Understanding of the concept of ‘uncertain risk’. A qualitative study among different societal groups

Tom Jansen\textsuperscript{a,b}, Liesbeth Claassen\textsuperscript{b,c}, Irene van Kamp\textsuperscript{a} and Daniëlle R. M. Timmermans\textsuperscript{b,d}

\textsuperscript{a}Centre for Sustainability, Environment and Health, National Institute for Public Health and the Environment, Bilthoven, The Netherlands; \textsuperscript{b}Amsterdam UMC, Vrije Universiteit Amsterdam, Department of Public and Occupational Health, Amsterdam Public Health research institute, Amsterdam, The Netherlands; \textsuperscript{c}Centre for Environmental Safety and Security, National Institute for Public Health and the Environment, Bilthoven, The Netherlands; \textsuperscript{d}National Institute for Public Health and the Environment, Bilthoven, The Netherlands

\textbf{ABSTRACT}

In environmental health science, the concept ‘uncertain risk’ refers to situations in which epistemic uncertainties prevent definitive statements about the presence or existence of risk. The concept is difficult for risk communication and may easily lead to miscommunications and misunderstanding. This research investigated how the concept of uncertain risk is understood by different societal groups. We conducted in-depth interviews with the general public ($N = 40$), and online open-ended questionnaires and online focus groups with scientists, policy makers and communication experts ($N = 49$). Results show that the understanding of ‘uncertain risk’ varied within and between groups. While at least some representatives of all groups described epistemic uncertainties, groups focused on different aspects of risk. That is, scientists based their descriptions only on uncertainties in risk assessment. Policy makers commonly indicated that these uncertainties caused uncertainty in risk management. Communication experts mainly gave general descriptions, but recognized aspects that were important for other groups. Representatives of the general public often described aspects that deviate from the scientific understanding, such as a lack of personal control. In risk communication, stating that ‘a risk cannot be excluded’ is not clear. Different associations and understanding have to be taken into account in risk communication. Explicating uncertainties may improve consistent understanding and foster a more balanced dialogue between different societal groups. Further (empirical) research is needed to demonstrate if and how explicating evidence and uncertainties in specific cases of uncertain risks improves understanding within and between groups.

\textbf{ARTICLE HISTORY}

Received 14 February 2018
Accepted 17 July 2018

\textbf{KEYWORDS}

uncertain risk; concept; risk communication; environmental health

\section*{Introduction}

The concept of ‘uncertain risk’ is used to indicate there is uncertainty about the presence or existence of risk (Tosun 2013; Van Asselt and Vos 2008; Zander 2010). In environmental health
the inability to make conclusive statements about the presence or existence of risk can be the result of different epistemic uncertainties (Jansen et al. 2017). Inconclusive statements, such as ‘a risk cannot be excluded’, may easily lead to miscommunication and misunderstanding when parties involved in communication have different perspectives on the meaning specific risk terminology (e.g. Scheer et al. 2014; Timmermans 1994) and terminology gives rise to different associations (Visschers et al. 2007).

The combination of ‘uncertainty’ and ‘risk’ makes the concept and verbal expressions of uncertain risk especially difficult to understand. At face value, uncertain risk seems to be a pleonasm because risks are inherently uncertain. It can be questioned whether all parties involved in environmental health risk communication consistently understand that ‘uncertain risk’ refers to situations in which epistemic uncertainties prevent conclusive statements about the presence or existence of risk. Therefore, with the aim of fostering effective risk communication, we research how different societal groups understand the scientific concept of ‘uncertain risk’. This research hereby joins a line of research and a broader discussion about the (semantic) value of risk concepts such as ‘risk’, ‘uncertainty’ and ‘uncertainty about uncertainty’ (Aven 2010, 2012, 2014; Aven and Renn 2009; Boholm 2017; Flage and Aven 2015; Jansen et al. 2017; Mazri 2017; Young, Brelsford, and Wogalter 1990).

The understanding of the concept of ‘uncertain risk’ may be influenced by the interpretation of two central concepts in risk research: ‘uncertainty’ and ‘risk’ (Collins and Loftus 1975). The concept of ‘uncertainty’ can be described differently in different situations (Smithson 2012). In the current article, we adopt the typology and general definition of uncertainty proposed by Walker et al. (2003). According to Walker and colleagues uncertainty is ‘any deviation from the unachievable ideal of completely deterministic knowledge of the relevant system’ (Walker et al. 2003). Two types of uncertainty are generally distinguished. First, epistemic uncertainties refer to uncertainty from a lack of, or imperfection of knowledge (Paté-Cornell 1996; Walker et al. 2003). Examples are a general lack of knowledge, data or observations (e.g. Brugnach et al. 2008; van Asselt 2000) and a difficulty to identify and quantify links of causality (Klinke and Renn 2012). Epistemic uncertainties may be reduced by more (empirical) research. Second, variability, or aleatory uncertainty refers to uncertainties due to inherent variability over space and time. Examples are behavioral diversity (Walker et al. 2003) and natural randomness (van Asselt 2000). These two types of uncertainty describe the nature of uncertainty (Walker et al. 2003), which expresses the causes of the imperfection or lack of knowledge. In their typology of uncertainty, Walker et al. distinguish two additional dimensions of uncertainty besides the nature: the level and location. The level of uncertainty is an expression of the scale of the uncertainty (i.e. from completely deterministic knowledge to total ignorance). The location of uncertainty describes about what aspects in a specific model uncertainty exist.

