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Draft Guidance on Communication of Uncertainty in Scientific Assessments

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Abstract

This document provides guidance for communicators on how to communicate the various expressions of uncertainty described in EFSA's Guidance document on uncertainty analysis in scientific assessments. It also contains specific guidance for assessors on how best to report the various expressions of uncertainty. The document provides a template for identifying expressions of uncertainty in scientific assessments and locating the specific guidance for each expression. The guidance is structured according to EFSA's three broad categories of target audience – 'entry', 'informed' and 'technical' levels. Communicators should use the guidance for the entry and informed audiences, while assessors should use the guidance for the technical level. The expressions of uncertainty form the basis for guidance, the discussion of evidence sources from the scientific, grey literature and two EFSA research studies, and the recommendations for further research on uncertainty communication.

Keywords: uncertainty communication, risk communication, transparency, probability, likelihood

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Summary

The European Food Safety Authority (EFSA) requested its Scientific Committee and Emerging Risk Unit (SCER) and its Communication, Engagement & Cooperation Department (COMCO) to establish a working group to develop practical guidance for EFSA communicators on how to communicate the various expressions of uncertainty resulting from the uncertainty analyses (e.g. qualitative, quantitative) described in EFSA's Guidance document on uncertainty analysis in scientific assessment (EFSA Scientific Committee et al., 2018a; henceforth the 'Uncertainty GD').

The EU Food Law identifies the target audiences of risk communication on EU food and feed safety: 'risk assessors, risk managers, consumers, feed and food businesses, the academic community and other interested parties'. To address this, EFSA tailors its communication messages in layers to the expected scientific literacy and interests of these audiences and targets them through a mixture of channels (meetings, media, website, social media, scientific journal) and formats (scientific opinions, news stories, multimedia, tweets). EFSA's target audiences can be split into three broad categories – 'entry', 'informed' and 'technical' levels.

EFSA's Uncertainty GD (EFSA Scientific Committee et al., 2018a) describes eight different possible expressions of uncertainty resulting from its uncertainty analyses: (1) No expression of uncertainty/unqualified; (2) Description of a source of uncertainty; (3) Qualitative description of the direction and/or magnitude of uncertainty (4) Inconclusive assessment; (5) A precise probability; (6) An approximate probability; (7) A probability distribution and (8) A two–dimensional probability distribution. These uncertainty expressions formed the basis for the discussion of evidence sources and also for the recommendations for communication.

This document is primarily aimed at communicators at EFSA, but could be applied by risk communicators in other institutions that provide scientific advice. It should be used as a supporting document and alongside the EFSA handbook: When Food Is Cooking Up a Storm – Proven Recipes for Risk Communications (EFSA, 2017; henceforth the EFSA Risk Communication Handbook). The guidance for the entry and informed audiences is addressed to communicators producing supporting communications (e.g. news stories), while the guidance for the technical level is addressed to assessors producing scientific outputs (e.g. opinions, reports).

The proposed guidance and strategy were developed based on an analysis of key evidence sources, including selected academic literature, extracts from frameworks or guidance documents similar in scope and purpose to this communication guidance document from other national, or international advisory bodies, and the results of target audience research commissioned or carried out by EFSA. The respective guidance was applied and tested on real examples of EFSA scientific assessments, to draft messages and select visual aids for communicating the related uncertainties. The insights derived from this exercise contributed to the final general and specific guidance for communication.

Although the available evidence on the best ways to communicate the uncertainty expressions was limited overall, the expert analysis of selected academic literature provided a useful starting point for reflecting on this Guidance. All but two of the eight expressions of uncertainty resulting from uncertainty analyses, 'no expression of uncertainty' and 'inconclusive assessment' were addressed in the literature. Recommendations for communication of uncertainty – as formulated by the authors themselves or drafted based on the group's interpretation – were extracted from the selected papers.

EFSA commissioned a focus group study in 2016 (Etienne et al., 2018) and carried out its own follow-up multilingual online survey in 2017 (EFSA, 2018). The studies provided indications on target audience perspectives regarding the usefulness of uncertainty information, the impact of language, culture and professional background, and on audiences' understanding of and/or preferences for messages describing four types of expressions of uncertainty: an 'uncertainty table' containing brief qualitative descriptions of sources of uncertainty accompanied by plus and minus symbols indicating the direction of their impact on the assessment, qualitative expressions of probability (e.g. 'likely'), approximate probabilities (e.g. '66-90% probability') and precise probabilities qualified by a hedging word (e.g. 'about 80%'). Both studies have limitations in their design and execution but considered cautiously they are a useful source of insights retrieved directly from the key target audiences of EFSA's communications.

How uncertainties should be conveyed to enable non-scientists to make informed decisions is still an under researched field. Experience gained during the implementation of this Guidance itself will provide new insights on the best way to communicate different expressions of uncertainty in scientific assessments. EFSA therefore intends to review and, if needed, update this Guidance over the next years.

Future research should address the question of how various subjective probabilities could be communicated to lay people so that they understand the information. Additional research should examine how well participants understand uncertainty communication and whether various communication formats result in different decisions. All such research should also involve decision-makers in the risk management domain, because these stakeholders may reach different conclusions depending on how uncertainty is communicated.

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1. Introduction

1.1. Background

The European Food Safety Authority's (EFSA) *Guidance document on uncertainty analysis in scientific assessment* (EFSA Scientific Committee et al., 2018a; henceforth the 'Uncertainty GD') describes the process of identifying limitations in scientific knowledge and evaluating their implications for scientific conclusions. In its *Scientific opinion on the principles and methods behind EFSA's Guidance on uncertainty analysis in scientific assessment* (EFSA Scientific Committee et al., 2018b), the Scientific Committee recommended closer interaction between assessors and decision-makers both during the assessment process and when communicating the conclusions.

"Understanding of the type and degree of uncertainties identified in the assessment helps to characterise the level of risk to the recipients and is therefore essential for informed decision-making." Communication helps them to understand the range and likelihood of possible consequences.

During the development of the Uncertainty GD, the Scientific Committee reviewed literature on the communication of uncertainty information as a basis for developing a common approach for EFSA's communications on uncertainty to different target audiences, including decision-makers and the general public. That initial review indicated that the literature is equivocal about the most effective strategies to communicate scientific uncertainties and that on the whole there is a lack of empirical data in the literature on which to base a working model.

Therefore, the Scientific Committee recommended that EFSA should initiate research activities to explore best practices and develop further guidance in areas where this would benefit implementation of the Uncertainty GD, and the communication of uncertainties in scientific assessments targeted at different audiences. This would allow EFSA to identify how changes could be made to its current communications practices in relation to uncertainties and to tailor key messages to specific target audience needs.

As EFSA completed its research activities on communication of uncertainties to different target audiences (EFSA,2018c; Etienne et al., 2018), the Scientific Committee proposed to develop a separate Guidance document on communication of uncertainty in scientific assessments (henceforth 'Communication GD'). The Scientific Committee considered that the significance of the research results and the different purpose, scope and target of the communication methodology warranted a stand-alone document for communication practitioners. The Communication GD is a companion document to the Uncertainty GD.

1.2. Terms of Reference as provided by the requestor

The European Food Safety Authority (EFSA) requested its Scientific Committee and Emerging Risk Unit (SCER) and its Communication, Engagement & Cooperation Department (COMCO) to establish a working group to develop guidance on how to communicate uncertainty on the basis of EFSA's Uncertainty GD.

The Scientific Committee advised that to carry out this work expertise in social sciences (e.g. psychology, risk communication, uncertainty communication and public perceptions) was needed to join its working group on uncertainty. The working group had the following three objectives:

1. Develop practical guidance for EFSA communicators on how to communicate the various expressions of the uncertainty analyses (e.g. qualitative, quantitative) described in EFSA's Uncertainty GD (EFSA Scientific Committee et al., 2018a), and in the *Scientific Opinion on the principles and methods behind EFSA's Guidance on Uncertainty Analysis in Scientific Assessment* (EFSA Scientific Committee et al., 2018b).
2. Advise assessors on the ways in which uncertainties are reported in EFSA assessments in relation to the need to communicate.
3. Advise EFSA on its current communication approach for dealing with uncertainty as described in the EFSA Risk Communication Handbook (EFSA, 2017).

1.3. Interpretation of the Terms of Reference

The working group developed the following work plan to reach the three objectives of the Terms of Reference:

1. Develop practical guidance for EFSA communicators on how to communicate the various expressions of the uncertainty analyses (e.g. qualitative, quantitative) described in EFSA's Uncertainty GD (EFSA Scientific Committee et al., 2018a) and in the *Scientific Opinion on the principles and methods behind EFSA's Guidance on Uncertainty Analysis in Scientific Assessment* (EFSA Scientific Committee et al., 2018b). The following tasks were planned to reach objective 1:

   - Identify review papers for risk communication and relate them to uncertainty communication.
   - Perform a literature search on uncertainty communication and review the resulting literature.
   - Complement the literature with the insights gained from the EFSA research projects on communication of uncertainty from 2016 and 2017.
   - Perform an online search on approaches to communicating uncertainty by relevant national and international organisations.
   - Identify a representative set of outputs with case studies upon which EFSA might communicate, map the different sensitivities of topics dealt with by EFSA, target audiences, different types of assessment and expressions of uncertainty (e.g. probabilities, quantitative, qualitative), linking them to the methods described in the Uncertainty GD.
   - Consider whether different communications on uncertainty are needed for EFSA's defined target audiences and/or whether new categories are required.
   - Develop a practical communications approach and supporting tools for communications practitioners who are required to communicate scientific uncertainties to different target audiences. Use the literature review and the results of EFSA's target audience research activities conducted in 2016 and 2017 to inform the approach.
   - Draft the guidance document for consultation and follow up on feedback from the consultation activities with a report and input for finalising the guidance document.
   - Consult EFSA's risk communication partners in EU Member States, the EU institutions and other interested parties (e.g. other EU agencies, international organisations, non-EU countries) before finalising the Communication GD.

2. Advise assessors on the ways in which uncertainties are reported in EFSA assessments in relation to the need to communicate. The following tasks were identified to reach objective 2:

   - With reference to the results of objective 1, consider whether there are additional requirements and/or recommendations (e.g. terminology, data format, graphics) that Panels should be aware of when drafting their opinions and especially the conclusions of their assessments.

3. Advise EFSA on its current communication approach for dealing with uncertainty as described in the EFSA Risk Communication Handbook (EFSA, 2017). The following tasks were identified to reach objective 3:

   - Review the relevant section of the EFSA Risk Communication Handbook.
   - Identify key examples of past communication challenges where uncertainty was a decisive issue to determine the impact of a new approach to uncertainty communication.

1.4. Scope and audience for this guidance and how to use it

The Terms of Reference require the provision of guidance for EFSA on how to communicate uncertainty on the basis of its Uncertainty GD. This Communication GD should provide a practical framework for communicating uncertainties in scientific assessments. It does not provide a template for EFSA's risk communication activities; however, it takes place within the well-defined legal framework for these activities. Therefore, a short description of EFSA's risk communication role, strategies and target audiences follows below as background (Section 1.5).

This document is primarily aimed at all risk communicators at EFSA, but it can be applicable to risk communicators in other institutions that provide scientific advice. It should be used as a supporting document and alongside the current EFSA Risk Communication Handbook (EFSA, 2017). It contains some specific guidance for assessors on how best to report the various expressions of uncertainty resulting from their uncertainty analyses.

This Communication GD explains first EFSA's three broad communication target audiences (section 1.5.2) and the eight different possible expressions of uncertainty as described in the Uncertainty GD (Section 2). Risk communicators and assessors looking for clear instructions on how best to communicate the various expression of uncertainty should go to Section 3, where the guidance for the entry and informed audiences is addressed to communicators, while the guidance for the technical level is addressed to assessors. Section 4 describes the evidence sources used to develop this Guidance. Finally, Section 5 provides recommendations for further research.

1.5. Risk communication at EFSA

EFSA's science communications role within the EU food safety system is discussed in this section. Regarding terminology, the Uncertainty GD refers to 'scientific assessment' rather than 'risk assessment' to recognise that the Uncertainty GD is applicable to all of EFSA's scientific advisory work, not solely its risk assessments. Notwithstanding this, most of the following section refers to EFSA's 'risk communication' role because this is the terminology used in the relevant legal texts establishing EFSA. However, the Communication GD applies to all of EFSA's 'science communication' activities and consequently is titled in full: 'Guidance on communicating uncertainty in scientific assessments'.

1.5.1. EFSA's risk communication role and strategies

Under the EU Food Law, Regulation (EC) No 178/2002[1], by which EFSA was founded, EFSA is 'an independent scientific source of advice, information and risk communication in order to improve consumer confidence'. It defines risk communication as 'the interactive exchange of information and opinions throughout the risk analysis process as regards hazards and risks, risk-related factors and risk perceptions'.

EFSA is charged with communicating the results of its work in the fields within its mission (food and feed safety, animal and plant health, nutrition) and with explaining its risk assessment findings. The European Commission is responsible for communicating its risk management decisions and the basis for them (i.e. scientific and/or other considerations). EU Member States are also charged with public communication on food and feed safety and risk. Given these overlapping roles, the Regulation also requires that EFSA collaborates closely with the Commission and the Member States to 'promote the necessary coherence in the risk communication processes'.

With a clear mandate to communicate its scientific assessment results 'on its own initiative', EFSA follows a communications strategy based on guidelines in its EFSA Risk Communication Handbook (EFSA, 2017) that was developed together with the European Commission and members of EFSA's Communications Experts Network, which comprises communications representatives of EU national competent authorities on food and feed safety. The guidelines provide a framework to assist decision-

1 Regulation (EC) No 178/2002 of the European Parliament and of the Council of 28 January 2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety. OJ L 31, 1.2.2002, p. 1–24

making about appropriate communication approaches in a wide variety of situations that can occur when assessing and communicating on risks related to food safety in Europe.

EFSA publishes over 500 scientific assessments and reports annually, but only a fraction of these are accompanied by supporting communications (e.g. press releases/interviews, FAQs, videos, briefings). EFSA's communicators weigh up several factors in selecting assessments for supporting communication and the mix of communication approaches and formats to employ for each:

- Significance of the scientific results (e.g. routine vs new findings)
- Nature of the risk (e.g. emerging, possible, identified or confirmed)
- Potential public/animal health/environmental impact (e.g. there is a safety concern)
- Public perception and anticipated reactions/sensitivity of subject area
- Legislative and market contexts (e.g. a request for authorisation)
- Urgency of request (e.g. in an outbreak situation, or a long-term review)
- Institutional risk (national, European, international contexts)

A positive evaluation for one or more of the above factors in relation to an upcoming assessment or report is a potential trigger for such supporting communications. The communicator analyses the key results of the assessment or report, discusses key messages and supporting points with the assessors (scientific officers, EFSA panel or working group members), agreeing a communications plan in the process. The plan identifies the rationale for communicating, the key messages and supporting points, and also defines the target audiences for the communication.

1.5.2. EFSA's target audiences

The EU Food Law identifies the target audiences of risk communication on EU food and feed safety: 'risk assessors, risk managers, consumers, feed and food businesses, the academic community and other interested parties'. Therefore, for EFSA's risk communication the potential audience is the 500 million people residing in the European Union. Their interest, knowledge and concerns about food and food safety vary widely. Language, tradition, culture, age and education (e.g. scientific literacy) are among the variables that affect their understanding of messages about food safety-related assessments.

Communicating directly to everyone is unrealistic given this diversity and complexity. Therefore, in the EU food safety system many actors share responsibility for communicating about food risks (and benefits) to consumers, food chain operators and other interested parties. EFSA cooperates with these other actors: its partners in the EU Member States, EU institutions and 'stakeholder' groups (e.g. consumer organisations and public health professionals) to further disseminate the outcomes of its scientific assessments. To enable this, EFSA tailors its communication messages in layers to the expected scientific literacy and interests of these audiences and targets them through a mixture of channels (meetings, the media, website, social media, scientific journal) and formats (scientific opinions, news stories, multimedia, tweets).

In devising its external communications EFSA follows an approach for mapping and targeting these audiences (see Table 1) that was codified internally in 2014–2015 for the redesign of EFSA's corporate website. It was subsequently adapted to other communication channels and formats; more detailed segmentation of the audiences is possible for specific types of communication (e.g. to attract participants to events on specialist topics). The approach was based on the analysis of extensive user-centred research involving interviews, online surveys, analytics data (web metrics, media pick up) and external expertise, as well as the frameworks that guide EFSA's work: the EU Food Law, EFSA's strategic documents and plans.

The table shows key target audience groups for EFSA that were identified through this research: decision-makers, assessors, industry, non-governmental organisations (NGOs)/specialised media, general media, and informed/concerned citizens. It also clusters them according to their scientific literacy and temporal relationship with EFSA's communications into three broad categories – 'entry', 'informed' and 'technical' levels.

The mapping of target audiences and strategy for content development comes with important caveats. There is much diversity within the target audiences and considerable overlap between them in terms of the assumptions made about them (e.g. their scientific literacy) and the communication products they may use when informing themselves about EFSA. Nevertheless this approach is practical and already in use at EFSA making it a functioning framework for the purposes of the Communication GD. Consequently, these groups of target audiences will be used as a parameter in structuring the guidance in Section 3. For communicators not involved in developing or further disseminating EFSA's communication activities but who may wish to use this guidance, this approach could probably be easily adapted to the characteristics of their target audiences.

Table 1: Mapping EFSA's target audiences for external communications (2015)

	AUDIENCE CATEGORIES	COMMUNICATION PRODUCTS		ASSUMPTIONS
ENTRY LEVEL	▪ General news media ▪ Informed citizens ▪ Concerned citizens	▪ Multimedia – disseminating results, explaining working practices, promoting opportunities ▪ Multimedia – raising awareness, campaigning ▪ Social media (e.g. Facebook)	**All target audiences** ▪ News story ▪ Feature ▪ Topic (reference material) ▪ Multimedia products (videos, infographics, data visualisation, interactives, etc.) can be aimed at technical and/or non-technical audiences	▪ Little or no familiarity with scientific assessment ▪ Little or no knowledge of institutional processes and relationships ▪ Little or no prior knowledge of EFSA
INFORMED LEVEL	▪ Political decision-makers ▪ NGOs & consumer organisations ▪ Specialised news media	▪ Plain language summaries ▪ Fact sheets ▪ FAQs ▪ Social media (mainly Twitter, LinkedIn)		▪ High knowledge of institutional processes and relationships ▪ High or advanced understanding of EU system ▪ Some or good understanding of scientific assessment but not advanced ▪ Good knowledge of EU legislation ▪ Knows EFSA very well
TECHNICAL LEVEL	▪ Assessors ▪ Scientist/academic ▪ Technical risk managers ▪ Industry representatives	▪ EFSA Journal Scientific publications ▪ Multimedia – providing tutorials and instructions, promoting opportunities		▪ Advanced understanding of scientific assessment, use of data, tools and methodologies ▪ Knows in broad terms EFSA role in EU risk assessment framework

1.6. Uncertainty communication

Communicating uncertainty aims to reduce ambiguity, report on the strengths and weaknesses of evidence, and consequently increase transparency and trust in the scientific assessment process (EFSA, 2018b). However, several factors require consideration in developing strategies for uncertainty communications. Aversion to ambiguity has been observed in many studies (Ellsberg, 1961). People tend to prefer a risky option (e.g. 30% chance of a gain) over an ambiguous option (e.g. 20–40% chance of a gain). This aversion does not imply, however, that uncertainty should not be communicated. Transparent and open communication requires that uncertainty is communicated. Furthermore, studies suggest that people prefer to be openly informed about uncertainty associated with scientific findings (Frewer at al., 2002; Miles and Frewer, 2011).

