tomorrow'). One source of confusion seems to be because forecasters have not been clear about what the percentage probability refers to (i.e. the reference class). Forecasters themselves have been found to be confused about the meaning of quantitative indicators and qualitative descriptors such as 'fine'. People seem to infer uncertainty into forecasts, so would rather receive forecasts with additional uncertainty data (e.g. on average the temperature will fall within this range five out of ten times).

- Experimental research on public responses to probabilistic information in hurricane warnings in the USA found that residents had a good understanding of the probability information, but that this did not influence decisions about evacuation as the specific advice or orders of local officials were most important. Other research on public understandings of a visual representation of probability during a hurricane season found consistent misinterpretation and reading of uncertainty information as deterministic.

- The very limited laboratory-based research seems to suggest that, when decision-makers such as professional partners are presented with uncertainty information as part of weather and hazard scenarios, they may make better decisions.

- Instead of trying to educate the public about the exact meanings of forecasts and probabilistic information, it may be more important and useful to first understand how the public use the information. Developing an iterative process in collaboration with end users would be a useful way of taking the development of probabilistic hazard warnings forward.

Contents

1 Aims, scope and method

1.1 Objective and tasks

This review addresses Objective 1 of the project which is to:

Determine how public and professional partners make sense of information about risk and uncertainty from literature and relevant sources of information.

This objective has four associated and overlapping tasks:

- Task 1 – review existing knowledge and evidence of how the public understand information about risk and uncertainty.
- Task 2 – review existing knowledge and evidence of how professional partners understand information about risk and uncertainty.
- Task 3 – review existing knowledge and evidence of how the public use information about risk and uncertainty.
- Task 4 – review existing knowledge and evidence of how professional partners use information about risk and uncertainty.

1.2 Scope of the review and definition of key terms

To operationalise the overall objective and undertake the four tasks, it proved necessary to define the scope of the review and key terms quite carefully – both to inform the wider project objectives usefully and to contain the scale of the review task. In this respect the following definitions and delineations of scope were applied to the review:

- **Information about risk**. The focus of the project is on the potential inclusion of probabilistic information in flood warnings. For this reason, 'information about risk' is defined for this review as 'information about likelihood, chance or probability'. This narrows the review to exclude research about information on consequences alone (e.g. the extent or severity of a flood), or information on what to do in an emergency situation (e.g. emergency procedures in aircraft) where likelihood is not also being conveyed. It also excludes a detailed review of research on risk perceptions per se, rather than on how information is understood and made sense of. Although there is a particular focus on information about the likelihood of flooding or other forms of environmental hazard, the review was left open to include information on other forms of risk if this proved productive.
- **Information about uncertainty.** In the context of the provision of probabilistic information about adverse consequences, it is difficult to neatly disentangle 'risk' from 'uncertainty'. The two terms are often used interchangeably, or given different meanings by different groups of scientists and professionals (Faulkner et al. 2007). A statement of a probability about whether or not an event will occur is, in one sense, also a statement about the lack of certainty as to whether or not it will occur – although there are other forms of uncertainty involved such as the uncertainty of the estimation of event likelihood. For the purposes of the

review therefore, a tight distinction between risk and uncertainty was not maintained – although searches specifically for studies focusing on understandings and uses of information about uncertainty were made.

- **'Understand' and 'use'**. These two terms are used to distinguish Tasks 1 and 2 from Tasks 3 and 4. For the review, the difference was taken to be that 'understanding' involves the interpretation of information and the articulation of what that information then means to the person involved. 'Use' was taken to be the decisions and actions that follow or do not follow as a result of receiving information. While conceptually clear, they sometimes proved difficult to clearly distinguish within the research literature.

The review was not restricted to the UK as there was an evident need to pick up on risk information initiatives and experiences in other countries. Caution does though need to be exercised in making use of research undertaken in sometimes very different risk, cultural and political contexts.

1.3 Undertaking the review

The various sources drawn on for this literature review were as follows:

- an internet search using Web of Science® database and Google™ Scholar search engine with specific search terms in the title and abstracts where this was possible;
- a search of the contents lists of specific journals:
  - *Health, Risk and Society*
  - *Risk Analysis*
  - *Public Understanding of Science*
  - *Journal of Risk Research*
  - *Disasters*
  - *Journal of Flood Risk Management*
  - *Environmental Hazards*
  - *Journal of Contingencies and Crisis Management*.
- the Natural Hazards Center database (HazLit)[1] at the University of Colorado at Boulder;
- communications with researchers in the USA, Canada and UK to obtain relevant current research.

Conducting social research within weather forecasting is a new development and some of the research discussed in this report is not from peer reviewed journals but poster presentations at recent conferences.

[1] http://www.colorado.edu/hazards/library/

2 The public and information on risk and uncertainty

2.1 Perspectives on risk and uncertainty

Before discussing more specific empirical research on how risk information is understood and utilised by the public, it is useful to contextualise this work within debates that have circulated for some time about questions of:

- public rationality and irrationality;
- understandings and misunderstandings of risk;
- capacities to deal with uncertainty.

One stream of argument has contended that the public typically think about risks in irrational and emotional ways, misunderstanding and failing to align their perceptions with the statistically proven or estimated likelihood of different types of adverse events occurring (Glassner 1999). Such critiques have been closely tied to arguments about the need to improve the public understanding of science and have, at various times, been expressed by:

- advocates for new technologies (nuclear, genetic modification);
- politicians attempting to contain ‘food scares’;
- those concerned with promoting more healthy lifestyles.

Prescriptions for addressing such deficits in understanding have typically centred on:

- providing the public with more information;
- improving education and media reporting so that this better represents and promotes understanding of expert positions – what has been called ‘a deficit approach’ (Irwin 2007).

Alternative reasoning, emerging in part in response to this critique of public understanding, argues that the expert perspective on risk is only one form of rationality that makes sense within the cultural and institutional conditions of the expert, science-based community, but not necessarily within others.

When faced with specific risks and risk information, lay people produce their own forms of judgement and evaluation. These may be based in part on their own subjective ways of thinking about a risk and its particular characteristics (Slovic 1987, 1993), but also on the wider socio-cultural context of the risk and how it fits into their everyday experience and encounters with mediated risk information (Krimsky and Golding 1992, Horlich-Jones 2007).

A wide range of factors not immediately related to the degree or probability of harm can come into play in processes of lay reasoning, providing an alternative form of rationality to that underpinning the work of technical risk assessors.

It follows from this perspective that simply providing people with more information through one-way communication will not automatically lead them to change how they think and act. Rather such information will be contextualised and evaluated, with the degree of trust placed in the source of information and the institutions that have produced it being particularly crucial (Renn and Levine 1991, Fischhoff 1998, William and Noyes 2007).

There has therefore been a call for mechanisms that can:

- achieve effective two-way communication between expert and lay communities;
- democraticise science;
- promote mutual understanding and learning (Renn 1998, Mohr 2007);
- create a 'translational discourse' between science producers and users (Faulkner et al. 2007).

Although the different perspectives on public perceptions of risk are still debated and remain in tension, academic and policy understandings have increasingly come round to:

- taking the need to understand public reasoning seriously;
- accepting that risk perception is complex and differentiated;
- the fact that information on risks will always be evaluated and interpreted in different ways.

Following the Bovine Spongiform Encephalopathy (BSE) epidemic and inquiry in the UK in the 1990s, the need to be more honest and open about the uncertainties of expert assessment has also been increasingly advocated (House of Commons Select Committee on Science and Technology 2000, Phillips et al. 2000).

This view has again divided opinion. Some have contended that:

- the public (and the media) want definitive rather than conditional statements about risk;
- being more open about uncertainty will confuse the public and undermine expert advice (Frewer et al. 2003).

Others have argued, in contrast, that:

- in being open about uncertainty a better understanding of the limits and dilemmas of scientific approaches will be developed;
- improved decision-making will result;
- ordinary people are in fact quite capable and willing to deal with the uncertainties around risk problems (Irwin and Wynne 1996, Irwin 2007).

Although floods and flood warnings are possibly significantly distinct from many of the forms of risk and risk information at the centre of these debates, several implications for this review and for the wider project can be brought out.

- As is readily evident and emphasised in research papers and reviews (e.g. Parker and Handmer 1998, Milleti and Fitzpatrick 1992, Rohrmann 1998, Milleti and Peek 2000, Sorensen 2000, Thrush et al. 2005) hazard warnings – as a particular type of risk information – cannot be expected to have immediate and predictable impacts when they are received by those at risk. Processes of interpretation, evaluation and judgement are involved before action/inaction ensues, and warnings received in different ways from different sources may be evaluated in quite distinct ways.

- While much debate generalises about ‘the public’, in practice there is not one public but many different ones which can be separated out by region and location, ethnicity, gender, age, social class, level of education and skills, and so on. Being aware of this differentiation and its potential significance for risk communication is crucial (Drabek 2001, Walker et al. 2006).

- The particular purpose of flood warnings (i.e. stimulating immediate attention and ‘appropriate behaviour’) is different to other forms of risk communication where, for example, the intention may be to reassure and downplay the risks involved (Walker et al. 2008). Such contextuality is significant when considering research examining different types and situations of risk communication.

- The potential shift towards including more explicit information on risk and uncertainty for the ‘at risk’ public (the focus of this project) is in line with wider trends and advocated principles. However, there are significant differences of opinion as to the consequences that may result. How such information is presented and conveyed can be important to its interpretation (see Section 2.3), but further questions such as the trust placed in institutions and individuals providing such information, the circulation of separate informal and local knowledge, the accumulation of experience over time and the way that such information feeds into different everyday and institutional situations may all also be significant.

2.2 The specific evidence base

Shifting from these more general debates and arguments and towards a more specific focus on the evidence base produced by empirical research examining the way that information about likelihood, chance or probability is understood and acted upon by the public, the research field begins to diminish and fracture to some degree.

