How Forecasts Expressing Uncertainty are Perceived by UK Students

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ABSTRACT

Probabilistic forecasts are uncommon in the UK, but becoming more widespread. To understand how members of the public interpret uncertainty information and to compare to studies in the USA, 92 University of Manchester students were surveyed. Responses revealed that many participants understood that deterministic forecasts are uncertain, demonstrated a working knowledge of probabilistic forecasts and preferred probabilistic forecasts explaining why the uncertainty existed. When participants misunderstood probabilistic forecasts, they did not know what the probability referred to. Careful wording of forecasts might allow for maximal uptake and minimal misunderstanding of probabilistic forecasts in the future.

Uncertainty is inherent in all weather forecasts (National Research Council 2006). Uncertainty forecasts can indicate the likelihood of a weather event occurring (e.g. “60% chance of rain”) or provide a range of possible outcomes (e.g. “a high temperature of 18–22°C”), in contrast to deterministic forecasts that provide a definitive statement (e.g. “high temperature of 20°C”). In the USA, the public have had access to probabilistic forecasts of precipitation from the National Weather Service (formerly the Weather Bureau) since 1965 (Murphy *et al.* 1980; Monahan and Steadman 1996), and a survey of the USA public found that chance of precipitation is the second most important component of a weather forecast (Lazo *et al.* 2009). By comparison, UK public probabilistic forecasts are difficult to find from many weather providers, although the Met Office (2011) began experimenting with the best approaches for offering probabilistic forecasts. Even Parliament recommended the Met Office develop a “communications strategy … to enhance the ways in which it presents probabilistic weather forecast information” and recommended that broadcasters “make greater use of probabilistic information in their weather forecasts, as is done in the United States” (http://www.publications.parliament.uk/pa/cm201213/cmselect/cmsctech/162/16204.htm).

Expressing the uncertainty in forecasts can be useful to experienced users of weather information and can improve decisions based on those forecasts (Joslyn and LeClerc 2012). For example, Savelli and Joslyn (2012) found that boaters in the Puget Sound area of Washington State, USA, may benefit from calibrated forecasts of uncertainty because they could make their own assessment of risk based on boat size. A question is whether users such as the general public would understand and prefer uncertainty forecasts provided in a specific, focused context.

However, greater implementation of probabilistic forecasts may be hindered by a view that the public does not understand them (World Meteorological Organization 2008), a view supported by evidence that the public often misinterprets what the percentage refers to (Murphy *et al.* 1980; Gigerenzer *et al.* 2005; Morss *et al.* 2008; Joslyn *et al.* 2009). In particular, the public may misinterpret probabilistic precipitation forecasts as the percentage of area covered by precipitation or the percentage of time that precipitation will occur rather than as the probability of precipitation from many possible realizations of the weather. Nevertheless, some evidence may suggest that the greater exposure to probabilistic forecasts in the USA leads to better understanding of such forecasts (Gigerenzer *et al.* 2005).

Another factor preventing more widespread adoption in the UK may be negative feedback from segments of the public over the language of probabilities. For example, the Plain English Campaign – who are “fighting against jargon, gobbledygook and other confusing language, while promoting crystal-clear language” – awarded the Met Office a 2011 Golden Bull award for their attempt to introduce more probabilistic forecasts. The award citation was “for ‘empowering people to make their own decisions’ by using the technical systems for the ‘probabilities of precipitation’” (Plain English Campaign 2012).

As a small step toward better understanding of how the UK public perceives uncertainty within weather forecasts and comparing the results to published results in the USA, this article focuses on the results of a survey designed to understand individuals’ perceptions, interpretations and uses of weather forecast information.

Method

A survey was conducted at the University of Manchester during autumn 2010. Participants filled out an anonymous survey during an untimed testing session. Ninety-two students participated: 62 second-year undergraduate students in EART20170 Computing, Data Analysis and Communication Skills and 30 third-year undergraduate students in EART30551 Meteorology (Schultz *et al.* 2012). These students were primarily in the earth- and environmental-science programmes, but had little prior academic experience with meteorology. As the results from these two groups were similar, they were combined into one dataset.

The survey questions were drawn from previously published studies in the USA by Morss *et al.* (2008, 2010), Joslyn *et al.* (2009), and Joslyn and Savelli (2010), with minor modifications (e.g. to adapt the questions to °C instead of °F, wording improvements). Because the questions were used previously, the questions were not pre-tested within the UK. The surveys presented participants with a series of human-behaviour questions designed to test four themes.

1. Perceptions of uncertainty in deterministic forecasts
2. Uses of forecasts in hypothetical decision-making scenarios
3. Interpretations of probability of precipitation forecasts
4. Preferred ways to receive forecast uncertainty information

Subsequent sections of this article address these four different themes.