There is no universal definition of risk. The concept is generally understood to express something uncertain, but for that uncertainty to constitute a risk, something must be known about it (Hansson 2002). Different approaches (e.g. ontological or epistemological) to risk and definitions (e.g. based on probabilities, expected values, uncertainty or undesirable events) have been discussed extensively in the risk literature (Althaus 2005; Aven 2010, 2012, 2014; Aven and Renn 2009; Aven, Renn, and Rosa 2011; Rosa 1998). In everyday use too the concept of risk may be used to refer to differ things (Aven 2014). In the current article, ‘risk’ is defined in the context of environmental health: ‘the probability of adverse effects resulting from exposure to an environmental agent or mixture of agents’ (US EPA 2015). In this metric ‘risk’ is inherently uncertain and expressed as a probabilistic value (i.e. the probability of adverse effects). A risk, as described here, can be defined as ‘certain’ when a hazard is known to exist and mathematical probabilities can be assigned to its occurrence (Zander 2010) (cf. Hansson 2002).

While these different interpretations of ‘uncertainty’ and ‘risk’ makes ‘uncertain risk’ a difficult concept, it should be noted that it is intended as a distinct concept (see e.g. Van Asselt and Renn 2011) and that uncertain risks need special attention in risk communication. Communicating about uncertain risk can result in the misinterpretation of risk. That is: people
may infer that there is a risk while the communication intends to convey it is unclear whether a risk exists. The concept, however, is often loosely defined and used in the policy and risk governance literature (Renn 2008a,b; Tosun 2013; Van Asselt and Renn 2011; Van Asselt and Vos 2008; Vos and Everson 2009; Zander 2010). For example, Van Asselt and Vos (2008) define uncertain risks as ‘new, imaginable hazards, with which society has no or limited experience’. Tosun (2013) defines uncertain risks as ‘[…] situations in which the relationship between activities and their potential hazard cannot be established’. In order to further clarify the scientific meaning of the concept ‘uncertain risk’ we conducted a conceptual review of the environmental health literature (Jansen et al. 2017) and tried to answer about what aspects of risk uncertainty exists (location of uncertainty) when scientists refer to ‘uncertain risk’. The review showed that the uncertainty about the presence or existence of risk may be the result of six different epistemic uncertainties (Figure 1). Epistemic uncertainty may exist about (1) whether an agent has hazardous properties; (2) what adverse effects the agent causes; (3) at what levels of exposure these effects occur; and (4) whether a suggested relationship exists between an agent and certain effects; (5) the source of adverse effects; or (6) actual exposure levels. Thus, ‘uncertain’ in ‘uncertain risk’ does not refer to the realization of outcomes as it does in the concept of ‘risk’ in the context of environmental health (US EPA 2015) but to the causes or ‘initiating events’ (Aven 2010).

When one or more of these uncertainties are present in scientific risk assessment, quantitative statements about probabilities of occurrence are arguably not be the best way to adequately express the uncertainties present in risk assessment (see e.g. Zander 2010). Moreover, depending on the specific ‘uncertain risk case’, the level of evidence and uncertainty about the presence of risk differs. For example, communicating uncertainty about the intrinsic properties of an agent (1), for example in newly engineered nanomaterials, implies a high level of uncertainty because there also is uncertainty about nature of effects (2) and the nature of the hazard (3). In contrast, uncertainty about the nature of the hazard, for example in chemicals with unclear toxicity, implies a lower level of uncertainty because there has to be sufficient evidence for an agent’s hazardous intrinsic properties and a certain effect must be associated (Jansen et al. 2017). These differences are not clear in the concept of uncertain risk, in verbal presentations of uncertain risks, such as ‘a risk cannot be excluded’ or ‘there possibly is a risk’, or in numerical expressions of probabilistic risk. This under-specificity (Carey and Burgman 2008) presents a first issue for risk communication about uncertain risks.

Furthermore, many different groups take part in public debates about uncertain risks. Research has shown that non-experts as compared to experts have different knowledge and

![Figure 1. Six situations in which reference is made to ‘uncertain risks’ in environmental health.](image)

1. Uncertainty about intrinsic properties of an agent. 2. Uncertainty about the nature of adverse effects. 3. Uncertainty about the nature of the hazard. 4. Uncertainty about the relationship between an agent and adverse effects. 5. Uncertainty about actual exposure levels. 6. Uncertainty about the source of observed effects. Note. Updated from (Jansen et al. 2017).
beliefs about environmental risks such as health risks due to electromagnetic fields (Claassen, Bostrom, and Timmermans 2016), wildland fires (Zaksek and Arvai 2004) or radon (Bostrom, Fischhoff, and Morgan 1992). These existing knowledge and beliefs form the mental framework in which new information is evaluated. This has implications for risk communication because different societal groups need information that is in line with their existing knowledge and beliefs (Morgan et al. 2002) to support decisions. For risk assessors, information about the uncertainties associated with scientific risk assessment may be important to be able to weigh the evidence underlying their scientific advice about uncertain risks. For policy makers, it may be important to convey how these uncertainties influence risk management options (Thompson and Bloom 2000). Non-experts, not familiar with the risk assessment process, do not clearly differentiate between different types of uncertainties in communications, and, therefore, may draw mistaken conclusions (e.g. about the presence or severity of a risk) (Miles and Frewer 2003; Wiedemann, Schütz, and Thalmann 2008). Non-experts may also be interested in information other than uncertainties in risk assessment, such as information about how someone can be exposed or whether the risk can be controlled (Lion, Meertens, and Bot 2002). When such topics are not covered in risk communication, the odds of misinterpretation are high and a balanced dialogue between different societal groups may be impeded.

