‘Unlikely’ Outcomes Might Never Occur, But What About ‘Unlikely (20% Chance)’ Outcomes?

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Abstract

A commonly suggested solution to reduce misinterpretations of verbal probability expressions in risk communications is to use a verbal-numerical (mixed format) approach, but it is not known whether this increases understanding over and above a purely numerical format. Using the ‘which outcome’ methodology (Teigen & Filkuková, 2013), we examined the effect of using verbal, numerical and mixed communication formats, as well as investigating whether marking outcomes as salient would alter the outcomes people perceived as ‘unlikely’ or having a 20% chance of occurring. We observed no effect of saliency, but replicated previous findings, with general preference for values at the high end of a distribution (including maximum/above maximum values) present in both verbal and mixed communication formats. This demonstrates the relevance of these findings for real-world consequential risk communication. Whilst the estimates differed between the mixed and numerical formats, we found that the mixed format yielded the more accurate estimates.

Keywords: verbal probability expressions; numerical probabilities; risk communication; geological hazards

Introduction

Effectively communicating information about risk and uncertainty remains an ongoing challenge for the scientific community. The process relies on recipients of risk communications both understanding the information, and also placing enough trust in it that it will be used in subsequent decision making. Most people do not have in-depth knowledge about, nor experience of, hazards and new technologies (Siegrist, Gutscher & Earle 2005). Individuals are therefore reliant on mediated information, which tends to be from an expert source (Sjöberg, 2000). Ensuring the audience understands the information as intended is a universal concern for scientific communications. Scientific forecasts are, however, typically probabilistic (at best). It is thus not possible to predict with certainty whether a destructive earthquake will occur in a certain place within the next month for example. A prediction that such an event is ‘unlikely’ does not imply that the event will not occur. Given that an estimate of ‘unlikely’ might be used to describe the likelihood of events with a 20% chance of occurrence (e.g., Theil, 2002), approximately 20% of the time, they will occur. As the prosecution of six experts following the L’Aquila Earthquake in 2009 attests (Cartlidge, 2012), such a lack of certainty is not always well received by the public, resulting in the potential for reduced trust in (and sometimes criminal proceedings against) the scientists who make such predictions.

Budescu and Wallsten (1995) proposed that the choice of risk communication format should be governed by the congruence principle: the precision of the risk communication should match the precision of the event in question, thus reflecting the nature of its uncertainty. Estimating the likelihood of a large earthquake might not be precisely quantifiable. In such instances, a specific numerical expression of the probability of this event might be perceived as overly precise. Using a verbal probability expression (VPE), however, better represents the uncertainty and underlying imprecision associated with the probability estimate. This characteristic is one reason for many organisations’ use of VPEs in risk communication (e.g., Intergovernmental Panel on Climate Change [IPCC], Mastrandrea, 2010).

There is, however, considerable variability in people’s usage and interpretations of VPEs (e.g., Budescu & Wallsten, 1985). In addition to ‘natural’ inter-individual variability, interpretations of VPEs are susceptible to contextual and cultural influences (e.g., Bonnefon & Villejoubert, 2006; Fischer & Jungermann, 1996; Harris & Corner, 2011; Harris, Corner, Xu, & Du, 2013; Juanchich, Sirota & Butler, 2012; Teigen & Brun, 1999, 2003; Weber & Hilton, 1990).

The abovementioned studies have typically used the ‘how likely’ translation approach to investigate interpretations of VPEs, whereby people are asked to translate VPEs to corresponding numerical probabilities. However, more recently, Teigen and colleagues have demonstrated that a ‘which outcome’ approach to understanding people’s interpretations of VPEs paints rather a different picture (Teigen, Juanchich & Riege, 2013; Teigen & Filkuková, 2013, Teigen, Juanchich & Filkuková, 2014). In this approach, participants are shown a distribution of outcomes and asked to complete probability statements (e.g. “It is unlikely that a battery will last… hours”) with a value they consider appropriate (see Figure 1 for example). This approach has highlighted a seemingly large qualitative disparity between the communicator’s intended meaning and the recipient’s understanding of the information. Teigen et al. (2013) found when the term ‘unlikely’ was used to describe outcomes which can be ordered on a unipolar dimension (e.g.,