There is relatively little research focused specifically on forms of **environmental hazard** – particularly in a British and European context, though there is some useful evidence from elsewhere in the world.

There is more available on the closely connected area of **weather forecasting**, where steps have been taken to include probability information and some experience has accumulated.

However, it is the field of **medical and health risks** which provides the most substantial body of empirical research into how information about risk and uncertainty is understood and acted on, including repeated experimentation with different forms of language and modes of presentation. Although this is clearly a significantly different form of risk and context to floods and flood warnings (e.g. the threat is typically less immediate, decisions more personal and defined, and the information context more controlled), there are potentially valuable insights to be gained from this field.

These three risk areas were therefore felt to provide the most useful and relevant bodies of evidence for the review.

In terms of demarcating research findings between the ‘understanding’ and ‘use’ of risk information (as directed within the four tasks) and also between risk and uncertainty information, there was considerable overlap within the reviewed research evidence. All four dimensions are therefore considered together in the following sections, although a distinction between work concerned with the public and with professional partners is maintained.

2.3 Risk and uncertainty information in health and medicine

Information about communication of risk to the public in the field of health and medicine is generally found around:

- issues of informed consent (e.g. risk associated with surgery);
- public health/ health promotion (e.g. about risks associated with smoking or other risky behaviour).

This risk communication can be undertaken with different goals. It may be to increase understanding of a particular issue, to induce behaviour change, to engage emotions, to allay fears or conversely to increase concern. Because of this, it can be difficult to compare the efficacy of different ways in which risk is communicated.

A further issue lies in the varying sources of risk information from statisticians, public health officials to individual clinicians. This has its own challenges, as Paling points out:

> 'In other industries where risks have to be conveyed to the public (such as chemical, nuclear, water, and food industries) usually only a few people carry out this task on behalf of their organisations and they are specially trained. In contrast, in health care (where the risks are usually far higher and more uncertain and complex) almost every doctor who interacts with patients has to communicate information on risk, yet few have any training' (Paling 2003a:745).

Empirical evidence suggests that clinicians rarely explain uncertainty of evidence to patients. Braddock et al. (1999) analysed 1,057 clinical encounters by surgeons and doctors within primary care and found that discussions about uncertainty occurred in only 1 per cent of cases for basic decisions, 6 per cent for intermediate decisions and 16.6 per cent for complex decisions.

The literature suggests that how people assess and process risk information depends on their circumstances, medical condition at the time and their emotional response. In line with the previous discussion about risk communication, there is an underlying premise that:

> '... people are not passive, unbiased recipients of information about their health. People's perception of risk is a complex phenomenon, colored with personal values and biases that challenge attempts to ensure the correct interpretation of risk information' (Vahabi 2007:34).

Despite the large number of studies, there is as yet no consensus on the best methods of communicating risk probabilities in health and medicine (Ghosh and Ghosh 2005, Lipkus 2007). As discussed below, many different methods have been tested using numeric, verbal or visual formats, but one common conclusion is that it seems to be necessary to engage people by making the data personally relevant and capable of arousing an emotional response:

> 'Although patients often desire more information than they are getting from their clinicians, their wish is not for raw data, complicated medical explanations, or population estimates. Rather they seek personally meaningful information that may prove helpful as they make their health care and lifestyles decisions' (Goldman et al. 2006:211).

Related to this, the level of literacy and numeracy among the recipient population is also a determining factor in whether information is accurately understood. Gordon et al. (2002) studied 127 rheumatology patients in Glasgow and found that one in six was illiterate and would seriously struggle with patient education materials as well as prescription labels. Vahabi and Ferris (1995) found that the average reading level of an adult in a developed country is between fifth and eighth (US) grade levels (equivalent to the reading level of 10–14 year olds). These findings have serious implications for those seeking to communicate probabilities whether verbally, numerically or graphically.

2.3.1 Numeric representations of health risks

Research examining numeric formats for presenting risk information has argued that these may be beneficial because they can be expressed in precise terms, potentially leading to more accurate perceptions of risk. Numbers are also considered to convey scientific credibility.

There are different ways of expressing risk in a numeric format. Probabilities may be expressed in:

- percentage terms (i.e. there is a 10 per cent chance that …);
- as odds (i.e. there is a 1-in-100 chance that …);
- as a natural frequency (i.e. 10 such events have been observed out of 100 cases of …).

Research has found that the perception of risk – or accuracy of understanding – can vary depending on the formats that probabilities are presented in.

When the frequency format is used, events are seen as more likely when larger numbers are used for the frequency and reference class. Yamagishi (1997) found that subjects judged a disease as more dangerous when it was described as killing 1,286 out of every 10,000 versus a disease that had mortality rates of 24.14 in 100. Expressing a ratio as two smaller numbers leads to a lower perception of event likelihood, as it seems that people focus on the absolute number of occurrences.

Cuite et al. (2008) tested three numerical formats on over 16,000 people visiting a health-related website. They presented subjects with numerical expressions in terms of percentages, 1-in-n and frequencies, and found that probabilities expressed in frequency and percentage terms were far more accurately understood. They also found that most people were not able to perform simple mathematical operations with risk data; therefore:

> '... rather than saying that a treatment would cut a risk of 12 per cent in half, for example, the communicator should state that the treatment would cut the risk from 12 per cent to 6 per cent. This simple strategy should significantly reduce misunderstandings in discussions of treatment options' (Cuite et al. 2008:384).

An internet-based study by Waters et al. (2006) involving 2,601 people found that accuracy increased when probability information was presented in graphic form rather than text, and in terms of percentages rather than frequencies.

But as mentioned above, people have issues with literacy and numeracy. In a study of in-patients at Huddersfield Hospital, Fuller et al. (2002) found that over 25 per cent of participants confused one in 20 as being the same as 20 per cent. And a 75 per cent probability was misrepresented by answers ranging from 6 per cent to 90 per cent. One particularly worrying finding quoted in Gigerenzer and Edwards (2003) relates to the accuracy of understanding of probability information by medical doctors; doctors were given probability information relating to colorectal cancer (percentages relating to prevalence, sensitivity of the test and false positive rate). While the correct answer was

5 per cent probability, the clinicians' answers ranged from 1 per cent to 99 per cent, with half estimating probability at 50 per cent.

In a review of studies investigating the ways in which evidence from clinical trials are presented and how this affects people's views about the benefits of treatment, Covey (2007) found that expressing probabilities in terms of **relative** risk was more effective than using absolute risk or number needed to treat. This result may be attributable to those studies being ambiguous about the relative risk changes or failing to provide baseline risk information. Therefore, saying, 'if you are a smoker, your chance of getting a disease is 10 times higher than that of a non-smoker' (Lipkus 2007:701) is likely to result in an overestimation in risk perception. Clearly, there are ethical issues with using this format as a persuasive tool and the literature suggests using baseline information along with relative risk data. For example:

> 'The chance of nonsmokers getting a disease is 1 per cent, while the chance of smokers is 10 per cent; therefore, smokers have a 10 times greater chance of getting a disease than do nonsmokers' (Lipkus 2007: 701)

Gigerenzer and Edwards (2003) also warn against offering data on single event probabilities without offering a reference class because people will impute their own reference class (e.g. saying the patient has a 30–50 per cent chance of developing a sexual problem if they take Prozac may be interpreted by patients as 30–50 per cent out of all their sexual encounters, whereas the doctor's reference class would have been the total number of patients taking Prozac) (See Appendix 2).

2.3.2 Verbal representations of health risks

Verbal expressions of probability – such as 'unlikely', 'possible', 'almost certain' and 'rare' – it is argued, are easy to understand and also convey a sense of uncertainty, but like other formats are open to differential interpretation.

The literature review by Lipkus (2007) on communicating health risks concluded that there was insufficient evidence for offering best practice guidelines for verbal formats. However such formats tend to be recommended in situations where there is general uncertainty about probabilities or where there is a low probability of a single event, such as contracting SARS[2] on an airplane (Burkell 2004).

Some writers have suggested using a standardised verbal format so that over time patients and doctors develop a shared understanding of the probabilities that terms such as 'likely' or 'unlikely' refer to. For example, Calman and Royston (1997) suggest using 'high risk' for risks 1 in less than 100 and 'moderate risk' for between 1 in 100 and 1 in 1,000.

In 1998 the European Commission (EC) produced a guideline for verbal descriptors in medicine leaflets which describe side effects, and assigned percentages of likelihood to the terms very common, common, uncommon, rare and very rare (European Commission 1998). Knapp et al. (2004) tested these words with patients attending hospital in Leeds and found that people who were given verbal descriptors overestimated likelihoods of harm from side effects compared with those given numerical descriptors. For example, 'common' was interpreted as 34 per cent (rather than the 1–10 per cent recommended by the EC). 'Rare' was interpreted as about 20 per cent (rather than less than 0.01 per cent recommended by EC). Participants who received the verbal descriptors were also more likely to believe they were at risk of the side effects than those who received the numerical descriptors. Knapp et al. therefore,

[2] severe acute respiratory syndrome

urged caution with the use of verbal formats where patients are being required to make choices for treatment options.

2.3.3 Visual representations of health risks

Graphical displays are argued to be a useful means of communicating health risks because, if well-designed, they hold people's attention and can provide a useful medium for summarising data and revealing patterns. They can also be useful in helping doctors and other clinicians develop a two-way communication between themselves and their patients. On the other hand, if badly designed, they may not be comprehensible and may discourage people from taking on board the numbers that are being represented.

Although little is known about the effect of graphs and other visual displays on behaviour, on the whole it appears that:

- displays that are perceived more accurately do not necessarily lead to behaviour change;
- those that lead to behaviour change may not have been perceived accurately (Ancker et al. 2006; Lipkus 2007).

This means that graphical displays are not necessarily interpreted or used as the designers of those graphs perhaps intended.

Stone et al. (1997) showed that using a graphical rather than numerical format to convey low probability events reduced professed risk behaviour where there was a 50 per cent reduction in risk.