Perceptions of uncertainty in deterministic forecasts

Surveys conducted in the USA indicate that most people expect uncertainty in deterministic forecasts (Morss *et al.* 2008; Joslyn and Savelli 2010; Savelli and Joslyn 2012). For example, in a survey of the US public, 95% of participants inferred uncertainty in deterministic high-temperature forecasts, with the most popular range being about ±1°C (±2°F) selected by more than 40% of participants (Morss *et al.* 2008). A question modeled after that in Morss *et al.* (2008) was asked to the UK participants: “Suppose the forecast high temperature for tomorrow for your area is 20°C. What do you think the actual high temperature will be?” Participants could select 20°C, write in a range that the high temperature may fall between, or respond “other” and provide a written response.

As in the results from the USA, 85 of the 92 UK participants (92%) predicted that the temperature was likely to fall within a range, whereas only 3 (3%) believed that the high temperature would be exactly 20°C (Figure 1a) and only 4 (4%) provided a written response. Excluding the 4 providing a written response, 41 of these 88 (47%) were centred on 20°C, with the most frequent response being 18–22°C (Figure 1a). Interestingly, this result is similar to the accuracy of Met Office forecasts; as of May 2012, the Met Office (2012) claims that 89% of its high-temperature forecasts for the current day are within ±2°C of the actual temperature. Figure 1b shows the results from the 53% of participants who provided a forecast range not centred on 20°C and the bias towards lower temperatures in their expectation of uncertainty in the forecast: only 8 (9.1%) were biased high (positive ranges) compared to 39 (44.3%) biased low (negative ranges). These results are consistent with the biases found in surveys by Joslyn and Savelli (2010) and Savelli and Joslyn (2012).

For those participants who provided ranges, the minimum value in the range was as small as 10°C and the maximum value in the range was as large as 32°C (the participant responded 28–32°C, possibly indicating that the respondent did not understand the question or did not take the survey seriously). This large range in values suggests variability among individuals when applying uncertainty to deterministic forecasts (Morss et al. 2008). These results also suggest some inexperience among participants in knowing that a forecast of 20°C would be quite unlikely to verify at either 10°C or 32°C (or an extreme distrust of the forecast!).

Uses of forecasts in hypothetical decision-making scenarios

Hypothetical scenarios can be used as tools for understanding possible uses of forecast information (e.g. Morss *et al.* 2008, 2010; Joslyn and Savelli 2010; Schultz *et al.* 2010). The survey asked participants to indicate their likelihood to take protective action given different types of weather forecasts in three hypothetical decision-making scenarios.

The first scenario posed a deterministic forecast scenario originating from Joslyn and Savelli (2010): “Imagine that it is December and you have a favourite potted plant outside that would be damaged by freezing temperatures. The nighttime low temperature for the next night is predicted to be 0°C (freezing).” When asked whether they would bring the plant inside (yes or no), 84% of the participants said that they would, suggesting that they believed the risk of temperatures 0°C or lower was high enough to warrant protective action. Participants were then asked to write in what they thought the nighttime low might be; 50% wrote in 0°C (Figure 2a). Participants were then asked to write in temperatures for the following two statements: “I would not be surprised if the nighttime low temperature was as high [low] as __°C.” Most of the answers were within 5°C of freezing (Figures 2b,c), further evidence that participants expected uncertainty from a deterministic forecast and a range of possible expected temperatures was generally within 5°C of the forecasted temperature.

Although the question being asked for Figure 2 was similar to the one for Figure 1 (i.e. asking the extent to which people expect or infer uncertainty in a deterministic forecast), many more people provided a deterministic interpretation of the forecast in the question associated with Figure 2 (3% in Figure 1a versus 50% in Figure 2a). Another difference is that the responses in Figure 1b indicated that participants generally responded by providing a range with a mean less than 20°C, whereas the responses in Figure 2 indicated relatively little bias. The reasons for these two differences are not clear, but may be a result of the way the questions were worded or the format of the required answer. For example, the multiple-choice question in Figure 1 forced participants to decide between 20°C only or a range. In contrast, the question in Figure 2 forced them to identify a specific temperature that they would expect. Therefore, most participants did not see a reason to bias their response above freezing or below freezing (Figure 2a). Given this result, further investigation into why these specific wordings might result in different types of responses is warranted.

The second scenario posed a probabilistic forecast scenario originating from Morss *et al.* (2010): “Imagine that it is August and you are organizing an outdoor picnic planned for tomorrow. At what forecast chance of rain for tomorrow would you decide today to move your picnic indoors?” Participants could choose to not take action, or to take action at a 10%, 20%, 30%, …, or 100% chance of rain. The most frequent response was moving the picnic indoors at 60% chance of rain tomorrow, although 7% would take no protective action today (Figure 3a). Similarly, the same question asked in a larger survey of the public in the USA yielded a maximum at 50% with a sharp drop off at smaller values, and 4% not moving the picnic (Morss *et al.* 2010).

The third scenario also posed a probabilistic forecast scenario derived from Joslyn and Savelli (2010): “Imagine that it is August and you work with elderly people who could become ill if temperatures are 40°C or higher. At what forecast chance of a 40°C or higher temperature would you prepare?” The majority of participants chose to take action at 10–50% probability (Figure 3b).