battery life), participants interpreted the term as referring to outcomes from the higher end of the distribution and most often completed the sentence with a lifetime that *exceeded* the maximum time any sampled battery had lasted (Study 3a) – hereafter the 'which outcome effect'. This was despite a mean translation of around 40% in a pre-test. Furthermore, when a climate expert claimed a sea level rise of 100 cm was 'improbable', participants gave a much lower estimate of the expected sea level rise, suggesting they were aware 'improbable' is used by experts to describe values above the expected outcome (Study 5c).

These findings from this novel methodology potentially paint an even gloomier picture for the effectiveness of risk communications using VPEs. An expert who uses 'unlikely' to mean 20% will quickly lose the trust of an audience if they expect 'unlikely' to refer to outcomes which never happen. More immediately, there could be catastrophic consequences for those who choose not to evacuate their homes after hearing the chance of a tsunami is 'unlikely' and mistakenly believe a tsunami will therefore not occur.[1]

One commonly proposed solution to reduce mis-communication (observed from the 'how likely' methodology) is the use of a dual-scale, mixed format approach to express uncertainty, for example, 'It is unlikely (less than 33%)' (see Budescu, Broomell & Por, 2009; Budescu, Por & Broomell, 2012; Budescu, Por, Broomell & Smithson, 2014**,** Harris & Corner, 2011; Harris et al., 2013; Patt & Dessai, 2005;Witteman & Renooij, 2003**)**. Budescu and colleagues have demonstrated that such a 'verbal-numerical' format increased the differentiation of participants' interpretations of VPEs, an effect that replicated across 24 countries (Budescu et al., 2014). A question yet to be explored, however, is whether the addition of a VPE, over a purely numerical communication, might influence interpretations of probability estimates in a way that could be potentially harmful. Teigen and colleagues' findings using the 'which outcome' methodology suggest that they might. A citizen who hears that the chance of a volcanic lava flow extending as far as their village is 'unlikely' may discount the information, believing it will not happen, even if a numerical estimate is also provided.

This possible consequence, however, relies on the assumption that the same result from the 'which outcome' methodology will be obtained even when one potential outcome is of particular consequence. Previous research using the 'how likely' methodology suggests that such an assumption might not necessarily hold, as people's interpretations of VPEs are higher when those VPEs describe a severe outcome than a neutral outcome (Harris & Corner, 2011). More generally, making one outcome particularly consequential in the 'which outcome' methodology will enhance its salience. When considering the potential extent of a volcanic lava flow, for example, the location of a school a certain distance from the volcano might consume the attention of a communicator, such that all risk communications are assumed to be relevant to that particular location. Whether such an influence of saliency could override the effects reported in Teigen et al. (2013, 2014) and Teigen and Filkuková (2013) is a question addressed in the present paper.

The present paper therefore aims to further our understanding of the ramifications of Teigen and colleagues' previous work using the 'which outcome' methodology by testing the robustness of the effect across differing situations and communication formats. Ascertaining the effect of using different communication formats is instructive for designing future risk communication instruments. Furthermore, it enhances our theoretical understanding of the effect by determining whether it is primarily related to the pragmatics of linguistic communication, or linked to something more fundamental about people's understanding of probability and frequency. As well as examining whether different communication formats influenced people's outcome estimates, we tested whether marking certain outcomes as salient would alter the way in which people understood the risk communication. Owing to our underlying interest in consequential risk communications, the study also extended the existing evidence base by investigating scenarios featuring geological hazards.

Method

Participants

155 participants were recruited for this online study via Prolific Academic (www.prolific.ac). They were paid £0.85 upon completion of the study. 8 participants were excluded (6 due to duplicate IP addresses and 2 due to lack of consent) leaving a final sample of 147 (83 male) participants, aged 18-60 years (Mdn = 27).

