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Trends in
Cognitive Sciences

Review

Communicating uncertainty using words and numbers

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Life in an increasingly information-rich but highly uncertain world calls for an effective means of communicating uncertainty to a range of audiences. Senders prefer to convey uncertainty using verbal (e.g., *likely*) rather than numeric (e.g., 75% chance) probabilities, even in consequential domains, such as climate science. However, verbal probabilities can convey something other than uncertainty, and senders may exploit this. For instance, senders can maintain credibility after making erroneous predictions. While verbal probabilities afford ease of expression, they can be easily misunderstood, and the potential for miscommunication is not effectively mitigated by assigning (imprecise) numeric probabilities to words. When making consequential decisions, recipients prefer (precise) numeric probabilities.

Highlights

The (positive and negative) directionality of verbal probabilities enables them to convey more than uncertainty. Probability terms can communicate uncertainty in a face-saving manner and implicitly shape receivers' cognitions and behavior.

Verbal probabilities preclude fine-grained uncertainty communication. Assigning numeric probability ranges to words does not eliminate their imprecise and variable meaning, but can have unintended effects on judgment and decision-making.

Senders are misplaced in their belief that verbal expressions of uncertainty are especially helpful for those with lower numeracy and in thinking that these individuals cannot benefit from numeric probability information.

The benefits of precise numeric expressions of uncertainty, coupled with receivers' preference for numeric information when it really matters, suggests that senders ought to embrace numeric precision over vague words if they wish to communicate uncertainty clearly.

Uncertain times call for effective uncertainty communication

Citizens and policymakers alike depend on information characterized by uncertainty to be informed and make decisions (Box 1). Many pressing problems facing humanity, from climate change to global pandemics, are characterized by deep uncertainties about the nature of the problem and the efficacy of proposed solutions [1]. The format in which these uncertainties are communicated, numerically or non-numerically (e.g., verbally), can affect how well they are understood and how they influence cognition and behavior. Numeric representations of uncertainty include percentages, decimals, ratios, and fractions. Numeric information can be expressed precisely (e.g., 75% chance), imprecisely (e.g., 65–85%), or with features of both (e.g., 75 ±10%). Common non-numeric representations include probability terms (e.g., *likely*) as well as words such as *slight hope* [2]. These natural language expressions may be used with modifiers (e.g., *very*) and hedges (e.g., *almost*) [3,4].

Senders often prefer to communicate uncertainty verbally [5] (Box 2). Indeed, people find it easier and more natural to use words than numbers [6]. The language system is learned earlier than the numeric system during individual development, and words are a more dominant mode of human communication than are numbers. However, research suggests that verbal probabilities do not fare well in expressing uncertainty unambiguously [7–9]. Additionally, terms may communicate information that goes beyond strict degrees of probability [10–12], raising concerns for their use in uncertainty communication. Senders and receivers may be unaware of miscommunication, given that their judgments of communicative success are unrelated to actual communicative success [13].

Here, we review the latest evidence on communicating uncertainty using verbal probabilities. We assess studies on the effectiveness of verbal probabilities in expressing uncertainty clearly. We also consider research on the benefits and drawbacks of combining words with numeric probabilities to make their intended meaning more transparent. The empirical evidence deals with both basic and applied problems and spans several domains, including climate science, intelligence

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 https://doi.org/10.1016/j.tics.2022.03.002

Box 1. Defining uncertainty

Recent reviews focus on applied domains [87,89–93] or specific readerships [94], while others consider the context of communication [95]. Researchers use the terms *uncertainty*, *risk,* and *probability* interchangeably (e.g., [19,72]) and so do previous reviews (e.g., [21]). In Boolean logic, propositions can be either true or false and there is no place for uncertainty. Past, present, and future events can all have uncertainty associated with them. Prominent examples of uncertainty around past events include criminal case investigations and prosecutions, uncertainty around present events includes medical diagnoses, and around future events includes climate change and national security threats.

Formally, extensions to three-valued logics included uncertainty such that possible states could be true, false, or unsure [96]. Probability allows degrees of certainty in the truth or falsity of a proposition to be scaled (from 0 to 1), adding the ability to quantify degrees of uncertainty. Knight made an important distinction between risk and uncertainty: situations in which the probabilities of propositions (often possible gains or losses) were specifiable were referred to as *risk* and situations in which the probabilities were not specifiable were called *uncertainty* [97]. Since risk has other connotations associated with it, such as possible loss, and because it can be conceived as the quantifiable subset of uncertainty, we use the term *uncertainty* to refer to any situation in which degrees of unsureness are communicated. However, we restrict the scope of our review to what traditionally falls under the category of Knightian risk; namely, the communication of probabilities that are assumed to be translatable into quantitative equivalents, even if communicated in nonquantitative formats (e.g., with words). These non-numeric equivalents can be assumed to be precise (e.g., translatable to 70% chance) or imprecise (e.g., translatable to 60–80% chance), but they are nonetheless assumed to be quantifiable (see Figure 1 in the main text).