Comparing the second and third scenarios (cf. Figures 3a and 3b) showed that participants would tend to take action in the 40°C scenario at lower probabilities than for the picnic scenario, with these two distributions being statistically different (Student’s t test, $p < 0.0001$). Perhaps participants perceived greater risk and more severe consequences in the high-temperature scenario for elderly people than being rained out at a picnic. Furthermore, the broad distributions in both scenarios (Figures 3a and 3b) indicate the wide range of choices that different people would make given the same scenario, confirming the results of previous work in the USA (Morss *et al.* 2010; Joslyn and Savelli 2010).

Interpretations of probability of precipitation forecasts

To investigate participants’ interpretations of probability of precipitation forecasts, we asked a survey question drawn from Murphy et al. (1980), Morss *et al.* (2008)

and Joslyn *et al.* (2009): “Suppose the following text is the forecast for tomorrow: ‘There is a 60% chance of rain tomorrow.’ In your own words, please explain what you think this means. Please be as specific as you can.” The results were classified into groups, which were similar to those previously published in Gigerenzer *et al.* (2005) and Morss et al. (2008) where possible (Table 1). In cases where participants provided multiple interpretations in their response, the dominant or most specific interpretation was the one into which the response was classified.

The most common way to interpret the forecast was to restate it in one of four ways (66%) (Table 1). Only 4% of participants provided an interpretation similar to “If tomorrow happens 10 times, 6 of them would be rainy” (“days” interpretation of reference class, following Gigerenzer *et al.* 2005). In previous studies, restatements have also been the most popular response to similar open-ended questions about interpretation of probability of precipitation forecasts (Murphy *et al.* 1980; Gigerenzer *et al.* 2005; Morss *et al.* 2008; Joslyn *et al.* 2009). One possible explanation may be that restating the forecast implies that participants thought they sufficiently understood the probability forecast as presented; another may be that they did not know and were unwilling to expose their lack of knowledge, although this was only a few percent in previous studies (Murphy *et al.* 1980; Morss *et al.* 2008; Joslyn *et al.* 2009). Additionally, Murphy *et al.* (1980) suggested that participants’ lack of adding further interpretation to the forecast implies they were willing to use numerical probability of precipitation forecasts. However, restating the forecast as a percentage is not sufficient to understand if participants interpreted it correctly. For example, when participants chose to be more specific with their responses, it was common for them to think that the percentage related to areal, temporal or precipitation amount (Murphy *et al.* 1980; de Elía and Laprise 2003), although those were not common interpretations in our data (Table 1). Therefore, in line with these previous studies, the numerical restating of the probability forecast does not highlight what the participants perceived the 60% as.

Preferred ways to receive forecast uncertainty information

The mass media (e.g. local television, newspapers, radio stations) have made weather forecasts easily accessible to the public (Tan 1976; Hayden *et al.* 2007) in a variety of different presentation methods and formats (World Meteorological

Organization 2008). Therefore, individuals are provided with the opportunity to pick and mix forecasts from sources that suit their understanding and needs (Demuth *et al.* 2011). Given this potential variety in the delivery and presentation of forecasts, how would people prefer uncertainty forecasts be presented? Three questions were aimed at addressing preferred wordings to possible uncertainty forecasts.

First, participants were asked their preference when presented with a deterministic weather forecast and a simple type of uncertainty forecast from evening news programs on two different television channels (question originating from Morss *et al.* 2008).

Channel A: “The high temperature will be 25°C tomorrow.”

Channel B: “The high temperature will be between 24°C and 26°C tomorrow.”

Participants could choose that they would prefer the forecast given by channel A, channel B, that they liked both channels, that they did not like either forecast or that they did not know. Similar to the results in Morss et al. (2008), most participants (56% + 14%) would prefer or be willing to receive the uncertainty forecast presented here compared to 20% that prefer the deterministic forecast alone (Figure 4), although the lack of a random order for the response options may confound that result.

Second, participants were asked to select their preferences in a more detailed scenario in a question originating from Morss *et al.* (2008): “The high temperature for tomorrow will probably be 30°C. However, a cold front may move through during the day, in which case the high temperature tomorrow will be 20°C. Based on this weather scenario, for the options listed below, would you like the forecast given in this way?” Participants were presented with seven examples of how the forecast could be worded (Figure 5) and were asked whether they liked the forecast presented in this manner (yes or no). The deterministic forecast 7 was the least popular option with only 13% of participants liking this wording. This result was substantially lower than the 35% of participants who preferred the deterministic forecast in the Morss et al. (2008) study from the USA. The top three choices gave an explanation of the weather leading to the uncertainty, receiving 78%, 76%, and 67% favorable ratings. The next three choices explained that there could be a range or the possibility of two different temperatures, receiving 57%, 41%, and 36% favorable ratings. In particular, consider forecasts 3 and 6, which present the same information probabilistically, but 3 explains the reason for the uncertainty. Similar to

Morss et al. (2008), forecast 3 is liked by nearly twice as many participants as forecast 6 (Figure 5). As discussed in Morss et al. (2008), these results suggest that providing a simple explanation may be a way of communicating forecast uncertainty many people like, at least as a supplement to other uncertainty information. Given the limited nature of this study, however, further testing of these results is needed in other contexts.