Schirillo and Stone (2005) replicated this earlier study for risk reduction ratios ranging between 3 and 97 per cent; they found a similar trend leading them to conclude:

> 'Risk communicators interested in decreasing risk-taking behaviour should seriously consider presenting their risk information graphically' (Schirillo and Stone 2005:556).

However, Stone et al. (2003) proposed that the differential impact of graphical formats as opposed to numerical formats may be due to framing rather than format per se. That is, risk perception is affected by whether 'foreground'/ numerator information (i.e. the number of people harmed) or 'background'/ denominator information (i.e. the potential population at risk of harm) is emphasised by the format. Risk reduction is seen as greater by participants when 'foreground' information is presented graphically than when both types of information are produced graphically or numerically.

Furthermore, graphics with a small denominator (such as 10) have been perceived by focus group participants as depicting a higher risk magnitude than larger denominators (100 or 1,000):

> 'Subjects appeared to focus on the increased number of figures in the denominator (indicating no disease) rather than the increased number of highlighted figures in the numerator (indicating disease)' (Schapira et al 2001:465).

The literature identifies many different methods of communicating risk in graphical format including:

- bar charts
- line graphs
- pictographs
- icons (e.g. human figures)
- risk tables
- risk ladders
- risk scales.

Appendix A contains examples of some of these graphical formats.

The systematic review by Ancker et al. (2006) concluded that the best design for a graphic depends on the purpose of the risk communication, i.e. whether it is to increase understanding, promote risk avoidance or allay fears. So for example where women were asked to respond to various formats used in the communication of breast cancer, they reported that frequency graphics using human figures (particularly drawn as a woman) were easy to identify with, better understood and conveyed a meaningful message. On the other hand, bar graphs were seen as analytical, difficult to understand and had less impact (Ancker et al. 2006).

2.4 Risk and uncertainty information in weather forecasts

Weather forecasts, by their nature, have an inherent element of uncertainty. In the UK and many other countries, verbal formats are used for communicating such probabilities and uncertainties (e.g. 'slight chance of rain') but, in some places, quantitative representations are used.

A range of research approaches have been used to explore what sense people make of indicators of uncertainty and which they appear to understand more easily – both when they are provided as part of operational systems and in more hypothetical or experimental situations.

In the USA, probabilistic weather forecasting has been used with the public since 1965 for precipitation only (i.e. rain, snow and hail) and is collectively known as Probability of Precipitation (PoP) forecasts. These forecasts are provided in percentage formats.

Several research studies on the public's understanding of such forecasts emphasise the complexities in how forecast probability information is communicated and understood.

Gigerenzer et al. (2005) provide this definition of what PoP percentages refer to:

> 'A 30 per cent chance of rain does not mean it'll rain tomorrow in 30 per cent of the area or 30 per cent of the time. It means that when the weather conditions are like today, at least a minimum amount of rain (such as 0.2 mm or 0.01 in.) will fall the next day in three out of 10 cases. We refer to this as the "days" definition of rain probability. It implies only a possibility of rain tomorrow – it may or may not rain – whereas the "time" and "region" definitions mean that it will rain tomorrow for certain, the only question being where and for how long' (Gigerenzer et al. 2005:624).

The study by Murphy et al. (1980) with 79 residents in Oregon showed that most people understood the PoP data and in fact expressed a clear preference for numerical expressions of uncertainty. However, many were confused about the event to which the probabilities referred to and the majority of participants believed that a PoP forecast is an area forecast. This led Murphy et al. to recommend that the National Weather Service should undertake a public education campaign in order to clarify what the probabilities were actually referring to.

Gigerenzer et al. (2005) followed up on this study and surveyed 750 people in five cities (in New York, Amsterdam and Berlin where they have probabilistic forecasts, in Milan where probabilistic forecasts are available on the internet, and Athens where they are not available to the public at all). They found two-thirds of New Yorkers interpreted the statement as intended by the forecasters, whereas only 20–30 per cent of European respondents did – whether they had been exposed to numerical probability forecasts or not. However, the researchers concluded that people do understand probabilities but do not understand the reference class the probability is referring to. For this reason, they recommended that **every** time a probabilistic forecast is made the reference class should be made clear. For example, instead of just saying 'there's a 30 per cent chance of rain tomorrow', the forecast statement should read:

> 'There is a 30 per cent probability of rain tomorrow. This percentage does not refer to how long, in what area, or how much it rains. It means that in three out of 10 times when meteorologists make this prediction, there will be at least a trace of rain the next day' (Gigerenzer et al. 2005:629).

More recently, Morss et al. (2008) have analysed results from a survey of 1,520 US residents using the internet. In order to follow up on the work of Gigerenzer's team on how the public understands PoP information, they also asked their participants 'what does 60 per cent chance of rain tomorrow mean?' Conversely to the earlier findings with New York residents, they found that only 19 per cent of people provided the meteorologically 'correct' interpretation. But Morss et al. argued that, even if people's interpretations are not technically correct, their interpretation may be sufficiently close to meet their needs. Instead of constantly trying to educate the public about scientific definitions, they contended that meteorologists should try and understand how the public use forecast information because:

> 'In many situations, the important question for providing PoP and other types of uncertainty forecasts may be not whether people know the technical definition or understand the forecast precisely, but whether it meets their information needs – in other words whether they can interpret the forecast well enough to use it in ways that benefit their decisions' (Morss et al. 2008:20).

Morss et al. were also keen to find out how the public relates to uncertainty in deterministic temperature forecasts. The interesting finding here was that fewer than 5 per cent of people expected the temperature to be the single value provided in the deterministic temperature forecast anyway. The large majority of people inferred uncertainty into the deterministic forecast; this means most people are aware that weather forecasts involve uncertainty. Since the overwhelming majority of participants inferred uncertainty into forecasts and the majority preferred to have probability information, the final recommendation made by Morss et al. (2008) was also that uncertainty should be communicated effectively on a forecast-by-forecast basis in order to support people in their decision-making.

Handmer and Proudley (2007) analysed the results of a survey of 642 members of the public across Australia about their understanding of weather forecasts. Participants were asked what they understood what is meant by 'a 30 per cent chance of rain'.

Given that no further information was given, 30 per cent chance of rain could have meant:

- ‘There’s a 30 per cent chance of rain anywhere in the forecast area.
- There’s a 30 per cent chance of rain at a specific location within the forecast area.
- If it does rain, only 30 per cent of the forecast area will be affected.
- It will rain 30 per cent of the time.’ (Handmer and Proudley 2007:83)

The overwhelming majority of the public chose ‘there’s a 30 per cent chance of rain anywhere in the forecast area’, although some believed it referred to a 30 per cent chance of rain at a specific location. So again, this study showed that people do have a basic understanding of probability information but there is confusion as to what the percentages are referring to.

Handmer and Proudley also asked 113 forecasters working for the Australian Bureau of Meteorology (BoM) what was meant by ‘a 30 per cent chance of rain’. There was confusion among them too; 55 per cent believed it meant rain anywhere in the forecast area, 36 per cent believed it meant chance of rain in a specific location in the area, and 8 per cent weren’t sure what it referred to.

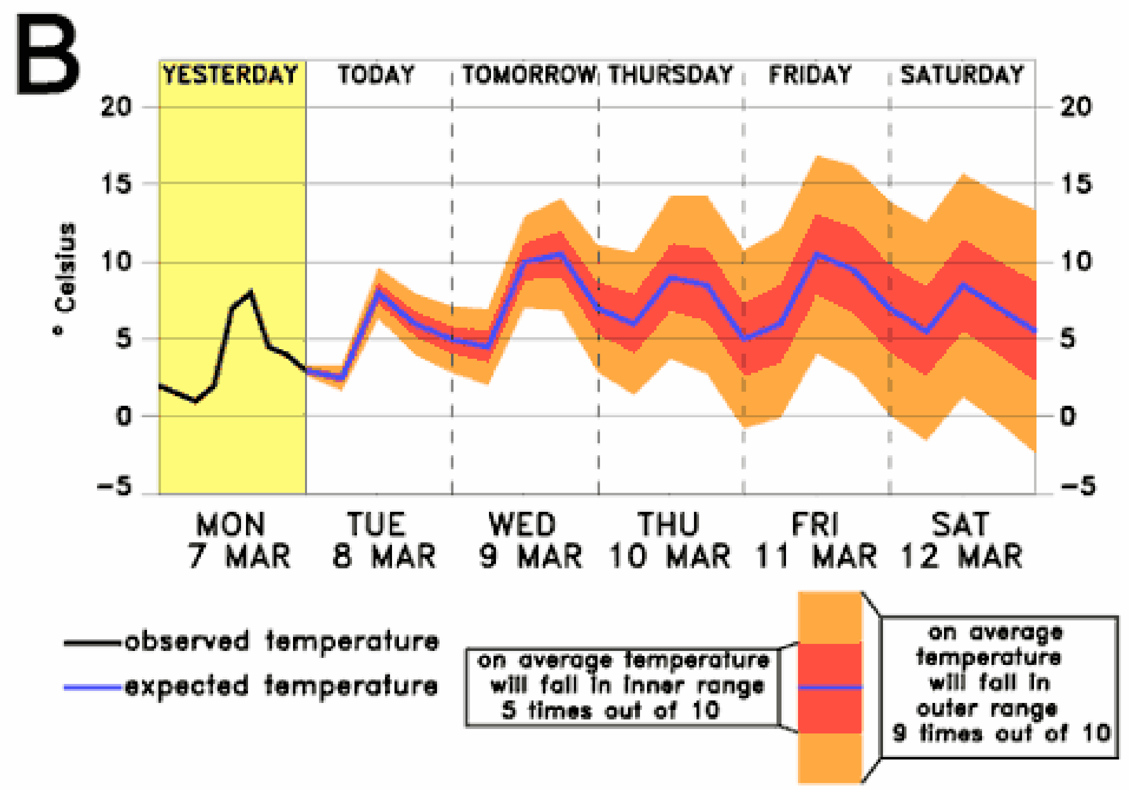
This lack of clarity was also evident when using verbal descriptors to communicate weather information, as the forecasters were asked what they understood to be the meaning of the word ‘fine’. The BoM defines ‘fine’ as ‘no rain or other precipitation (hail, snow, etc.). The use of ‘fine’ is generally avoided in excessively cloudy, windy, foggy or dusty conditions. In particular, note that fine means the absence of rain or other precipitation, such as hail or snow – not ‘good’ or ‘pleasant’ weather’ (Handmer and Proudley 2007:85). But although almost all forecasters knew ‘fine’ meant absence of rain, many also thought it could be ‘sunny/sunshine’ or ‘lovely weather/nice day’, ‘good day for outside activities’. Members of the public also had varying understandings of the word ‘fine’; the implication being that the use of less ambiguous words with clearer additional information would help forecasts to be given and received more accurately.