In order to understand how and when uncertainty could be best formulated in qualitative terms, Frewer et al. (2002) tested the reception of 10 uncertainty statements, and found that people wanted to be provided with uncertainty as soon as it was identified and in full. Miles and Frewer (2011) tested the communication of eight types of uncertainty: about who is affected, about past and future states, measurement uncertainty, due to scientific disagreement, from extrapolation from animals to humans, about the size of the risk and about how to reduce the risk. Their results were different across five different food hazards and confirmed higher risk perceptions in the presence of uncertainty for technological risks (genetically modified organisms, pesticides) than for natural risks (BSE, fat diets, *Salmonella*). High perceived personal risk in conditions of uncertainty was associated with high perceived risk to consumers in general, risk to future generations, greater personal worry about the risk, more serious harmful effects, a greater perception that society was responsible for protecting consumers, decreased perceptions of personal control over exposure, and reduced perceptions that current laws and regulations were adequate.

Frewer et al. (2002) found that uncertainty associated with the scientific process was more readily accepted than uncertainty due to lack of action by the government. This suggests that communication of uncertainty is less likely to cause public alarm if it is accompanied by information on what actions are being taken by the relevant authorities to address that uncertainty. However, such actions are risk management measures, which are outside the remit of EFSA. Therefore, when EFSA communications include information on uncertainty, consideration should be given to coordinating with the Commission regarding what can be said about any measures aimed at addressing the uncertainty.

1.6.1. EFSA's context

Transparency is one of EFSA's basic principles and has important implications for risk communication. A transparent approach to explaining how an organisation works, its governance and how it makes its decisions, is crucial as it helps to build trust. Communications must always clearly convey any areas of uncertainty in the scientific assessment, whether and how these can be addressed by the assessors and decision-makers, and the implications of these remaining uncertainties for public health (EFSA, 2017).

It is important to distinguish between the understanding of EFSA's message by the audience, and the audience's perception of risk and uncertainty after receiving the message. Article 40 of EFSA's founding Regulation requires that EFSA 'shall ensure that the public and any interested parties are rapidly given objective, reliable and easily accessible information, in particular with regard to the results of its work'. This implies that EFSA's communications should be designed to ensure the results of its work (including its assessment of risk and uncertainty) are correctly understood by its audience, which is therefore the objective of this guidance. How people perceive risk and uncertainty themselves, after receiving EFSA's communications, will be influenced by many factors including their own prior beliefs, their stake in the issues involved, and their values. While authorities may consider it appropriate to communicate options for managing risk and uncertainty, this is outside EFSA's remit. This has implications for the review of the literature and the guidance, as most studies have focused on the perceptions of subjects after receiving information on risk and uncertainty, rather than their understanding of the information as it was communicated (see Section 4).

1.6.2. International context

Many national and international risk communication guidance documents include only general rather than specific considerations about communication of uncertainty (EPA, 1993; NAS, 2003; FDA, 2012; EEA, 2013; NAS, 2017). A few national and international guidance documents on uncertainty analysis include a section with suggestions on how to communicate the findings of uncertainty analysis most effectively (RIVM/MNP, 2003; Mastrandrea, M. D., et al. 2010; BfR, 2015). Some of these suggestions reiterate some of the basic principles of good risk communication in the context of uncertainty such as the need for transparent reporting of, for example, lack of sufficient knowledge, shared assumptions, criteria by which evidence is included or dismissed.

Specific guidance on how to communicate on uncertainty has not generally been developed yet with rare exceptions such as that included in the guidance for uncertainty assessment and communication series by the Dutch environmental assessment agency (Wardekker, 2013) and in environmental decisions in the face of uncertainty by the Institute of Medicine in the USA (NAS, 2013). In both, general recommendations for communicating uncertainty are provided along with more specific recommendations for addressing the different target audiences and on how to present the uncertainty. These documents are more general in nature and do not provide detailed guidance on the different expressions of uncertainty that may result from the application of EFSA's Uncertainty GD (see next section).

2. Expressions of uncertainty

This section describes the possible expressions of uncertainty resulting from uncertainty analyses performed in accordance with the Uncertainty GD. These uncertainty expressions form the basis for the discussion of evidence sources (Section 4) and for the guidance for crafting communication messages and selecting communications tools such as visual aids (Section 3).

The Uncertainty GD contains several options for carrying out an uncertainty analysis. However, there is a finite number of expressions of uncertainty that any uncertainty analysis should produce when following the guidance. These are summarised in Table 2.

Table 2: Types of expressions of uncertainty produced by uncertainty analysis. The same analysis may produce one or more of these expressions.

Type of uncertainty expression	Description
No expression of uncertainty	This occurs in two situations: • When a standardised assessment procedure only takes into account standard uncertainties, its conclusion may be communicated without qualification of uncertainties (see EFSA Scientific Committee et al., 2018a,b for more explanation). • When uncertainty is present in an assessment, but decision-makers or legislation require an unqualified conclusion (e.g. safe, not safe or 'cannot conclude'), the basis for the conclusion should be documented in the body of the assessment report or an annex, and may include one or more expressions of uncertainty.
Description of a source of uncertainty	Verbal description of a source or cause of uncertainty.
Qualitative description of the direction and/or magnitude of uncertainty	Words or an ordinal scale describing how much a source of uncertainty affects the assessment or its conclusion (e.g. low, medium, or high uncertainty; conservative, very conservative or unconservative; unlikely, likely or very likely; or symbols indicating the direction and magnitude of uncertainty:. ---, --, -, +, ++, +++).

Type of uncertainty expression	Description
	Because the meaning of such expressions is ambiguous, EFSA's guidance on uncertainty recommends that they should not be used unless they are accompanied by a quantitative definition (EFSA Scientific Committee et al., 2018a).
Inconclusive assessment	This occurs in two situations: • When decision-makers or legislation require an unqualified conclusion but assessors judge there is too much uncertainty to give one and report that they cannot conclude. The basis for this uncertainty expression should be documented in the body of the assessment report or an annex, and may include one or more uncertainty expressions. • When it is not required that conclusions must be unqualified, but the assessors are unable to give any quantitative expression of uncertainty or, where they judge that the probability for a conclusion could be anywhere between 0 and 100%. This should be accompanied by a qualitative description of the uncertainties (see description of 'A precise probability').
A precise probability	A single number (in EFSA outputs, a percentage between 0 and 100%) quantifying the likelihood of either: • A specified answer to a question (e.g. a 'yes' answer to a 'yes/no' question), or • A specified quantity lying in a specified range of values, or above or below a specified value (e.g. 90% probability that between 10 and 100 infected organisms will enter the EU in 2019; 5% probability that more than 100 infected organisms will enter). Note that the term 'precise' is used here to refer to how the probability is expressed as a single number and does not imply that it is actually known with absolute precision, which is not possible.
An approximate probability	Any range of probabilities (e.g. 10–20% probability) providing an approximate quantification of likelihood for either: • A specified answer to a question (e.g. a 'yes' answer to a 'yes/no' question), or • A specified quantity lying in a specified range of values, or above or below a specified value (e.g. 1–10% probability that more than 100 infected organisms will enter the EU in 2019). The probability ranges used in EFSA's approximate probability scale (see Table 4) are examples of approximate probability expressions. Assessors are not restricted to the ranges in the approximate probability scale and should use whatever ranges best reflect their judgement of the uncertainty (EFSA Scientific Committee et al., 2018a).
A probability distribution	A graph showing the probabilities of different values for an uncertain quantity that has a single true value (e.g. the average exposure for a population). The graph can be plotted in various formats, most commonly a probability density function (PDF), cumulative density function (CDF) or complementary cumulative density function (CCDF) (see Section 4.1.4.2).

Type of uncertainty expression	Description
A two-dimensional probability distribution	In this guidance, the term 'two dimensional (or 2D) probability distribution' refers to a distribution that quantifies the uncertainty of a quantity that is variable, i.e. takes multiple true values (e.g. the exposure of different individuals in a population). This is most often plotted as a CDF or CCDF representing the median estimate of the variability, with confidence or credibility intervals quantifying the uncertainty around the CDF or CCDF.

Currently, it is expected that, in many assessments, the conclusion, summary and abstract of the assessment will not contain expressions of uncertainty. This may arise in two types of situation, as indicated in the 'No expression of uncertainty' definition on Table 2.

The first type of situation arises in standard assessment procedures, which are most commonly used in assessment of regulated products. A standard procedure is an assessment methodology established for routine use in a specified type of assessment (e.g. acute or chronic risk for a specified class of chemicals). Standard assessment procedures include standard provisions (e.g. uncertainty factors) for addressing 'standard uncertainties', i.e. uncertainties which routinely occur in that type of assessment, and their conclusions are expressed in a standard form (e.g. 'no health concern', 'health concern', etc.) (EFSA Scientific Committee et al., 2018a; 2018b). Provided only the standard uncertainties are present, the standard conclusion can be reported and communicated without qualification.

The second situation relates to other contexts where legislation or decision-makers require an unqualified conclusion (EFSA Scientific Committee et al., 2018a; 2018b). This may apply to standard procedures where non-standard uncertainties are present, and to some types of non-standard (case-specific) assessments. In both cases, the assessment conclusion will have been based on an analysis of the uncertainties that are present but will be reported in an unqualified manner, which should then also be the primary message in communication. If the uncertainties are reported in the body of the assessment or an annex, then they may also be referred to in supporting parts of communication but should not be included in the primary message.

When non-standard uncertainties are present, the Uncertainty GD recommends that assessors quantify the combined impact of as many as possible of the uncertainties they identify, for reasons explained in detail by EFSA Scientific Committee et al. (2018b). However, in some assessments, the assessors will be unable to include all the identified uncertainties in their quantitative expression of overall uncertainty, which will then be accompanied by a qualitative description of the unquantified uncertainties.

Note that the Uncertainty GD uses a single technical term, 'probability bound', to refer to two of the uncertainty expressions listed in Table 2: a precise probability or an approximate probability for a specified quantity lying in a specified range of values, or above or below a specified value.

The Uncertainty GD quantifies uncertainty using probability expressed as a percentage (0–100%). This leads to potential for confusion when the uncertainty refers to a quantity that is itself a percentage, e.g. a 10% probability that 10% of people have exposures above a reference dose. Extra care will be required when communicating uncertainty expressions of this type (see section 3.1).

When the uncertainty expression from an uncertainty analysis includes a probability distribution or two-dimensional probability distribution, this can be used to generate a simpler uncertainty expression for communication. From a probability distribution, assessors can derive a probability for any range of values of interest, or the probability of the true value being above or below a value of interest (e.g. the probability that more than 100 infected animals enter the EU). Similarly, a two-dimensional probability distribution can be used to derive a probability for a specified quantile lying above or below a value of interest (e.g. the probability that the 90th percentile exposure is above the reference dose).

If an output refers to a qualitative conclusion or the answer to a yes/no question, the probability expresses uncertainty about whether the specified conclusion or answer is correct. It does not express how often it happens because there is only one true answer. An important example of this is where uncertainty about a hazard is expressed as a probability about the hazard. This is the assessors' probability that the hazard exists at all, not how often it occurs or how many people it could affect. For example, when communicating a percentage probability that a chemical is neurotoxic it is essential to make clear that this refers to the *likelihood* that the chemical has the *capability* to cause neurotoxic effects, and not to *the percentage of people* that will experience neurotoxic effects: that will depend on whether the chemical actually is neurotoxic, and how much of the chemical people are exposed to.

3. Guidance on communicating uncertainty

This section contains practical guidance for communicators and some guidance for assessors on providing information needed for communication. It gives clear and concise instructions, practical tips and examples, and further choices to consider – where necessary case-by-case – when communicating uncertainty in scientific assessments. The guidance for the entry and informed audiences is addressed to communicators. The guidance for the technical level is addressed to assessors.

The guidance presented is based as far as possible on the evidence sources described in Section 4. The available evidence does not, however, address every aspect of communicating uncertainty, so some specific guidance is based on judgement and common sense. The guidance was tested and refined by applying them to concrete EFSA examples, which are listed in Section 4.4. For transparency, the basis for each recommendation is summarised in Appendix B.

3.1. General guidance

This section presents EFSA's general guidance for communicating uncertainty, which applies to all scientific assessments. You should apply it together with the specific guidance that is relevant for the different uncertainty expressions (Section 2). You can find the specific guidance in separate Boxes by completing the template in Table 3.

These recommendations complement those already published in the EFSA Risk Communication Handbook (EFSA, 2017), including the requirements to use plain language as far as possible, explain technical terms where they are unavoidable, and provide links to more detailed information (e.g. factsheets, videos, FAQs or EFSA's scientific outputs) for those readers who are interested. Most of the general guidance is intended for communicators but some is intended for assessors, as indicated below.

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Overall

All parts of communication, including entry and informed level material and any accompanying titles or headlines, should be consistent with the degree of certainty or uncertainty attributed by the assessors to their scientific conclusions. Any forms of expression that would imply more or less certainty than is expressed in the assessment should be avoided.

Providing context

State clearly what the message and uncertainty information refer to, e.g. a specific event or outcome, and the population, geographic region and time period for which it has been assessed. If the outcome has any particular importance (e.g. exposure exceeding a reference dose), ensure this is made clear. If the conclusion conveyed by the message is subject to any conditions or assumptions, these should be clearly stated (see also Guidance for assessors, below).

Describing uncertainty with words

If the scientific output uses words that imply a magnitude of uncertainty or probability (e.g. low uncertainty, unlikely), with or without quantitative expression, avoid altering the wording used in the

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scientific assessment and only do so after checking the replacement with the assessors. If quantitative expressions are provided in the scientific output, follow the specific guidance in the following section for communicating them, and do not replace them with words.

Describing uncertainty with numbers

(1) Communicate the quantities that are part of the message explicitly – do not require the audience to infer them. For example, if you have to communicate a central estimate, communicate its value explicitly and do not require the audience to derive it by looking at a graph.

(2) When the uncertainty refers to a quantitative estimate (rather to than a yes/no question), ensure that the message clearly differentiates the central estimate and the associated uncertainty, e.g. by putting them in separate sentences.

(3) Do not refer to a mean, median or mode as a 'best' estimate, because the meaning of 'best' is ambiguous and using this term might lead people to focus excessively on that estimate; instead, use 'central estimate' and make clear which type of central estimate it is.

(4) Be cautious in using 'hedging' words such as 'about', 'approximately', etc. to qualify quantitative expressions, as they are ambiguous.

(5) When giving a range for an uncertain quantity, always accompany it with an expression of the probability that the quantity lies in the specified range, e.g. 'exposure was estimated to be between 5 and 20 mg/kg bw/day, with 95% probability'. Without this, the meaning of the range is ambiguous. Also indicate which values within the range are more likely, using information provided by the assessors (see point 3 in Guidance for assessors, below), if this is important for understanding and decision-making.

(6) Refer to uncertainty expressed as probability as percentage certainty (e.g. 'the experts considered it 66–99% certain that…') rather than percentage probability, to make clear that this is an expert judgement of subjective probability, and to distinguish it better from the use of probability and percentage as measures of frequency. The word 'certainty' is preferred to confidence because the latter has different connotations, including a special technical meaning when used in the term 'confidence interval'. If the probability is low, communicate the complementary probability, e.g. if the assessment is '10% probability' for an outcome to occur, communicate it as 90% certain that the outcome will not occur.

(7) Avoid using percentage both for the outcome of interest (e.g. a proportion of something, or the incidence or risk of an outcome or effect) and for expressing its uncertainty. If this is unavoidable, ensure the two uses of percentages are distinguished and the meaning is clear, e.g. 'the assessors are 90% certain that the effect will occur in fewer than 5% of cases'.

(8) If communicating EFSA's percentage probability that a hazard exists, explain clearly that this does not refer to the percentage of people who will be affected.

(9) When communicating information on the uncertainty of a quantity that is not also variable, make clear that it is uncertainty and not variability that is being communicated (see Box 8 below for an example). When the message concerns a quantity that is variable as well as uncertain (e.g. exposures in a population), make this clear in communication and distinguish carefully between information on variability and information on uncertainty (see Box 9 below). Also, consider whether it is relevant to include information on the relative magnitudes of variability and uncertainty and, if so, request this from the assessor.

(10) Include, where relevant, a link to general FAQs for explanation of all commonly used ways of communicating uncertainty. This should include FAQs on probabilities, approximate probabilities and the terms in EFSA's approximate probability scale (e.g. 'likely'). Also provide general FAQs on commonly used forms of visualisations, with their advantages and limitations (e.g. use of

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boxplots, see Box 8 below).

Describing the most important uncertainties

When the assessment includes information on the main sources of uncertainty and their relative magnitude (e.g. from sensitivity or influence analysis), provide this information.

Addressing the uncertainties

(1) In cases where the uncertainty is substantial or might cause concern, it is advisable to communicate it together with information about options for addressing it. However, this must be done without implying risk management judgements, which are outside the remit of EFSA, unless done so in agreement with decision-makers (e.g. the European Commission).

(2) If the assessment evaluates any risk management options for dealing with uncertainty (e.g. precautionary action), be careful to present these as options. Do not imply any preference between options, as this would involve risk management considerations.

(3) If the assessment specifies any options or requirements for further data or analysis, aimed at reducing uncertainty, then communicate these as follows:

- At the entry level, optionally mention that the assessors identified aspects where further data are needed; listing the most important of them is optional if considered relevant.
- At the informed level, briefly list the options or requirements, being careful to differentiate formal requirements for applicants from recommendations without formal status, which may be better described as 'options'.

Guidance for assessors

(1) Assessors should make clear whether scientific conclusions relate to real world conditions and outcomes or to specific conditions and assumptions. When the conclusion is based on the result of a model or statistical analysis, remember to consider uncertainties not quantified within the model or analysis, including uncertainties about the assumptions of the model or analysis and any extrapolation from it to the real quantity or question of interest. This should be done as part of characterising overall uncertainty, which is one of the steps in the Uncertainty GD (EFSA, 2018a).

(2) Do not express more precision than is justified by the scientific assessment; in particular, do not express quantities or probabilities with more significant figures than is justified – usually one or two.

(3) When reporting a range for a quantitative estimate, always accompany it with an indication of the probability for that range (preferably a precise or approximate probability, see Boxes 6 and 7). Also indicate which values within the range are more likely, if this is important for understanding and decision-making. Presenting a central estimate as well as the range will indicate whether the distribution is skewed to one side. If more detail on the shape of the distribution is needed, consider including quartiles or a boxplot (see Box 8).

(4) Ideally, uncertainty information should be included in the abstract of the scientific assessment, where it is easily and unequivocally accessible to communicators. This information should include the overall impact of uncertainty on the conclusions and the major sources of uncertainty.