Within this scope, the bases for quantifiable probability communications are varied. Such communication might originate in objective or external sources, such as a base rate of event occurrence. Alternatively, it might originate in subjective or internal sources, such as an individual's feeling of sureness (or *confidence*) that they answered a question correctly [98,99]. Internal uncertainty tends to be conveyed in first-person (e.g., 'I am X% certain…'), whereas external uncertainty is conveyed in third-person ('there is an X% chance…') [100]. Although we acknowledge these and other distinctions [63], our review of the literature cuts across them. Additionally, we focus on the communication of different levels of uncertainty, rather than simply on the communication of certain (deterministic) outcomes versus uncertain ones (e.g., [101–103]).

analysis, law, and medicine, with a compatible pattern of findings. The present review should be of interest to those seeking to broaden and deepen their understanding of uncertainty communication as well as those scoping potential solutions to communicating uncertainty.

Box 2. Communication mode preference paradox

An individual's role in the communication process (i.e., sender/receiver) influences their preferred format for communicating uncertainty. Early research revealed a 'preference paradox', namely that, while most senders prefer to convey uncertainty verbally, most recipients prefer numeric uncertainty information [5,104].

Although recent research demonstrates senders' preferences for verbal probabilities in domains such as medicine [105], extreme weather forecasting [33], and intelligence analysis [106–108], such preferences depend on specific factors. One is the nature of the uncertainty being communicated (e.g., lack of knowledge versus variation in the outcome being predicted). Epistemic and dispositional uncertainty are more likely to be conveyed using words, whereas distributional (aleatory) uncertainty is more likely to be expressed numerically [31]. Another influential factor is the severity of the predicted outcome. For instance, physicians' preference for communicating uncertainty using verbal probabilities over the numeric 1-in-X representation is reduced when conveying the more severe adverse effects of a drug than its less severe effects [105]. Thus, the qualitative–quantitative nature of the uncertainty matches senders' preference for a qualitative versus quantitative communication format, and the potential consequence of a decision (i.e., to take a drug) leads senders to increasingly favor the numeric format.

In recent years, research on the receiver side has branched out to other evaluative measures, and these do not suggest a superiority of words over numbers. For instance, there was no difference in receivers' initial perceptions of the credibility (i.e., knowledge and trustworthiness) of senders who used verbal probabilities or precise or imprecise numeric values to express uncertainty [19,20]. One study suggests that the public perceives verbal hurricane forecasts as more reliable if they are combined with numeric probability information [33]. Similarly, receivers said they 'like' information about low-probability, high-impact industry-related environmental risks less when they are expressed using words alone than when the words are combined with point numeric values [79].

Indeed, recent research shows that receivers prefer either a combination of numbers with words [33,54] or (numeric) precision [89]. Receivers' preference for numbers over words is reflected in their preference for precise over imprecise numbers. For instance, when receiving information about food safety risk, people prefer numeric point values over numeric ranges [74]. Examples of policymakers requesting uncertainty information to be provided as point numeric values rather than ranges have also been documented [109]. Together, these findings suggest that, when it really matters, both senders and receivers prefer the (precise) numeric expression of uncertainty.

Communicating uncertainty clearly

Communicating uncertainty is important because even accurate estimates, if miscommunicated, can result in poor decision-making. Erroneous and biased decisions resulting from a misunderstanding of uncertainty can erode trust and confidence in those making assessments and those acting on them. Finally, some complex and/or evolving problems necessitate reliance upon prior assessments, which, if misunderstood, can result in compound estimation errors.

The clear or unambiguous communication of uncertainty requires, at minimum, that the rank ordering of probabilities is preserved under whatever communication format is used. Formats should also be resistant to anything that introduces variability of interpretation within- and between-individuals (i.e., undermining ordinal consistency). Beyond this, formats that afford mental ease of operation on uncertainty information (e.g., aggregating multiple probabilities) [14,15] as well as fostering unbiased decision-making, ought to be favored. Finally, senders may have other goals beyond simply being informative (e.g., conveying bad news politely [16,17] or maintaining credibility [18–20]) and such social-interactional concerns may favor a particular format ([21] see also [22]).

We review research on the size and variety of individuals' uncertainty communication lexicons, and the imprecise, variable, and malleable numeric meanings people assign to verbal probabilities. We also consider the non-uncertainty-related inferences that people may draw from probability terms and the other communicative functions such terms may serve. Finally, we document efforts to clarify the meaning of verbal probabilities using imprecise and precise numbers and assess this combined approach.