With the many ways ‘risk’ and ‘uncertainty’ can be understood; the specific situations in which the environmental health literature refers to ‘uncertain risk’; and the different mental frameworks in which information is evaluated it is likely that communications about ‘uncertain risks’ may lead to miscommunications and misunderstanding. A better understanding of how the concept is understood within and between various societal groups is important for improving the match between risk assessment, communication practices, and risk perceptions of different societal groups. This study aims to explore how the general public, scientists, policy makers, and communication experts involved in the assessment and communication about environmental health risks understand the concept of ‘uncertain risk’.

Method

A qualitative public-centered approach was used. We included four societal groups: the general public, and three expert groups that play a formal role in the assessment of and communication about uncertain risks in the Netherlands: scientists, policy makers, and communication experts. Representatives of the expert groups had to be experts in their respective fields.

First, we performed in-depth, open-ended semistructured interviews with 40 representatives of the general public. After this, 49 representatives of the expert groups completed an online open-ended questionnaire based on the same questions. Finally, after completing the questionnaire, 45 of the expert representatives participated in online focus groups. Below we discuss these three steps in further detail.

Interviews with members of the general public

Members of the general public were recruited through a snowball sampling method. We aimed to achieve a balanced male–female ratio, including individuals with a non-native Dutch cultural background, of all levels of education (low, intermediate, high; according to the International Standard Classification of Education [ISCED] 2011 (UNESCO Institute for Statistics (2012)), and from different parts of the Netherlands. See Table 1 for an overview of participant characteristics. Participants did not receive any compensation for their participation.

Participants were interviewed in their own homes or, when more convenient for the respondent, at a public location offering some privacy. The interviews generally lasted between 30 to 45 min and were audio recorded with the participant’s permission. All interviews were conducted
between August and November 2016 by the first author. The interview followed a semi-structured protocol and started by introducing the goal and general topic of the research.

This brief introduction was followed by open-ended questions addressing the participant’s understanding of the concept of ‘risk’ and of ‘uncertain risk’. After these questions, the interview addressed a specific case of an uncertain risk. See Table 3 for the questions discussed in this article.

Open-ended questionnaires and focus groups with experts

Experts from public authorities, universities, hospitals and ministries involved in the assessment of and/or communication about environmental health risks in the Netherlands were approached to participate in our study. Participants were invited based on expertise in their respective fields (science, communication and policy). Scientists were selected based on their expertise on: (1) antibiotic resistance; (2) chemical substances in food packaging materials; or (3) nanomaterials in food. In total, 45 experts divided across three expert groups agreed to participate in the study. See Table 2 for an overview.

First, experts received an online questionnaire. Table 3 presents the questions discussed in the current article. Questionnaires were completed in February and March 2017. Next, the experts participated in a focus group with 2–4 other participants within their field of expertise through video conferencing. Focus groups were chaired by scientific experts from the same field. The chairs were instructed to intervene as little as possible and to focus on moderating the process. The focus groups lasted 1 hour and were audio- and video-recorded with the participants’ permission. All focus groups were conducted in March 2017. Table 3 provides a complete overview of methods, questions and statements addressed in the current article.

Qualitative coding and analysis

The audio recordings of the interviews and focus groups were transcribed verbatim. Data from the online open-ended questionnaire and the transcriptions were analyzed using Atlas.ti 7 (Friese 2014). Qualitative data analysis comprised two phases. In the first phase, the first author applied descriptive level coding to text fragments that were identified to be relevant. We decomposed participants’ descriptions of their understanding of uncertain risks in specific aspects that provide

| Table 1. Sociodemographic characteristics of the representatives of the general public. |
|----------------------------------------|-----|-----|
| M (min–max) | N  |
|----------------------------------------|-----|-----|
| Total | 40 |
| **Gender** |     |     |
| Men | 21 |
| Women | 19 |
| **Age** | 44 (27–66) |
| **Education** |     |     |
| Low | 5 |
| Intermediate | 13 |
| High | 22 |
| **Cultural Background** |     |     |
| Dutch | 33 |
| Indonesian-Dutch | 2 |
| Turkish-Dutch | 2 |
| Antillean | 1 |
| Moroccan-Dutch | 1 |
| Moluccan-Dutch | 1 |

*Non-native Dutch cultural backgrounds are reported here, as reported by the participants.

aLow, intermediate, and high categorization in accordance with the International Standard Classification of Education (ISCED) 2011.*
meaningful information about their understanding of the concept of ‘uncertain risk’. Descriptions of individual participants could consist of one or several aspects. Judgment of relevance of text fragments was guided by the three dimensions of uncertainty proposed by Walker et al. (2003).