3.2. Specific guidance

Communicators should adapt their existing working practices for all communication about a scientific assessment. To identify the specific guidance that applies to each case, communicators should follow the steps indicated below:

1. Examine the scientific output to identify proposed messages and supporting points for communication according to the EFSA Risk Communication Handbook.
2. Consult the appropriate assessor (scientific officer, head of unit, working group chair, etc.) to confirm the selection and accuracy of messages.
3. Identify which messages refer to scientific conclusions. For each of these messages, either ask the assessor to fill in a separate copy of the template below (Table 3) or complete it yourself in discussion with them. For each message, answer all the questions in the template.
4. The completed templates will identify the types of uncertainty expression associated with each message, and direct you to boxes containing recommendations for communicating each type of expression. **Note that in many cases more than one type of uncertainty expression will have been used for the same message (e.g. description of some sources of uncertainty and an approximate probability for the conclusion) and so the relevant recommendations should be considered together.**
5. Craft entry-level and informed-level communications for each message, applying **both** the general guidance in Section 3.1 **and** the specific guidance for communicating the types of uncertainty expressions that are associated with the respective messages in Section 3.2.
6. Integrate the crafted communications into a coherent story in the chosen format (e.g. news story). For example, it may be appropriate to combine the material developed for the entry and informed levels together in a single story, starting with the entry level material and followed by the informed level for readers who want more detail.
7. Validate the draft communication following the standard operating procedure.

Assessors will find specific guidance for them, where needed.

Table 3: Template for identifying messages with associated uncertainty expressions, and specific guidance for their communication.

QUESTIONS	SPECIFIC GUIDANCE	NOTES
How is the message expressed in the EFSA scientific output, and on which page?	(Paste here a copy of the message and the page number)	See Section 3.1 (general guidance, to follow in all communications)
Is this message the outcome of/based on a standardised procedure?	If yes, see Box 1	See Glossary for definition of standardised assessment procedure
Does the output list or describe the sources or causes of any uncertainties affecting this message?	If yes, enter the page number(s) where the uncertainties are listed or described and see Box 2	
Is the direction and/or magnitude of uncertainty expressed in qualitative terms (e.g. 'low', 'medium', 'high')?	If yes, see Box 3	It is recommended that the impact of uncertainty should not be expressed qualitatively unless it is also expressed quantitatively (EFSA, 2018)
Does this message report an inconclusive assessment outcome?	If yes, see Box 4	See Glossary for definition of inconclusive uncertainty outcome
Is it expected or required by risk managers or legislation that this message should be expressed as an unqualified conclusion?	If yes, see Box 5	See Glossary for definition of unqualified conclusion
Is the impact of uncertainty quantified using a precise probability?	If yes, see Box 6	Examples of this include a precise probability for an outcome occurring, or a stated probability for the confidence or credibility interval of an estimate
Is the impact of uncertainty quantified using an approximate probability?	If yes, see Box 7	An approximate probability is expressed as a range of probabilities, e.g. 66–90%
Is the impact of uncertainty quantified by a one-dimensional probability distribution?	If yes, see Box 8	See Glossary for examples of one-dimensional probability distributions
Is the impact of uncertainty quantified by a two-dimensional probability distribution?	If yes, see Box 9	See Glossary for an example of a two-dimensional probability distribution

The guidance in Boxes 1–9 is specific to particular types of information on uncertainty, one or more of which will be present in every scientific output. Guidance for the entry and informed levels should be applied by communicators, with input from assessors where needed. Guidance for the technical level refers to tasks for assessors to support the communication process, and should be applied in conjunction with the existing guidance for uncertainty analysis (EFSA, 2018a). After you have used the template in Table 3 to identify which types of uncertainty information are present, apply the relevant guidance for each from Boxes 1–9 below, while also applying the general guidance (Section 3.1) and the seven steps at the start of section 3.2.

Note that communications material generated by following the different boxes should be integrated into a coherent story in the sixth of those steps. Also, when communicating at the informed level, it may be helpful to start with the entry level material and present the informed level as a second layer.

Box 1. Guidance for communicating assessments using standardised procedures

Did the scientific assessment for this message identify any non-standard uncertainties?	**Yes**	▪ **If an unqualified conclusion is required** (as identified in the completed template for this message) follow the approaches recommended for unqualified conclusions (see Box 5 for details and examples) ▪ **If an unqualified conclusion is not required** state the result of the standardised procedure in the form expressed by the assessors, for both entry and informed level, and then communicate the uncertainty expressions for this message (as identified in the completed template for this message), consulting the respective boxes for recommended approaches.
	No	▪ **For entry and informed levels,** report the conclusion as expressed by assessors and state that a standardised assessment procedure was followed, which takes account of standard uncertainties, and no non-standard uncertainties were identified.

Box 2. Guidance for communicating a description of sources of uncertainty

ENTRY LEVEL	▪ State that uncertainties exist using the wording in the scientific output. Example: 'The experts identified limitations in the data on exposure and toxic effects of ZEN and its modified forms (…).' (based on the Zearalenone (ZEN) in feed example, EFSA CONTAM Panel, 2017)
INFORMED LEVEL	▪ As for the entry level, state that uncertainties exist. ▪ Include in the message a brief description of the sources of uncertainty that have the biggest impact on the respective key messages. If it is not possible to distinguish those among the sources of uncertainty listed by the experts, just give some examples of sources of uncertainty included in their list. Example: 'The experts identified limitations in the data on exposure and toxic effects of ZEN and its modified forms, for example (…).' (based on the Zearalenone (ZEN) in feed example, EFSA CONTAM Panel, 2017)
TECHNICAL LEVEL	▪ Assessors should try to identify which sources of uncertainty have most influence on their conclusions, either by qualitative assessment or by sensitivity or influence analysis.

Box 3. Guidance for communicating qualitative descriptions of the direction and/or magnitude of uncertainty

ENTRY LEVEL	▪ Wherever words are used by assessors to describe the direction and/or magnitude of uncertainty, avoid altering their wording and only do so after checking the replacement with the relevant assessor. ▪ State clearly what outcomes and conditions this expression of uncertainty refers to (see Box 1). Example: 'The Panel noted that there was very high uncertainty about the exposure estimates.' (based on the Zearalenone (ZEN) in feed example, EFSA CONTAM Panel, 2017)
INFORMED LEVEL	▪ As for entry level, with the following differences: – Before communicating the uncertainty expression, describe a few examples of the evidence/data that was considered and the uncertainties affecting the assessment, and state that the experts took them into account in their assessment. – Optionally, mention specific methods that were used in evaluating the uncertainty. Example: 'The Panel noted that a high proportion of measurements of ZEN and its modified forms in feed were below the limit of detection, leading to very high uncertainty when estimating exposure.' (based on the Zearalenone (ZEN) in feed example, EFSA CONTAM Panel, 2017)
TECHNICAL LEVEL	▪ The Uncertainty GD (EFSA, 2018) recommends that uncertainty should not be expressed qualitatively unless it is also expressed quantitatively, or is a standard outcome of a standardised procedure. ▪ If using '+' and '–' symbols to indicate the direction of uncertainty, accompany them with quantitative definitions of their meaning, as discussed in Annex 5 of EFSA Scientific Committee et al. (2018b).

Note: the Uncertainty GD (EFSA Scientific Committee et al., 2018a) recommends that uncertainty should not be expressed qualitatively unless it is also expressed quantitatively or is a standard outcome of a standardised procedure. However, the use of qualitative expressions only will continue in some assessments until the Uncertainty GD is fully implemented. Therefore the following guidance applies to those cases as well as to cases where quantitative information is also provided.

Box 4. Guidance for communicating inconclusive assessments

ENTRY LEVEL	▪ Communicate clearly that EFSA is unable to give any conclusion on the quantity or question of interest that this message refers to. If the assessment is literally inconclusive, this implies that nothing can be said about the risk and therefore the communication should avoid using language that might suggest otherwise. ▪ Indicate very briefly the sources of uncertainty that contribute most to this outcome (e.g. lack of data, poor quality or limited relevance of data.). Example: 'EFSA's experts could not conclude on the risk for cattle, ducks, goats, horses, rabbits, mink and cats because of a lack of data.' (based on the Zearalenone (ZEN) in feed example, EFSA CONTAM Panel, 2017)
INFORMED LEVEL	▪ Describe the main sources of uncertainty in more detail, but concisely, following the approaches recommended in Box 2 ▪ As the assessment for this message is inconclusive, assessors are especially likely to have identified options or requirements for obtaining further data. If so, communicate them as recommended in Section 3.1 General guidance. Example: 'EFSA's experts could not conclude on the risk for cattle, ducks, goats, horses, rabbits, mink and cats due to limitations in available data on exposure and toxic effects of ZEN and its modified forms, for example (…).' (based on the Zearalenone (ZEN) in feed example, EFSA CONTAM Panel, 2017)
TECHNICAL LEVEL	▪ Consider whether the science really provides no information at all about the question or quantity of interest. If it is not totally uncertain then try to express what the science can say and quantify the uncertainty, unless the risk manager/legislation requires that only unqualified conclusions be given.

Box 5. Guidance for communicating unqualified conclusions (no expression of uncertainty)

ENTRY LEVEL	▪ Report the unqualified conclusion for this message, using the same wording as the assessors. Example: 'EFSA's experts concluded that the exposure to feed containing ZEN 'in farm situations' is a low health risk for sheep, dog, pig and fish, and an extremely low health risk for poultry.' Note that in this example, the word 'low' refers to the conclusion regarding the level of health risk. There is no expression of uncertainty about this – no indication that the risk might be other than 'low', so this an unqualified conclusion. (based on the Zearalenone in feed example, EFSA CONTAM Panel, 2017)
	▪ Include a link to an FAQ that explains the meaning of the unqualified conclusion and the definition used for it in the scientific assessment. For example, when an assessment concludes there is a 'low concern' that a chemical is a genotoxic carcinogen, it should be mentioned that this conclusion is defined as referring to a margin of exposure greater than 10 000.
INFORMED LEVEL	▪ Communicate the unqualified conclusion(s) for this message and include a link to an FAQ that explains its meaning and scientific definition, in the same way as for the entry level. ▪ Optionally, describe briefly how the assessment was made (i.e. what evidence and methods were used to arrive at the conclusions). ▪ Briefly describe some examples of uncertainties affecting the assessment for this message, as identified in your completed template, consulting Box 4 for guidance on how to communicate this. ▪ If the assessment contains any qualitative or quantitative expression of the impact of the uncertainties, as identified in your template, then follow the respective guidance in Boxes 6–9 below. ▪ Say that the assessors took the uncertainties into account when reaching their conclusion(s) for this message. Example: 'Following the standard assessment procedure (or 'Using the evaluation system agreed for contaminants in feed'), experts estimated that high exposure to feed containing ZEN is below the reference value for a health risk for sheep, dog, pig and fish, and well below the reference value for chicken and turkeys. They therefore concluded that the exposure to feed containing ZEN 'in farm situations' is a low health risk for sheep, dog, pig and fish, and an extremely low health risk for poultry.' 'In reaching this conclusion the experts took account of limitations in the data on exposure and toxic effects of ZEN and its modified forms, for example (…).' (based on the Zearalenone (ZEN) in feed example, EFSA CONTAM Panel, 2017)

TECHNICAL LEVEL	
	▪ Assessors should specify what level of certainty is associated with each unqualified conclusion, and risk managers should explain why that level of certainty is appropriate for decision-making.

Box 6: Guidance for communicating a precise probability

ENTRY LEVEL	▪ State clearly what the probability refers to, including whether it refers to a quantitative estimate or a qualitative conclusion. Where the probability refers to a quantitative estimate, the range of the quantity that the probability refers to should be stated (see example below). ▪ Communicate the assessors' probability, referring to it as '% certainty' and using at most 2 significant figures (see also general guidance in Section 3.1). Example: 'The Panel estimates that, under current regulations, the total number of infested tulips in greenhouses is 60 000. Based on what is known, the Panel is 50% certain that the number is between 10 000 and 200 000 infested plants.' (based on the Nematodes example, EFSA PLH Panel, 2017)
INFORMED LEVEL	▪ As for entry level, with the following differences: – Before giving the probability, describe a few examples of the evidence/data that was considered and the uncertainties affecting the assessment, and state that the experts took them into account when assessing their level of certainty. – Optionally, mention specific methods that were used in quantifying the uncertainty, e.g. statistical analysis, expert knowledge elicitation, probabilistic modelling. Example: 'The Panel performed its assessment using a mathematical model of the entry of nematodes into the EU and their establishment and spread in greenhouse tulips. Uncertainty regarding the factors represented in the model was quantified by expert judgement, taking into account the limitations of the available data. The Panel estimates… (continue as for entry level)' (based on the Nematodes example, EFSA PLH Panel, 2017)

Box 7. Guidance for communicating an approximate probability

ENTRY LEVEL

- State clearly what the probability refers to, including whether it refers to a quantitative estimate or a qualitative conclusion. Where the probability refers to a quantitative estimate, the range of the quantity that the probability refers to should be stated.
- An approximate probability may comprise a range of probabilities chosen by the assessors from the approximate probability scale (Table 4), or a different range of probabilities specified by the assessors.
- In all cases, it is recommended to communicate the quantitative range of probabilities, because this expresses the assessors' conclusion without ambiguity. Although other options may be simpler (e.g. replacing 66-90% with 'likely' or 'about 80%') they will be interpreted by different people in different ways. If a simpler option is used at the entry level, it is essential that the assessors' range of probabilities is provided at the informed level, so that the meaning is clear to those who read both.

Example:

'The experts were 66-90% certain that the increasing proportion of elderly and susceptible persons has contributed to the rise in listeria cases.'

(based on the Listeria in ready-to-eat foods example, EFSA BIOHAZ Panel)

INFORMED LEVEL

- As for entry level, with the following differences:
  - Before giving the probability, describe a few examples of the evidence/data that was considered and the uncertainties affecting the assessment, and state that the experts took them into account when assessing their level of certainty.
  - Optionally, mention specific methods that were used in quantifying the uncertainty, e.g. statistical analysis, expert knowledge elicitation, probabilistic modelling.

Example:

'Experts began work on the scientific opinion after the 2015 EU summary report on foodborne zoonotic diseases identified an increasing trend of listeriosis over the period 2009–2013. The Panel performed a statistical analysis, which confirmed the increasing trend, and developed a mathematical model of the factors influencing the incidence of infections. Taking into account the modelling results and the degree of support from indicator data, the experts… (continue as for entry level)'

(based on the Listeria in ready-to-eat foods example, EFSA BIOHAZ Panel)

Table 4: Approximate probability scale recommended for harmonised use in EFSA to express uncertainty about questions or quantities of interest.

Probability term	Subjective probability range	Additional options	
Almost certain	99-100%	More likely than not: >50%	Unable to give any probability: range is 0-100% Report as 'inconclusive', 'cannot conclude', or 'unknown'
Extremely likely	95-99%		
Very likely	90-95%		
Likely	66-90%		
About as likely as not	33-66%		
Unlikely	10-33%		
Very unlikely	5-10%		
Extremely unlikely	1-5%		
Almost impossible	0-1%		

This table was adapted from a similar scale used by the Intergovernmental Panel on Climate Change. Additional details and guidance on use can be found on the EFSA Scientific Committee et al., 2018b.

Box 8. Guidance for communicating a probability distribution

ENTRY LEVEL

- State clearly what the distribution refers to (see Section 3.1 General guidance).
- Provide the central estimate (mean or median), the P5–P95 range (within which it is 90% certain that the true value lies) and/or the P25–P75 range (within which it is 50% certain the true value lies), expressed in such a way that the meaning of the ranges is clear. If it is critical to understanding the message, also give an idea about the form of the distribution behind the range (likelihood associated with particular values/outcomes). If the assessors have provided different quantiles (e.g. P1-P99, see example below), these may be used.

  Example:

  'Experts estimated that, on average in Europe in 2015, 16 out of 100 slaughtered dairy cows are pregnant. Their assessment is based on limited data, but the experts are 50% certain that the European average for 2015 is between 9 and 27, and 98% certain it is between 2 and 60.'

  Note that the example refers to a quantity that is uncertain but not variable: although the average will vary between countries and over time, 'the European average for 2015' has a single true value, which is uncertain. For guidance on communicating quantities that are both variable and uncertain, see Box 9.

  (based on the 'Prevalence of pregnant slaughtered animals in the EU' example, EFSA AHAW Panel, 2017)

- In addition, or alternatively: If a regulatory (reference) value exists, or a value of particular interest for other reasons (e.g. more than zero occurrence of an adverse outcome), provide the probability of exceeding that value.

  (See Box 9 for an example of this)

INFORMED LEVEL

- As for the entry level, with the following differences:
  - Before giving the results, describe a few examples of the evidence/data that was considered and the uncertainties affecting the assessment, and state that the experts took them into account in their assessment.
  - Optionally, mention specific methods that were used in quantifying the uncertainty, e.g. statistical analysis, expert knowledge elicitation, probabilistic modelling.
  - Provide a visual representation of the uncertainty if possible, especially if the uncertainty information is part of the key messages. Graphical representations of full distributions (PDF or CDF) are misunderstood by many people and should not be used in entry or informed level communications. Therefore a box plot is recommended for this purpose at the informed level. However, when using a box plot it is very important to explain clearly that it is being used to represent uncertainty, as they are more commonly used to represent variability and people may be predisposed to interpret them that way.
  - Every visualisation should be accompanied by sufficient textual explanation for it to be understood by the informed audience.

Example:

'Experts in 10 selected EU countries each surveyed a sample of slaughterhouses to gather information on the prevalence of animals being pregnant at slaughter in 2015. Six of those experts used the survey results and other available evidence to estimate the average prevalence in Europe for different species in 2015, taking account of the uncertainties involved. The Panel's conclusions are based on the results. Experts estimated… (continue as in entry level communication).'

In case you want to communicate using box plots:

- Box plots should generally show the median (P50, which the true value is equally likely to be above or below), P25–P75 (the box) and P5-P95 (the whiskers). If other quantiles are used for the whiskers, the reasons for choice of quantiles should be explained.
- If there is a value or quantity that is of particular interest to risk managers or the public (e.g. a regulatory/reference value) the probability of being above or below this (depending which is of interest) should be communicated alongside the box plot, following the specific guidance in Box 6.

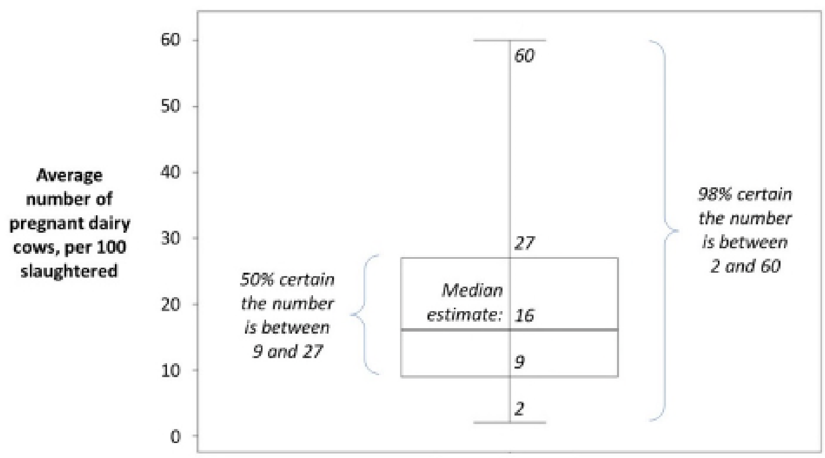

Figure 1: Example of a box plot for the average prevalence of pregnant slaughtered animals in the EU in 2015 (EFSA AHAW Panel, 2017)

Example of text explaining the boxplot in Figure 1:

'The horizontal line inside the box is the median estimate: the value is considered equally likely to be above or below this estimate. There is 50% certainty that the value is in the box and 98% certainty it is between the whiskers. There is still a 2% chance that the value is outside the whiskers.'