Design

A 3×4×4 mixed design was employed with communication format (verbal/numerical/mixed) as a between subjects factor; scenario (volcano/flood/earthquake/landslide) and salient site (non-existent/close/far/multiple sites) as within-subjects factors. Scenario and saliency were randomised using the Latin Square Confounded method (Kirk, 1969), such that each participant only saw each scenario and each salient site once, but the combinations of these differed systematically across participants. Participants were required to type a numerical response which corresponded to the outcome that they believed was being described as either "unlikely" (verbal format), "there is a 20% chance" (numerical format), or "unlikely (20% chance)" (mixed format). We focused on the VPE 'unlikely' as it is an approved VPE of the IPCC. 20% is a plausible value for 'unlikely' given the IPCC's likelihood scale, as well as it being the average numerical translation of 'unlikely' in Theil's (2002) meta-analysis.

[1] This effect could occur over and above the effects of directionality (Teigen & Brun, 1995, 1999, 2003).

Materials and Procedure

Participants were first informed about the nature of the study and told they could withdraw at any time during the experiment. After consenting to participate, they were asked to indicate their age and gender, before reading the introductory text. The introductory text informed participants that they would see reliable projections of a model designed to predict future geological events and asked to make a series of judgements about these.

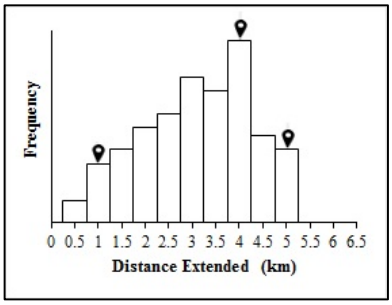
Each of the next four screens showed one of the four vignettes describing outcomes of how far lava flows, floodwater, earthquake tremors and debris flows would extend. These vignettes were developed in conjunction with geologists at the British Geological Survey to ensure they reflected plausible real-world situations. Each vignette was illustrated by a histogram with 10 bars, which reflected the number of times the model had produced the outcome. The shape of the distributions were similar and approximately normal across the scenarios, though the volcano and flood histograms had a slightly negative skew. The zero-frequency options were explicitly included in the histogram. The sentence completion task was presented at the bottom of each vignette (see Figure 1 for an example).

Saliency was manipulated through the inclusion of sites of particular scientific interest, which the event might extend as far as. These sites either homed rare plants or critically endangered animal species (e.g., the last habitat of 'white-spotted Antis' in Figure 1). There were four saliency conditions: No site of interest, one close site of interest (located in the second bin of the histogram), one far site of interest (last bin of the histogram), or multiple sites (second bin, modal bin and last bin, see Figure 1). After completing the study, participants were given a code to claim their reward, thanked and debriefed.

Reminder: The number of times the model has produced each outcome is a reliable indication of how likely that particular outcome is.

Mount Ablon has a history of explosive eruptions forming lava flows. An eruption has been predicted; the figure below shows the model's predictions of the distance extended by lava flows for this eruption, given the volcano's situation and recent scientific observations.

Due to the highly fertile soil and rich vegetation, multiple sites of special scientific interest home to the critically endangered 'white-spotted Antis', exist in the area surrounding the volcano. Sites A, B and C lie **1km**, **4km** and **5km** respectively away from the volcano (shown below). If lava flows reach any of these sites, the last surviving populations of 'white-spotted Antis' in the wild (at the site) would be lost.



Complete the sentence below with a <u>number</u> that seems appropriate in this context.

In the event of an eruption, it is **unlikely (20% chance)** that the lava flow will extend to a distance of ___ km.

Figure 1. Example vignette (volcano scenario, multiple salient sites, mixed format)

Results

Effect of Saliency

Because the different scenarios referred to different geological events, the x-axes on the histograms (see Figure 1) were all different. As it was predicted that responses would be pulled towards salient outcomes, to investigate the effect of saliency we standardised the outcomes across scenarios by 'binning' responses in accordance to where they were in relation to the salient points in the multiple site condition.