The second author independently coded part of the data to ascertain that no relevant fragments had been missed and to validate the descriptive level coding. The second coder identified a few additional text fragments to be relevant. The two coders discussed and resolved minor differences in the coding and in the second phase categorized the descriptive level codes to create higher-level, conceptual coding. The third author who did not participate in the first phase of the coding process reviewed the categorization of all descriptive level codes. Categorization was subsequently discussed by the first and third authors and minor adjustments were made. Simultaneously, the second author coded a part of the data using the conceptual codes. No additional text fragments were identified. In total, 10% of the data was coded by the first two authors.

**Results**

Within the studied sample, the aspects used to describe their understanding of the concept of ‘uncertain risk’ varied within and between groups. Some individuals described multiple epistemic uncertainties found in Jansen et al. (2017), while others (including experts) described only one. Additionally many different associations were found in the participants’ descriptions of the concept of ‘uncertain risk’ (Appendix A). Some participants of the general public stated that the distinction between ‘risk’ and ‘uncertain risk’ was not clear. Many participants had negative associations with risk and specifically put forward that ‘risk’ is directly related to ‘danger’, inherently uncertain, or represented a deliberate choice (e.g. ‘taking a risk’). Some participants stated that ‘a risk’ represents something that could either go wrong or right; that risks are part of our daily lives; and that risk also has positive aspects.
In our results we follow (Neale, Miller, and West 2014) and make a distinction between commonly mentioned aspects, and rarely or occasionally mentioned aspects with the aim to clarify patterns in the qualitative data. Because of the explorative and qualitative nature of this study the results are not meant to convey generalizability beyond the study population (Neale, Miller, and West 2014). Table 4 presents all aspects that were commonly used to describe the understanding of the concept of uncertain risk by at least one group. Table 5 presents example quotes for each of these aspects. A single quotation can describe several aspects and could, therefore, be allocated to multiple categories.

The commonly described aspects were categorized in six overarching themes and two detached aspects.

1. Participants often described causes of uncertainty that define the concept of ‘uncertain risk’. For example, participants mentioned that scientific knowledge can be insufficient, inconsistent or contested. Additionally, participants from the general public put forward a lack of personal awareness and knowledge.

2. Many participants identified specific uncertainties about qualitative properties of risk, such as uncertainty about the nature of (adverse) effects, and uncertainty about, or due to, delayed effects (i.e. effects that occur in the long term). Specific uncertainties were often described in the context of a specific example or in abstract terms (see e.g. the quotations referring to delayed effects and actual exposure levels in Table 5).
Table 5. Example quotations of commonly mentioned aspects.

| Theme                                      | Aspect in description                                                                 | Example quotation (group representative)                                      |
|--------------------------------------------|----------------------------------------------------------------------------------------|--------------------------------------------------------------------------------|
| Causes of uncertainty                      | Level of available knowledge\(a\)                                                     | [...] Something is known, but not to what extent ... (Female, 55, low education) |
|                                            | Lack of scientific knowledge                                                           | [...] That insufficient data is available in order to calculate a risk (Policy maker) |
|                                            | Inconsistent knowledge or judgment                                                     | What is the risk? Do we even agree on that? (Communication expert)            |
|                                            | Risks you are personally unaware of                                                    | What comes to mind is that often ... you are not aware that you are at risk (Female, 29, high education) |
|                                            | Lack of personal (public) knowledge                                                   | Well, maybe, there's something in our food. Substances or something. About which we, as ordinary people, do not know. And that is an uncertain risk, yes, uncertainty. (Male, 27, low education) |
|                                            | Risks the public does not concern itself with                                          | There are so many things ... that are either good or bad. You aren't concerned with these kind of things ... Until you contract an illness or something (Male, 61, intermediate education) |
| Uncertainty about qualitative aspects related to risk assessment | Hazardous properties                                                                  | [...] Because you do not know what that does to you ... whether it is harmful for your health (Female, 55, low education) |
|                                            | Nature of (adverse) effects                                                           | We know too little about the effects of an exposure (Scientist)                |
|                                            | Delayed or long-term effects                                                          | [...] Particulate matter is, let's say, more or less known now ... But that is a risk that we didn't know about for a long time. (Male, 57, high education) |
|                                            | Nature of the hazard                                                                  | Uncertainty about the danger (toxicity) and [...] Often there is a lack of good data about the dose-response relationship (Scientist) |
|                                            | Exposure                                                                               | We know too little about the [...] and the exposure (Scientist)                |
|                                            | Actual exposure levels                                                                | [...] Sometimes the degree of exposure to substances is unclear. (Scientist)   |
| Uncertainty about quantitative aspects related to risk assessment | Statistical margins                                                                  | Risks for which there are unclear or very broad margins (Communication expert) |
|                                            | Probability                                                                           | But that makes it a difficult description, because for an uncertain risk, in essence the chance that something goes wrong, is uncertain. (Female, 28, high education) |
|                                            | Risks a risk with a(n) (extra) small chance                                           | I find risk a bit heavier. Heavier ... yes, an uncertain risk I think maybe ten to fifteen percent, but a risk then I go to forty, fifty percent. That the chance is a bit bigger. (Male, 37, intermediate education) |
| General statements about risk assessment   | Risks that are difficult to assess                                                     | What comes to mind are risks that cannot be exactly determined (Scientist)     |
|                                            | Risk that are difficult to quantify                                                    | That there is too little data to calculate the risk (Scientist)                |
|                                            | Risks that are difficult to assess by the public                                       | Exactly, I cannot judge that as a layman and that gives an uncomfortable feeling ... I think at least in my case and maybe more people, so to say (Male, 60, high education) |
| Uncertainty about risk management          | Risk management                                                                       | [...] or when you cannot say for certain, when you take a measure, by how many percent you reduce a disease burden. (Policy maker) |
|                                            | Action perspectives                                                                   | If there would be a fire somewhere or something, and I do not know if asbestos was released. That may also be an uncertain risk [...] because you do not know whether you should close the windows and doors, those kinds of things. (Female, 35, high education) |
|                                            | Risks the public cannot control                                                        | Yes ... What I think of? Uncertain risks ... Things I cannot control myself. Things I cannot influence. (Male, 35, intermediate education) |
| General uncertainty statements about risk  | Presence of risk                                                                       | Risks for which it is uncertain whether they are actually there. (Policy maker) |
|                                            | Magnitude of risk                                                                      | Risks for which no definitive statements can be made about how big the risk is, and therefore whether it is safe or not. (Communication expert) |