TECHNICAL LEVEL

In all cases:

- The scientific output should include: a table of the distribution and a boxplot.
- The assessors should provide P5, P25, P50, P75 and P95 ranges. In addition, if there are values of specific interest to the public/risk managers (e.g. a reference dose/value), then the probability of exceeding that should be provided.

- Assessors should state which sources of uncertainty are considered in the distribution and provide a qualitative or quantitative description of uncertainties not considered in the distribution (e.g. uncertainty about the quality and representativeness of entry data, assumptions in modelling exposure, and assumptions about the distribution of different parameters of a model).
- Assessors should state clearly how each distribution was obtained, and in particular whether it was derived by statistical analysis, mechanistic modelling or expert judgement.

Optional:

- The assessors may optionally provide a PDF graph of the distribution, and should do so when only communicating the quantiles would fail to communicate something important about the distribution, e.g. bimodal, skewed.
- The assessors may optionally accompany the PDF with a CDF graph of the distribution, if this is expected to be useful to technical readers of the assessment (e.g. to enable them to read off approximate estimates for quantiles other than those reported explicitly). The CDF should be plotted above the PDF, with the same horizontal scale, and with the location of the central estimate (and optionally the P5, P25, P75 and P95) clearly marked on both curves.
- When a PDF or CDF is used, it should be accompanied by a text explanation of how to read it, expressed in the simplest terms possible. If there is a value or quantity that is of particular interest to risk managers or the public (e.g. a regulatory/reference value) this should be explicitly marked on both curves.

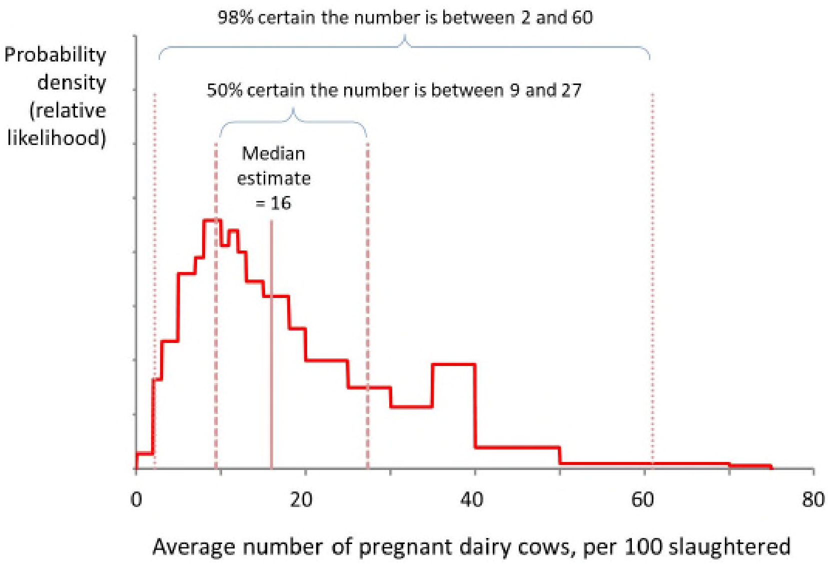

Figure 2. PDF graph based in the 'Prevalence of pregnant slaughtered animals in the EU' example (EFSA AHAW Panel, 2017)

Example of a text explaining the PDF illustrated by Figure 2:

'The red line shows a probability distribution quantifying uncertainty about how many dairy cows out of a hundred on average are pregnant when slaughtered in the EU in 2015, i.e. the prevalence of being pregnant when slaughtered. The height of the red curve shows the relative likelihood of the prevalence values in each part of the horizontal axis. The central (median) estimate is 16 out of 100, with 50% certainty that the European average for 2015 is between 9 and 27, and 98% certainty it is between 2 and 60 (as shown on the graph).'

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Box 9. Guidance for communicating a two-dimensional probability distribution

ENTRY LEVEL

- In this guidance, the term '2D probability distribution' refers to a distribution that quantifies both variability and uncertainty for the same quantity (e.g. uncertainty about the variability of exposure in a population). Such distributions are difficult to interpret even for technical audiences. Therefore it is recommended to restrict communication for entry and informed levels on selected results extracted from the 2D distribution.
- Consult with the assessors to identify which results from the 2D assessment are expected to be of interest to the audience. This will generally be one or both of the following:
  - The median estimate for a specified quantile of variability, e.g. the 95th percentile, together with a P5 and P95 (or other quantiles) to represent its uncertainty.
  - The median estimate for the frequency of exceeding (or being below) a specified value of the quantity, e.g. the proportion of a population that exceeds a regulatory reference value, together with a P5 and P95 (or other quantiles) to represent its uncertainty.
- Obtain the selected results from the assessors. As the range of values between the P5 and P95 has a specified probability (90%), communicate this following the approach in Box 6.

  Example:

  'The Panel estimated that the number of "toddler-days" in which more than the safe level for carbendazim is ingested from eating apples is 10 per 10 000, and is 95% certain the number is between 1 and 40 per 10 000.' (Note: in this case, assessors reported the P2.5 and P97.5 instead of the P5 and P95, hence the probability for the cited interval is 95% not 90%)

  (based on the IESTI example, EFSA, 2007)

INFORMED LEVEL

- Before giving the results, describe a few examples of the evidence/data that was considered and the uncertainties affecting the assessment, and state that the experts took them into account in their assessment.
- Optionally, mention specific methods that were used in quantifying the uncertainty, e.g. statistical analysis, expert knowledge elicitation, probabilistic modelling.
- Provide a visual representation of the uncertainty if possible, especially if the uncertainty information is part of the key messages.
- For the informed level, the recommended visualisation is a box plot showing median, P5, P25, P75 and P95 for the specific result(s) selected from the 2D distribution. Ask the scientific officer to provide a box plot for the selected result, and communicate it as recommended in Box 8.
- Graphical representations of full 2D distributions are misunderstood by many people and should never be used in entry or informed level communications.

  Example:

  'The Panel developed a mathematical model of the exposure of toddlers to carbendazim in apples, using UK data on the occurrence of carbendazim in apples and the consumption of apples by toddlers. The model quantified variability of consumption between toddlers by using the data to simulate apple consumption and carbendazim intake for 10 000 'toddler-days'. The simulation also quantified five types of uncertainty affecting the model, including uncertainty due to the limited number of measurements of occurrence and consumption, and limitations in the precision of the occurrence data. Using this model, the Panel estimated that the number of 'toddler-days' in which more than the safe level for carbendazim is ingested from eating apples is 10 per 10 000, and is 95% certain the number is between 1 and 40 per 10 000. However, this takes account of only the five sources of uncertainty that were quantified: other uncertainties were taken into account separately by expert judgement.'

Note: the above text should be followed by information on the experts' judgement about other uncertainties which were not quantified in the model, applying this guidance for the form in which it was expressed.

(based on the IESTI example, EFSA, 2007)

TECHNICAL LEVEL

- Provide a box plot and/or or relevant table containing quantiles for selected results from the distribution.
- Provide a description of the relative magnitude of variability and uncertainty.
- A graphical representation of the 2D distribution may be included in the technical level communication (EFSA scientific output). When this is done, proceed as follows:
  - Use a 2D CDF rather than a 2D CCDF unless there are strong reasons for using the latter, as there is some evidence that CCDFs are less well understood.
  - Ensure the graph is well-formatted, with clear labelling of axes and values, and markers to show the specific results that were selected for use in the entry level communication (see above). If helpful for communication, also request a box plot for the selected result and display it alongside the 2D graph.
  - Provide sufficient textual explanation for the 2D graph to be understood by the intended audience.
  - Also provide a box plot derived from their 2D distribution.
  - Consider whether it is helpful to include accompanying text on the relative magnitudes of variability and uncertainty and, if so, request this from the scientific officer.

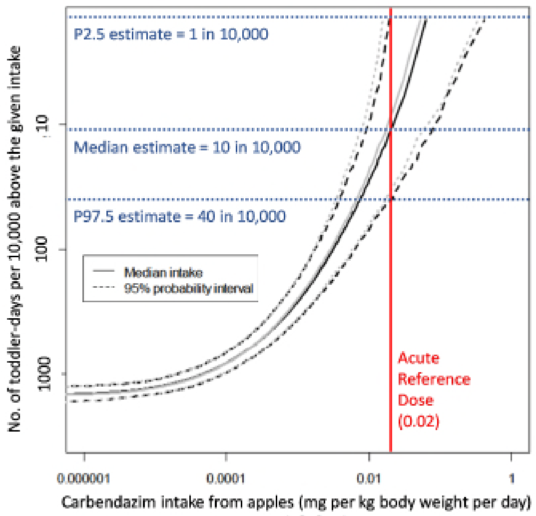

Figure 3. Example of graphical representation of 2D distribution

Example of accompanying text for the graphical representation of 2D distribution:

'The Panel developed a mathematical model of the exposure of toddlers to carbendazim in apples, using UK data on the occurrence of carbendazim in apples and the consumption of apples by toddlers. The model quantified variability of consumption between toddlers by using the data to simulate apple consumption and carbendazim intake for 10 000 'toddler days'. The simulation also quantified five types of uncertainty affecting the model, including uncertainty due to the limited number of measurements of occurrence and consumption, and limitations in the precision of the occurrence data.'

'A graph showing the results of the model is presented in Figure 3. The horizontal axis is the amount of carbendazim ingested per day: the vertical solid red line shows the safe level for this. The vertical axis is the number of 'toddler days' per 10 000 on which carbendazim intake exceeded any given level on the horizontal axis. The median estimate for this is shown by the solid curve: each point on the curve shows the number of toddler days (on the vertical axis) where ingestion of carbendazim exceeded the level shown below that point on the horizontal axis. The dashed curves show the upper and lower 95% confidence interval for the estimates: i.e. there is 95% certainty that any selected estimate lies between the dashed curves. However, this takes account of only the five sources of uncertainty that were quantified: other uncertainties were taken into account separately by expert judgement.'

'From the results shown in the graph, the Panel estimated that the number of toddler-days in which more than the safe level for carbendazim is ingested from eating apples is 10 per 10 000, and is 95% certain the number is between 1 and 40 per 10 000. These results are indicated by the horizontal dotted lines shown in the graph.'

Note: the above text should be followed by information on the experts' judgement about the other uncertainties, applying this guidance for the form in which it was expressed.

Note: 2D graphs have very rarely been used in past EFSA outputs. The graphical example in Figure 3 is unusual because the vertical axis is inverted. Also, the example contains a second distribution (shown in grey) that is not referred to in the text above. Care should be taken to use a format that facilitates understanding of the key results.

(based on the IESTI example, EFSA, 2007)

4. Evidence sources

This section describes the key evidence sources on which this guidance is based. These include an expert analysis of selected academic literature, extracts from frameworks or guidance documents similar in scope and purpose to this Communication GD from other national and international advisory bodies, and the results of research commissioned or carried out by EFSA to inform the development of this Communication GD.

4.1. Scientific literature

There follows an expert analysis of key papers on communicating uncertainty. The criteria used to select the key papers are described first.

4.1.1. Scope of literature search

A first initial list of 37 references was drafted based on:

- Working group members' knowledge of the literature,

- References included in a major recent review paper on risk and uncertainty communication, (van der Bles 2018),
- References already available at EFSA from different sources.

This list was used for a literature search performed to identify current publications reporting primary research on communicating uncertainties. The emphasis was to identify the most recent and specific publications, as the overview of research will be retrieved from existing reviews.

Due to the ubiquitous appearance of the search terms 'communication' and 'uncertainty' in scientific literature the usual search strategies were not specific enough to narrow the search to a feasible number.

Instead, the working group identified 37 initial references considered relevant to the topic. An analysis of these articles revealed a common feature: that the topic was somehow mentioned in the title. From this the final search terms were defined as:

A topic search on 'perception'/'communication' and a description of the relevant audience, e.g. 'policy maker'/'public' was further filtered by two options: a title search on actions, e.g. 'express', of uncertainties or on actions, e.g. 'lose', of credibility. An English thesaurus was used to identify alternative wordings. The final search terms were defined by optimising the retrieval of the main references, and the sensitivity of the search. The exact search terms with the complete search strategy is documented in Appendix A.

TOPIC: Communication terms **AND** TOPIC: Audience types terms
AND TITLE: (Action terms **AND** Uncertainty terms)

OR

TOPIC: Communication terms AND **TOPIC**: Audience types terms
AND TITLE: (Action terms AND Credibility terms)

The search strategy has some limitations as only 31 of the 37 initial references appeared in the database 'Web of Science', and only 26 of those 31 were retrieved by the search. To overcome this restriction the search was extended to 'Scopus'. The search in 'Web of Science' and 'Scopus' resulted in 1 353 references.

The references were screened to deselect articles clearly not addressing communication of scientific uncertainties, e.g. articles on 'transmission uncertainties'. The remaining articles were classified as the main references from the initial list and after screening of the title and abstract. References not classified were not reviewed, but kept as a pool for more detailed searching as required.

A list of criteria for including papers in the literature review was drafted collectively by the working group. Studies were included that:

- provide guidance on how uncertainty should be communicated (best practice)
- include experimental data, but also literature reviews on uncertainty communication
- provide recommendations for uncertainty communication
- cover at least one of the possible expressions of uncertainty from the main Uncertainty GD (EFSA, 2018a).

The relevance of the subject area was also taken into account; studies relating to food safety/public health/environment being preferred.

Studies essentially arguing about the importance of communicating uncertainty were excluded, as they were considered to be of low relevance for the practical needs of the Communication GD.

These criteria were applied by the working group to the '4 stars (initial papers)' and '3 stars (first rating)' papers, plus five additional papers resulting from the literature search ('2 stars (remaining after screening)' list). This resulted in 25 papers being considered in the first round of the literature review. These papers were read in full and further relevant references were identified from them. The final list of papers considered in the literature review included 46 titles.

4.1.2. Relevance of the literature included

A large set of risk communication studies has not been included in this review, because they examined how to best communicate risks (e.g. the risk of having cancer given a positive test result) (Gigerenzer and Hoffrage, 1995). These studies provide only limited advice on how to communicate uncertainty. There is also considerable variation among the included studies as to how they dealt with uncertainty and it is often not explicitly stated whether the authors focused on how to communicate frequentist or Bayesian expressions of uncertainty. There seems to be a lack of research that focused on the communication of subjective probabilities, which is the type of uncertainty almost always expressed by EFSA.

Most of the reviewed studies presented uncertain information to subjects and then asked them to express their response to the information. The form of response that was requested varied between studies, but in nearly every study it was explicit or implicit that the requested response referred to the subject's own interpretation or perception after receiving the information, and/or what actions they might take or wish to be taken in response to it. Only one study (Ibrekk and Morgan 1987) was identified where the participants were explicitly asked 'what the forecast says'. In some further studies (e.g. Edwards et al., 2012) it was ambiguous whether the subject was being asked for their understanding of the communication or for their own opinion, having seen the communication. The former is more relevant for this guidance, as its purpose is to ensure that EFSA's communications are understood (see Section 1.6.1). This varying relevance has been taken into account when using the findings from the literature (reviewed below) to inform the EFSA's Guidance (Section 3).

Twenty-six of the selected studies investigated the communication of uncertainty expressed as a range for a quantity of interest; only in five of these studies were the ranges accompanied by confidence levels or probabilities.

The subjects considered in the reviewed studies were mostly selected to represent the common 'lay person', and in many cases reflect convenience choices for the experimental settings. Most studies used convenience samples: students form the biggest pool of subjects, followed by people recruited in shopping malls, parks, at cinema exits, via advertisements on university networks or campuses, via the Decision Research web panel subject pool, and/or via Amazon Mechanical Turk.

Only four studies (Patt and Dessai, 2005; Wardekker et al., 2008; Beck et al., 2016; Pappenberger et al., 2013) experimentally dealt with some of the real main target audiences for EFSA, namely decision-makers, policy advisers and stakeholders.

4.1.3. General findings

Maxim et al. (2012) found that laypeople raise more and different uncertainties than those communicated by researchers. Moreover, laypeople had different reactions to the different sources of uncertainty.

Visschers (2017) found that their respondents differentiated between different types of uncertainty: ambiguity in research, measurement uncertainty and uncertainty about future impacts (in their study, of climate change). Finally, Wardekker et al. (2008) reported, similarly, a preference of experts and users of uncertainty information at the science-policy interface for communication of different types and sources of uncertainty. Together, these results indicate that communicating different sources of uncertainty together with communication of aggregated uncertainty might be welcomed.

4.1.4. Expressions of uncertainty studied in accordance with the EFSA Uncertainty GD

4.1.4.1. Ranges

Ranges can refer to a quantity of interest or to a probability used to express uncertainty (Section 2). Most of the literature reviewed studied ranges for a quantity of interest (e.g. the 95th percentile of a population), sometimes accompanied by a probability for the range. Some papers studied communication of ranges for probabilities describing uncertainty regarding the occurrence of an event. The parameters examined in the studies were diverse and are reviewed below in six categories:

- influence on risk perception[2]
- effectiveness of communication leading to accurate understanding of the uncertainty information
- impact on decision-making (of forms of uncertainty communication, use of uncertainty information in taking decisions, ambiguity aversion[3], ability to take a decision)
- effects on emotions (e.g. worry)
- role of source credibility on risk perception
- focus on the end values of the range.

Although not all of these effects relate to the specific needs of the Communication GD they may be valuable for deriving further recommendations for uncertainty communication.

The influence of uncertainty communication on risk perceptions is by far the most frequent parameter investigated, followed by effectiveness.

Influence on risk perception

Dieckmann et al. (2010), Han et al. (2011) and Kuhn (2000) found no significant difference in the magnitude of risk perception associated with communication of a probability range (i.e. a probability with associated uncertainty expressed by giving a range: x% to y%), as compared to communicating a precise probability (i.e. a point estimate for the probability without expressing associated uncertainty: x%). Han et al. (2011) provided both uncertainty information and comparative risk information together. They found that uncertainty information moderated the increase in risk perception that was observed when comparative risk information was provided in addition to individual risk information (i.e. the individual risk compared to the average risk in a population). For the hypothetical situation of a terrorist attack, tested by Dieckmann et al. (2010), there was no difference in perceived harm with or without uncertainty information.

In the experiments by Dieckmann et al. (2010), uncertainty information was presented as scenarios that included probabilities and narrative information; the latter adding context and an explanatory story in addition to describing the logic and evidence used to generate the assessment. Risk perception increased when the probability increased, and also when the narrative was provided. The effect of increased probability was the same, whether it was presented as a point probability or a range, and whether it was accompanied by narrative information or not.

Johnson and Slovic (1995) reported an increase in risk perception when uncertainty was communicated as probability ranges, as compared to point estimates. More generally, low risk estimates were deemed more ‘preliminary’, whether uncertainty was communicated or not. In Kuhn (2000), when no mention was made of uncertainty, or when the ends of the probability range were explained as the conclusions of two different sources with opposing biases, peoples’ environmental attitudes predicted risk perception. However, environmental attitudes predicted risk perception less well when the probability range was centred on the best estimate. The average level of risk perception did not differ between point estimates and uncertainty communication. Viscusi et al. (1991) emphasised that the number of people who are influenced by the most adverse or the most favourable uncertainty estimates is quite constant.

Overall, although influence on risk perception is relevant to risk management, for the purpose of this Communication GD the main consideration is the impact of uncertainty information on accurate understanding.