Moving to the UK context, a survey about uncertainty and forecasts was undertaken for the Met Office (Mylne 2008). A questionnaire was placed on the Met Office website asking participants to consider various formats for communicating uncertainty for a five-day temperature forecast; 1,144 respondents completed the survey, being presented with the following formats:

- bar charts;
- two forms of line graphs with box plots;
- two kinds of line graphs with shading.

Most of these formats had a verbal statement explaining the uncertainty information, e.g. ‘on average the actual temperature will fall in the shaded region eight out of 10 times’.

The line graph shown in Figure 2.1 was said by 72 per cent of people to be the most useful format; 49 per cent preferred the line graph plus two levels of probability information (‘on average temperature will fall within inner range five out of 10 times, on average temperature will fall in outer range nine out of 10 times’). The overwhelming majority of people also stated that the line graphs were the easiest format to understand.



Source: Mylne (2008)

Figure 2.1 Graphic representation of temperature forecast with uncertainty information.

Following this survey, Kaplan and Roulston (2007) carried out a laboratory experiment in the UK with 153 undergraduates who were each presented with a sequence of 20 'lotteries' in which they had to choose between two events. They were paid 50 pence if the event they chose occurred. Participants were divided into two groups. One group received deterministic forecasts; the other received the same forecast with additional uncertainty information. Kaplan and Roulston found that those who received uncertainty information were significantly more likely to choose the most probable event, which suggests that they were interpreting the information contained in the uncertainty graphic correctly.

Research in various countries has therefore shown that:

- people prefer to receive forecasts with uncertainty information;
- people do have a basic understanding of probability in terms of weather forecasts.

However, it has also revealed some confusion and differences in interpretation of what percentage indicators and graphical representations of forecast uncertainty refer to.

While this research has produced useful evidence, attention needs to be given to the different cultural settings in which it has been undertaken and also, in some cases, the limited experimental designs used.

Research that goes further into understanding how forecasts are interpreted and used by the public in real life scenarios, as opposed to controlled laboratory experiments, is far more limited. This could be an important gap because, in practice, information given by forecasters will be interpreted in particular personal and social contexts, and actions taken as a result of forecast information will vary because of this.[3] One example is a study by Powell and O'Hair (2008) conducted on 769 people in Oklahoma, Texas and California regarding their uses of, and reactions to, weather information, sources of information and their emotional response to certain types of weather. They found that:

- women had higher levels of anxiety than men in relation to severe weather forecasts;
- there is a correlation between feelings of anxiety and **trust** in weather forecasts, i.e. individuals with low anxiety are more likely to:
    - maintain less trust in weather information and the National Weather Service;
    - ignore weather information and show signs of complacency should a severe weather event actually occur.

Conversely, people with feelings of high anxiety may unjustly worry about unlikely weather scenarios.

2.5 Risk and uncertainty information on environmental hazards

Research on how members of the public understand and respond to information on risk and uncertainty in relation to environmental hazards and specifically within hazard warnings is limited in extent and scope. Most substantial is work from the USA which examined the consequences of including probability information in hurricane warnings.

2.5.1 Hurricanes

Since 1983, the US National Weather Service's National Hurricane Center has issued hurricane advisories with probability information to warn residents of the likelihood of the centre of a hurricane coming within 65 miles of specific locations within a set time period.

Baker (1995) interviewed 400 residents in Florida to assess the effect of probability forecasts and other risk indicators on the public in terms of how they would respond. Residents were presented with maps and text representing 16 threat scenarios similar to real-life hurricane situations. For example, they were told:

> 'The storm has 85 mph winds, is in position A on the map, the National Hurricane Center has issued neither a watch nor a warning for this area, and local officials have neither advised nor ordered evacuation' (Baker 1995:140).

One group was given threat scenarios with probability information (such as 10 per cent, 30 per cent or 50 per cent likelihood). The other group was not given probabilities.

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[3] There is a growing movement to develop a closer working relationship between meteorologists, the scientific community and social scientists. In the USA, a national multi-disciplinary project was initiated in 2006 by The National Center for Atmospheric Research, Boulder, Colorado. This project is called WAS*IS (Weather and Society Integrated Studies). See Demuth et al. (2007) for background on this project. The project programme is given o its website (www.sip.ucar.edu/wasis). In the UK, the Met Office initiated the first such meeting in 2007 in collaboration with the University of Exeter. The programme and papers for this gathering, *Meteorology meets Social Science: Risk, Forecast and Decision*, are available from: http://www.people.ex.ac.uk/trkaplan/met/conferencetest.html.

The threat scenarios had four issues factored in:

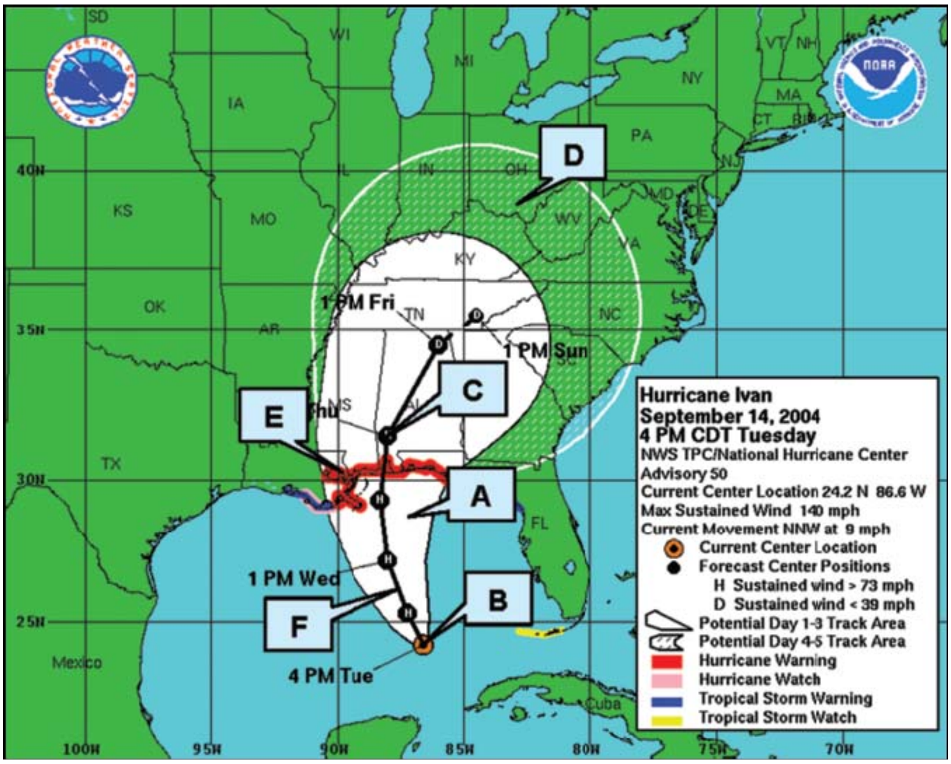
- severity of the storm;
- track and position;
- National Hurricane Center alerts;
- local official's evacuation notice.

In addition, numerous surveys were carried out with residents after real hurricane threat scenarios.

Baker's finding from the experimental study and the surveys was that residents had a good understanding of probability information and, crucially, that local officials' advice or orders regarding evacuation remained by far the most important issue **regardless** of whether residents were presented with probabilities or not. Baker comments:

> 'Overall, the probabilities do not affect public response a great deal one way or the other. In low risk situations probability information might increase response somewhat. As a storm nears land, people just outside the warning area might be deterred slightly from evacuating when they observe that their probability is only a fifth as high as another location in the center of the warning area. The National Weather Service can continue disseminating probabilities to the public without concern that their revelation will be detrimental to evacuation response' (Baker 1995:147).

The National Hurricane Center has used visual methods of communicating risk through a graphic tool known as 'the cone of uncertainty' (Figure 2.2). The cone contains information on the forecast track line of the hurricane (solid black line), margin of error (the white cone), and watch and warning areas. It does not present any information about the size of the storm or its severity.



Source: Broad et al. (2007)

Figure 2.2 'Cone of uncertainty' hurricane forecast graphic produced by the US National Weather Service's National Hurricane Center.

Despite attempts by the National Hurricane Center to present forecast information in a user-friendly graphic to the public and emergency managers, a study by Broad et al. (2007) concluded that the cone was misinterpreted by many people through the 2004 Florida hurricane season. For example, some people noted that the track line did not go through their community and therefore presumed they were safe, even though their locality was within the cone. Yet others presumed they were safe because they lived outside the cone. Both these situations highlight the problem that, rather than the cone being understood as the cone of **uncertainty**, many people interpreted the graphics as a deterministic forecast.

Broad et al. (2007) suggested two questions that or risk communicators should ask themselves:

- Who is the intended audience and what information do they want and need (which they may not realise they need yet)?
- How relevant is this information and does it provide enough detail for people to assess the risk to themselves, their property, or their communities?