There were thus 8 response categories. Responses were similar across all four scenarios. Three Kruskal-Wallis tests were run to investigate if there was an influence of saliency in a) verbal b) numerical and c) mixed formats. These showed that outcome values were not significantly affected by saliency in either the verbal, χ^2 (3) = 0.482, p = .932, numerical, χ^2 (3) = 6.581, p= .087 or mixed format conditions, χ^2 (3) = 3.274, p = .351. In the following analyses,

Effect of Communication Format

Responses were similar across scenarios. Typical outcomes for 'unlikely' were chosen from the higher end of the distribution, from maximum and above maximum observed values. In contrast, typical outcomes for '20% chance' tended to correspond to lower values, primarily chosen from the intermediate values[2]. Results for the mixed format were in the middle of results for the verbal and numerical formats; outcomes tended to be chosen from the intermediate values, but this did not preclude a sizable proportion choosing from maximum and above maximum values (Bins 11 & 12). The contrasting patterns of responses are clearly evidenced in Figure 2.

The proportion of responses indicating high amplitude outcomes (the maximum value present in the histogram or above – bin 11 or 12) was highest in the verbal condition,

[2] Effects of communication format were unchanged if responses were binned into five categories (below minimum, minimum, intermediate, maximum and above maximum), as in Teigen et al. (2013).

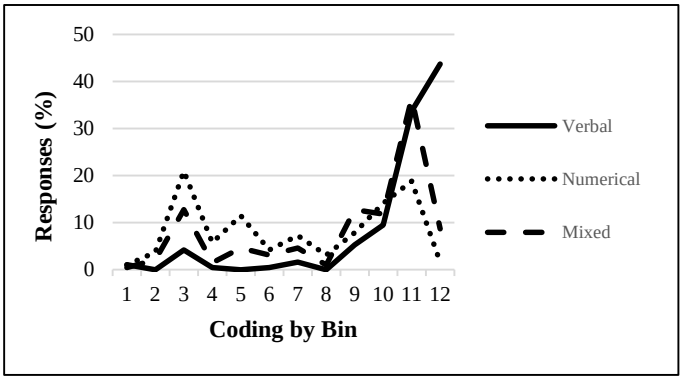


Figure 2. The distribution of responses by communication format.

followed by the mixed format condition. The numerical condition had the lowest proportion of responses indicating high amplitude outcomes, χ^2 (2) = 126.64, p < .001 (see Figure 3). A Kruskal-Wallis test showed a significant difference between the three communication formats χ^2 (2) = 163.29, p < .001. The verbal format yielded the highest estimates (mean rank = 402.61) followed by the mixed format (mean rank = 273.43), with numerical format yielding the lowest estimates (mean rank = 190.37). Three pairwise comparisons using Mann Whitney U-Tests were all significant (all *p*s < .001).

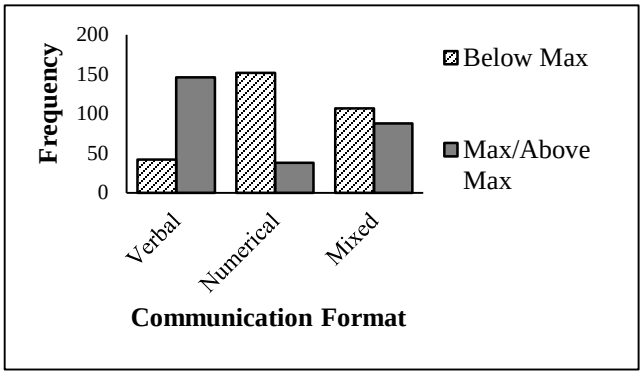


Figure 3. Frequencies of maximum/above maximum responses in the three communication format conditions (collapsed across saliency).