[2] Risk perception is the subjective judgement people make about the severity of a risk. This is related to, but different from, their understanding of the risk message sent by the communicator: one can have an accurate understanding but a different appreciation about the importance of the risk.

[3] Preference for known over unknown risks.

Effectiveness in terms of accurate understanding of uncertainty information

Dieckmann et al. (2015) presented subjects with ranges for various quantities, but no information on the underlying distribution. Subjects were then asked to choose between three options for the underlying distribution: uniform, central values more likely, or extremes more likely. Distributional perceptions were similar whether the range referred to a quantity (e.g. temperature) or to the probability of an event occuring. Without clues about the form of the distribution, people tend, in relatively balanced proportions, either to consider all the values in a range as being equally probable (uniform distribution) or to perceive the central values as more likely (particularly the more numerate). A small percentage perceived a U-shaped distribution (see below). Providing a best estimate and a confidence level with the range reduced the perceptions of both uniform and U-shaped distributions. Further studies by the same team (Dieckmann et al., 2017) confirmed that perceptions of the distribution underlying numerical ranges are affected by the motivations and worldviews of the recipients. This motivated reasoning effect remained after controlling for numeracy and fluid intelligence, but was attenuated (in one instance described as 'eliminated') when the correct interpretation of the distribution was made clear through the use of a graph. In other words, people interpret the uncertainty information in a motivated way only if they are given the opportunity, and they do not do so when the correct information about the distribution is made clear.

Impact on decision-making

Participants in the experiments of Dieckmann et al. (2010) thought that at higher levels of probability the probability range was more useful for decision-making than the point probability, whereas at a lower probability the point estimate was more useful. However, the magnitude of the difference was not provided and the authors stated that the reasons for it were unclear.

Kuhn (1997) showed that for the low to high range condition (e.g. 10–30%), vague options are more likely to be preferred when decision problems are framed negatively (i.e. losses) than when they are framed positively (i.e. gains). Morton et al. (2011) showed that communication of a probability range combined with a positive framing (possibility of losses not materialising) increased individual intentions to behave environmentally for limiting climate change effects.

Worry

Cancer-related worry was found to increase (Han et al., 2011) when uncertainty was communicated in the form of probability ranges, compared to point estimates. However, this effect was moderated by the format and people's personality: textual communication (vs. visual) and low optimism (vs. high) were associated with higher worry. In the study by Johnson and Slovic (1998), giving zero as the lower bound created problems, as on average people agreed that zero, versus one in 10 million, as a lower bound meant that the government could be wrong, that the true risk was not at that level but must be higher. Respondents were therefore less likely to worry if the lower bound was one in 10 million than if it was zero. But the effect is relatively small (see Table 4 of Johnson and Slovic, 1998) and of limited practical relevance for recommendations on describing the bounds.

Role of source credibility on risk perception

Han et al. (2011) found no relationship between the credibility of the probability ranges provided in the study and worry or risk perceptions. The results of Johnson and Slovic (1995; 1998), who studied communication by a governmental agency in charge of risk assessments, indicated that providing uncertainty ranges is deemed by most people to be honest and competent. Most people in the studies of Johnson and Slovic (1998) said they did not expect risk assessment to be certain, or that a single number could describe an environmental health risk.

Dieckmann et al. (2010) found no substantial difference in perceived source credibility between point and range communication related to a forecast situation, except for the case when the forecast was evaluated in hindsight. In this latter case, source credibility was higher for the range. Also, the credibility of the narrative evidence about uncertainty was found to be directly correlated with the credibility of the source.

Focus on end values of the range

In all of the studies, having discussed the choice of extreme values among those in a range, a substantial minority of the respondents strongly focused on the extreme values of the ranges. In Dieckmann et al. (2015), 11%, 8.3% and 12.1% (for the three different risks considered) perceived the values towards the ends of the range (i.e. further from the best estimate) as being more likely (U-shaped distribution). One of their experiments included the additional option 'None of the above: please specify' and participants who selected this indicated that it was due to a lack of trust in the data or forecaster. In a subsequent study, Dieckmann et al. (2017) showed that subjects were less likely to say extreme values were more likely when provided with a graphic and narrative indicating a normal-shaped distribution, though some still did so.

In Johnson and Slovic (1998), when a range of risk values (frequencies) was presented, 22% of the subjects focused on the highest value of the range. In the study by Viscusi et al. (1991), 20% of the sample chose an extreme value from the range presented. The authors concluded that there is quite some prevalence of people who are influenced by the most adverse or the most favourable piece of information presented.

4.1.4.2. Probability distributions

Only two studies (Ibrekk and Morgan, 1987; Edwards et al., 2012) looked experimentally at how people understand probability distributions, a third (Pappenberger et al., 2013) being of low relevance for the current guidance, because of its high specificity to the field of meteorology.

Ibrekk and Morgan (1987) studied nine pictorial displays: a traditional point estimate with an error bar that spans a 95% confidence interval; a conventional probability density function (PDF); a discretised version of a PDF; a discretised PDF using a pie chart; a PDF and its mirror image plotted above and below a horizontal line – to help users focus on the area enclosed between the curves; horizontal bars of constant width shaded to display a PDF using dots and vertical lines; a boxplot modified to indicate the mean as a solid point; and a cumulative density function (CDF); and the integral of a PDF. Their results indicated that the performance of a display depends on the information that a subject is trying to extract. Thus, a CDF, used alone (without indicating the mean and without explanation), severely misled some subjects in estimating the mean. However, a CDF allowed very good estimations of the probability that x>a, and the probability that b>x>a. The results obtained with engineers were similar to those obtained with a nontechnical audience.

As regards PDFs, when asked to indicate the mean, people rather selected the mode, unless the mean was explicitly marked. The various PDFs tested gave similar results.

This was the sole study to explicitly ask the participants what the assessor was trying to communicate (e.g. about the best estimate) rather than their own understanding of the true value.

Edwards et al. (2012) looked at 10 commonly used graphical display methods: PDF; CDF; complementary cumulative probability distribution function (CCDF); multiple probability distribution function (MPDF); multiple cumulative probability distribution function (MCDF); Multiple complementary cumulative probability function (MCCDF); box plots (box-and-whisker plots); standard error bars; 3D-PDF (tridimensional probability distribution function) and scatterplots. Participants were asked to estimate the mean for each variable and the probability that an observed measurement of each variable was more or less than a given amount. The influence of these methods on decision-making was studied.

Complementary cumulative probability functions led to the highest probability estimation accuracy, and CDFs and 3-D PDFs led to poor accuracy, which in the case of CDFs is contrary to the results of Ibrekk and Morgan (1987). However, similar to Ibrekk and Morgan (1987), Edwards et all (2012) found that background knowledge in statistics or familiarity with a display method did not influence accuracy.

Both studies focused on the participants' ability to correctly extract specific information from the graph (e.g. best estimate), but not on the question of which type of graph would be most helpful for people to make informed decisions. Ibrekk and Morgan (1987) did not investigate the use of their graphical formats for decision-making. Edwards et al. (2012) found that the box plot and the error bar performed best in a simple decision task, which only required the estimation of probabilities and did not require any weighing of probabilities against outcomes. They also asked participants to rate the different formats for usefulness for decision-making. The box plot, error bar and scatterplot were perceived as more useful for deciding what to do than the CDF, MCCDF, MPDF and 3D-PDF.

4.1.4.3. Expression of expert judgement using ordinal scales

There is a rich and long-established literature on the use of verbal uncertainty expressions (e.g. 'likely') and their associated numerical formulations. The most recent papers looked at the ordinal scale provided by the Intergovernmental Panel on Climate Change (IPCC) for climate change. Table 4 in this guidance is an adaptation of the IPCC scale, recommended for use in EFSA (see EFSA, 2018b). All of this literature consensually criticises the use of verbal uncertainty expressions alone, which can be responsible for significant misunderstanding of uncertainty messages. Consistency between people's numerical interpretation of IPCC's verbal expressions, and IPCC's conversion table, was found to be low. Making the conversion table available to subjects slightly reduced this inconsistency (Budescu et al., 2009). The variability in the numerical meanings assigned to the probability terms was found to be very high, with significant overlap between the terms (Druzdzel, 1989; Budescu et al., 2009; Budescu et al., 2012) and reversal of the order established between the terms (Budescu et al., 2009). Interpretations were regressive, i.e. underestimating high probabilities and overestimating low probabilities (Budescu et al., 2009; Budescu et al., 2012; Budescu et al., 2014). The range of values associated with each term and the level of agreement with the IPCC guidelines increased when dual verbal and numerical expressions were communicated (Budescu et al., 2009; Budescu et al., 2012; Budescu et al., 2014). Negatively worded terms (e.g. 'unlikely') resulted in greater variability than positively worded terms (e.g. 'likely') (Smithson et al., 2012).

Authors repeatedly concluded on the context-dependency of individual interpretations of these verbal terms (Wallsten et al., 1986; Druzdzel, 1989; Mosteller and Youtz, 1990; Weber and Hilton, 1990; Patt and Schrag, 2003; Patt and Dessai, 2005; Harris and Corner, 2011). Verbal uncertainty expressions embody not only their probabilistic meaning, but also other things such as an expression of the magnitude of the event: language referring to a severe (in terms of consequences) event might be interpreted as indicating either a lower probability event (Patt and Schrag, 2003; Patt and Dessai, 2005) or as a higher probability event (Harris and Corner, 2011, results obtained based on criticism of the experimental setting of Patt and Schrag, 2003) than those referring to a more neutral event, for the same objective probability of the two events. Contextual influences can also be related to the expected frequency/base rate of the event being described (Wallsten et al., 1986) and the emotional valence of the terms being used (unpleasantness, desirability) (Weber and Hilton, 1990). As a matter of principle, qualitative probability terms express both amounts of uncertainty and degrees of confidence in that uncertainty, expectations that uncertainty may change with information, and probably other factors (Wallsten et al., 1986).

However, the variability of understandings of verbal expressions is severely underestimated by those using them, who think these expressions are more precise and more extreme (farther from 0.5) than they really are (for the receivers) (Druzdzel, 1989).

The authors (Patt and Schrag, 2003; Patt and Dessai, 2005; Budescu et al., 2009; Harris and Corner, 2011; Budescu et al., 2012; Smithson et al., 2012) unanimously recommend at least accompanying verbal uncertainty expressions with their corresponding probabilities, as intended by the authors, at each use (and not only somewhere in the annexes where a correspondence table was usually included). Budescu et al. (2009) additionally recommend adjusting the width of the numerical range within the generic range (i.e. as specified in IPCC's correspondence table), to match the uncertainty of the target events.

4.1.4.4. Qualitative expressions of uncertainty

Studies testing qualitative expressions of uncertainty are diverse in their objectives and formulations of uncertainty. Several authors looked into accompanying numerical expression of uncertainty with narrative evidence. Dieckmann et al. (2010) found that narrative description of the available evidence had a large effect on people's judgements (in particular, risk perception) when they were associated with probabilistic point estimates of a risk, but this effect was smaller when the narrative was combined with a probability range. Also experimenting on the communication of a verbal qualification of a single point probabilistic estimate ('estimated to be around x%'), Kuhn (1997) highlighted framing effects: verbal qualification led to greater vagueness aversion with a positive frame, whereas a negative frame reduced vagueness aversion. A best estimate with verbal qualification of associated uncertainty (i.e. due to incomplete knowledge) did not amplify perceived risks for environmentally oriented people (Kuhn, 2000). More generally, the study concluded that aggregate levels of uncertainty in hazard risk evaluation might not be sufficient, and using several approaches to present uncertainty could increase the potential of reaching different audiences.

Similarly, discourse-based uncertainty expression (entire sentences describing limitations of studies) did not have a significant effect on the parameters studied by Jensen et al. (2017), namely fatalism, backlash and informational overload.

Han et al. (2011) found greater ambiguity aversion for textual explanations related to cancer treatment (e.g. breast screening) than visual representations (bar graphs) of a probability range, when people were generally prone to low dispositional optimism. However, textual description had similar effects on people's worry when visual representations were changed (depicting a confidence interval using a bar graph, and adding blurred edges to reinforce the presence of ambiguity and the idea that probability distributions lack firm boundaries).

Evaluative labels ('high', 'low') associated with numerical probability ranges facilitated the understanding of uncertainty; they were considered easy to use and appeared to be employed even when numerical uncertainty ranges were provided (Dieckmann et al., 2012). In that study, participants were more likely to choose the option with the highest confidence (e.g. 'high' confidence, corresponding to the lowest uncertainty) when presented with the range and evaluative labels, as opposed to the range alone. They were also more likely to choose the lowest confidence, lowest cost option with the range only. While such evaluative labels might be useful for reflecting the amount of uncertainty, they might be less relevant for expressing the confidence levels. Indeed, it might be difficult to separate likelihood and confidence, as likelihood implicity contains confidence levels (a statement about an extremely likely event can hardly be characterised as being of low confidence: then why would the likelihood be high?) (Han, 2013).

Hedging (i.e. natural-language words used to express numerical values, such as 'about', 'around', 'almost', etc.) is understood in a wide variety of ways by different users, with important inter-individual variation and overlap for many approximators. Furthermore, its use is modulated by context, including the magnitude of the number, its roundness and even its units (Ferson et al., 2015). However, Jensen (2008) found that hedging was positively associated with perceptions that study limitations were reported clearly.

Communication of uncertainty with plain language necessarily brings in the rhetorical properties of the words used. Even if numbers are used, the phrasing which accompanies them naturally introduces perspectives too (Moxey and Sandford, 2000).

4.1.4.5. Visualisation

Ibrekk and Morgan (1987) found that a box plot or simple error bar performed well if the mean was the primary attribute to be communicated, but less well if one was trying to communicate probability intervals for which CDFs were most effective. The results of Edwards et al. (2012) indicated that error bars and box plots were the most accurate for estimating the mean. Participants rendered more accurate means when using a graphical display method that explicitly provides the necessary information. Error bars with the mean explicitly labelled led to the highest accuracy in mean estimation of all graph types, followed by the box plot, while CCDFs led to the highest accuracy for probability estimation. The box plot, error bar, and scatterplot were perceived by the subjects as more useful for deciding what to do than the CDF, MCCDF, MPDF and 3D-PDF.

While efficient for conveying information about the mean, box plots performed less well for conveying information about the distribution underlying a range. For this kind of distributional information, a simple density graph was better, confirming the idea that visualisation tools have different levels of performance depending on the kind of information to be conveyed (Dieckmann et al., 2015).

Similarly, bar charts with error bars can be misleading, as values inside the bar are seen as likelier than values outside the bar (Correll and Gleicher, 2014).

Only one experimental study produced results about the pedigree chart (NUSAP), which was considered useful by the interviewed experts (Wardekker et al., 2008). NUSAP (Numeral, Unit, Spread, Assessment, Pedigree) is a notational system for displaying different sorts of uncertainty as quantitative information. The pedigree chart allows an evaluative description of the mode of production of that information, and can be represented as a spider/radar chart using traffic lights symbols (e.g. green for good quality, red for low quality) (EFSA Scientific Committee et al., 2018b).

Visualisation might have an effect on understanding and emotions, but there is weak evidence in the literature for this. Han et al. (2011) found, for example, that people with a personal predisposition to optimism were more tolerant of ambiguity when uncertainty of cancer risk was communicated using bar graphs than as a textual description. However, enhanced visual representations (depicting a confidence interval using a bar graph, and adding blurred edges to reinforce the presence of ambiguity and the idea that probability distributions lack firm boundaries) had a similar impact to the textual description. In Johnson and Slovic (1995), accompanying numerical information on uncertainty with simple graphics (different values of risk indicated on a vertical line) helped people recognise uncertainty but made the information seem less trustworthy.

Based on a review of various visualisation examples, Spiegelhalter et al. (2011) and Spiegelhalter (2017) concluded that the choice of visualisation depends closely on the objectives of the presenter, the context of the communication and the audience. They formulated a number of general recommendations for visualising uncertainty. Even in areas that are not controversial, the wide variability of audiences, in terms of numeracy and ability to understand graphs, needs to be considered.

No relevant references were found for the communication of sensitivity analyses.

4.1.5. Implications of the scientific literature for the guidance

In this section, we combine recommendations formulated by the cited authors themselves with recommendations that can be drawn based on their results. We formulate the recommendations both for uncertainty communication in general, and specifically for each type of expression of uncertainty. Recommendations formulated by the authors are referenced with their names, and recommendations developed by the authors of this guidance, based on interpretation of the results found in the literature are referenced using the wording ‘based on…’.

General aspects for uncertainty communication are summarised as follows:

- As no single representation suits all audiences, a pluralistic approach to uncertainty communication (multiple formats) can allow different target audiences to use different clues in your message that are most adapted to their ways of understanding (Patt and Dessai, 2005; Spiegelhalter et al., 2011; Spiegelhalter, 2017; also based on Kuhn, 2000).
- Repetition of the same information under different forms is not a problem as long as it is consistent, while misunderstanding of your message can become one. You may consider simultaneously using numbers, verbal descriptions, graphs, more or less detailed information in the same document or in different (e.g. background) documents or communication platforms (based on Spiegelhalter et al., 2011; Edwards et al., 2012; Kuhn, 2000; Dieckmann et al., 2017).
- Provide information on uncertainty as soon as it is identified and in full. Information about what is being done to reduce uncertainty should be included (Frewer et al., 2002).

The mains aspects related to specific expressions of uncertainty are summarised in the following sub-sections.

4.1.5.1. Ranges

- Each probability range should be accompanied by a verbal, numerical or graphical description of the distribution of values behind it (e.g. uniform, normal, etc.). Providing a central estimate (e.g. mean, mode) and a confidence interval is recommended, as well as a description of how to interpret the range (Dieckmann et al., 2015; Dieckmann et al., 2017).

- Whatever range is communicated, a (potentially significant) minority of people will focus on the values close to the ends of the range, for different reasons: lack of clarity in the communication, general lack of trust in the scientific advisory process, or by strategic choice for influencing the political decisions.
- In communicating ranges, two options are possible, between which the choice is unavoidable and will depend on each particular case considered. One option is to communicate the 'largest' range of scientific relevance (e.g. P1 to P99 or P5 to P95), which has the advantage of ensuring transparency about all the available values. The disadvantage of this option is that the range can be potentially large, and the difference between the minimum and maximum values extremely wide. A second option is to communicate a range with end values narrower than the scientifically possible minimum and maximum (e.g. P25 to P75). In this case, a minority of people will still focus on values at the ends of the range, but the advantage is that the ends of this range are less extreme. The disadvantage of this option is that it may backfire, for example, if people criticise EFSA for not communicating the higher values available in the full assessment (based on Viscusi et al., 1991, Johnson and Slovic, 1998).

4.1.5.2. Probability distributions

- For highlighting the mean, a CDF used alone (without indicating the mean and without explanation), is not a good way to communicate (Ibrekk and Morgan, 1987).
- CDFs and multivariate density function graphs should be used with caution (Edwards et al., 2012).
- A CDF plotted directly above a PDF with the same horizontal scale, and with the location of the mean clearly marked on both curves, should be used (Ibrekk and Morgan, 1987).
- CCDFs should be preferred for communicating precise probabilities (Edwards et al., 2012).
- Pie charts to represent uncertainty (discretised PDFs) show potential for confusion and should be avoided (even if many people declared that they prefer this representation) (Ibrekk and Morgan, 1987).