Third, to assess participants' preferences for ways of communicating probability of precipitation forecasts, a question originating from Morss *et al.* (2008) asked, "All the choices listed below are the same as a probability of rain of 20%. For the options listed below, do you like this information given this way? Please think about each option separately (i.e., do not compare each option to the others listed). For each question, circle either Yes or No." By far, the most popular format was "chance of rain tomorrow is 20%" with 90% of participants saying that they liked this format (Figure 6). The second most popular format was "There is a slight chance of rain tomorrow" with 65% in favor, and the third most popular format was "There is a 1 in 5 chance of rain tomorrow" with 33% in favor. The least popular format was "The odds are 1 to 4 that it will rain tomorrow" with only 7% in favor. These findings are consistent with those in Morss et al. (2008) from the USA. The responses indicate that, even in the UK where probability forecasts are less commonly used, participants preferred the probability forecasts, similar to that preferred in the USA.

Generality of results

This survey was given to 92 undergraduate earth- and environmental-science students at the University of Manchester. Whether these results can be generalized to the general public is important to consider. This same survey was also given to 126 undergraduate students (generally non-science students) in an introductory weather course at the University of Washington, Seattle, USA, in autumn 2010. These results, not presented here, are quite similar to those from the University of Manchester. Furthermore, many of the questions asked in this survey were also asked in surveys administered by Morss *et al.* (2008, 2010) and Joslyn and Savelli (2010), yielding similar results and providing some support for their generality. Nevertheless, surveys of this type should be extended to the UK population as a whole to examine generality, to obtain a larger sample size, and to probe further some of the results presented here.

Implications for communicating forecasts

Although studies suggest that many members of the public can interpret probability of precipitation forecasts in a general sense (i.e. 70% is higher than 30%), the specific meaning of the forecasts remains unclear to many (Murphy *et al.* 1980; Gigerenzer *et al.* 2005; Morss *et al.* 2008; Joslyn and Savelli 2010). Furthermore, data from other studies indicates some ways that modifying the presentation of forecasts can enhance clarity. Three examples follow. First, Joslyn *et al.* (2009) found that users better understood the forecast when the probability of *no precipitation* was communicated (e.g. "30% chance of precipitation, but 70% chance of no precipitation"). Second, Gigerenzer *et al.* (2005) suggested that forecasts should make clear to what the probability refers (e.g. "6 out of 10 days like today would produce rain"). Third, distilling the complexity of a day's weather into a single icon is a poor substitute for the knowledge that meteorologists have about the forecasted weather (e.g. Kahl and Horwitz 2003; Ryan 2003a,b; Le Blancq 2012). For example, pie charts filled 25% with raindrop icons to represent a 25% probability of precipitation confused users who thought that 25% of the area would be covered by rain or 25% of the time it would be raining (Joslyn *et al.* 2009), similar to some of the responses in Table 1. Building on these three examples, we propose that when uncertainty, and more specifically probabilistic, forecasts are first revealed to a new audience such as the public, it will be helpful to clarify the meaning and use of these new formats. Finding innovative, yet simple, ways to communicate uncertainty and probabilistic forecasts will go a long way to improving public understanding and to alleviating confusion and misunderstanding (Ryan 2003b; Gigerenzer *et al.* 2005; Hirschberg *et al.* 2011; Le Blancq 2012).

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Table 1. Ninety-two participants' free-text responses when interpreting the statement "There is a 60% chance of rain tomorrow". (Percentage may not equal 100% because of rounding.)

Interpretation	Example Answer	Participants (%)
Restatement: Worded	"It is likely to rain."	37
Restatement: Probability or relative frequency	"There is a 60% chance it will rain tomorrow."	14
Restatement: Probability and reverse	"There is a 60% chance of rain tomorrow or there is a 40% chance it will not rain tomorrow."	11
Weather conditions causing or associated with rain	"Cloudy, and windy. Even if it is rainy tomorrow, it won't last a long time."	8
Forecast or forecaster	"There is a good chance it will rain but the forecast is not certain."	5
Restatement: Reverse	"There is a 40% chance it won't rain."	4
"Days" interpretation of reference class	"If exactly the same weather conditions occur on 10 days, 6 of these days will experience rain in any amount or length of time."	4
Areal coverage interpretation of reference class	"In roughly 60% of areas it is likely to rain whereas 40% of places will have no rain."	3
Personal	"It is more likely than not that in my area that I will experience rain at some point during the forecast period."	3
Relative probability	"It is more likely to rain than not as figure is above 50% but still not very certain of rain as figure isn't close to 100% chance of raining."	2
Use	" It will rain tomorrow, as we are in Manchester. Take a brolly!"	2
Other	"There is only a 50% chance to rain anyways: either it rains (50%) or not (50%)."	2
Deterministic forecast	"It's going to rain at some point during the day."	2
Temporal coverage interpretation of reference class	"Just over half of the day there will probably be rain."	1