(continued)
3. Participants from all groups suggested that the concept of ‘uncertain risk’ indicated that there was uncertainty about quantitative properties of risk. For example, uncertainty about the probability of occurrence (i.e. one in a hundred or one in a thousand) was one of the commonly mentioned elements for all groups. A few members of the general public understood the concept of ‘uncertain risk’ to refer to a risk with a small chance, or extra small chance (relative to the probability that the concept of ‘risk’ referred to).

4. Scientists in particular made general statements about the risk assessment process by stating that uncertain risks are difficult to assess or quantify. Participants from the general public stated that uncertain risks are difficult to assess by the public.

5. Several uncertainties about risk management were put forward. For example, uncertainty about the effectiveness of policy options, but also uncertainties about the action perspectives for the general public. Uncertain risks were commonly associated with a lack of personal control by participants from the general public.

6. When no specific uncertainties were put forward, participants typically made general uncertainty statements about risk. For example, participants in each group suggested that the concept of ‘uncertain risk’ refers to uncertainty about the presence of the risk and/or that ‘uncertain risks’ were defined by uncertainty about the nature of the risk.

Finally, and not classifiable in any of the themes above, ‘uncertain risk’ evoked statements that referred to uncertainty about individual risk (i.e. will an individual experience adverse effects or not) and participants of the general public expressed that ‘uncertain risks’ referred to situations that are unpredictable.

Figure 2 shows the overlap between commonly mentioned aspects by the different groups involved in this study. It shows that all groups commonly mentioned uncertainties associated with risk assessment and commonly made general statements about uncertain risks (e.g. ‘uncertainty about the presence of risk’). Scientists and representatives of the general public commonly put forward aspects that were not shared with any other group (e.g. actual exposure levels and a lack of personal [public] knowledge). Communication experts put forward one general statement (uncertainty about the severity of risk) that was not (commonly) mentioned by other groups. All groups mentioned unique topics that are relevant for their own (professional) group. For example, policy makers put forward that ‘uncertain risks’ also signified uncertainties in risk management. Members of the general public specified uncertainties that pertained to personal relevance (e.g. lack of control). Communication professionals (shaping communication between different groups) identified uncertainties that were considered relevant for specific groups: uncertainties in risk assessment for scientists, uncertainty in risk management for policy makers, and uncertainty about action perspectives for the public. Scientist relied on uncertainties associated with risk assessment in their descriptions of the concept of uncertain risk.
Discussion

This research aimed to gain insights into how the scientific concept of ‘uncertain risk’ is understood by different societal groups. The concept intends to describe situations in which epistemic uncertainties prevent definitive statements about the presence or existence of risk.

Results show that the understanding of ‘uncertain risk’ varied within and between groups. While at least some representatives of all groups described epistemic uncertainties, some recognized that the concept could refer to multiple epistemic uncertainties, while others only put forward one. Different groups also focused on different aspects of (uncertain) risk. Scientists based their descriptions only on uncertainties in risk assessment. Policy makers commonly indicated that these uncertainties in risk assessment caused uncertainty in risk management (options). Communication experts mainly gave general descriptions, but also recognized aspects that were considered important for other groups. Representatives of the general public often described associations with uncertain risks that deviate from the scientific understanding, such as a lack of personal control. Additionally, participants commonly mentioned uncertainties (e.g. ‘uncertainty about the magnitude of the risk’) that imply the understanding that a risk exists.
The general public in particular attributed many aspects to ‘uncertain risk’ that deviate from the scientific-technical concept. Most of these attributions were not mentioned by scientists, policy makers, or communication experts. For example, members of the general public commonly mentioned a low perceived likelihood and uncertainty due to delayed effects. These factors are identified to attenuate people’s risk perceptions (Slovic 2016). In addition, representatives of the public stated that they ‘do not concern themselves with’ uncertain risks. This indicates that part of the public may not find uncertain risks an important issue and, as a consequence, are not worried about ‘uncertain risks’ (Powell et al. 2007).