4.1.5.3. Expression of expert judgement using ordinal scales[4]

- Verbal expressions of the different levels of the ordinal scale (Approximate Probability Scale (APS)) should be accompanied with their numerical translation each time they are used, whether in a short or longer text. Only providing a correspondence table (between verbal and numerical) is not sufficient, especially if such a table is difficult to locate in an annex (Patt and Schrag, 2003; Patt and Dessai, 2005; Budescu et al., 2009; Harris and Corner, 2011; Budescu et al., 2012; Budescu et al., 2014; also based on Wallsten et al., 1986; Mosteller and Youtz, 1990).
- A verbal-numerical probabilistic ordinal scale should be used primarily for unambiguous events (e.g. 'large and abrupt event' could be interpreted differently by people). The target events should be very precisely defined, for avoiding confusion between the ambiguity in the description of the event itself and the uncertainty associated with it (Budescu et al., 2009).
- Negatively-worded terms (e.g. 'unlikely') produce higher levels of misunderstanding than positively worded terms (e.g. likely). It should be borne in mind that that these are not the inverse of each other (Budescu et al., 2012; Smithson et al., 2012).

4 In the outcome-references correspondence table, the papers about verbal qualifications of probability ranges associated to an ordinal scale (IPCC-like) were included both in 'expression of expert judgement, using ordinal scales' and in 'probability range'. Here, recommendations are, however, addressed only in the sub-section 'expression of expert judgement, using ordinal scales' for avoiding confusion between these probability ranges ordered on a scale (APS) and uncertainty ranges that are not and that can be much more frequently used.
The references and recommendations including any other verbal qualification of uncertainty (e.g., explanations of uncertainty, narratives, verbal qualification of a single point estimate) are included in 'qualitative (verbal)'.

- Online versions of communication documents could provide links between probability terms and optional graphic displays related to the sources of uncertainty and to uncertainty scales (Spiegelhalter et al., 2011; Spiegelhalter, 2017)

4.1.5.4. Qualitative expressions of uncertainty

- The various sources of uncertainty that underly key events should be specified (e.g. incomplete scientific understanding of a process, lacking data for informing the parameters of a model, unreliability of measurements, etc.), as well as their nature and magnitude (Budescu et al., 2009; also based on Kuhn, 2000; Maxim et al., 2012; Maxim and Mansier, 2014; Visschers, 2017; Wardekker et al., 2008).
- When appropriate, the extent to which some of these uncertainties could be reduced should be communicated (Frewer et al., 2002).
- Hedging terms should be avoided ('about', 'almost', etc.) (based on Ferson et al., 2015).
- There may be advantages in using evaluative labels ('high', 'moderate', 'low') together with numeric uncertainty ranges, as they can highlight aspects of uncertainty information that may otherwise be overlooked in more complex numerical displays. However, the cut-offs for high, medium and low have to be precisely defined. Also, the decision about the aspects of uncertainty to which evaluative labels are applied has to be explained. However, be aware that evaluative labels are a double-edged sword, as they may signal to a layperson that this element is paramount to the decision at hand, even though other factors could also be important for decision-making. Furthermore, people might focus on the evaluative labels and ignore other ways of looking at uncertainty like examining upper and lower values (Dieckmann et al., 2012).

4.1.5.5. Visualisation (other than probability distributions)

- Visual communication should include the elements that are important. For example, simple visual cues (e.g. highlighting where the mean is on a PDF) could increase the interpretability of display methods (Edwards et al., 2012; also based on Spiegelhalter et al., 2011).
- Error bars and box plots are preferred for allowing mean estimation and deriving a follow-up action (Edwards et al., 2012).
- A simple density graphic accompanying an uncertainty range is useful to decrease the inter-individual variance in distributional perceptions (Dieckmann et al., 2015).
- A box plot should not be used to represent an uncertainty range without additional information describing the underlying distribution (verbal or graphic) (Dieckmann et al., 2015).
- Graphics should be accompanied by verbal and numerical descriptions of what they represent (Spiegelhalter et al., 2011; Spiegelhalter, 2017).
- For the online versions of communication documents, interactive links and animations can help to adapting the information to the user's needs and ways of understanding (Budescu et al., 2012; Spiegelhalter et al., 2011).

4.2. EFSA research studies

EFSA commissioned a target audience research study in 2016 and carried out its own follow-up study in 2017 in preparation for this Communication GD. In the first study (Etienne et al., 2018) the authors used qualitative methods to design and communicate an opinion summary and related statements about the uncertainty. Evidence was collected from selected representatives of EFSA's key partners in the EU institutions and Member States and stakeholders, who completed a questionnaire individually then discussed their responses in five focus groups of 6–10 participants (39 in total). The second study (EFSA 2018c) was undertaken to further test the initial findings with an increased sample size. The authors adapted materials from the first study and conducted an online survey in six EU languages. EFSA and eight members of its Communication Experts Network, composed of communication representatives from the EU Member State food safety authorities, promoted the survey, generating over 1 900 responses. Appendix C contains an overview of the statements that were tested and the questions that the participants were asked.

Both studies have limitations in their design and conduct which restrict their use. Nevertheless, considered cautiously they provide some useful insights and indications retrieved directly from the key target audiences for EFSA's communications: officials in the EU institutions and EU Member States, civil society organisations, members of the public, the scientific community, the media and food industry operators.

4.2.1. Usefulness of uncertainty information

In both EFSA studies the response to receiving uncertainty information was positive. In the first study, a majority of the focus group participants indicated that most of the statements on uncertainty were informative. Opinions were more balanced on the usefulness of the information. The discussions revealed differences among individuals within the groups, in particular some participants in the general public group found the information overwhelming. In the second study, 96% of respondents replied positively about the need to communicate uncertainty information, considering it at least helpful, important or essential. The trend was similar for all languages and professions. Favourable comments indicated that uncertainty communication aids transparency, but should be clear, concise and tailored to different audiences whose perceptions, experiences and expectations vary. A few less favourable comments were made, mainly by industry or political-decision makers. These commenters considered uncertainty information useful for decision-makers and scientists but not for the general public, who they suggested may misinterpret the information, which they thought might decrease public trust in EFSA and regulatory bodies.

4.2.2. Positive vs negative framing

The framing effect is a type of cognitive bias, in which people react to the same choice in different ways depending on how it is presented; e.g. in a positive or negative way. The EFSA studies included several examples of framing including the following, with the framings in italics: "EFSA's scientists said that, *based on what we know*, there is about an 80% chance that exposure of the most exposed group of consumers is *within the safe level*" (positive); and "EFSA's scientists said that, *given the uncertainties*, there is about a 20% chance that exposure of the most exposed group of consumers *exceeds the safe level* (negative).

The focus group study provided some indication that the framing of uncertainty statements had an impact on risk perception. However, only one statement was tested for alternative framings and the sample was small. With these caveats, the findings suggest that emphasising the high probability of a low risk to the most exposed group contributed to keeping risk perceptions stable. Emphasising the low probability of a higher risk stimulated participants to reconsider their assessment of the risk, both to revise it up and revise it down.

In none of the focus groups did a majority of participants prefer statements combining both framings, as in *'POSITIVE FRAMING. In other words, NEGATIVE FRAMING'*. This contradicts common advice that uncertainty statements should be in a format that combines positive and negative framings. For example, one commenter in the online survey suggested that negative framing overestimates uncertainty and a way to overcome this is to present negative and positive framings.

In the online survey positive framings received many more first rankings for understanding and for clarity than negative framings, although the large size of the difference may have been partly due to the order in which they were presented in the survey (positive first).

4.2.3. Confidence in EFSA

In the focus group most participants' confidence in EFSA was unchanged after reading uncertainty statements, although there was some impact on trust from statement to statement and from group to group. The small sample size means it is not possible to build any firm conclusions on the basis of the observed variations. However, the focus group findings suggest that the perceived lack of clarity of some statements negatively affected trust in EFSA. Statements considered to be more simply worded were received more positively and generally did not lead participants to revise their confidence in

EFSA. For some stakeholders, their predispositions towards EFSA, positive or negative, coloured and possibly amplified the manner in which they responded to the uncertainty statements.

4.2.4. Professional background

Most of the participants of the focus group were carefully selected and therefore this study provides insights on responses by partners and stakeholders who have frequent contact with EFSA, its scientific advice and its communication outputs:

- *Technical policy-makers* disagreed on the best ways to communicate scientific uncertainties. Some preferred detailed information on the sources, extent and direction of uncertainties. Others preferred a qualitative assessment of the general direction (over-/underestimate the risk). Some preferred qualitative statements because these improved their own understanding, while others expected these statements would be easier to communicate to others (i.e. their own audiences). Some expressed concerns that detailed uncertainty information could confuse lay readers and create unnecessary concerns.
- *Political decision-maker* views on uncertainty statements were influenced by how such information might be perceived and understood by their own audiences, such as citizens. This group stressed the need to ensure consistency between the content of scientific opinions and communication materials.
- *NGOs/civil society groups* believed that EFSA should communicate on uncertainties, but had negative views on the uncertainty statements presented during the focus group. The way statements were formulated (e.g. double negatives) was deemed confusing. Some participants believed that the presence of uncertainties contradicted EFSA's risk assessment conclusions regarding the absence of health concerns (in the example used).
- *Industry representatives* had varying degrees of scientific literacy skills. Some preferred statements providing information on the probabilities associated with uncertainties. However, most preferred a qualitative description of uncertainty, with an assessment of whether safe exposure levels are exceeded. Industry was the only group where a strong majority preferred a qualitative statement when asked to rank their preference for three similar statements (the other two were quantitative).
- *The general public* differed in their views regarding the best formats for uncertainty communication: some participants preferred qualitative statements, while others were more interested in statements providing percentages and ranges associated with uncertainties. Those less familiar with scientific research found uncertainty information confusing, and preferred to only be informed about risk assessment conclusions rather than about uncertainties.

In the online study, responses were grouped differently. More respondents in the political/NGO, scientist/academic and industry groups considered the qualitative statement most helpful, while in the general public/media group more considered the quantitative probability statement most helpful. The differences between groups, however, were not large, i.e. a large proportion in all groups found both quantitative and qualitative statements helpful in understanding the risk assessment. Also, the real cause of the differences is unclear, because the differences between professional backgrounds were confounded with differences between languages, and perhaps other factors too.

4.2.5. Culture and language

The online survey produced some results that might indicate some differences in understanding of and preference for, receiving uncertainty information depending on language and/or cultural background. For example, differences between English and French were larger than any differences between professions. The quantitative statement received more first rankings than the qualitative option in French (54%) and to a lesser extent Greek (35%). The higher proportion of general public respondents in these languages (30% in Greek, 16% in French) may have influenced this outcome. The English responses include the highest proportion (45%) of scientists/academics (who prefer qualitative) and the lowest proportion of general public (who prefer quantitative), but the real causes of the preferences are not completely clear.

When participants in the focus groups were asked to rate how understandable the different uncertainty statements were, preferences for qualitative or quantitative wordings varied depending on the clarity and simplicity of the expressions. This also influenced their preferences when choosing between different wordings of similar statements. Generally speaking, therefore, the results indicate that the more concise the statements, the more likely the respondents would find them favourable.

One statement tested in the online survey included a hedging word (about an 80% chance) and another included an approximate probability (likely (66–90% probability)). However, due to the sequential structure of the survey, preferences between them were not assessed.

4.2.6. Messages for expressing uncertainty

In the focus group study participants rated how understandable, informative and useful they found different uncertainty statements. More concise statements were generally rated more understandable than complexly-worded statements. The online survey provides indications on which expressions participants found most helpful for understanding the risk. Five types of expressions of uncertainty were included in the two studies, although not all of them were directly compared: an 'uncertainty table' containing brief qualitative descriptions of sources of uncertainty accompanied by plus and minus symbols indicating the direction of their impact on the assessment, qualitative description of the direction of uncertainty (conservative or unconservative), qualitative expressions of probability (e.g. 'likely'), approximate probabilities ('66-90% chance' and 'more than 50% chance') and a precise probability qualified by a hedging word (e.g. 'about 80% chance').

Table 5 summarises the key indications on each.

Table 5: Indications of the audiences' perceived understanding of different expressions of uncertainty and their preferences among different formats of similar statements

	Entry	**Informed**	**Technical**
Qualitative descriptions of sources of uncertainty			
Focus group	The whole group found the uncertainty table confusing and misinterpreted the +- signs as cancelling each other out.	-	2 out of 9 of the technical group participants described the +- table as 'incomprehensible'.
Qualitative expressions of probability			
Focus group	2 out of 7 in the public group preferred the qualitative statement.	3 out of 7 in the policy group and 0 out of 5 in the NGO group preferred the qualitative statement.	6 out of 7 in the industry and 4 out of 9 in the technical groups preferred the qualitative statement.
Online survey	35% of the public/media group ranked the qualitative statement most helpful for understanding the risk.	47% of the policy/NGO group ranked the qualitative statement most helpful for understanding the risk.	46% of the industry, 39% of the risk assessors and 41% of scientist/academic groups ranked the qualitative statement most helpful for understanding the risk.
A precise probability with hedging word ('about')			
Focus group	5 out of 7 of the public group preferred the quantitative probability	4 out of 5 in the NGO and 3 out of 7 in the policy groups preferred the quantitative probability	4 out of 9 in the Technical group but only 1 out of 8 in industry groups
Online survey	45% of the public/media group ranked the quantitative probability most helpful for understanding the risk.	37% of the policy/NGO group ranked the quantitative probability most helpful for understanding the risk.	35% of the industry, 38% of the risk assessor, and 35% of the scientist/academic ranked the quantitative probability most helpful for understanding the risk.
An approximate probability (range)			

	Entry	Informed	Technical
Focus group	None of the public group preferred the approximate probability using ranges.	1 out of 5 in the NGO and 1 out of 7 in the political groups preferred the approximate probability using ranges.	1 out of 8 in the industry and 1 out of 10 in the technical groups preferred the approximate probability using ranges.

4.2.6.1. Qualitative descriptions of sources of uncertainty

Some technical and political participants found the uncertainty table useful when accompanied by a qualitative expression of the overall uncertainty. However, the table is easily misunderstood by individuals from all audience levels.

4.2.6.2. Qualitative expression of probability

In both studies a large share of participants was favourable to qualitative statements about the uncertainties, with differences among professions. Comments from the focus group discussions are consistent with a preference for qualitative information. A majority of industry participants ranked them higher than the quantitative options for understanding, as did large minorities of risk assessors and other scientists, but in many cases they were answering according to what they thought was the best format for the general public. Fewer political and public respondents favoured the qualitative information and in the focus group study the NGO participants rejected them outright when given the choice. By language, the English and Spanish language groups ranked these statements most useful in the online survey. As noted above, the differences between languages and professional backgrounds were confounded so their real cause is unclear.

4.2.6.3. A precise probability with hedging word ('about')

In both studies a large share of participants was favourable to probability statements expressed quantitatively, with differences among professions. The public/media and NGO groups ranked them slightly more helpful for understanding risk than qualitative expressions, while political participants were more balanced between the two. In the focus group studies the industry group opposed use of such information but one third ranked them highest in the online survey (also about one-third of risk assessors in both studies). By language, the French, Spanish and Greek groups ranked these statements most useful in the online survey.

The findings may support the use of quantitative probability statements about the uncertainties in communication aimed at the entry level audiences. Support for such an approach may be higher in languages/cultures more open to use of numerical expressions (e.g. French).

4.2.6.4. An approximate probability

In the focus groups the precise probability statement with a hedging word ('about') was clearly preferred to the approximate probability, with strong first preferences among the public, NGO and political decision-makers groups in particular. In the online survey, the approximate probability statements were not directly compared with precise probabilities.

4.2.7. Implications of the grey literature for the guidance

Recommendations about how to communicate uncertainty have been published by various institutions (IOM, 2013; Wardekker et al., 2013). The approaches taken in these documents differ considerably, however. Some of them provide a comprehensive literature review without concrete examples of how best to communicate uncertainty (e.g. IOM, 2013), others describe in a very practical way what needs to be taken into account when communicating uncertainty to the public without providing much evidence for the recommendations (Wardekker et al., 2013). Due to the fact that this grey literature does not report original research, these publications have not been included in the literature review. In the examples described in the present document, insights from the grey literature have been taken into account when necessary, and in section 4.1.5. on the implications of the scientific literature for the guidance, the differences and the commonalities between the present document and guidelines from other institutions are discussed.

4.3. EFSA examples used to further develop the recommendations

The insights from the scientific literature and the findings of EFSA's research provided a starting point for proposed recommendations and strategies. These were applied and tested on real examples from EFSA scientific assessments to draft messages and select visual aids for communicating the related uncertainties. The effective application of the proposed recommendations strengthened the case for including them among EFSA's guidance in Section 3 of the Communications GD. Obstacles encountered by the authors in applying the proposed recommendations to the examples led them to consider additional factors (e.g. cognitive biases) and the development of alternative strategies for message development, choice of content formats and possible use of visuals.

The selection of examples aimed to provide a representative view of the different types of EFSA's assessments (e.g. food safety, animal and plant health, chemical, biological) and also to provide examples of all eight types of uncertainty expressions explained in Section 2. Table 6 lists the examples. It is important to note that the choice of EFSA scientific assessments for this exercise was limited since at the time of writing only a few of them had been developed according to approaches and methods required by the Uncertainty GD. A smaller number of older assessments were also available but in many cases the uncertainty information they contain and the way that information is presented is not fully in line with the requirements of the Uncertainty GD. Once applying the Uncertainty GD becomes the norm for EFSA's scientific assessments, further appraisal of the Communication GD is planned.

Table 6: Selected EFSA scientific assessments used as examples

Expressions of uncertainty	EFSA scientific assessments used as examples
No expression of uncertainty	Zearalenone in feed (EFSA CONTAM Panel, 2017)
Description of a source of uncertainty	Zearalenone in feed (EFSA CONTAM Panel, 2017)
Qualitative descriptions of the direction and/or magnitude of uncertainty	Zearalenone in feed (EFSA CONTAM Panel, 2017)
Inconclusive assessment	Zearalenone in feed (EFSA CONTAM Panel, 2017)
A precise probability	Nematodes 2017 (EFSA PLH Panel, 2017)
An approximate probability	Animal welfare aspects in respect of the slaughter or killing of pregnant livestock animals (AHAW Panel, 2017) Listeria monocytogenes in RTE foods (EFSA BIOHAZ Panel, 2017)
A probability distribution	Animal welfare aspects in respect of the slaughter or killing of pregnant livestock animals (prevalence) (AHAW Panel, 2017) Nematodes 2017 (EFSA PLH Panel, 2017)
A two-dimensional probability distribution	IESTI Opinion (EFSA PPR Panel, 2007)

The authors provided expertise in scientific assessment, social sciences and communications. This expertise was used to analyse the above examples and develop communications for each one. The process involved: extraction of the salient information from the assessments (EFSA's scientific opinions) including conclusions on risk, types of effects, affected populations and foods/feed, and type of uncertainty analysis. Different questions were applied, e.g. what is the central estimate? do the assessors use words or numbers to describe probabilities about the uncertainties. Messages for different target audience levels were then developed and requirements for further information (e.g. visual aids, FAQs). These results then provided the basis for feedback to assessors to make them aware of how best to support effective communication by including the required information in their assessments.

The most critical outputs from this exercise are the examples of messages, descriptions and visual aids and the resulting guidance, which in some cases – particularly where the academic literature is weak or missing – are derived solely from this process. For the purpose of transparency, the table in Appendix B indicates which evidence source formed the basis for each point of guidance.