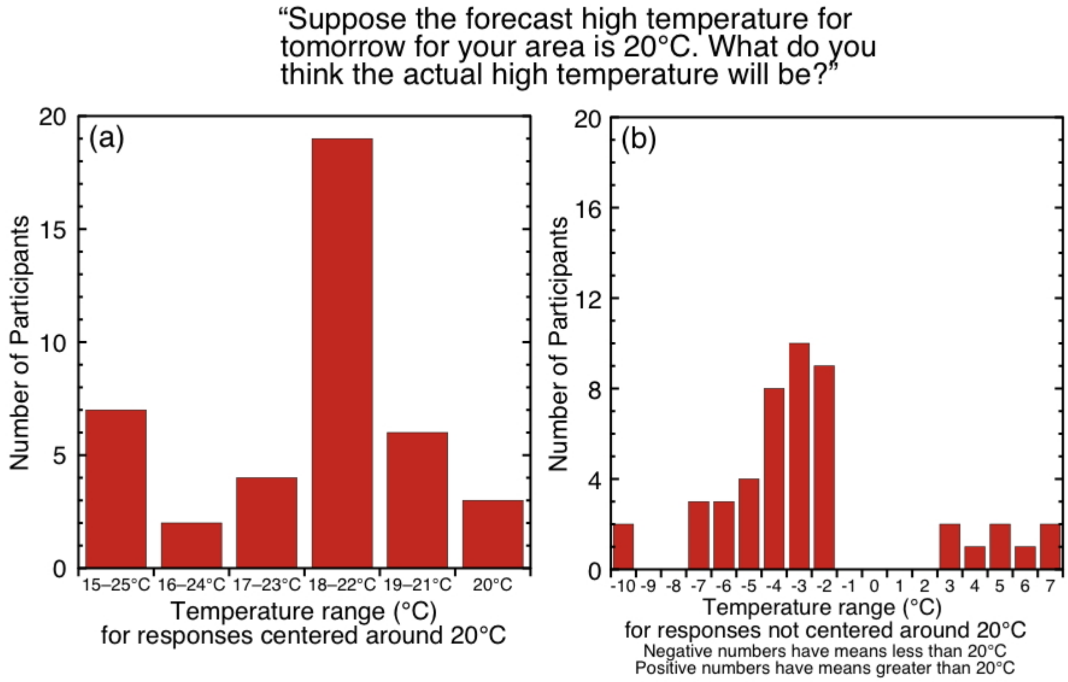

Figure 1: Participants' responses (*N*=88) to the open-ended question, "Suppose the forecast high temperature for tomorrow for your area is 20°C. What do you think the actual high temperature will be?" (a) 41 responses (47%) that are centred around or equal to 20°C. (b) 47 responses (53%) that are not centred around 20°C. For panel (b), a temperature range of –5°C could represent 17–22°C or 15–20°C, for example. Four responses to this question were omitted from this figure: "other" with such write-in answers as "Mostly dependent on time of day, wind and cloud cover," or "20°C is an estimate of general area; cloud cover and wind can change the temperature."