Verbalizing uncertainty

Researchers have adopted different approaches to studying verbal probabilities. Whereas some ask participants to select or respond to probability terms from a predefined list (e.g., [23–28]), others capture free-text responses or uncertainty language use in natural settings (e.g., [29–33]). Several recent studies have examined terms in existing official uncertainty communication policies (e.g., [34–36]). However, many examine one or a few probability terms (e.g., [12,17,19,37,38]).

Consistent with early work (e.g., [6,39]), recent research suggests that the size of an individual's verbal probability lexicon is, on average, no more than ten terms [30]. This broad-brush approach to communicating uncertainty is also observed at the organizational level [29] (Box 3). Even the numeric interpretation of probability terms is rounded up or down to the nearest 0% or 5% [26]. Thus, words provide fewer distinguishable levels of probability, and receivers believe that terms do not provide enough information compared with point numeric values [40]. This lack of granularity means that, despite efforts to convey small probabilities of less than 0.1 [41], terms are interpreted as much greater [34]. In one study, people overestimated low chances (e.g., two out of 100) and underestimated high chances (e.g., 85 out of 100) of the adverse effects of a drug when these were expressed verbally than when words were combined with precise numeric information [42]. Coarsening the probability scale also adversely affects forecasting accuracy [43].

Although the size of an individual's uncertainty lexicon may be limited, across individuals, a variety of terms are used to communicate uncertainty, particularly when referring to probabilities other than at the central and end-points of the probability scale [30]. Given that most senders intend to communicate uncertainty unambiguously [17], interindividual variation in term selection poses challenges to achieving that goal.

Box 3. Communicating uncertainty in consequential decision domains

International organizations operating within consequential decision domains from food safety [110,111] to defense and security [112] (see also [87]) to climate science [113] (also see also [114]) have chosen to communicate uncertainty using standardized lexicons. These require senders to use a small, preselected, rank-ordered set of probability terms that are each assigned a numeric probability range.

However, evidence points to a lack of agreement where users' (both senders' and receivers') numeric interpretations of terms do not map directly onto the prescribed numeric ranges [7,30,34,40,47,48,60,63]. In some cases, interpretations are either below or above the category ranges. Terms that are deemed to be synonymous may not be regarded as such by users [30]. Although the rank order of terms in users' personal lexicons generally corresponds to that in the official lexicons, users do not use the terms as mandated [30]. Finally, lexicons also implicitly imply the occurrence or nonoccurrence of outcomes. For instance, lexicons typically contain negatively directional terms (e.g., *unlikely*) to express low- to mid-range probabilities, which negate outcomes associated with these probabilities [55].

Alternative methods for implementing standardized lexicons to avoid the implications of linguistic directionality or to improve agreement between users' interpretations and the lexicons have been explored. Some propose using only positively directional terms [55]. Others suggest providing numeric translations of terms in brackets alongside the terms in text [7,48], enabling individuals to view a 'guideline table' containing numeric translations, or introducing a 'tooltip' where translations appear on screen when readers hover over a term [48]. However, positively directional terms can bias decisions [55]. Additionally, although brackets increase agreement, it is moderate [e.g., from 28% to 54% for the Intergovernmental Panel on Climate Change (IPCC) lexicon] [7] (see also [47,48,60]), and users do not sufficiently engage with the other interventions (i.e., around 50% of participants did so) [48].

An evidence-based approach to the development of standardized lexicons has also been explored. Statistical methods have been used to optimize the fit between the stipulated numeric ranges and users' numeric interpretations of terms [34,48]. These empirically derived lexicons were validated using data from another sample of users by examining the proportion of their numeric interpretations that fell in the ranges stipulated by the various lexicons. Although agreement is improved, it remains far short of complete agreement. Thus, research points to the ineffectiveness of organizational attempts to assign fixed meanings for a circumscribed set of probability terms.

Numeric meanings of verbal probabilities

To capture what individuals mean by specific probability terms, researchers have traditionally measured their numeric interpretations, assuming terms represent fuzzy subsets of the 0–1 probability interval [2]. The 'membership function' method maps a term onto a 'goodness-of-meaning' curve over the probability interval (Figure 1). Some studies elicit full membership functions [24,30,34,36,44–46], while others ask for a three-point (i.e., best, lower, and upper bound) or single-point (i.e., best) interpretation (e.g., [7,26,28,34,47–49]). The findings based on numeric measurement approaches are compatible with those grounded in non-numeric approaches (e.g., [23,30,50]).

Imprecision at the individual level

Individuals have broad or fuzzy interpretations of verbal probabilities [7,24,26,30,34,36,44–46,48] (M. Herbstritt, PhD thesis, University of Tubingen, 2020). For example, *possible* spans 63% points for some physicians [26]. Even well-known probabilistic expressions are imprecise (i.e., the average 'spread' of numeric interpretations of *reasonable doubt* is around 40% points) [36,45] (Figure 1). Imprecision is negatively related to confidence in using this term for decision-making [36].