5. Further research needs

Communication of uncertainties is a challenge, and even researchers often incorrectly interpret confidence intervals or other measures of uncertainties, for example (Greenland et al., 2016). Even more difficult is the communication of uncertainties to lay people or non-scientists. The present literature review shows that how uncertainties should be conveyed to enable non-scientists to make informed decisions is still an under researched field. In the medical field, some knowledge has been accumulated regarding the best approach to best communicate risks (e.g. the risk of having cancer given a positive test result) (Gigerenzer et al, 2007). In these studies frequentist probabilities were communicated, and these formats are often not adequate for the communication of subjective probabilities.

- There is a clear lack of research that focused on the communication of subjective probabilities. Future research should address the question how various subjective probabilities should be communicated to lay people so that they understand the information.
- Good evidence on how subjective probabilities should be communicated is scarce. Future research should examine how well participants understand the uncertainty communication and whether various communication formats result in different decisions. More specifically, it is important to test which formats are best understood and how they influence the decision-making process.
- Most of the research reviewed related to lay people's understanding of uncertainty communication used in a rather limited way for evaluating various communication formats. In some studies participants had to read out values from graphs, for example. Such research provides hardly any information about the effectiveness of communication formats.
- Another important question that needs to be addressed in future research is whether prior attitudes towards hazards or trust in the communicator interact with the acceptance of uncertainty information.
- Future research should also include decision makers in the risk management domain, because these stakeholders may come to different conclusions depending on how uncertainty is communicated.
- Finally, much of the research has examined convenience samples therefore future research efforts should follow more structured approaches, e.g. random sampling.

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Glossary

Ambiguity	The quality of being open to more than one interpretation. A type or cause of uncertainty that may apply for example to questions for assessment, evidence, models or concepts, and assessment conclusions.
Approximate probability	Any range or bound for a probability. This includes but is not limited to the ranges that are used in the approximate probability scale (q.v.).
Approximate probability scale	A set of approximate probabilities with accompanying verbal probability terms, shown in Section 12.3 of the EFSA Uncertainty Guidance Document (EFSA Scientific Committee et al., 2018a) and recommended for harmonised use in EFSA scientific assessments.
Assessor	A person conducting a scientific assessment and/or uncertainty analysis.
APS	Acronym for approximate probability scale (q.v.)
Bayesian	A school of statistics that uses probability to quantify judgement regarding the likelihood of a particular range of a quantity, or the likelihood of a specified category (e.g. low/medium/high). See also the glossary entries for 'probability' and 'frequentist'.
Best estimate	Often used as a synonym for 'central estimate' in the literature (q.v.), but not recommended in this Guidance because the term 'best' has a normative content, as it implies a preference for a value, whereas 'central' just communicates the place of that value in a set of relevant values.
Box plot	A simple way of representing statistical data on a plot in which a rectangle is drawn to represent the second and third quartiles, usually with a line inside to indicate the median value. Lower and upper probability bounds are shown as lines ('the whiskers') outside the rectangle.
Characterising uncertainty	The process of making and expressing an evaluation of uncertainty either for an assessment as a whole or for a specified part of an assessment. Can be performed and expressed either qualitatively or quantitatively.
Central estimate	Descriptive term for a central value in a distribution, most commonly the arithmetic mean, the geometric mean, the median or the mode. Which is used depends on the shape of the distribution, and should be specified.
Certainty	Used in this document as a synonym for probability (when the probability is over 50%), to facilitate communication when appropriate. For example, 90% probability of X would be communicated as 90% certainty of X. See Annex X for explanation.
Confidence (confidence level/ confidence interval)	Levels of confidence (e.g. high, low) are often used to express the probability that a conclusion is correct. In frequentist statistics, a confidence interval is a range that would include the true value of the parameter to be estimated in a specified proportion of occasions (the confidence level) if the experiment and/or statistical analysis that produced the range was repeated an infinite number of times.

Decision-maker	A person with responsibility for making decisions; in the context of this document, a person making decisions informed by EFSA's scientific advice. Includes risk managers but also people making decisions on other issues, e.g. health benefits, efficacy, etc.
Description of sources of uncertainty	Verbal description of the nature or causes of sources of uncertainty
Distribution	A probability distribution is a mathematical function that relates probabilities with specified intervals of a continuous quantity or values of a discrete quantity. Applicable both to random variables and uncertain parameters.
Expert judgement	The judgement of a person with relevant knowledge or skills for making that judgement.
Expert knowledge elicitation (EKE)	A systematic, documented and reviewable process to retrieve expert judgements from a group of experts, often in the form of a probability distribution.
Expression of uncertainty	A verbal or numerical statement that characterises uncertainty associated with the outcome of scientific assessments. In this document is used to refer to any characterisation of the source, direction or magnitude of uncertainty, which may include words, numbers or graphics or any combination of these.
Frequency	The number of occurrences of something, expressed either as the absolute number or as a proportion or percentage of a larger population (which should be specified).
Frequentist	A school of statistics that uses probability to quantify the frequency with which sampled values arise within a specified range of a quantity or for a specified category (e.g. low/medium/high). See also the glossary entries for 'probability' and 'Bayesian'.
Hedging	Words used to limit or qualify (something) by conditions or exceptions, e.g. 'about', 'approximately', 'nearly', etc.
Inconclusive assessment	Used in this document to refer to two types of situation: 1) an assessment where an unqualified conclusion is required by legislators or risk managers, but the assessment does not reach the level of certainty regarded as necessary for that (see section 3.5 of EFSA 2018b); 2) an assessment where assessors are unable to give a probability or approximate probability for any possible answers to the assessment question, and therefore no conclusion can be drawn.
Lay people/ layperson	In this document: People who are not professionally involved in uncertainty assessment, scientific assessment or science communication.
Likelihood	In everyday language, refers to the chance or probability of a specific event occurring: generally replaced with 'probability' in this document. In statistics, maximum likelihood estimation is one option for obtaining confidence intervals.
Lower bound	Lower value of a range, e.g. a range of probabilities

Non-standard uncertainties	Any deviations from a standardised assessment procedure or standardised assessment element that lead to uncertainty regarding the result of the assessment. For example, studies that deviate from the standard guidelines or are poorly reported, cases where there is doubt about the applicability of default values, or the use of non-standard or 'higher tier' studies that are not part of the standard procedure.
Numeracy	A person's ability to understand and process numerical concepts
Ordinal scale	A scale of measurement comprised of ordered categories (e.g. low/medium/high), where the magnitude of the difference between categories is not quantified.
Overall uncertainty	The assessors' uncertainty about the question or quantity of interest at the time of reporting, taking account of the combined effect of all sources of uncertainty identified by the assessors as being relevant to the assessment.
Point estimate	Used in this document to refer to a single value that is used by assessors as an estimate for an uncertain quantity. Also called point probability. Synonym of precise probability.
Plain language	Clear, straightforward expression, using only as many words as are necessary and avoiding obscure or inflated vocabulary, technical or scientific terms, and convoluted construction.
Precise probability	Probability expressed as a single number, as opposed to a range of probabilities.
Probabilistic	(1) Representation of uncertainty and/or variability using probability distributions. (2) Calculations where one or more inputs are probability distributions and repeated calculations give different answers. Related term: deterministic.
Probability	Defined depending on philosophical perspective: 1) from a frequentist perspective, the frequency with which sampled values arise within a specified range of a quantity or for a specified category (e.g. low/medium/high); 2) from a Bayesian perspective, quantification of judgement regarding the likelihood of a particular range or category.
Probability range	The upper and lower bound for an approximate probability. .
Probability judgement	A probability, approximate probability or probability bound obtained by expert judgement.
Qualitative assessment	Sometimes refers to the form in which the conclusion of an assessment is expressed (e.g. a verbal response to a question of interest), or to the methods used to reach the conclusion (not involving calculations), or both.
Qualitative conclusion	Used in this document to refer to an assessment conclusion that refers to something (e.g. an outcome, condition or mechanism) that is described in words, and not quantified.
Qualitative expression of uncertainty	Expression of uncertainty using words or ordinal scales.

Qualitative description of the direction and/or magnitude of uncertainty	Verbal description of how large the overall uncertainty or the single uncertainties are and how this impacts the outcome of the scientific assessment
Quantitative estimate	The result of assessing an uncertain quantity, expressed numerically (e.g., a bound, range or distribution).
Quantitative expression of uncertainty	Expression of uncertainty using numeric measures of the range and relative likelihood of alternative answers or values for a question or quantity of interest.
Quantity	A property or characteristic having a numerical scale.
Range	Two numbers (an upper and lower bound) used to specify an inclusive set of values for an uncertain or variable quantity, or for an approximate probability.
Risk communication	The interactive exchange of information and opinions throughout the risk analysis process as regards hazards and risks, risk-related factors and risk perceptions, among assessors, risk managers, consumers, feed and food businesses, the academic community and other interested parties, including the explanation of scientific assessment findings and the basis of risk management decisions.
Risk perception	Lay people's subjective or intuitive risk judgement to evaluate hazards.
Risk manager	A type of decision-maker, responsible for making risk management judgements.
Scientific assessment	The process of using scientific evidence and reasoning to answer a question or estimate a quantity.
Sensitivity analysis	A study of how the variation in the outputs of a model can be attributed to, qualitatively or quantitatively, different sources of uncertainty or variability. Implemented by observing how model output changes when model inputs are changed in a structured way.
Source of uncertainty	Defined by EFSA (2018a) as an individual contribution to uncertainty, defined by its location (e.g. a component of the assessment) and its type (e.g. measurement uncertainty, sampling uncertainty). Used in this document more informally, to refer to any distinct cause of uncertainty.
Standard outcome	The conclusion of a standardised assessment procedure (q.v.), expressed in a standardised way (e.g. no concern, safe, etc.).
Standard uncertainties	Sources of uncertainty that are considered (implicitly or explicitly) to be addressed by the provisions of a standardised procedure or standardised assessment element. For example, uncertainties due to within and between species differences in toxicity are often addressed by a default factor of 100 in chemical risk assessment.
Standardised assessment	An assessment that follows a standardised procedure (q.v.).

Standardised procedure	A procedure that specifies every step of assessment for a specified class or products or problems, and is accepted by assessors and decision-makers as providing an appropriate basis for decision-making. Often (but not only) used in scientific assessments for regulated products.
Subjective probability	Quantification of judgement regarding the likelihood of a specified category or a specified range of a quantity. This is the Bayesian concept of probability (q.v.), which is used in EFSA's guidance on uncertainty analysis (see section 5.10 in EFSA Scientific Committee et al., 2018a).
True value	The actual value that would be obtained with perfect measuring instruments and without committing any error of any type, both in collecting the primary data and in carrying out mathematical operations. (OECD Glossary of Statistical Terms, https://stats.oecd.org/glossary/detail.asp?ID=4557)
Uncertainty	In this document, uncertainty is used as a general term referring to all types of limitations in available knowledge that affect the range and probability of possible answers to an assessment question. Available knowledge refers here to the knowledge (evidence, data, etc.) available to assessors at the time the assessment is conducted and within the time and resources agreed for the assessment. Sometimes 'uncertainty' is used to refer to a source of uncertainty (see separate definition), and sometimes to its impact on the conclusion of an assessment.
Uncertainty analysis	The process of identifying and characterising uncertainty about questions of interest and/or quantities of interest in a scientific assessment.
Unqualified conclusion / No expression of uncertainty	A conclusion that is not presented together with the associated uncertainty, because the respective regulation or risk managers require a yes/no decision (see section 3.5 of EFSA Scientific Committee et al., 2018b).
Unquantified uncertainty	An identified source of uncertainty in a scientific assessment that the assessors are unable to include, or choose not to include, in a quantitative expression of overall uncertainty for that assessment.
Variability	Heterogeneity of values over time, space or different members of a population, including stochastic variability and controllable variability (e.g. body weight measured in different individuals in a population, or in the same individual at different points in time).
Weight of evidence assessment	A process in which evidence is integrated to determine the relative support for possible answers to a scientific question.
Upper bound	Upper value of a range, e.g. a range of probabilities

Appendix A – Literature search strategy

A.1. Uncertainty communication searches

A.1.1. Sources of information

Web of Science (WoS) Core Collection (Web of Science platform):

- Science Citation Index Expanded (SCI-EXPANDED) --1975-present
- Social Sciences Citation Index (SSCI) --1975-present
- Arts & Humanities Citation Index (A&HCI) --1975-present
- Conference Proceedings Citation Index- Science (CPCI-S) --1990-present
- Conference Proceedings Citation Index- Social Science & Humanities (CPCI-SSH) --1990-present
- Book Citation Index– Science (BKCI-S) --2005-present
- Book Citation Index– Social Sciences & Humanities (BKCI-SSH) --2005-present
- Emerging Sources Citation Index (ESCI) --2015-present
- Current Chemical Reactions (CCR-EXPANDED) --1985-present
- Index Chemicus (IC) --1993-present

Scopus (Scopus platform) – inception-present

A.1.2. Search strategies

A.1.2.1. Search structure

TOPIC: Communication terms **AND** TOPIC: Audience types terms **AND** TITLE: (Action terms **AND** Uncertainty terms) **OR TOPIC**: Communication terms AND **TOPIC**: Audience types terms **AND** TITLE: (Action terms AND Credibility terms)

A.1.2.2. Search strings

Web of Science Core Collection

Date of the search 06/09/2017

Limits: no date, language or type of publications limits applied

Set	Query	Results
# 4	#2 OR #1 Refined by: [excluding] DOCUMENT TYPES: (LETTER OR EDITORIAL MATERIAL) Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC Timespan=All years	851
# 3	#2 OR #1 Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC Timespan=All years	867
# 2	TS=(Perceiv* OR Percept* OR Communicat*) AND TS=(Expert* OR Science OR Scientist* OR Decisionmaker* OR 'Decision maker*' OR 'Policy maker*' OR Policymaker* OR Public OR Citizen* OR People OR Stakeholder*) AND TI=((Perceiv* OR Percept* OR Understand* OR Manag* OR Handl* OR Gain* OR Lose OR Losing OR Increas* OR Decreas* OR Damag*) AND (Trustworthin* OR Credibilit*)) Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC Timespan=All years	134
# 1	TS=(Perceiv* OR Percept* OR Communicat*) AND TS=('Lay' OR Layperson* OR 'Lay person*' OR Consumer* OR Patient* OR Decisionmaker* OR 'Decision maker*' OR 'Policy maker*' OR Policymaker* OR Public OR Citizen* OR People* OR Stakeholder*) AND	734

Set	Query	Results
	TI=((Empiric* OR Interpret* OR Express* OR Describ* OR Present* OR Perceiv* OR Percept* OR Understand* OR Explor* OR Frame OR Framing OR Cope OR Coping OR Inform* OR Conceptuali* OR Manag* OR Handl* OR Reasoning OR Prefer* OR Communicat* OR Visuali* OR Decision* OR Decid*) AND (Uncertain* OR Probabil* OR Ignoranc* OR 'lack of knowledge' OR Doubt*)) Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC Timespan=All years	

Scopus

Date of the search 06/09/2017

Limits: no date, language or type of publications limits applied

Set	Query	Results
4	(TITLE-ABS-KEY (perceiv* OR percept* OR communicat*) AND TITLE-ABS-KEY (lay OR layperson* OR 'Lay person*' OR consumer* OR patient* OR decisionmaker* OR 'Decision maker*' OR 'Policy maker*' OR policymaker* OR public OR citizen* OR people* OR stakeholder*) AND TITLE ((empiric* OR interpret* OR express* OR describ* OR present* OR perceiv* OR percept* OR understand* OR explor* OR frame OR framing OR cope OR coping OR inform* OR conceptuali* OR manag* OR handl* OR reasoning OR prefer* OR communicat* OR visuali* OR decision* OR decid*) AND (uncertain* OR probabil* OR ignoranc* OR 'lack of knowledge' OR doubt*))) OR (TITLE-ABS-KEY (perceiv* OR percept* OR communicat*) AND TITLE-ABS-KEY (expert* OR science OR scientist* OR decisionmaker* OR 'Decision maker*' OR 'Policy maker*' OR policymaker* OR public OR citizen* OR people OR stakeholder*) AND TITLE ((perceiv* OR percept* OR understand* OR manag* OR handl* OR gain* OR lose OR losing OR increas* OR decreas* OR damag*) AND (trustworthin* OR credibilit*))) AND (EXCLUDE (DOCTYPE , 'le') OR EXCLUDE (DOCTYPE , 'ed'))	1,195 document results
3	(TITLE-ABS-KEY (perceiv* OR percept* OR communicat*) AND TITLE-ABS-KEY (lay OR layperson* OR 'Lay person*' OR consumer* OR patient* OR decisionmaker* OR 'Decision maker*' OR 'Policy maker*' OR policymaker* OR public OR citizen* OR people* OR stakeholder*) AND TITLE ((empiric* OR interpret* OR express* OR describ* OR present* OR perceiv* OR percept* OR understand* OR explor* OR frame OR framing OR cope OR coping OR inform* OR conceptuali* OR manag* OR handl* OR reasoning OR prefer* OR communicat* OR visuali* OR decision* OR decid*) AND (uncertain* OR probabil* OR ignoranc* OR 'lack of knowledge' OR doubt*))) OR (TITLE-ABS-KEY (perceiv* OR percept* OR communicat*) AND TITLE-ABS-KEY (expert* OR science OR scientist* OR decisionmaker* OR 'Decision maker*' OR 'Policy maker*' OR policymaker* OR public OR citizen* OR people OR stakeholder*) AND TITLE ((perceiv* OR percept* OR understand* OR manag* OR handl* OR gain* OR lose OR losing OR increas* OR decreas* OR damag*) AND (trustworthin* OR credibilit*)))	1,201 document results
2	TITLE-ABS-KEY (perceiv* OR percept* OR communicat*) AND TITLE-ABS-KEY (expert* OR science OR scientist* OR decisionmaker* OR 'Decision maker*' OR 'Policy maker*' OR policymaker* OR public OR citizen* OR people OR stakeholder*) AND TITLE ((perceiv* OR percept* OR understand* OR manag* OR handl* OR gain* OR lose OR losing OR increas* OR decreas* OR damag*) AND (trustworthin* OR credibilit*))	230 document results
1	TITLE-ABS-KEY (perceiv* OR percept* OR communicat*) AND TITLE-ABS-KEY (lay OR layperson* OR 'Lay	972 document

Set	Query	Results
	person*' OR consumer* OR patient* OR decisionmaker* OR 'Decision maker*' OR 'Policy maker*' OR policymaker* OR public OR citizen* OR people* OR stakeholder*) AND TITLE ((empiric* OR interpret* OR express* OR describ* OR present* OR perceiv* OR percept* OR understand* OR explor* OR frame OR framing OR cope OR coping OR inform* OR conceptuali* OR manag* OR handl* OR reasoning OR prefer* OR c ommunicat* OR visuali* OR decision* OR decid*) AND (uncertain* OR probabil* OR ignoranc* OR 'lack of knowledge' OR doubt*))	results

Final number of results after first de-duplication: 1353

Appendix B – Summary table mapping evidence found in the literature with the guidance

This Guidance is based as far as possible on the evidence sources described in Section 4. The available evidence does not, however, address every aspect of communicating uncertainty, so some guidance is based partly or wholly on expert judgement and reasoning. The guidance proposed was also tested and refined, and then further elaborated by applying it to concrete EFSA examples, which are listed in Section 4.4. For transparency, the basis for each recommendation is summarised in the table below.