For example, people living near the coast may be concerned with storm surges, those in trailer parks would want to know about wind speed, and those who rely on electricity for medical reasons would be concerned with information regarding the loss of the power supply.

> 'Merely knowing the likelihood that a hurricane might strike a particular area does not provide the more specific information people need to consider when assessing the risks and choosing a course of action' (Broad et al. 2007:664).

Additionally, the authors stress that:

> 'There is no perfect "one size fits all" image. No one presentation format or piece of information will be interpreted in the same way by all people. Many other factors influence risk perception and decision making, including the nature of the risk; the trustworthiness and credibility of the messenger; the knowledge, values, and worldviews of the recipient; etc. (Slovic 1999). Thus, the utility of any single risk communication product must be evaluated within the individual, social, and institutional contexts of the recipient' (Broad et al. 2007:664).

These observations stress the need to consider:

- the contexts within which hurricane risk information in hazard warnings will be received;
- why people make decisions, especially in times of crisis.

For example, in her study of Hurricane Katrina, De Marchi (2007) noted that often the poorest members of the community chose not to evacuate because they did not want to leave their possessions behind, regardless of the forecast.

Eisenmann et al. (2007) interviewed 58 Hurricane Katrina evacuees in order to understand factors that influenced their evacuation decisions. They were particularly interested in learning from impoverished communities who were most badly affected by the hurricane and ensuing floods, almost all of whom were African Americans on a low income and from New Orleans. Even though Hurricane Katrina was graded Category Five[4] with a mandatory evacuation order[5], they found the most important factor that

[4] For a detailed description of the categories used by the National Hurricane Center see http://www.nhc.noaa.gov/aboutsshs.shtml.
[5] De Marchi (2007) has argued that those who could have left had already left New Orleans by this point.

was raised spontaneously by interviewees was their ties to extended family and friends and community groups, either raised as a hindrance to evacuation or as an aid.

> 'I could have made it on my own, but it was just my aunt and my uncle. Every few steps he made ... she forgot his walker ... every few steps he made he was falling down.'

> 'I mean, if you've got 20 people trying to get in one car it's not going to happen. So some people, you just stay because you have to' (Eisenmann et al. 2007: S111)

Furthermore, collective memory coupled with distrust of authorities may have led some people to minimise risk to themselves and their families. Eisenmann et al. suggest that:

> 'During times of stress, networks composed of intense ties, such as extended families, may be less adaptive, because they are less likely to exchange new information. In such cases, disaster planners partnering with organizations that are part of these networks, such as churches in the African American community, may better communicate new information to individuals and families who value information received from inside their network' (Eisenmann et al. 2007:S114).

In such contexts, the particularities of how probability information is presented in warning messages may well be entirely irrelevant to the actions that are then taken.

2.5.2 Flooding

Although many technical research projects are currently seeking to improve forecasting of severe weather conditions and/or flooding, and communication of uncertainty,[6] there is very little social science research looking into how the public may understand or respond to risk or uncertainty information in probabilistic flood warnings.[7] Various authors have put forward arguments about the value that **could** be gained from providing such information to partner agencies; these are discussed in Section 3.

There is some tentative evidence to suggest that it may be beneficial to communicate probabilistic information about flooding in conjunction with other information. For example, Bell and Tobin (2007) carried out a survey with a random sample of residents living in a village in Texas, USA. As part of the survey, participants were given four choices and asked to identify which aspect of flooding concerned them most. About half chose 'level of flooding', and 42 per cent chose 'level of flooding and frequency'. None chose 'frequency' by itself.

This finding supports recommendations by others (e.g. NRC 2006) that damage estimates and concrete statements should be included in flood risk communication in order to make the risk more real to individuals, i.e. providing probabilistic information by itself may not be the most useful way of communicating risk.

[6] For example, see the World Meteorological Organisation's THORPEX (The Observing System Research and Predictability) programme (which is itself part of a larger WMO programme on disaster reduction and mitigation) http://www.wmo.ch/pages/prog/arep/thorpex/ and the European Commission's EFAS (European Flood Alert System) programme (http://efas.jrc.ec.europa.eu/).

[7] See, for example, the report produced by Martini and de Roo (2007) for the European Exchange Circle for Flood Forecasting (EXCIFF) (http://exciff.jrc.ec.europa.eu/).

3 Professional partners and information on risk and uncertainty

While it was possible to identify various bodies of research that have dealt directly with the questions of how members of the public understand and use information on risk and uncertainty, this proved much more difficult for professional partners. In general, the information needs and risk communication practices related to emergency services and the like are under-researched, and many of the risk information initiatives that have been examined have related to personal rather than institutional decision-making. However, a few instances of directly and less directly relevant research were identified and are discussed below.

Krzysztofowicz (2001) argued that deterministic forecasts create the illusion of certainty, thus having the potential to lead to wrong decisions with serious economic and social consequences. As an example, he cited the case of flooding in North Dakota in 1997 where the city suffered major loss due to deterministic predictions of river levels by the National Weather Service. City officials later said that, had they been made aware of the level of uncertainty in the predicted river levels, they would have made preparations that may have prevented so much loss. Krzysztofowicz therefore argued that probabilistic flood forecasts would help decision-makers make better decisions. He lists the benefits of probabilistic flood forecasting as being:

- scientifically honest;
- allowing local authorities and other responders to set risk-based criteria for flood watches, flood warnings and emergency response;
- informing users of the risk and level of uncertainty in order for them to make rational decisions.

> 'Probabilistic forecasts mollify the potential for misperception of responsibilities and misattribution of decisions. This is so because they decouple the task of forecasting, which ought to involve solely the principles of science, from the task of decision-making, which should involve the decision maker's evaluation of consequences of alternative actions and possible events. A predictive probability distribution function of, say, flood crest, does not pinpoint a single estimate. Rather, for each possible river stage, it species the probability of this stage being exceeded. The choice of the protection level is thus left entirely to the decision maker, as it should be' (Krzysztofowicz 2001:5).

A few experimental pieces of work have used simulated situations to examine how the provision of uncertainty information may affect the type of decision-making undertaken by professional partners. However, a major limitation of this research is that it has not necessarily been undertaken with actual decision-makers in anything like their real work contexts. For example in relation to weather forecasts, a few studies suggest that better emergency management decisions are made when people are provided with uncertainty information.

Roulston et al. (2006) presented participants with a computer-based risk task in order to assess how uncertainty information on weather conditions would affect their decision-making. The task was a game in which they had to manage a road maintenance company responsible for salting the roads. The company had a contract with the city and participants were told that the city would pay them on a monthly basis, but the company would have to pay a penalty to the city if it failed to salt the roads on a night when the temperature fell below zero. The game was played for 30 rounds (to reflect 30 days) and, in each round, participants were provided with a forecast of the overnight minimum temperature. At this point they had to decide whether to salt the roads or not. What Roulston et al. found was that participants who were given uncertainty information were able to increase their expected profits while reducing their risk, i.e. those with uncertainty information made better decisions.

Joslyn et al. (2007) were also interested to find out how probability information affects decision-making, in particular whether probability information can improve threshold forecasts (i.e. the point at which a decision is made whether to close schools, evacuate cities, divert flights, etc.). They tested 10 male atmospheric science students (not typical professional partner personnel), who were given instructions to assess the forecast and decide whether to post high wind advisories for boat users, while being reminded that too many false alarms would have a negative impact. Each subject made four forecasts – two without being given probability data, and two with probability data of winds above 20 knots. What Joslyn et al. found was that participants increased the number of advisories when high winds were very likely and decreased advisories when high winds were very unlikely when they had the probability data, i.e. providing probability information substantially improved decision-making. In the real world, this would have the effect of fewer false alarms, and therefore increased trust and confidence in weather forecasts.

Morss et al. (2005) undertook a multi-disciplinary project to investigate the interplay between scientific knowledge, uncertainty and flood risk. This project far more directly engaged with the real world of decision-making processes. They consulted with:

- climatologists;
- hydrologists;
- engineers;
- planners;
- employees of government agencies at local, regional and national level;
- private sector consultants;
- researchers across the disciplines.

The practitioners they consulted viewed uncertainty as an unavoidable factor which was part of their every day decision-making processes, but because of time and information constraints, they tended to use data they could quickly access and interpret for a particular decision and then move quickly on. So, for example, within this process, uncertainty is merely one factor in the decision-making processes of flood managers. When asked about barriers to their work, practitioners were more concerned about flood risk perceptions in the communities they served than not having sufficient scientific information.

One interesting issue raised by Morss et al. (2005) is that increased provision of scientific information may not necessarily lead to different decisions because the effects of uncertainty may be negligible compared with other factors. For example, they make the point that increasing flood damage and loss:

> '... are due as much (or more) to societal factors … physical science and engineering advancements can often only make a difference when societal factors, such as warning response and risk communication, are understood and addressed … even when additional scientific research could reduce or better characterize scientific uncertainty, other actions (such as addressing societal

> components of vulnerability …) may be more cost effective' (Morss et al. 2005:1596).

Another important issue raised in the paper by Morss et al. is that scientists often think of the end users of flood information in terms of some abstract notion of 'decision makers', (wrongly) implying that this is a coherent category of people, with a unified or consistent set of needs.

In reality, people receiving and using scientific information are a diverse range of individuals each with their own personalities, professional backgrounds, training, institutional contexts and political dictates. Understanding decision-makers in this way necessitates increased two-way dialogue and iterative processes to develop scientific information that meets the particular needs of specific users. Morss et al. (2005) warn that, because of issues of trust and credibility, such cross-disciplinary partnerships and processes may take a long time to set up but are necessary if scientists want to produce information that is capable of being used.

4 Summary of key findings

It was not possible to base the findings of this review on a large body of relevant research. While this is a limitation, a number of specific and broader points on what is known about the use and understanding of probabilistic information can still be made.