However, some members of the general public expressed that ‘uncertain risks’ refers to ‘risks that they are not aware of’, that is, environmental health risks that are known to science or policy but are unknown to the public. An example is an incident in which tap water in contaminated, that is not communicated to the public because exposure levels are too low to cause adverse effects. If the public is informed by the media about these risks and not by the government, this may undermine their trust in the government, even though there was no risk to personal health (Powell et al. 2007). Additionally, a feeling of a lack of personal control – also commonly mentioned – may amplify public perception of the seriousness of risk (Miles and Frewer 2003; Slovic 2016).

Some participants did not differentiate between the concept of ‘uncertain risk’ and ‘risk’, and associated ‘risk’ with ‘danger’ and something that could go either wrong or right. These attributions will influence how the general public responds to communications about uncertain risks. For example, just mentioning the word risk in the statement ‘A risk cannot be excluded’ – commonly used in scientific reports to indicate there is no evidence for risk – may elicit unintentional associations with danger.

The concept of uncertain risk may be a useful catchall term to describe situations in which there is uncertainty about the existence or presence of risk. Current findings suggest that respondents of different groups may have partial, different or conflicting representation of what the concept entails. The ambiguity of the concept of ‘uncertain risk’ challenges risk communication efforts as much as the epistemic uncertainties in risk assessment that define the concept (Lundgren and McMakin 2013). For example, the statement ‘Research is conducted into the risks of nanomaterials in food. Currently, these risks are uncertain.’ intends to convey that it is uncertain whether (specific) nanomaterials in food are hazardous to human health. The results of the current study show that policy makers and scientists may understand there is uncertainty about the hazardous properties – and thus uncertainty about whether a risk exists –, but that the general public may believe that the presence of risk is already determined. They may feel that they are unnecessarily exposed and that their concerns are not being heard, which may complicate a balanced dialogue. While previous research suggests that the general public does not clearly differentiate between specific types of uncertainties in communications (Miles and Frewer 2003; Wiedemann, Schütz, and Thalmann 2008), clarifying the available evidence and remaining uncertainties about the presence of a risk may improve consistent understanding between different societal groups (Wiedemann et al. 2011). When ‘uncertain risk’ evokes the idea that a person has no control over a risk, this has to be accounted for in risk communication in order to fit an individual’s existing knowledge and beliefs (Morgan et al. 2002). Otherwise, different terminology should be used to avoid associations that are unwanted or may have unintended consequences.

Overall, results of this explorative study show that the concept of ‘uncertain risk’ elicits different associations within and between groups. Contrary to the scientific-technical understanding of the concept, individuals may understand that the presence of risk is determined or feel they have no control over the situation. In risk communication, stating that ‘a risk cannot be excluded’ is not clear. Explicating uncertainties may improve a mutual understanding and foster a more balanced dialogue between different societal groups. Further (empirical) research is needed to demonstrate if and how explicating evidence and uncertainties in specific cases of uncertain risks improves consistent understanding within and between groups.
Limitations

The focus on the semantic value of the concept of ‘uncertain risk’ may be considered an important limitation of the current study because (especially for the general public) risk concepts may only acquire (different) meaning in a specific context. However, participants were explicitly asked to put their descriptions in context. Conversely, participants also commonly put forward examples in order to explain their understanding of the concept.

Results from qualitative analysis are susceptible for bias due to the coder’s perspective. We minimized this potential for bias by involving three authors in the coded process. In this process we stayed close to the participants’ own words. That is, when participants talked about risk, we coded ‘risk’; when participants talked about effects, we coded ‘effects’, etc. This assures that the general statements presented in this research can be interpreted as the participants’ own, free of interpretation by the researcher.

Notes

1. In addition, four medical experts with expertise on antibiotic resistance participated in the current study. Because this group was too small to make meaningful comparisons, the results will not be discussed in this article.
2. Four experts who completed the online questionnaires could not participate in the focus groups. Due to technical issues, some participants could only participate via an audio connection.
3. Communication experts recognized that some of these aspects would be mentioned by the general public.

Acknowledgements

We would like to thank Ilse Gosens, Henk van Kranen and Jim van Steenbergen for their efforts in chairing the focus groups. We would also like to thank everyone involved in recruiting participants and organizing the focus groups for their effort.

Disclosure statement

The authors declared no conflicts of interest.

Funding

This research was carried out in the framework of RIVM Strategic Programme [grant S/121003/01/PU], in which expertise and innovative projects prepare RIVM to respond to future issues in health and sustainability.

ORCID

Tom Jansen https://orcid.org/0000-0003-0087-937X

References

Althaus, C. E. 2005. “A Disciplinary Perspective on the Epistemological Status of Risk.” Risk Analysis 25 (3): 567–588.
Aven, T. 2010. “On How to Define, Understand and Describe Risk.” Reliability Engineering & System Safety 95 (6): 623–631. doi:10.1016/j.ress.2010.01.011.
Aven, T. 2012. “The Risk Concept—Historical and Recent Development Trends.” Reliability Engineering & System Safety 99 (Supplement C): 33–44. doi:10.1016/j.ress.2011.11.006.
Aven, T. 2014. Fundamental Ideas and Concepts in Risk Assessment and Risk Management. London: Routledge Taylor & Francis Group.
Aven, T., and O. Renn. 2009. “On Risk Defined as an Event Where the Outcome Is Uncertain.” Journal of Risk Research 12 (1): 1–11.
Aven, T., O. Renn, and E. A. Rosa. 2011. “On the Ontological Status of the Concept of Risk.” Safety Science 49 (8–9): 1074–1079.