Variability across individuals

The interindividual variability in numeric interpretations of verbal probabilities [51] continues to be observed in English-speaking samples, and is evident among experts/professionals [25–27,30,34,35,52,53] as well as lay people (e.g., [17,19,20,24,32,36,44–47,54,55]). Such variability is also documented among non-native English-speakers, where probability terms may or may not be translated [7,28,35,49,56,57]. These non-native language users have reduced numeric discriminability of terms that lie above and below the mid-point of the probability scale [7,49,57].

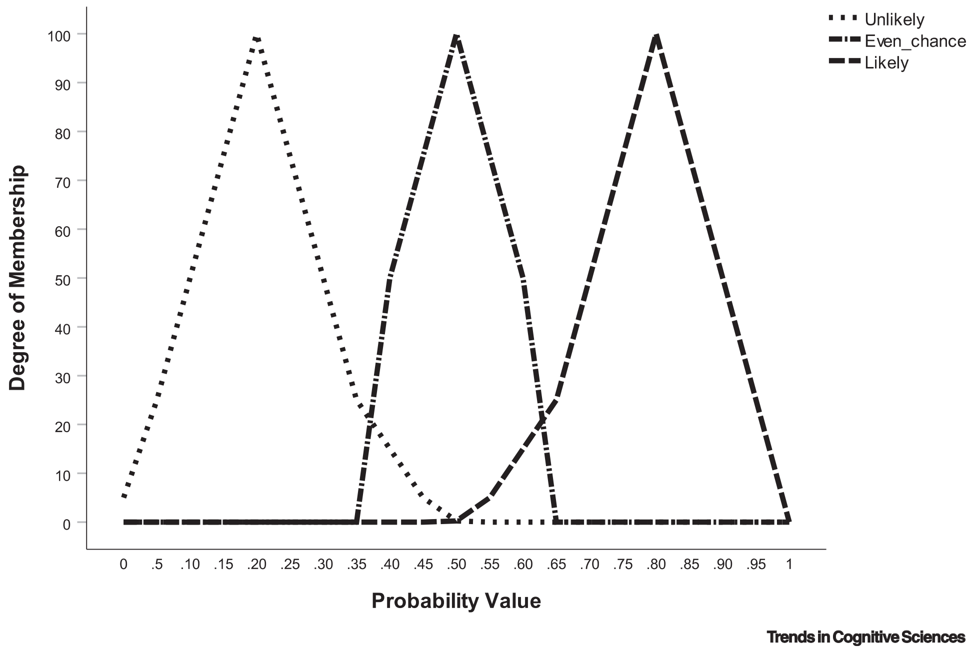

Figure 1. Hypothetical membership functions for three probability terms. Participants are asked to determine how well they think each numeric probability value (e.g., 0, 0.5, 0.10,…1) represents a specific term (e.g., *likely*). Responses are provided by marking a point on a scale (from 0 to 100) for each probability value. This yields several measures, such as the 'minimum', 'maximum', and 'peak' numeric values that the term represents, as well as the 'spread' (i.e., maximum minus the minimum) of values.

Interindividual variability in 'best' numeric interpretations is greater for probability terms that suggest the nonoccurrence (e.g., *unlikely*) rather than occurrence (e.g., *likely*) of an outcome [48,58]. Even terms such as *certain* and *impossible* show interindividual variability in meaning [26] (see also [30]). Similarly, probability terms mandated in law to have a specific meaning show variability in interpretation (i.e., the average 'peak' numeric interpretation of *reasonable doubt* across individuals has an up to 11% point standard deviation) [36,45,46] (Figure 1).

A consequence of interindividual variability is that receivers of uncertainty information may not interpret it as intended [8], undermining informed and shared decision-making. In the medical domain, patients interpret probability terms as referring to greater risk than do clinicians [27]. In both the climate science and intelligence analysis domains, the public and security practitioners, respectively, misinterpret the intended meaning of terms in a regressive fashion (i.e., underestimating high probabilities and overestimating low probabilities) [7,47,48,59,60].

Context effects

Eye-tracking data reveal that individuals fixate longer on the contextual information of a verbal than a numeric uncertainty communication [37]. Indeed, context affects the language being used to describe uncertainty [61] (M. Herbstritt, PhD thesis, University of Tubingen, 2020). The numeric interpretation of verbal probabilities is also context dependent [9,32,42,62] (M. LaCour, PhD thesis, Texas Tech University, 2021). For example, the numeric interpretation of a probability term differs when it appears in opposing informational contexts. These polarity effects have been observed for an increase/decrease in accounting [56], success/failure in intelligence analysis [53], and being hesitant/willing to act in a legal setting [44] (Figure 1). Contexts can even reduce the numeric discriminability of probability terms [49,53]. Terms ranked below the mid-point of the probability scale are given higher best numeric interpretations when describing the chances of failure than success, whereas terms ranked above the mid-point are assigned lower interpretations [53].