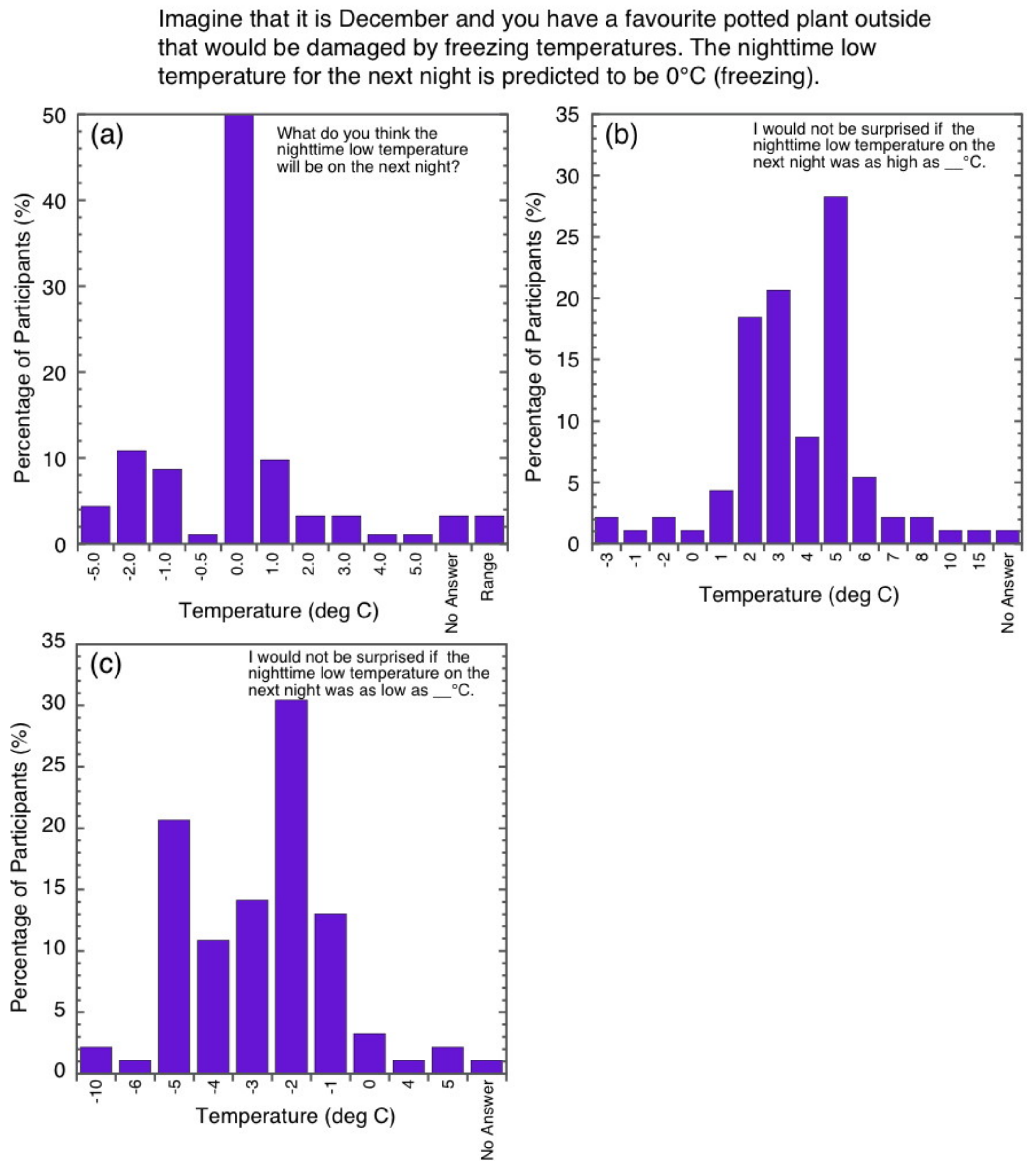

Figure 2. Given a low temperature forecast of 0°C, participants' responses (*N*=92) to the questions (a) "What do you think the nighttime low temperature will be on the next night?", (b) "I would not be surprised if the nighttime low temperature on the next night was as high as __°C", and (c) "I would not be surprised if the nighttime low temperature on the next night was as low as __°C".

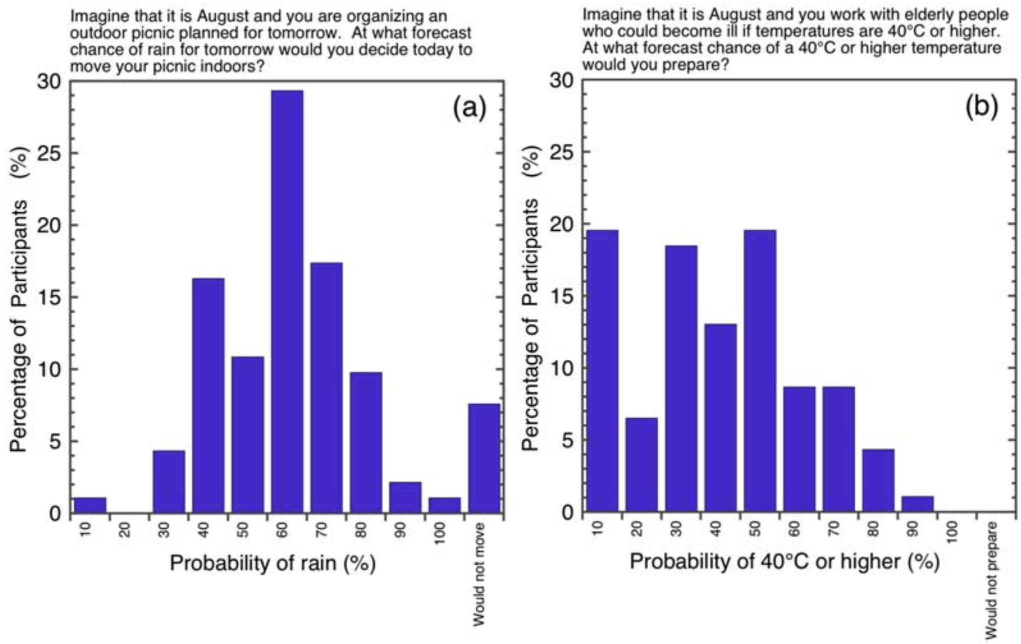

Figure 3: Participants' responses (*N*=92) for (a) at what percentage forecast probability of rain they would take protective action for a planned picnic; and (b) at what percent forecast probability of temperature ≥40˚C they would take protective action working with elderly people.