Boholm, M. 2017. “The Semantic Field of Risk.” Safety Science 92: 205–216.

Bostrom, A., B. Fischhoff, and M. G. Morgan. 1992. “Characterizing Mental Models of Hazardous Processes: A Methodology and an Application to Radon.” Journal of Social Issues 48 (4): 85–100.

Brugnach, M., A. Dewulf, C. Pahl-Wostl, and T. Taillieu. 2008. Toward a relational concept of uncertainty: about knowing too little, knowing too differently, and accepting not to know. Ecology and Society 13 (2): 30. https://www.ecologyandsociety.org/vol13/iss2/art30/.

Carey, J. M., and M. A Burgman. 2008. “Linguistic Uncertainty in Qualitative Risk Analysis and How to Minimize It.” Annals of the New York Academy of Sciences 1128 (1): 13–17.

Classen, L., A. Bostrom, and D. R. M. Timmermans. 2016. “Focal Points for Improving Communications About Electromagnetic Fields and Health: A Mental Models Approach.” Journal of Risk Research 19 (2): 246–269.

Collins, A. M., and E. F. Loftus. 1975. “A Spreading-Activation Theory of Semantic Processing.” Psychological Review 82 (6): 407.

Flage, R., and T. Aven. 2015. “Emerging Risk – Conceptual Definition and a Relation to Black Swan Type of Events.” Reliability Engineering & System Safety 144: 61–67. doi:10.1016/j.ress.2015.07.008.

Friese, S. 2014. Qualitative Data Analysis with ATLAS.ti. London, UK: Sage.

Hansson, S. O. 2002. “Uncertainties in the Knowledge Society.” International Social Science Journal 54 (171): 39–46. doi:10.1111/1468-2451.00357.

Jansen, T., L. Claassen, R. van Poll, I. van Kamp, and D. R. M. Timmermans. 2017. “Breaking Down Uncertain Risks for Risk Communication. A Conceptual Review of the Environmental Health Literature.” Risk, Hazards & Crisis in Public Policy 9 (1): 4–38.

Klinke, A., and O. Renn. 2012. “Adaptive and Integrative Governance on Risk and Uncertainty.” Journal of Risk Research 15 (3): 273–292.

Lion, R., R. M. Meertens, and I. Bot. 2002. “Priorities in Information Desire about Unknown Risks.” Risk Analysis 22 (4): 765–776.

Lundgren, R. E., and A. H. McMakin. 2013. Risk Communication: A Handbook for Communicating Environmental, Safety, and Health Risks. Hoboken (NJ), USA: Wiley.

Mazri, C. 2017. “(Re) Defining Emerging Risks.” Risk Analysis 37 (11): 2053–65. doi:10.1111/risa.12759

Miles, S., and L. J. Frewer. 2003. “Public Perception of Scientific Uncertainty in Relation to Food Hazards.” Journal of Risk Research 6 (3): 267–283.

Morgan, M. G., B. Fischhoff, A. Bostrom, and C. J. Atman. 2002. Risk Communication: A Mental Models Approach. Cambridge: Cambridge University Press.

Neale, J., P. Miller, and R. West. 2014. “Reporting Quantitative Information in Qualitative Research: Guidance for Authors and Reviewers.” Addiction 109 (2): 175–176.

Paté-Cornell, M. E. 1996. “Uncertainties in Risk Analysis: Six Levels of Treatment.” Reliability Engineering & System Safety 54 (2–3): 95–111.

Powell, M., S. Dunwoody, R. Griffin, and K. Neuwirth. 2007. “Exploring Lay Uncertainty about an Environmental Health Risk.” Public Understanding of Science 16 (3): 323–343.

Renn, O. 2008a. Risk Governance: Coping with Uncertainty in a Complex World. London, UK: Earthscan.

Renn, Orwin. 2008b. “White paper on risk governance: Toward an integrative framework” In Global risk governance, edited by O. Renn and K. Walker, 3-73. Dordrecht, The Netherlands: Springer.

Rosa, E. A. 1998. “Metatheoretical Foundations for Post-Normal Risk.” Journal of Risk Research 1 (1): 15–44.

Scheer, D., C. Benighaus, L. Benighaus, O. Renn, S. Gold, B. Röder, and G.-F. BöI. 2014. “The Distinction Between Risk and Hazard: Understanding and Use in Stakeholder Communication.” Risk Analysis 34 (7): 1270–1285.

Slovic, P. 2016. The Perception of Risk. New York, USA: Routledge.

Smithson, M. 2012. “The Many Faces and Masks of Uncertainty.” In Uncertainty and Risk, edited by B. Gabrielle and S. Michael, 31–44. New York, USA: Routledge.

Thompson, K. M., and D. L Bloom. 2000. “Communication of Risk Assessment Information to Risk Managers.” Journal of Risk Research 3 (4): 333–352.

Timmermans, D. R. M. 1994. “The Roles of Experience and Domain of Expertise in Using Numerical and Verbal Probability Terms in Medical Decisions.” Medical Decision Making 14 (2): 146–156.

Tosun, J. 2013. “How the EU Handles Uncertain Risks: Understanding the Role of the Precautionary Principle.” Journal of European Public Policy 20 (10): 1517–1528. UNESCO Institute for Statistics. 2012. International standard classification of education: ISCED 2011, UNESCO Institute for Statistics Montreal.