Accuracy of Estimates

We have demonstrated that the 'which outcome' effect is robust against a contextual influence of saliency. We have also shown that numerical and mixed format conditions produce different estimates, but is it possible to identify which format yields the most accurate estimates? The '20%' in the numerical and mixed communication formats enables the calculation of an objectively correct answer to the statement "there is a 20% chance that the *x* will extend to a distance of …" for the four scenarios by using the data the histograms were created with. The correct answer fell in the middle, or mid-to high saliency category in every scenario (either the 7th or 8th bin). It was thus possible to calculate the proportion of participants' estimates which were correct or not. Overall in the numerical and mixed format conditions, only 7% of all estimates (n= 386) were exactly correct. There was no significant association between communication format (numerical/mixed) and number of correct estimates, χ^2 (1) = 0.86, p = .426.

Given the low level of correct estimates, this simple, dichotomous categorisation of responses seemed rather crude. A more sensitive measure of accuracy was to therefore calculate a difference score (correct response – observed response) which was standardised across scenarios. We first calculated the mean and standard deviation of the outcomes implied by the histograms (see Figure 1) for each of the four scenarios, assuming that each histogram represented 200 datapoints. We consequently represented both the objectively correct response and the observed response as a z-score in this distribution. The difference score was subsequently calculated by subtracting the 'correct z-score' from the 'observed z-score.' Lower difference scores, indicating greater accuracy, were observed for the mixed format (M = -.003, SD = 1.4) than for the numerical format (M = -0.8, SD = 1.4), F (1, 377) = 34.45, p < .001, η^2_p = 0.08 (inferential statistics performed on reflect and square root transformed values to correct skew- results unchanged without transformation). There was no effect of scenario (p = .111), nor was there an interaction between communication format and scenario (F < 1).[3]

Discussion

We replicated Teigen et al.'s (2013) results and tested whether these would hold for numerical and mixed format expressions of probability. We also examined whether marking certain outcomes as salient would influence interpretations of the risk communication. We found evidence that the tendency to describe outcomes at the very end, or beyond the range of, a distribution as 'unlikely' generalised to consequential scenarios, wherever the word 'unlikely' was included - the verbal and mixed format conditions. This tendency was not apparent in the numerical condition. We found no evidence that responses were affected by increasing the saliency of the outcome.

Finding the 'which outcome' effect is generalisable to consequential scenarios in the applied domain of geological hazards has implications for organisations who are responsible for communicating the risk of such dangers. As previously suggested, there exists the real possibility that citizens will completely disregard the communication, believing that if the probability of a disastrous event is described as 'unlikely', it will not affect them. The potential for catastrophic consequences increases further given that

[3] Similar results to this study were also obtained using a voluntary, laboratory sample (n= 81).

marking outcomes as salient was not sufficient to attenuate the 'which outcome' effect.

Our findings also clearly demonstrate that format influences interpretations of risk communications. The fact that the 'which outcome' effect extends to mixed but not numerical formats indicates that the effect is related to the pragmatics of communication rather than people's understanding of probability and frequencies. Finding the effect occurred more in the mixed format than numerical conditions is of particular relevance to current literature, given the recent recommendations to use a dual scale, mixed format approach to express uncertainty (Budescu et al., 2009; Budescu et al., 2012; Budescu et al., 2014**,** Harris & Corner, 2011; Harris et al., 2013; Patt & Dessai, 2005;Witteman & Renooij, 2003). Our results suggest that this may not solve the problem of misinterpretations as much as first thought.

Given that this preference for values at the high end of the distribution was not present in the numerical condition, it was unexpected that estimates in the mixed format were more accurate than those in the numerical condition. This increase in accuracy was even more surprising given that the presence of 'unlikely' in the verbal condition was enough to significantly shift estimates towards outcomes at the higher end of the distribution and to those with a predicted 0% frequency of occurrence. There are two complementary explanations for this which stem from the proposition that VPEs contain an 'inbuilt hint' (Teigen & Brun, 1995) which provides the participant with extra information.