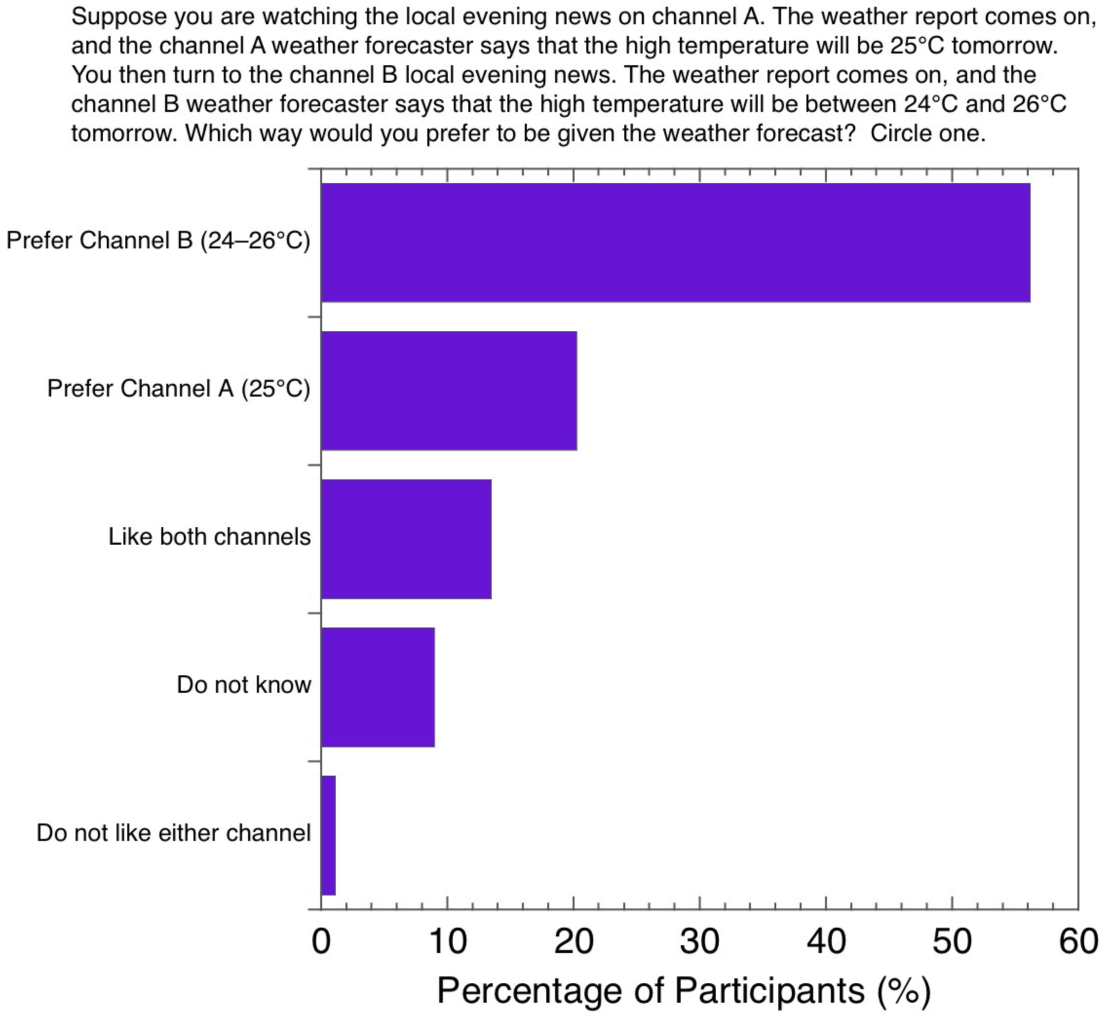

Figure 4: Participants' responses (*N*=92) to the following question: "Suppose you are watching the local evening news on channel A. The weather report comes on, and the channel A weather forecaster says that the high temperature will be 25°C tomorrow. You then turn to the channel B local evening news. The weather report comes on, and the channel B weather forecaster says that the high temperature will be between 24°C and 26°C tomorrow. Which way would you prefer to be given the weather forecast? Circle one."