US EPA. 2015. “IRIS Glossary.” Accessed 29 July 2015. http://www.epa.gov/iris/

van Asselt, M. B. A. 2000. “Uncertainty.” Perspectives on Uncertainty and Risk. The PRIMA Approach to Decision Support, 75–139. Dordrecht: Kluwer Academic Publishers.

Van Asselt, M. B. A., and O. Renn. 2011. “Risk Governance.” Journal of Risk Research 14 (4): 431–449.
Van Asselt, M. B. A., and E. Vos. 2008. "Wrestling with Uncertain Risks: EU Regulation of GMOs and the Uncertainty Paradox." *Journal of Risk Research* 11 (1–2): 281–300.

Visschers, V. H. M., R. M. Meertens, W. F. Passchier, and N. K. DeVries. 2007. "How Does the General Public Evaluate Risk Information? The Impact of Associations with Other Risks." *Risk Analysis* 27 (3): 715–727.

Vos, E., and M. Everson. 2009. *Uncertain Risks Regulated*. London, UK: Routledge.

Walker, W. E., P. Harremoës, J. Rotmans, J. P van der Sluijs, M. B. A. van Asselt, P. Janssen, and M. P. Krayer von Krauss. 2003. "Defining Uncertainty: A Conceptual Basis for Uncertainty Management in Model-Based Decision Support." *Integrated Assessment* 4 (1): 5–17.

Wiedemann, P., H. Schütz, A. Spangenberg, and H. F. Krug. 2011. "Evidence Maps: Communicating Risk Assessments in Societal Controversies: The Case of Engineered Nanoparticles." *Risk Analysis* 31 (11): 1770–1783.

Wiedemann, P., H. Schütz, and A. Thalmann. 2008. "Perception of Uncertainty and Communication about Unclear Risks." In *The Role of Evidence in Risk Characterization: Making Sense of Conflicting Data*, edited by W. Peter and S. Holger, 163–179. Weinheim: Wiley-VCH.

Young, Stephen L., John W. Brelsford, and Michael S. Wogalter. 1990. "Judgments of Hazard, Risk, and Danger: Do They Differ?" In Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 503–507. Los Angeles, CA: SAGE Publications Sage CA.

Zaksek, M., and J. L. Arvai. 2004. "Toward Improved Communication about Wildland Fire: Mental Models Research to Identify Information Needs for Natural Resource Management." *Risk Analysis* 24 (6): 1503–1514.

Zander, J. 2010. *The Application of the Precautionary Principle in Practice: Comparative Dimensions*. Production Editor: Cambridge, UK: Cambridge University Press.

### Appendix A

Overview of all associations put forward by the groups.

| Gen Pub | Com | Pol | Sci |
|---------|-----|-----|-----|
| Action perspectives | X | X | | |
| Actual exposure levels | X | X | X | |
| Animal-human extrapolation | X | X | | X |
| Available knowledge | X | X | X | X |
| Danger unclear | X | | | X |
| Delayed effects | X | X | X | X |
| Different perceptions | | X | X | |
| Exposure | | | X | |
| Impact | X | X | | |
| Inconsistent knowledge or judgments | X | X | X | |
| Individual risk | | X | | X |
| Intrinsic properties | X | X | X | X |
| Is it safe? | X | X | X | |
| Lack of personal (public) knowledge | X | | | X |
| Lack of scientific knowledge | X | X | | X |
| Magnitude of risk | X | X | | X |
| Measurement uncertainty | | X | | |
| Nature of effects | X | X | X | X |
| Nature of hazard | | X | | X |
| Nature of risk | X | X | X | |
| Presence of danger | | X | | X |
| Presence of risk | X | X | X | |
| Probability | X | X | | X |
| Realization of risk | | X | | |
| Relationship | X | | | X |
| Risk factors unknown | X | X | | |
| Risk Management | X | | | |
| Risk you personally are unaware of | X | | | X |
| Risks that are difficult to assess | | X | | |
| Risks that are difficult to assess by the public | | | | X |
| Risks that are difficult to estimate | | X | | X |
| Risks that are unknown | | | X | |
| Risks that are wrongly estimated (by an individual) | | | X | |
| Risks the public cannot control | | X | | |
| Risks the public does not concern itself with | | | X | |
| Risks with a(n) (extra) small chance | | | X | |

(continued)
| Risks you cannot quantify | X | X |
|---------------------------|---|---|
| Severity Effects          | X | X | X |
| Severity of danger        |   |   | X |
| Severity of risk          |   |   | X | X |
| Situations that are unpredictable | X |   |   |
| Situations that have not occurred before |   | X |   |
| Societal discussion       | X |   |   |
| Source of effects         | X |   |   |
| Statistical Margins       | X | X | X |
| Transmission              | X | X |   |
| Uncertainties not quantified | X |   |   |
| Uncertainty in exposure estimates | X |   |   |
| Variability               | X |   |   |
| Vulnerable or susceptible groups | X |   |   |
| Working mechanism (mode of action) | X | X |   |

Note. Results are presented in alphabetical order.
Gen Pub: General Public; Com: Communication experts; Pol: Policy Makers; Sci: Scientists.