- Broad societal debates about public understanding of risk and uncertainty have moved in the direction of arguing that it is a good thing that government institutions are more explicit and open about risk and uncertainty, promoting greater social trust and understanding. Counterarguments, however, point to the misunderstandings and undermining of expertise which might arise.

- Neither 'the public' nor 'professional partners' are a homogenous group. For example, a large number of members of the public may have issues with literacy and numeracy. Age, gender, ethnic, cultural and socioeconomic differences can all also be important in how information is received and interpreted. In addition, the various professional partners might have quite different information needs.

- Research does not point to one single effective means of communicating probabilistic and uncertainty information. It is clear that communications are **interpreted** within personal, social or institutional contexts, and according to individual personality predispositions. Providing additional information may not lead to different decisions, as new information is merely one factor in the process of decision-making in the real world. Trust in the source of information can be particularly important.

- There is limited research to draw on to understand how probabilistic information on the likelihood of imminent hazard events is understood and used. This is the case for 'the public' and even more so for professional partners where there is very little work on risk communication in general. Research on probabilistic information in hurricane warnings provides the only limited examples.

- There is a more substantial body of research on the use of probabilistic information in the fields of health and medicine, and weather forecasting. These fields can both provide some useful insights. However, it is important to remember the differences between these communication contexts. These include the types of information involved, who is communicating, the context of communication and the implications of actions taken.

- Literature from health and medicine suggests that how people assess and process risk information depends on their circumstances, medical condition at the time and their emotional response. Research has tested many different formats for presenting probabilistic risk information. Numerical formats such as percentages can suggest precision but are in practice interpreted in different ways. Expressing probabilities in terms of relative risk and using reference classes have been recommended as more effective in some circumstances. Verbal qualitative formats might be easy to understand and suggest uncertainty. Guidelines have been developed, but some studies urge caution with assuming that these are clearly understood. Visual methods can hold people's attention and communicate summaries of data. The exact formats used appear important to understanding, but it is not necessarily the case that formats that are better understood lead to a greater degree of desired behaviour change.

- Research on weather forecasts tends to suggest that the public do understand basic probability information when it is presented clearly (e.g. ‘there is a 30 per cent chance of rain tomorrow’). One source of confusion seems to be because forecasters have not been clear about what the percentage probability refers to (i.e. the reference class). Forecasters themselves have been found to be confused about the meaning of both quantitative indicators and qualitative descriptors such as ‘fine’. People seem to infer uncertainty into forecasts, so would rather receive forecasts with additional uncertainty data (e.g. on average the temperature will fall within this range five out of 10 times).

- Experimental research on public responses to probabilistic information in hurricane warnings in the USA found that residents had a good understanding of the probability information, but that this was not influential in decisions over evacuation as the specific advice or orders of local officials were most important. Other research on public understandings of a visual representation of probability during a hurricane season found consistent misinterpretation and reading of uncertainty information as deterministic.

- The very limited laboratory-based research seems to suggest that, when decision-makers such as professional partners are presented with uncertainty information as part of weather and hazard scenarios, they may make better decisions.

- Instead of trying to educate the public about the exact meanings of forecasts and probabilistic information, it may be more important and useful to first understand how the public use the information. Developing an iterative process in collaboration with end users would be a useful way of taking the development of probabilistic hazard warnings forward.

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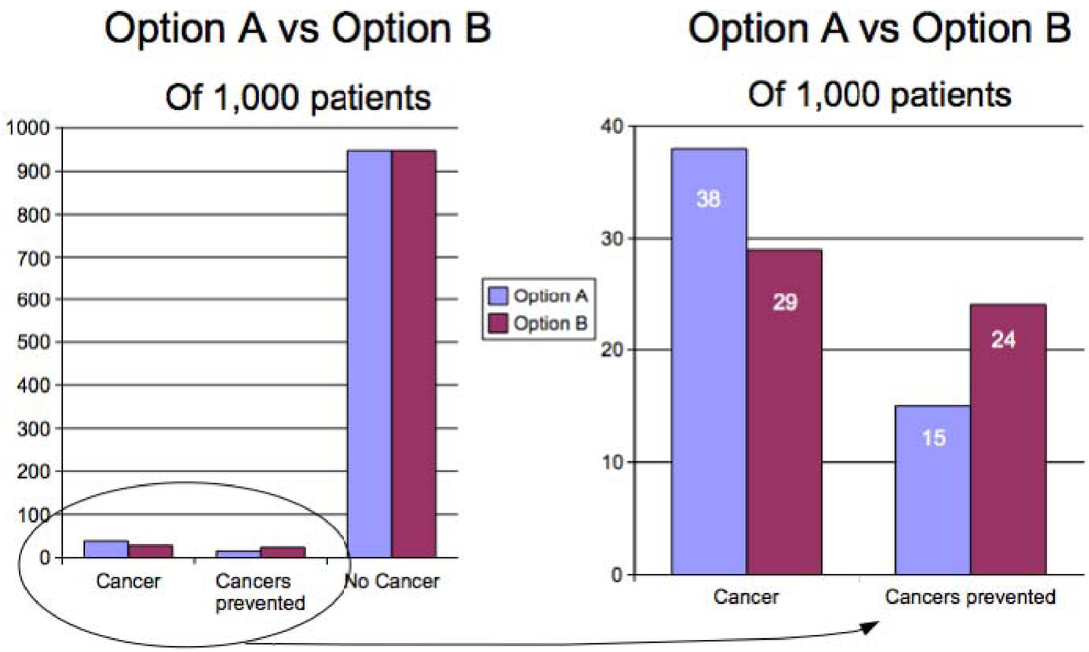
Appendix 1 – Examples of graphical formats

Augmented bar chart

The left hand panel is a standard bar chart showing the entire dataset.

The right hand panel magnifies the differences between the two options so the magnitude of the differences can be seen more clearly.



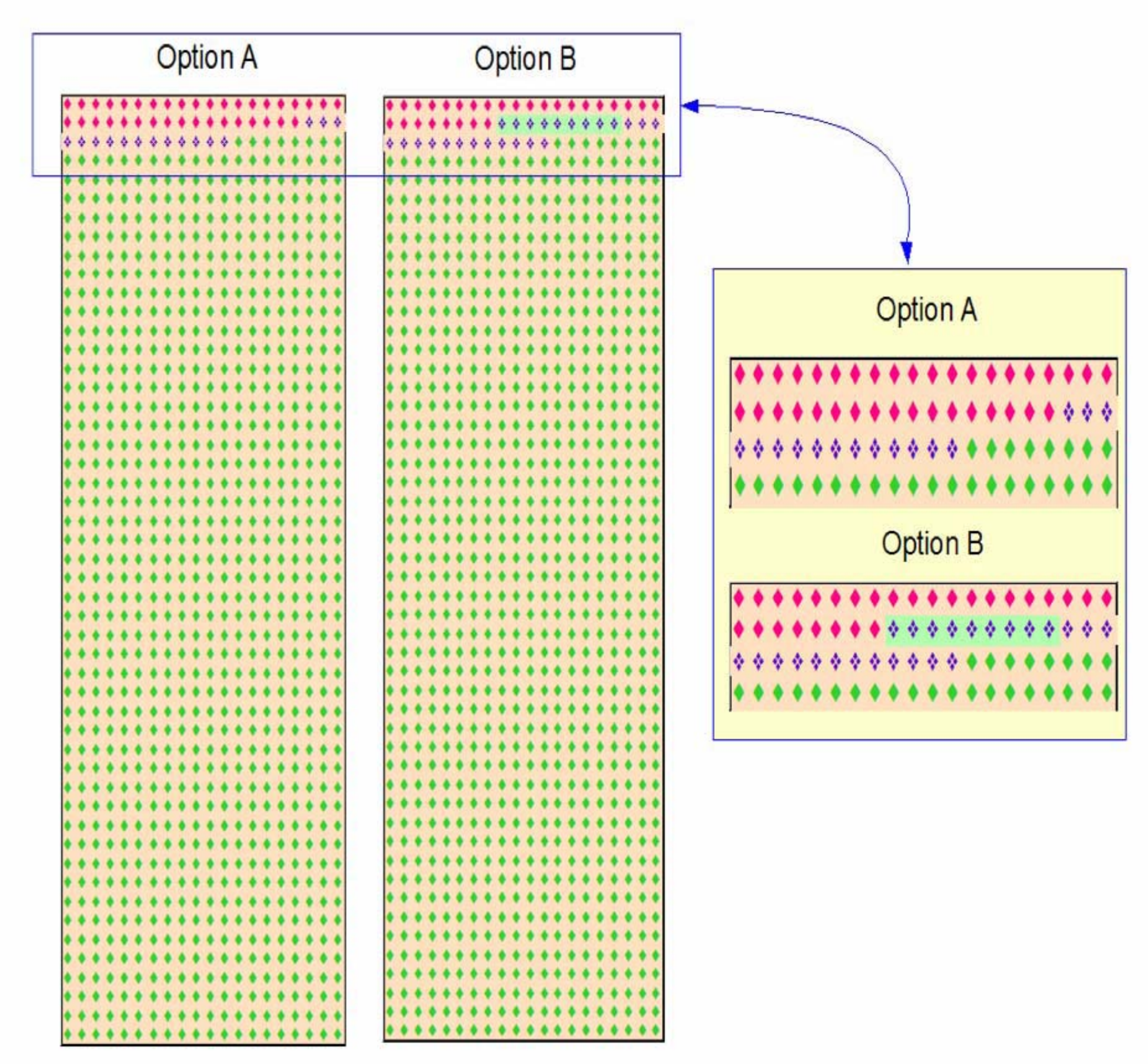
FORMAT 1: Augmented bar chart
Source: Dolan and Iadarola (2008)

Augmented icon display

The left hand panel is a standard icon display showing the entire dataset.