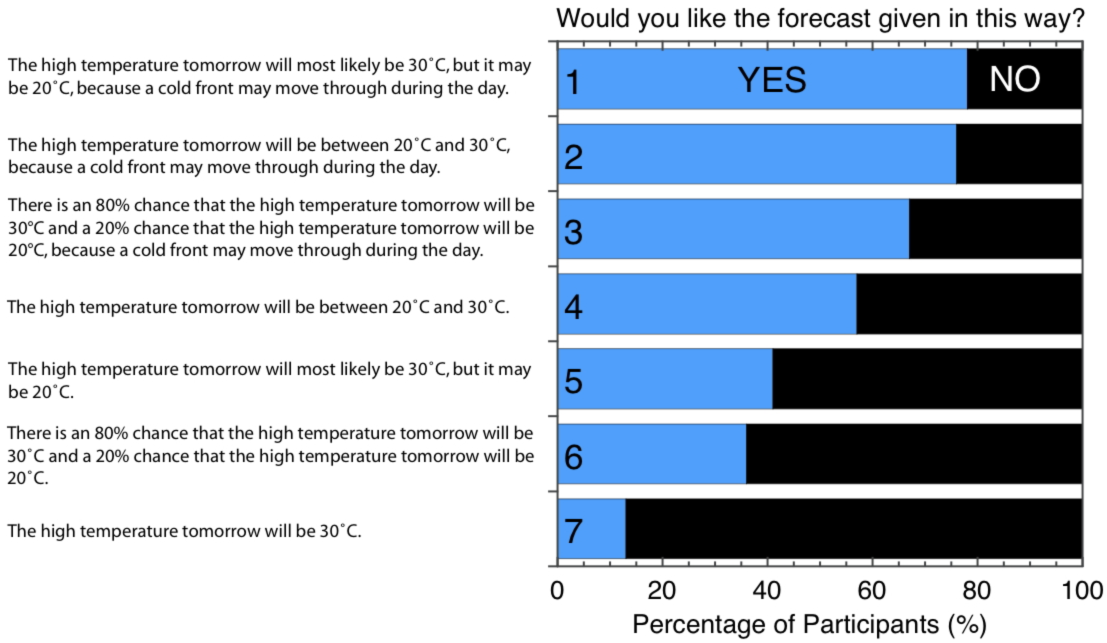

Figure 5. Participants' responses (*N*=92) to the following question: "Suppose that weather forecasters think the high temperature tomorrow will probably be 30°C. However, a cold front may move through during the day, in which case the high temperature tomorrow would only be 20°C. Based on this weather scenario, for the options listed below, would you like the forecast given in this way? Please think about each option separately (i.e., do not compare each option to the others listed). For each question, circle either Yes or No." For each of the seven different wordings of forecasts (1–7) provided, the percentage of participants responding Yes (blue) and No (black) is shown.

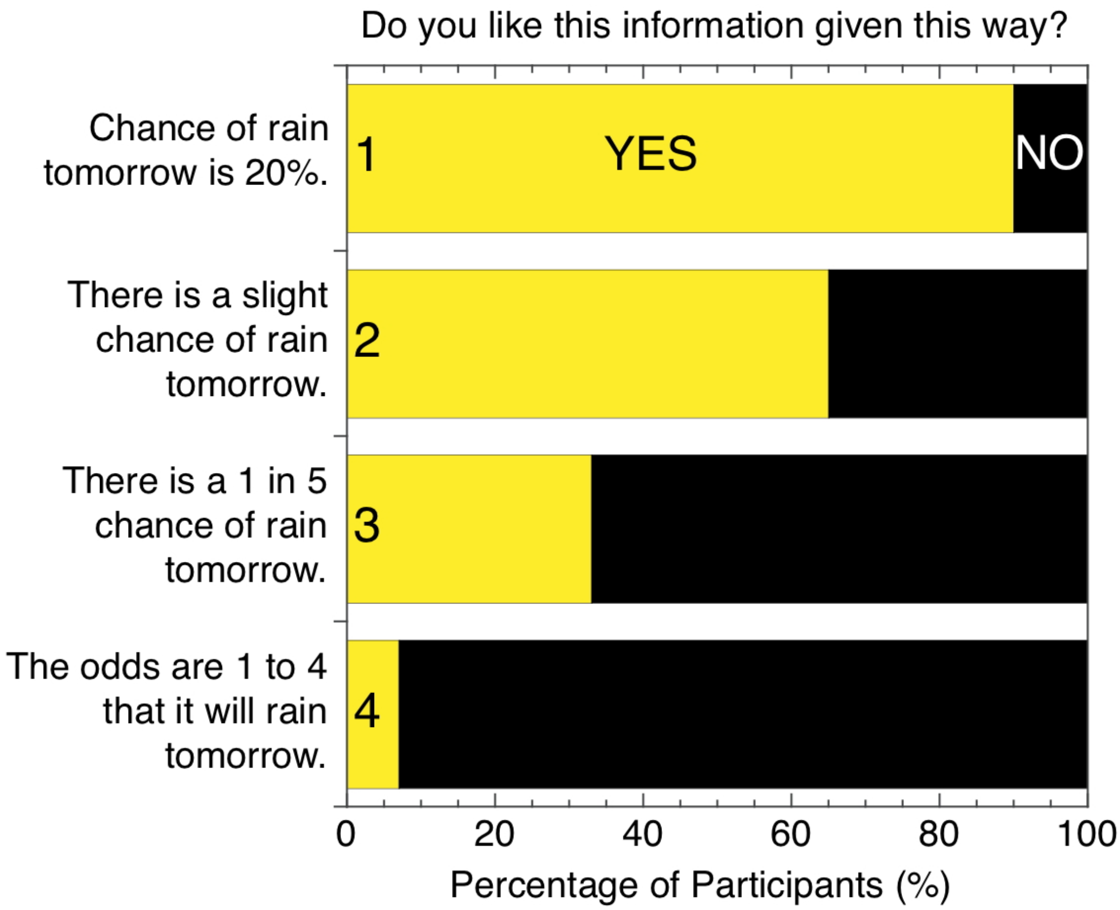

Figure 6. Participants' responses (*N*=92) to the following question: "All the choices listed below are the same as a probability of rain of 20%. For the options listed below, do you like this information given this way? Please think about each option separately (i.e., do not compare each option to the others listed). For each question, circle either Yes or No." Four different wordings of forecasts (1–4) and the percentage of participants responding Yes (yellow) and No (black).