Directionality of verbal probabilities

Verbal probabilities have (positive or negative) directionality [10,11]. Positively directional terms (e.g., *small probability*) bring to mind the occurrence of an outcome, whereas negatively directional terms (e.g., *unlikely*) suggest nonoccurrence [55]. This directionality (or attentional focus) is stronger when terms are expressed in an individual's native language [49]. Therefore, words can be used to affirm or negate the numeric probability underlying an outcome (e.g., by using a positive term to convey a <0.5 probability and a negative term for >0.5). Directionality is not fully captured numerically and so positive and negative terms can have similar numeric estimates [55]. Numeric interpretations of positive terms are not always above 0.5 [17], although their peak interpretations are typically higher than the peaks for negative terms [24] (Figure 1).

The directional properties of verbal probabilities mean that they can convey something other than probability. Receivers can infer a sender's initial expectations depending on how the sender uses positive and negative terms. For instance, if a positive term is used to communicate 20% (e.g., *a slight hope*), receivers infer that the sender expected the probability to be greater than it is, whereas if a negative term is used to convey 80% (e.g., *there are minor concerns*), receivers infer that the sender expected a lower probability [38]. These inferences match the sender's use of positive and negative terms in this way [38]. By contrast, no such inferences are made when senders use point numeric values.

Verbal probabilities can also imply specific actions. Indeed, terms are viewed as providing clearer implicit recommendations compared with probability information, even though these recommendations are not communicated explicitly [18]. Authors of the Intergovernmental Panel on Climate Change reports admit selecting probability terms to suit policymakers' demands for information they can act upon [63]. They suggest that urgent policy decisions are better facilitated by claims described with high certainty than the uncertainty that is characterized by knowledge gaps [63].

The above findings suggest that verbal probabilities can bias decision-making. Individuals are more likely to recommend a medical treatment when its potential efficacy is described using a positively than a negatively directional term, even though the peak numeric interpretation of the former is lower than the latter [24] (Figure 1). Similarly, individuals make more precautionary decisions when the risk of an adverse climate-related event is communicated using positive rather than negative terms, which then increases false positives [55]. Erring toward protection also occurs when positive terms are compared with an equivalent point numeric value [37].

Other communicative functions of verbal probabilities

Senders can use probability terms to fulfill other communicative functions beyond the faithful expression of uncertainty. Some of these functions refer to the social-interactional nature of uncertainty communication [16–20,64,65].

Using verbal probabilities to save face

Senders can use terms as a receiver- [64,65] or self-face-saving strategy [65], particularly when communicating the chances of adverse outcomes [16]. For instance, when conveying a 50% probability that a friend's stocks could lose value, senders with a receiver-face-saving intention are more likely to use terms such as *a small probability* than are senders with solely informative intentions, who are more likely to say *evenly probable* [17]. In a dyadic exchange, such face-saving strategies can result in receivers judging more severe adverse events as being less probable than less severe ones [16]. This can be problematic because the numeric interpretations of terms used in a face-saving manner predict decisions (e.g., intention to sell stocks) [65].

Using verbal probabilities to maintain credibility

Probability terms can also be used to maintain a sender's credibility (e.g., being perceived as knowledgeable and trustworthy), which is particularly beneficial after an erroneous prediction. Senders can use terms that are congruent with an outcome occurring or not occurring rather than simply reflecting the probability of an outcome [19]. For instance, senders who used a positive term (i.e., *small chance*) to convey a probabilistically unexpected outcome, which was congruent with it occurring, suffered less credibility loss than did senders who used an outcome-incongruent negative term (i.e., *doubtful*) [19]. Similarly, when conveying the likelihood of a probabilistically expected outcome, senders who used a negative term, which was congruent with the outcome not occurring, experienced less credibility loss than did senders who used an outcome-incongruent positive term [19].

In some circumstances, senders have greater credibility if they use outcome-congruent terms than if they use numbers, which are perceived as positively directional [19,20]. For instance, senders who used a negative term to make an accurate low-probability forecast were perceived as more credible than those who used a (low) point numeric value [18]. There is no effect of communication format for accurate high-probability forecasts because both positive terms and numbers are positively directional [18,19]. However, greater credibility loss results when senders make erroneous predictions using outcome-incongruent terms compared with if they had used numbers. For instance, after making an inaccurate low-probability forecast, senders were perceived as less credible if they had used a negative term (e.g., *unlikely*), which is incongruent with the outcome having occurred, than if they had used a low (i.e., 20%) point numeric value [18,20] or a low numeric range (i.e., 10–30%) [19,20]. Again, there is no effect for inaccurate high-probability forecasts [18]. Therefore, although verbal probabilities can be manipulated to affect judgments of a sender's credibility, words depend more than do numbers on postoutcome accuracy information.