The first explanation focuses on the calculation of the objectively correct answer. A shallow reading of the scenario might have led those in the numerical condition to (wrongly) calculate 20% from the 'likely' end of the scale (given 'chance' focuses one's attention towards the occurrence of the event). This would shift estimates to the left of the scale, supported by Figure 2, which shows the numerical condition has two peaks, one to the left of the scale and one to the right, clustered around the correct answer's location. In contrast, those in the mixed format condition have additional information, with the inclusion of 'unlikely', which tells them to start from the 'unlikely' side of the scale, discouraging a shallow reading. This would shift their estimates towards the right of the scale, evidenced by the big peak to the right in Figure 2.

The extra information contained in VPEs is: "not only the probabilistic premise, but also the behavioural conclusion" (Teigen & Brun, 1999, p.163). VPEs can be positive or negative. If an outcome is described with a positive expression (e.g. 'possible'), the focus is on the fact that the outcome may occur (probability > 0), but if it is described with a negative expression (e.g. 'unlikely'), the focus is on the fact that it may not occur (probability < 1). Numerical probabilities tend to be presented in conjunction with other terms such as 'chance', which have positive directionality (as was the case in our study). Therefore, participants in the numerical condition may have interpreted chance as an indication that the event would indeed happen and thus given estimates closer to the likely end of the scale (the left). In contrast, those in the mixed format condition may have seen the 'unlikely' as extra information, interpreted it as pointing towards the non-occurrence of the outcome and thus given estimates closer to the 'unlikely' end of the scale.

Teigen and Brun (1999) suggest that neutrality may be achieved if two VPEs of opposing directionality are presented, but this was not achieved in the current study. Although the response pattern for the mixed format condition lies between the numerical and verbal formats, the general preference for values at the high end of the distribution in the mixed format condition is still present in around 45% of cases (see Figure 2) suggesting that participants are focusing more on the term 'unlikely', but why is this?

It is possible that people who focused more on the term 'unlikely' had lower numeracy levels and thus felt uncomfortable using the '20%' to form their estimates. Research has shown that less numerate decision makers are: "left with information that is less complete and less understood, lacking in the complexity and richness available to the more numerate" (Peters et al, 2006, p.412). Those lower in numeracy are also more likely to trust information presented in verbal form (Gurmankin, Baron & Armstrong, 2004). It would therefore be prudent to include a measure of numeracy in future studies to establish if the focus on 'unlikely' lessens as levels of numeracy increase.

Overall, although our results show the mixed format yielded more accurate responses, we would be hesitant to fully endorse calls to adopt such an approach as *the* solution to the problem of misinterpretations in risk communication research. Only a small proportion of responses were exactly correct. It is arguable that the increased endorsement of outcomes with a 0% frequency of occurrence as 'unlikely' in the mixed format over the numerical format (see Figure 2) represents a more consequential error, which is most critical to avoid. The degree to which the enhanced accuracy in the mixed format condition will generalise across different outcome distributions is also an open question. These are questions which future research can seek to address to maximise the effectiveness of future risk communication.

Conclusion

The present research provides an example of the disparity between what is communicated by scientists and what is understood by the audience in the context of geological risk communications. Whilst it is generally acknowledged that there is no 'optimal' presentation format and no one single 'fix' for risk communication (Budescu et al., 2012), identifying instances in which the format of uncertainty has a significant impact on audience's understanding is key to improving risk communication. Our findings show that the 'which outcome' effect extends to risk communications which use a mixed-format approach. Our study has significant practical implications for organisations responsible for communicating risk. Not only may people discount a hazard described as 'unlikely', the addition of a numerical translation may not be enough to prevent this disregard, leading to potentially catastrophic consequences.

Acknowledgements

SJ was supported by a UCL IMPACT studentship, half funded by the British Geological Survey. RML's contribution is published with permission of the Director, British Geological Survey.

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