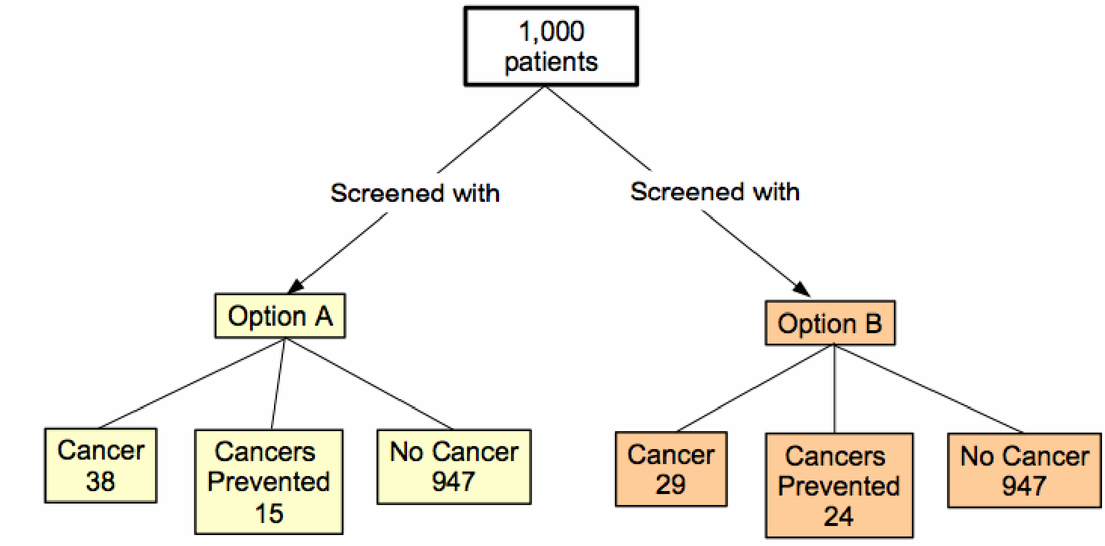
The right hand panel magnifies the differences between the two options so the magnitude of the differences can be seen more clearly.

The red diamonds indicate patients with cancer, the green diamonds indicate patients without cancer, and the broken diamond symbol () indicates cancers prevented through screening and screening-related interventions.



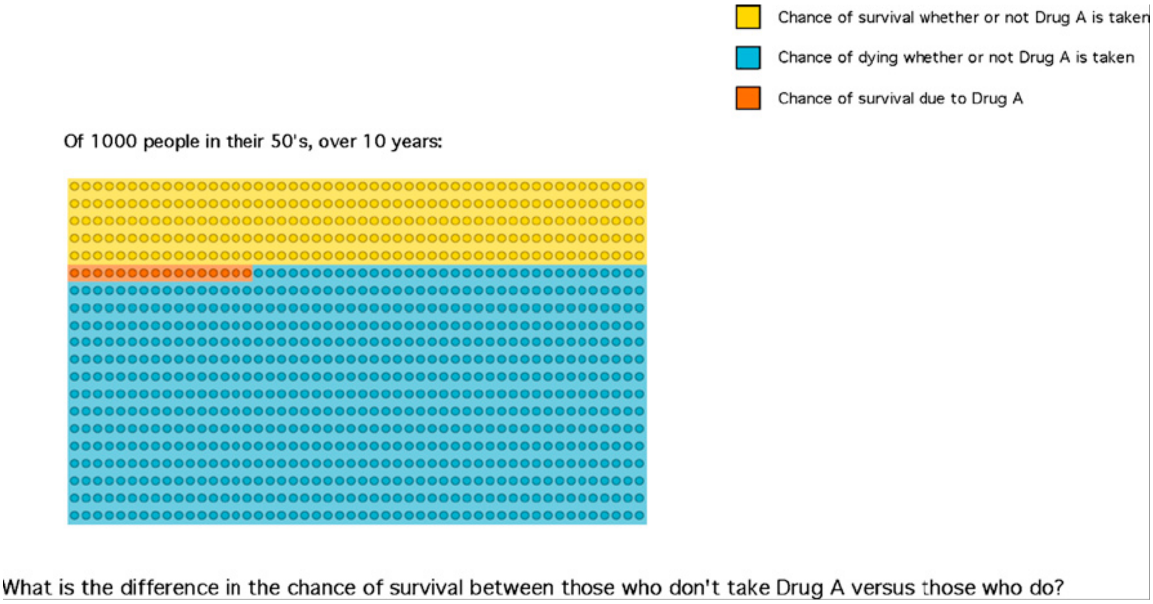
FORMAT 2: Augmented Icon Display
Source: Dolan and Iadarola (2008)

Flow diagram



FORMAT 3: Flow Diagram
Source: Dolan and Iadarola (2008)

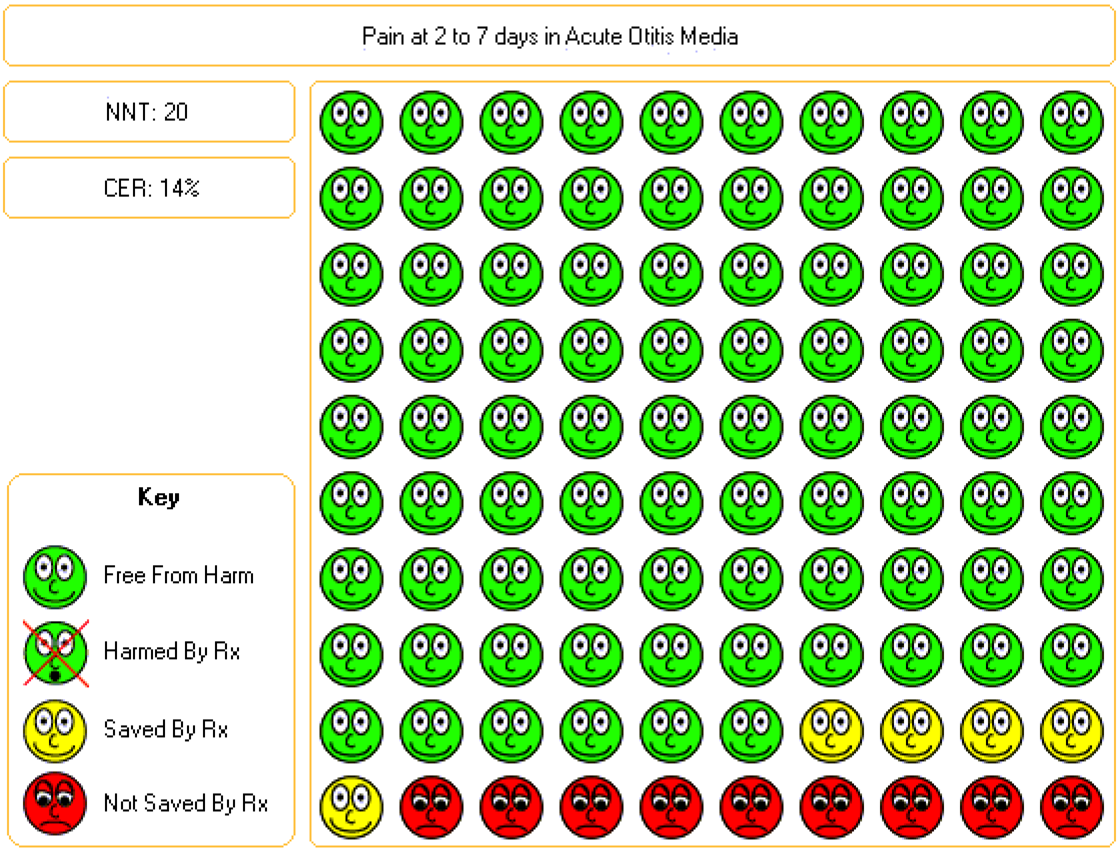
Data along horizontal pictograph perceived faster and more accurately than if presented vertically



FORMAT 4: Horizontal Pictograph
Source: Price et al. (2007)

Visual Rx

Visual Rx is designed to help translate statistical evidence into a format that is easily understood.



FORMAT 5: Visual Rx
Source: C Cates, http://www.nntonline.net; quoted in Edwards et al. (2002).

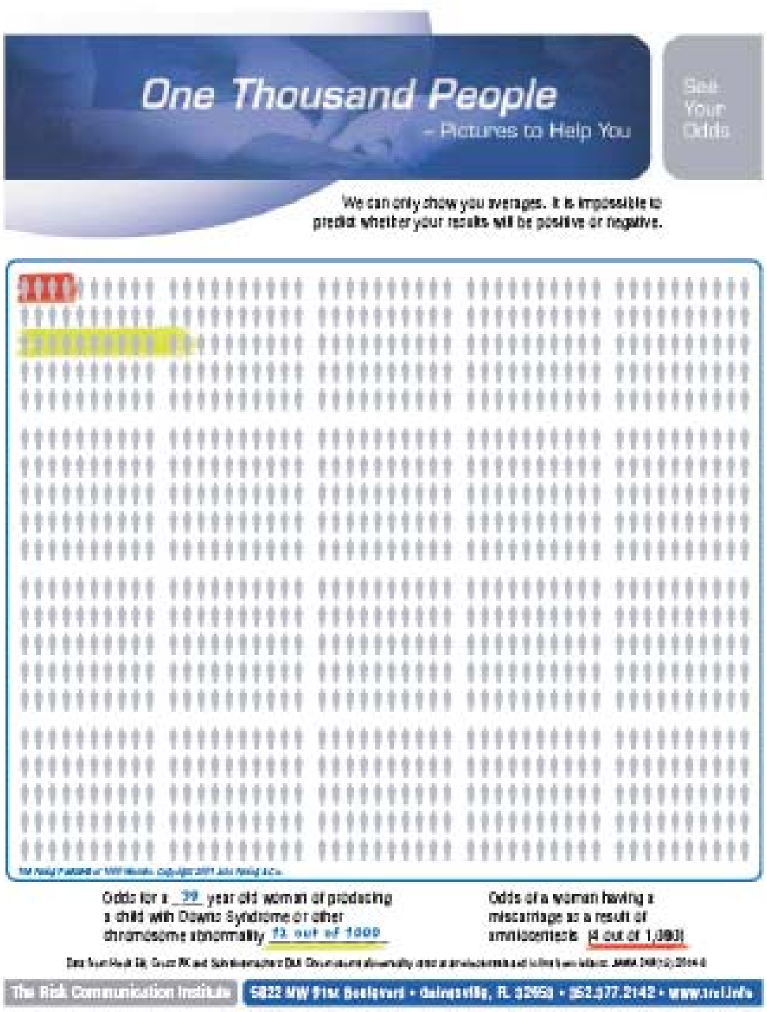
Paling Palette©

This is used to display most medical risks with a probability of higher than 1 in 1,000.