Using verbal probabilities to imply outcomes

A new avenue of research suggests that probability terms also imply specific outcomes [12,66–68]. In the so-called 'extremity effect', people overestimate the probability of extreme outcomes in a distribution (i.e., at the tail ends or even beyond), so that, for example, terms such as *unlikely* and *possible* are used to describe high-end outcomes. This occurs for normal and non-normal distributions [66,67] and categorical outcomes [67]. The effect is reduced when using a point numeric value alone [66,67], although assigning precise values [66] or numeric ranges [68] to probability terms does not fully mitigate the effect. Receivers have some awareness of senders' tendency to use terms to describe outcomes at the tail of a distribution [12].

Integrating multiple verbal probabilities

The effectiveness of verbal probabilities as a method of uncertainty communication is sometimes benchmarked against the performance of a numeric representation of uncertainty (e.g., [14,15,20,38,66,69]) (M. LaCour, PhD thesis, Texas Tech University, 2021). In this case, studies have examined how verbal probabilities fare when uncertainty information needs to be integrated. The arithmetic accuracy and logical coherence of averaging and multiplying probabilities are lower when these are expressed verbally than when expressed as point numeric values [14]. Similarly, when aggregating two forecasts, people make more extreme estimates if they are presented verbally rather than numerically (as ranges or point values) [15].

Individuals are more likely to report using guesswork than mental calculation when computing averages or products from probability terms than from point numeric values, and this predicts poorer performance [14]. Individuals are also more likely to 'count' when aggregating verbal forecasts and average when aggregating numeric (range or point value) forecasts [15]. Here, resulting (extreme) estimates predict decisions [15]. Such findings have concerning implications for tackling problems such as climate change, where multiple uncertainties, expressed verbally, need to be integrated to form an overall judgment that informs decision-making [63].

Mandating the meaning of verbal probabilities

Despite the concerns that the use of verbal probabilities raise for informed and shared decision-making, international organizations operating in domains such as climate science and intelligence analysis choose to convey uncertainty using words (Box 3). Their efforts to mitigate against the potential pitfalls of using probability terms involve adopting 'standardized lexicons' in which preselected terms are assigned numeric probabilities. Indeed, there are potential advantages of combining probability terms with numbers. The reliable ratio scale properties of numbers can benefit such terms, which have unreliable ordinal scale properties. Even imprecise numeric probabilities may be beneficial because whereas terms have fuzzy ranges, numeric ranges have crisp lower and upper bounds. A crisp range can be converted to a point value (e.g., 65–85% can be reframed as 75 ± 10%).

Although assigning numeric ranges to probability terms can reduce their variability of meaning across people [7,47,70], recipients of standardized lexicons do not necessarily interpret terms according to the values assigned to them, instead defaulting to their personal (numeric) interpretations [48,60] (Box 3). Thus, assigning numbers to words does not completely clarify their meaning and, as we note later, combining verbal probabilities with imprecise or precise numeric probabilities may have unintended consequences.

Combining verbal probabilities with imprecise numbers

Imprecise numeric probabilities may not help clarify the meaning of probability terms. People may not fully understand what is being expressed by a numeric range and may need to be aided by graphical representations (e.g., [71]). Whereas some individuals perceive ranges as implying a normal probability distribution [71,72], others perceive them as uniform distributions [71,73], and a few perceive them as U-shaped distributions. This occurs even when told that the best estimate is the mid-point of the range [71] (see also [72–74]).

Numeric ranges may also communicate more information than just event probabilities. For instance, 60–80% might be interpreted as a best estimate of 70% with a margin of error equal to ± 10%. Here, the range provides information on the sender's probabilistic estimate as well as information about the sender's uncertainty in that estimate. Indeed, receivers perceive senders of numeric range information as being 'not sure' [74], with wider ranges conveying less certainty [75]. Yet, the range falls short of a clear statement about the sender's confidence since the meaning of its width is not defined. One could say, it is with 90% certainty that the true chances lie between 60% and 80%. There is concern that numeric ranges may be conflated with a sender's confidence in the estimate [63,76].

Numeric ranges can be difficult to operate on, and assigning imprecise numbers to words may be unhelpful for integrating uncertainty information. The arithmetic accuracy and logical coherence of averaging and multiplying uncertainties are no better when operating on imprecise numeric probabilities compared with verbal probabilities [14]. Similarly, assigning numeric ranges to words does not fully mitigate against the extreme estimates people make when aggregating two verbal forecasts [15].