Guidance	**Evidence/reasoning**
General guidance	
Context	Reasoning: Minimises ambiguity about what has been assessed and what conditions and outcome the scientific conclusion and uncertainty relate to, which is essential for the information to be understood.
Describing uncertainty with words	Reasoning: To be understood, a meaningful and unambiguous metric is needed for expressing the magnitude of uncertainty. This requirement is met by probability but not by other quantitative or qualitative means of expressing uncertainty. Furthermore, it is well-established that verbal expressions of probability (e.g. likely) are ambiguous and interpreted by different people in widely different ways. Evidence: See EFSA (2018) for further discussion and evidence on these points.
Describing uncertainty with numbers (1)	Evidence: Several studies have shown that people perform poorly at inferring central estimates from graphical representations of distributions (e.g. Ibrekk and Morgan, 1987).
Describing uncertainty with numbers (2)	Evidence and reasoning: Several studies provide evidence that, when uncertainty is represented by a range, people tend to focus on one or other end of the range (Dieckmann et al., 2015, 2017), Johnson and Slovic, 1998, Viscusi et al.,1991). It seems likely that this results not from misunderstanding of the range (which is a primary concern in this guidance) but from subsequent interpretation and value judgements by the recipient (e.g. choosing to be precautionary), which are outside EFSA's remit. Nevertheless, it seems appropriate to communicate both a central estimate and range, and to distinguish clearly between them, because this indicates which part of the range is most likely (except in rare cases, where the underlying distribution is multimodal) and provides more understanding for the recipients.
Describing uncertainty with numbers (3)	Reasoning: The term best has a normative content, as it embeds already a preference for a value, whereas 'central' just communicates the place of that value in a set of relevant values.
Describing uncertainty with numbers (4)	Reasoning: This is a generally-accepted principle in science, to avoid implying more precision than is justified.
Describing uncertainty with numbers (5)	Evidence: Hedging is understood in different ways by different users, with important inter-individual variation and overlap. Furthermore, their use is modulated by context, including the magnitude of the number, its roundness and even its units (Ferson et al., 2015).

Guidance	Evidence/reasoning
Describing uncertainty with numbers (6)	Reasoning for indicating a probability: When a range is given on its own, the probability for it is ambiguous and could in principle be anything, although it is usually implicit that it is at least possible the value lies in the range (probability greater than zero). To avoid ambiguity the probability must be indicated. Evidence and reasoning for indicating the shape of distribution: Several studies provide evidence that, when a range is given, people tend to focus on one or other end of the range (Dieckmann et al. (2015, 2017), Johnson and Slovic (1998), Viscusi et al. (1991)). While there are various possible reasons for this (see above), it seems prudent to communicate at least some indication of which part of the range is more likely, and more detail if this is needed for adequate understanding.
Describing uncertainty with numbers (7)	Reasoning: Because both probabilities and percentages can be used to express other things as well as uncertainty, there is potential for misunderstanding. To avoid this, it is proposed to refer to '% certainty'. This also provides a positive framing (certainty rather than uncertainty), which some prefer. This approach could be misleading for low probabilities (5% certain sounds low but is actually 95% certainty of non-occurrence), so it is suggested to communicate low probabilities as their complement (e.g. 10% probability of X is communicated as 90% probability of not X).
Describing uncertainty with numbers (8)	Reasoning: Referring to % certainty about an outcome that is expressed in % (e.g. % of people affected) may cause confusion for some readers.
Describing uncertainty with numbers (9)	Reasoning and evidence: The risk of this type of misinterpretation has been raised by EFSA experts and others on several occasions and instances of it were observed during the trial period for EFSA's Uncertainty GD.
Describing uncertainty with numbers (10)	Reasoning: It is important to distinguish between variability and uncertainty because variability is a property of the real world that may be altered by risk management action, while uncertainty refers to limitations in human knowledge of the world and may be reduced by gathering additional information (see EFSA 2018b).
Describing uncertainty with numbers (11)	Reasoning: It is essential to provide explanation and background on the concept of uncertainty and the methods used for expressing it, and of any unavoidable technical terms. Providing this in the form of general FAQs on EFSA's website avoids repeating the same information in every communication, and the risk of inconsistency that would arise from that.
Describing the most important uncertainties	Evidence: Many publications emphasise the importance of specifying the sources of uncertainty and/or describing their nature (Budescu et al., 2009; also based on Kuhn, 2000; Maxim et al., 2012; Maxim and Mansier, 2014; Visschers, 2017; Wardekker et al., 2008). Also, people's response to uncertainty depends in part on what caused the uncertainty (Frewer et al. 2002, Miles and Frewer 2011).

Guidance	Evidence/reasoning
Addressing the uncertainties (1 and 2)	Evidence and reasoning: Frewer et al. (2002) found that uncertainty associated with the scientific process was more readily accepted than uncertainty due to lack of action of the government. This suggests that communication of uncertainty is less likely to cause public alarm if it is accompanied by information on what actions are being taken by the relevant authorities to address that uncertainty. While such actions are risk management measures and are therefore outside the remit of EFSA, as is current practice, such communication may take place if done in coordination with decision-makers (e.g. the European Commission).
Addressing the uncertainties (3)	Evidence and reasoning: Frewer et al. (2002) found that uncertainty associated with the scientific process was more readily accepted than uncertainty due to lack of action of the government. Investigations aimed at reducing uncertainty are one type of action that can be taken. However, it is important to make distinguish actions that have already been decided on (e.g. in areas where EFSA has the authority to set data requirements) and those which are options for risk managers to consider.
Overall	Reasoning: It is essential for transparency and consistency that all parts of the communication should convey the same message.
General recommendations for assessors (1)	Reasoning: This is necessary to ensure communicators can interpret correctly what the scientific conclusion refers to and convey this correctly in their communications.
General recommendations for assessors (2)	Reasoning: When a range is given on its own, the probability for it is ambiguous and could in principle be anything, although it is usually implicit that it is at least possible the value lies in the range (probability greater than zero). To avoid ambiguity the probability must be indicated.
General recommendations for assessors (3)	Reasoning: This is desirable because it requires assessors to draft an expression of the uncertainty that is concise enough to serve as a starting point for crafting communications, without the communicators having to interpret it (and potentially misinterpret it) from more detailed technical material. It also makes the information more accessible to the communicators.
Specific guidance	
Assessments using standard procedures Box 1	Reasoning: Standardised procedures usually have standard language for expressing their conclusions (e.g. no concern), which should be used also in communications. If there is a requirement for conclusions to be unqualified then this should be respected by both assessors and communicators. Reasoning: If there is not a requirement for the conclusion to be unqualified then any information about uncertainty that is provided by the assessors may optionally be included in the communication, following the recommendations applicable to the forms of expression involved.

Guidance	Evidence/reasoning
Descriptions of sources of uncertainty Box 2	Evidence: Many publications emphasise the importance of specifying the sources of uncertainty and/or describing their nature (Budescu et al., 2009; also based on Kuhn, 2000; Maxim et al., 2012; Maxim and Mansier, 2014; Visschers, 2017; Wardekker et al., 2008). Also, people's response to uncertainty depends in part on what caused the uncertainty (Frewer et al. 2002, Miles and Frewer 2011).
Qualitative description of the magnitude or impact of uncertainty Box 3	Reasoning: This form of expression is discouraged by the Uncertainty GD due to its ambiguity. If the assessors have nevertheless used such expressions, then it is important that the communicators avoid rewording them in ways that the assessors would consider incompatible with their judgement of the uncertainty. It seems likely that the informed level audience would like to receive some description of the uncertainties that contribute to the qualitatively described magnitude, and how they were assessed. Evidence: Findings from EFSA studies support the use of general qualitative statements on the direction of the uncertainties in communication aimed at the informed and technical audiences. The +/- table currently used in some EFSA assessments is considered helpful by some users, but limited or misleading by others including some users with high scientific literacy.
Inconclusive assessments Box 4	Reasoning: If the assessors were unable to make any conclusion then it is essential that the communication should reflect this clearly and not use any language that implies more is known. When there is this much uncertainty, it seems prudent to give some indication of the reasons for it at entry level as well as informed level. At the informed level it seems desirable to mention also any options that have been identified for reducing uncertainty.
Unqualified conclusions (no expression of uncertainty) Box 5	Most unqualified conclusions follow a standard wording which has special meaning and should therefore be retained in all communications. For transparency, the special meaning should be made explicit at the informed level. It seems likely that the informed audience may want to have access to a concise plain language explanation of how the conclusion was reached (evidence and methods), and of the types of uncertainty that are present, and to know that the latter were taken into account in reaching the conclusion.
A precise probability Box 6	Reasoning: For entry level, see reasoning for general recommendations. It seems likely that the informed audience may want to have access to a concise plain language explanation of how the conclusion was reached (evidence and methods), and of the types of uncertainty that are present; to know that the latter were taken into account in reaching the conclusion; and to have a plain language outline of how that was done. Evidence: the findings support the use of quantitative probability statements about the uncertainties in communication aimed at the entry level audiences, perhaps combined with a verbal expression to describe their impact on the risk assessment. Support for such an approach may be higher in languages/cultures more open to use of numerical expressions (e.g. French, EFSA studies).

Guidance	Evidence/reasoning
Approximate probability Box 7	Evidence: Many studies have shown that using verbal expressions to communicate approximate probabilities results in widely varying interpretations, and that this is reduced when the numeric range is presented alongside the verbal expression (Patt and Schrag, 2003; Patt and Dessai, 2005; Budescu et al., 2009; Harris and Corner, 2011; Budescu et al., 2012; Budescu et al., 2014; also based on Wallsten et al., 1986; Mosteller and Youtz, 1990). Reasoning: It is recommended to communicate the quantitative range of probabilities, because this expresses the assessors' conclusion without ambiguity. Although other options may be simpler (e.g. replacing 66-90% with 'likely' or 'about 80%'), and there was some indication from the EFSA studies that more subjects preferred them, they will be interpreted by different people in different ways. If a simpler option is used at the entry level, it is essential that the assessors' range of probabilities is provided at the informed level, so that the meaning is clear to those who read both. Reasoning: It seems likely that the informed audience may also want to have access to a concise plain language explanation of the basis for the approximate probability (evidence and methods), and of the types of uncertainty that were taken into account.
A probability distribution Box 8	Evidence and reasoning: A number of studies in the literature review compare alternative means for visual representations of probability distributions. In summary, boxplots appear to be best understood, though they only provide partial information about distribution shape. CDFs and PDFs provide more information but will be badly misinterpreted by some people. Therefore it is proposed to use only boxplots in communications except at the technical level, where the boxplot may be accompanied by a PDF and/or CDF if this is useful to communicate more information about distribution shape (PDF) or enable readers to read off additional quantiles (CDF); in all cases all graphics should be well-labelled and the key results should be marked on them. There is evidence that the choice of quantiles to report will influence how people respond (their perception of the uncertainty) but it is unclear whether this implies a failure to understand what is communicated or subsequent interpretation by the recipient. There is a trade-off between giving excessive weight to extreme values and understating the uncertainty. Also, it is unlikely to be prudent for EFSA to limit reporting to ranges that are expected not to contain the outcome in a substantial proportion of cases. Therefore, it is proposed in general to communicate the median together with both the 50% and 95% range (the latter because this is conventionally used in science). In addition to this, results for specific values or quantiles of interest when these are known.
Two-dimensional probability distribution Box 9	Reasoning: None of the selected studies examined the communication of 2D probability distributions, but it is expected that they will be less well understood than 1D distributions. Therefore it is proposed to focus communication for entry and informed levels on selected results extracted from the 2D distribution, and communicate quantiles for these numerically at entry level with the addition of boxplots at informed level. 2D distributions should be used only at the technical level, and then with great care and explanation.

Appendix C – EFSA studies design overview

EFSA commissioned a target audience research study in 2016 and carried out its own follow-up study in 2017 in preparation for this Communication GD. Both studies have limitations in their design and conduct which restrict their use. Nevertheless, used cautiously they are a rich source of insights and indications retrieved directly from the key target audiences of EFSA's communications: officials in the EU Institutions and EU Member States, civil society organisations, members of the public, the scientific community, media and food industry operators.

C.1. Focus group study (Etienne et al., 2018)

Evidence was collected from selected representatives of EFSA's key partners in the EU institutions and Member States and stakeholders, who completed a questionnaire individually then discussed their responses in five focus groups of 6-10 participants (39 in total). After seeing a one-page summary of a scientific assessment (based on an EFSA assessment of the natural toxins T-2 and HT-2), the participants were provided different information about the resulting uncertainties and asked to answer a series of questions. This took place during the written part of the test. They discussed the results in the subsequent Focus Group stage with a moderator.

The uncertainty information *statements* were as follows (A to G):

A. Sources of uncertainty taken into account by the EFSA scientists in their assessment of health risks posed by the sum of T-2 and HT-2 toxins in food.

Sources of uncertainty	Direction*
Uncertainties in the analytical measurement of T-2 and HT-2 in foods	+/-
Effect of food processing	+/-
Use of highest and lowest toxin level estimates in the exposure estimations	+/-
Limited data on exposure for infants	+/-
Limited data on exposure for vegetarians	+/-
No data on absorption, metabolism and elimination of T-2 and HT-2 toxins in humans	+/-
Lack of information on the contribution of the toxicity of HT-2 toxin and other metabolites to overall toxicity	+/-
Limited data on combined effects with other mycotoxins or other toxic substances in food	+/-

* the '+' and '-' signs indicate only in which direction uncertainty affects the risk assessment;
\+ = uncertainty with potential to cause over-estimation of exposure/risk;
\- = uncertainty with potential to cause underestimation of exposure/risk

B. Taking account of the uncertainties, EFSA's experts concluded that the risk assessment of human exposure to the sum of T-2 and HT-2 toxins is more likely to over- than under-estimate the risk.

C. Taking account of the uncertainties, EFSA's experts concluded that there is a more than 50% chance that the risk assessment of human exposure to the sum of T-2 and HT-2 toxins over-estimates the risk, and a less than 50% chance the risk is under-estimated.

D. Taking account of the uncertainties, EFSA's experts concluded that it is unlikely that exposure for the highest consuming toddlers exceeds the safe level. In other words, it is likely that exposure for the highest consuming toddlers is below the safe level.

E. Taking account of the uncertainties, EFSA's experts concluded that it is unlikely (10-33% probability) that exposure for the highest consuming toddler exceeds the safe level. In other words, it is likely (66-90% probability) that exposure for the highest consuming toddler is below the safe level.

F. Taking account of the uncertainties, EFSA's experts concluded that there is about 20% probability (1 in 5 chance) that exposure for the highest consuming toddler exceeds the safe level. In other words, there is about 80% probability (4 in 5 chance) that exposure for the highest consuming toddler is below the safe level.

G. Taking account of the uncertainties, EFSA's experts concluded that there is about 75% probability (3 in 4 chance) that the exposure for the highest consuming toddler is between 23 and 91 ng/kg b.w./day. In other words, there is about 25% probability (1 in 4 chance) that the exposure for the highest consuming toddler is either below 23 or above 91 ng/kg b.w./day.

The participants answered the following questions multiple times for each uncertainty statement, qualifying their answers (e.g. strongly agree, agree, disagree, strongly disagree). The full list of questions is available in the report (Etienne et al. 2018). An overview of the key questions follows below:

1. To what extent do you agree or not with the following statement: 'It is normal that scientific advice is subject to a degree of uncertainty'?
2. Having read the summary of EFSA's opinion, how much confidence do you have in EFSA to give you accurate information about the risk to human health posed by T-2 and HT-2?
3. Considering that additional piece of information, how likely do you think it is that any toddler will experience ill health caused by T-2 and HT-2?
4. How does this additional piece of information influence how much confidence you have in EFSA to give you accurate information about the risk to human health posed by T-2 and HT-2?
5. On a scale from 1 to 4 (1 = strongly agree; 4 = strongly disagree), please indicate whether you find this statement: Understandable; Informative; or Useful.

The participants were also asked to compare statements B and C (expressing effects of combined uncertainties on risk assessment), and also statements D, E and F (describing the uncertainties qualitatively and quantitatively) and to answer questions about their preferences among these statements.

C.2. Online survey study (EFSA, 2018)

The second study (EFSA, 2018) was undertaken to further test the initial findings with an increased sample size. The authors adapted materials from the first study and conducted an online survey in 6 EU languages. The survey was designed by EFSA staff/experts and run on the *EU Survey* platform hosted by the European Commission's DG DIGIT. EFSA and eight members of its Communication Experts Network, composed of communication representatives from the EU Member State food safety authorities, helped to translate and promote the survey, generating over 1,900 responses.

As with the Focus group study, the respondents were given a short text describing the risk assessment of a natural toxin found in cereals. They were then asked the following questions in relation to the information on the uncertainties:

1. The outcome of EFSA's uncertainty assessment for the natural toxin can be described in various ways. Here are three examples. Please rank the three additional sentences by how helpful they are for understanding the risk.
    A. EFSA's scientists said that, based on what we know, the assessment is more likely to over- than underestimate the risk for the most exposed group of consumers and therefore the actual risk is more likely to be lower than estimated.
    B. EFSA's scientists said that, based on what we know, it is likely that exposure of the most exposed group of consumers is within the safe level.
    C. EFSA's scientists said that, based on what we know, there is about an 80% chance that exposure of the most exposed group of consumers is within the safe level.

Depending which of the answers A, B or C they ranked highest they were then asked to consider the clarity of some alternative wordings of their first ranked statements.

2. Please rank these three expressions in order of the clarity of information.
   A. EFSA's scientists said that, based on what we know, the assessment is more likely to over- than underestimate the risk for the most exposed group of consumers and therefore the actual risk is more likely to be lower than estimated.
   B. EFSA's scientists said that, given the uncertainties, the assessment is more likely to over- than underestimate the risk for the most exposed group of consumers and therefore the actual risk is more likely to be lower than estimated.
   C. EFSA's scientists said that, based on what we know, there is a more than 50% chance that the assessment overestimates the risk for the most exposed group of consumers and therefore there is a more than 50% chance that the actual risk is lower than estimated.
3. Please rank these three expressions in order of the clarity of information.
   A. EFSA's scientists said that, based on what we know, it is likely that exposure of the most exposed group of consumers is within the safe level.
   B. EFSA's scientists said that, given the uncertainties, it is unlikely that exposure of the most exposed group of consumers exceeds the safe level.
   C. EFSA's scientists said that, based on what we know, it is likely (66-90% probability) that exposure of the most exposed group of consumers is within the safe level.
4. Please rank these three expressions in order of the clarity of information.
   A. EFSA's scientists said that, based on what we know, there is about an 80% chance that exposure of the most exposed group of consumers is within the safe level.
   B. EFSA's scientists said that, given the uncertainties, there is about a 20% chance that exposure of the most exposed group of consumers exceeds the safe level.
   C. EFSA's scientists said that, based on what we know, there is about a 4 in 5 chance that exposure of the most exposed group of consumers is within the safe level.

They were also asked how useful they thought their preferred form of uncertainty information was.

5. Regarding your selected top ranked uncertainty statement, please rate the usefulness of this information on uncertainties: [Please select one answer only]
   - Essential (must always be mentioned)
   - Important (should be mentioned)
   - Helpful (nice to have)
   - Unnecessary (should only be mentioned on request)
   - Unhelpful (should never be mentioned)

Other questions asked at the beginning and end of the survey provided information about professional/geographical background, the wish for further information (e.g. about the hazard, about the risk assessment) to provide a more detailed indication of the profiles of respondents.