The doctor or genetic counsellor fills in the relevant data while sitting beside the patient.

This format shows the estimates of positive and negative outcomes simultaneously and presents unambiguous visual representations of the probabilities.

The patient may take a printout home for further consideration, or the form may be signed by the patient and a copy kept on file.



FORMAT 6 – Paling Palette
Source: Paling (2003b)

Paling Perspective Scale©

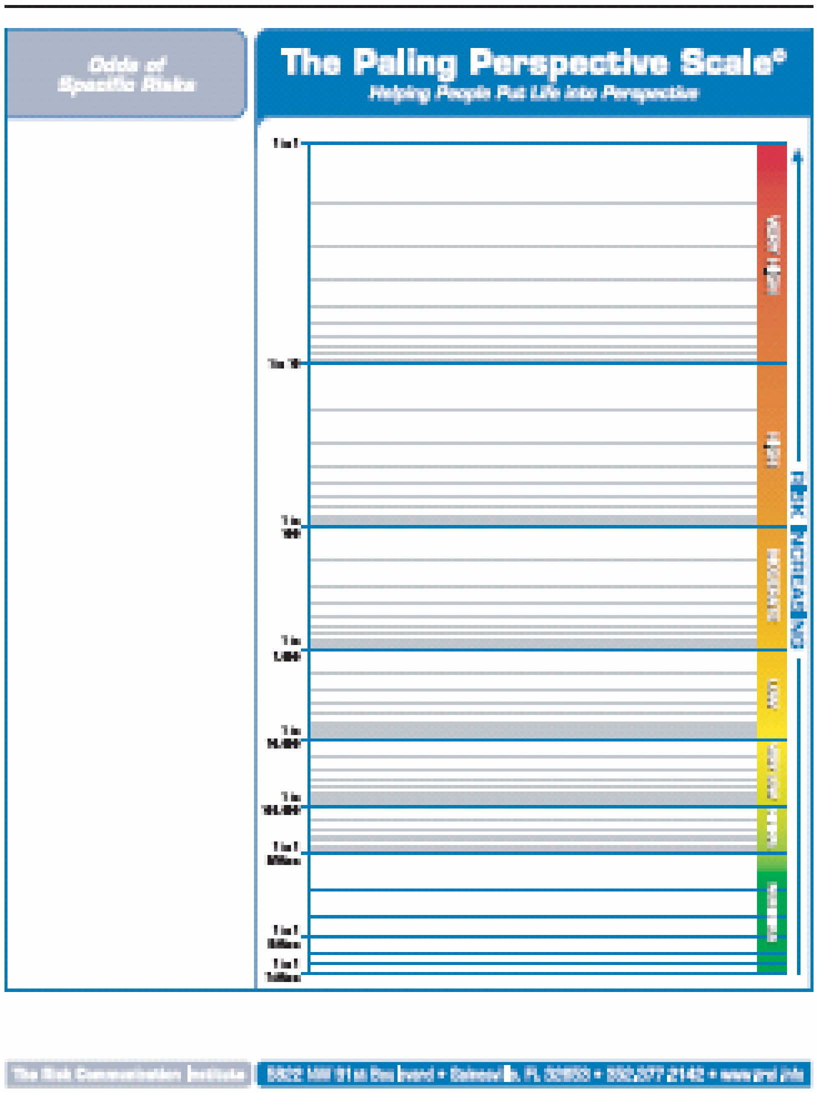


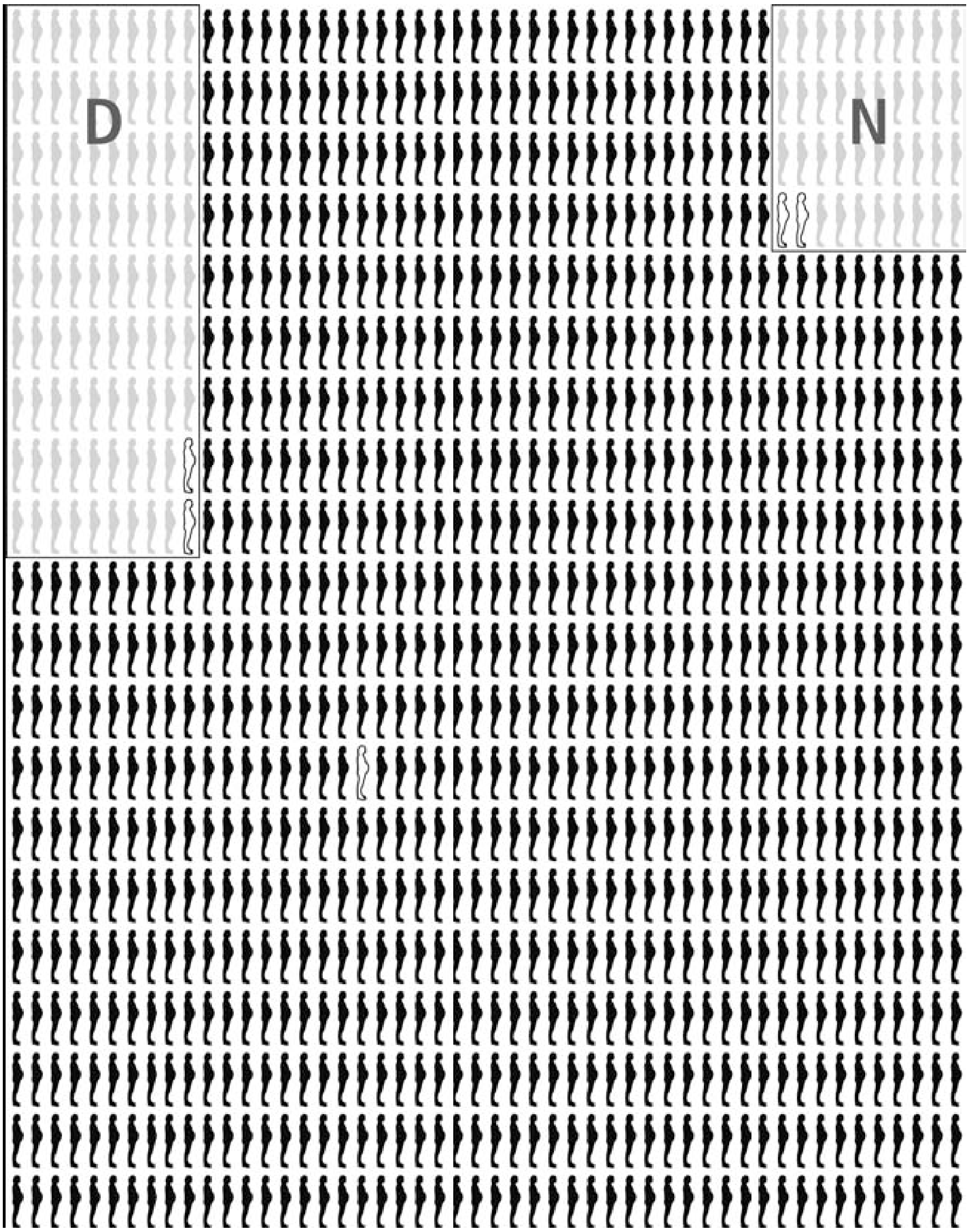
Fig 4 Revised Paling Perspective Scale© —for displaying risks covering widely different orders of magnitude

FORMAT 7: Paling Perspective Scale©
Source: Paling (2003b).

Population diagram

“This population diagram represents 1,000 pregnant women who have undergone the Triple Test (routine screening test used in the USA to indicate potential genetic disorders).

The 90 individuals forming the group in the upper left-hand corner test positive for Down’s syndrome (D) and the 40 individuals in the upper right-hand corner test positive for a neural tube defect (N). Yet most positive tests are false positives; only the two individuals shown in white among each group have the respective clinical condition. Among those who test negative, i.e. the individuals shown in black, there is one pregnant woman whose child will nonetheless have one of these clinical conditions” Kurze-Milcke et al. (2008).



FORMAT 8: Population Diagram
Source: Kurze-Milcke et al. (2008).

Appendix 2 – Examples of confusing statistical information, with alternatives that foster insight

Type of information	Examples	How to foster insight
Single event probabilities	'You have a 30 per cent chance of a side effect from this drug.'	Use frequency statements: 'Three out of every 10 patients have a side effect from this drug.'
Conditional probabilities	The probability of a positive test result if the patient has the disease (sensitivity).	Use natural frequencies, alone or together with conditional probabilities
	The probability of a negative test result if the patient does not have the disease (specificity).	
	The probability of the disease if the patient has a positive test result (positive predictive value).	
Relative risks	If four out of every 1000 women (aged 40 or older) who do not undergo mammography screening die of breast cancer, compared with three out of every 1000 who are screened, the benefit is often presented as a relative risk: 'Mammography reduces breast cancer mortality by 25 per cent.'	Use absolute risks, alone or together with relative risks: 'In every 1000 women who undergo screening one will be saved from dying of breast cancer.'
		Use the number needed to treat or harm: 'To prevent one death from breast cancer, 1000 women need to undergo screening for 10 years.'

Source: Gigerenzer and Edwards (2003)

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