Numeric ranges can also have unintended effects on decision-making. Decisions may be influenced by the width of a range itself rather than by the best estimate it covers, so that individuals choose a riskier option [77]. Some individuals make so-called 'deterministic construal errors' believing that the lower or upper bound is also the most likely value, thereby converting uncertain information into deterministic information, and this affects their decisions [73]. Likewise, some people believe that the value represented by the upper bound is the 'correct one' [74], while others base their decision solely on the lower bound [77].

Finally, numeric ranges may result in decisions being delayed when such delay is not beneficial. In one study, even when provided with a best estimate, range information resulted in nearly half of individuals waiting to obtain further information to resolve the uncertainty, despite delay being costly and the value of information diminishing with time [77]. Indeed, people are less likely to prefer numeric range uncertainty information when under time pressure [78].

Combining verbal probabilities with precise numbers

Combining probability terms with precise numeric probabilities may also be unhelpful because the vagueness of words can undermine the potential benefits of numeric precision. Indeed, although probability information is rated as clearer when it is conveyed using point numeric values rather than verbally [18,40], combining point values with terms does not increase perceptions of information clarity and ease of understanding or of information trustworthiness, although it does increase perceptions of terms being more 'exact' [79].

Adding precise numbers to probability terms, where the terms nevertheless take primacy, can have detrimental effects. For instance, senders who expressed the term before the assigned point numeric value (e.g., *unlikely,* 20%) suffer greater credibility loss after an erroneous prediction than do senders who conveyed the point value before the term [20]. The extremity effect in outcome selection is also greater when terms appear before their assigned point numeric value [66]. Additionally, using a combined format (e.g., *common* and 1-in-X), as recommended by the European Medicines Agency, does not increase patient satisfaction with the information, but it does result in them having higher estimates of cancer treatment side-effects compared with a precise numeric format [69]. Finally, combining terms with precise numbers does not eliminate the effect of context on their interpretation [42].

Beyond words: an alternative to verbal probabilities when it really matters

Despite concerns over the effect of numeracy in understanding numeric probability information (Box 4), the (precise) numeric format confers several advantages over the verbal format when communicating uncertainty. Individuals perceive the probability information conveyed by point numeric values to be clearer than that expressed verbally [18,40]. Additionally, in contrast to probability terms [34], point values can describe rare events, and are more accurately aggregated [14,15]. Compared with verbal probabilities, point numeric values are also less likely to result in the selection of extreme outcomes in a distribution [66,67], leak information about the sender's reference point [38], or damage a sender's credibility after making erroneous predictions [18–20]. One study found that expressing uncertainty via precise numeric as opposed to verbal probabilities did not result in national security officials making riskier decisions, even for optimistic scenarios, and did not lead to overconfidence in decisions, but did increase willingness to gather additional information, desirable in this circumstance [80].

Box 4. Is lower numeracy a good reason to avoid numeric probabilities?

Senders may be reluctant to communicate uncertainty numerically, believing that less numerate people will not understand the information (e.g., [25,41,88]). Those with greater math education state that probability terms provide insufficient information than do those with lower math education [40]. However, studies suggest that more numerate individuals also do better with verbal probabilities than do their less numerate counterparts. Compared with less numerate individuals, more numerate people, such as superforecasters [86], show better discrimination among the numeric meanings of terms [32,62,115], and their interpretations of terms are less influenced by changes in subject content [62]. Numeracy is also positively related with agreement between users' numeric interpretations of terms and standardized lexicons [48,60]. Additionally, early signs are that numeracy may be negatively correlated with the spread of numeric interpretations of terms, suggesting that these are fuzzier in the minds of less numerate people (S.G. Prunier, PhD thesis, University of Toledo, 2017).

Numeracy does not interact with communication format (i.e., verbal, precise, and imprecise numeric, combined) in affecting individuals' perceptions of the correctness of forecasts that were erroneous; neither does numeracy affect decisions based on these forecasts [20]. Similarly, numeracy has little impact on reducing the extremity effect [66].

Indeed, low numeracy may not be a barrier to understanding numeric probability information. In one study, although higher numeracy was associated with better recall of (numeric) uncertainty information, and less interindividual variability in estimates of medical treatment effectiveness, numeracy was unrelated to evaluations of information understandability and usefulness, perceived trustworthiness of the information, and intention to take a medication [72]. Numeracy does not moderate the effect of risk estimates using the 1-in-X (e.g., one in 12) numeric representation on decisions to take a health safety measure, and neither is the effect of such representations explained by perceived computation difficulty [116]. Numeracy also does not fully account for the deterministic construal errors people make when using numeric ranges [73].

Rather, compared with their more numerate counterparts (and albeit in a sample with relatively high levels of numeracy), less numerate individuals perceived the sender as less correct after making an erroneous prediction using a point numeric value, or a narrow or wide numeric range [20]. Precise numeric probability information also does not 'hurt' the performance of those with extreme low numeracy scores compared with those with extreme high scores [117]. Therefore, senders of uncertainty communications may be misplaced in their belief that less numerate people will benefit from verbal expressions of uncertainty and cannot benefit from precise numeric uncertainty information.

Where outcome data are available, in contrast to the verbal approach to uncertainty communication, the (precise) numeric approach enables verification of estimates, which can be useful for making senders accountable and honing their estimation skills. For instance, studies on geopolitical forecasting using precise numeric probabilities demonstrated the feasibility of measuring forecast accuracy as well as pinpointing approaches to estimation that improve accuracy (e.g., [43,81–86]). In the intelligence analysis domain, which has historically used verbal probabilities to communicate uncertainty (see [87]), recent numeric precision has enabled measurement and feedback on the accuracy of predictive assessments [82–84]. This can, in turn, better inform decision-makers who prefer to receive precise uncertainty information to make consequential decisions (Box 2).

Concluding remarks

Recent research reinforces concerns about the coarse, imprecise, variable, and malleable nature of verbal probabilities, which undermines the clear communication of uncertainty using words. These concerns are not allayed by studies showing that, when probability terms are combined with numeric ranges, people may be confused and delay decision-making. Additionally, empirical tests of uncertainty communication policies adopted by organizations tackling climate change and national security suggest that these are ineffective, raising questions about the clarity of official communications of uncertainty around these complex problems.

If the goal is the unambiguous communication of uncertainty, then the evidence suggests that verbal probabilities are less effective than are precise numeric probabilities. Nevertheless, recommendations have recently been made to formally introduce uncertainty language in areas such as predictive legal analysis [88] and extreme event analysis [41].

Outstanding questions

What are the potential benefits and drawbacks of using precise and imprecise numeric probability information in addition to, and instead of, verbal probabilities? How can the understanding of probability terms be improved (e.g., by using graphical representations to improve the understanding of numeric ranges associated with terms)?

How do social and communicative contexts promote the transparency and clarity of the meaning of verbal probabilities across people?

How does the mode of delivery of verbal and numeric uncertainty information (e.g., orally or written) affect the understanding of this information?

Does the degree of uncertainty being conveyed alter along the chain of communication (e.g., as it is consumed through the media or one's social network)? How is any such distortion affected by the format in which these messages are expressed (i.e., verbally or numerically)?

What is the effect of communication format on metacognition? Do users of uncertainty information have greater insight into their processing of this information when it is conveyed verbally or numerically?

Is the 'blind spot' that people have in recognizing how uncertainty information is understood by others greater when this information is expressed verbally or numerically?

How will the fact that artificial intelligence and machine learning are becoming a common source of expert probabilistic assessments affect senders' and receivers' communication mode preferences?

Although verbal probabilities may not be effective in the faithful expression of uncertainty, they can serve other useful functions, particularly given their directionality. Interpreted from the sender's vantage point, the findings represent desirable features of verbal expressions of uncertainty. For example, senders can convey uncertainty in a face-saving manner, they can reduce credibility loss, imply the occurrence of specific outcomes, and imply actions that should be taken. By contrast, when viewed from the receiver's perspective, verbal probabilities can leave them not only less well informed, but also potentially manipulated and misled.

We do not claim that receivers are always at such a disadvantage. In most everyday situations, verbal probabilities may not only suffice, but may also be ideal, given that they afford free-flowing communication. A previous review suggested that social and communicative contexts shape the interpretation of probability terms, thus potentially promoting effective uncertainty communication [21] (see also [22]). Unfortunately, there remains little research on the effects of conversational contexts on uncertainty communication (see Outstanding questions). We conclude that, where the communication of uncertainty can affect receivers' processing of information about consequential personal or societal issues, the evidence suggests that precise numeric probabilities have several distinct advantages over verbal probabilities.

Concerns over receivers with lower numeracy being unable to benefit from numeric precision and being better suited to receiving uncertainty information verbally are not fully justified by recent evidence. Additionally, the finding that both senders and receivers want numeric uncertainty information when it really matters suggests that precise numeric probabilities are preferable over verbal expressions of uncertainty. Nevertheless, the complexities of the modern world imply that problems are often characterized by multiple uncertainties, and it may not be feasible to offer precise assessments of these uncertainties, without misrepresenting them. In such cases, communicating imprecise numeric probabilities may be the best available option.

Acknowledgments
Thanks to Sarah Gibbons, Georgina Gray, and Brooke MacLeod for their research assistance.

Declaration of interests
None are declared.

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