

See discussions, stats, and author profiles for this publication at: <https://www.researchgate.net/publication/23998211>

Improving Communication of Uncertainty in the Reports of the Intergovernmental Panel on Climate Change

Article *in* Psychological Science · February 2009

DOI: 10.1111/j.1467-9280.2009.02284.x · Source: PubMed

CITATIONS

151

READS

341

3 authors:



[David V. Budescu](#)

Fordham University

190 PUBLICATIONS **6,265** CITATIONS

SEE PROFILE



[Stephen B. Broomell](#)

Carnegie Mellon University

16 PUBLICATIONS **308** CITATIONS

SEE PROFILE



[Han-Hui Por](#)

Educational Testing Service

10 PUBLICATIONS **271** CITATIONS

SEE PROFILE

Research Article

Improving Communication of Uncertainty in the Reports of the Intergovernmental Panel on Climate Change

David V. Budescu, Stephen Broomell, and Han-Hui Por

University of Illinois at Urbana-Champaign

ABSTRACT—*The Intergovernmental Panel on Climate Change (IPCC) assesses information relevant to the understanding of climate change and explores options for adaptation and mitigation. The IPCC reports communicate uncertainty by using a set of probability terms accompanied by global interpretational guidelines. The judgment literature indicates that there are large differences in the way people understand such phrases, and that their use may lead to confusion and errors in communication. We conducted an experiment in which subjects read sentences from the 2007 IPCC report and assigned numerical values to the probability terms. The respondents' judgments deviated significantly from the IPCC guidelines, even when the respondents had access to these guidelines. These results suggest that the method used by the IPCC is likely to convey levels of imprecision that are too high. We propose an alternative form of communicating uncertainty, illustrate its effectiveness, and suggest several additional ways to improve the communication of uncertainty.*

The Intergovernmental Panel on Climate Change (IPCC) was established by the World Meteorological Organization and the United Nations Environmental Programme to gather and assess information relevant to the understanding of climate change and its potential impact, and to explore options for adaptation and mitigation. The panel's conclusions are condensed into Assessment Reports, which have been instrumental in making climate change an important topic for policymakers and the

public (Agrawala, 1998; Oppenheimer, O'Neill, Webster, & Agrawala, 2007; Oreskes, 2004). The 2007 Nobel Prize for Peace committee cited the panel's "efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change" (Nobelprize.org, 2008).

Recent events have pushed the debate about climate change to the top of the public agenda. Climate change is considered an important public-policy topic that merits immediate attention (CBS News & New York Times, 2007). Much of the disagreement between the two camps in this debate relates to the uncertainty surrounding the science of climate change and the projections of its models. Some critics of the IPCC use this uncertainty strategically; that is, they invoke it as an excuse to dismiss the findings altogether (e.g., Begley, 2007). We believe that social scientists specializing in risk assessment and communication can, and should, play a major role in the debate on this important public-policy issue, by ensuring that all sides understand the state of the scientific findings and their underlying uncertainty.

To this end, we studied how the public understands the IPCC's communication of uncertainty. We present results of an experiment that tested how the public interprets the probabilistic statements in the 2007 report and document some of the shortcomings of the method used currently. We propose and demonstrate the efficacy of an alternative reporting format, and conclude with a set of recommendations that could alleviate many of the existing problems and improve communication of the key uncertainties.

COMMUNICATION OF UNCERTAINTY IN THE IPCC REPORT

The guidelines for the lead authors of the IPCC fourth report (IPCC, 2005) recommended using a scale consisting of seven

Address correspondence to David Budescu, Department of Psychology, Fordham University, Dealy Hall, Bronx, NY 10458, e-mail: budescu@fordham.edu.

TABLE 1
Likelihood Scale of the Intergovernmental Panel on Climate Change

Phrase	Likelihood of occurrence
Virtually certain	> 99%
Very likely	> 90%
Likely	> 66%
About as likely as not	33% to 66%
Unlikely	< 33%
Very unlikely	< 10%
Exceptionally unlikely	< 1%

Note. The report we analyzed used *more likely than not* (probability > 50%), instead of *about as likely as not*.

verbal terms (Table 1 lists the recommended terms and the numerical values associated with them). Verbal terms can minimize problems associated with misinterpretation of numerical probabilities (e.g., Budescu & Wallsten, 1995; Fox & Irwin, 1998; Lipkus, 2007). Because verbal probability descriptors are vague and elastic, they are consistent with wide ranges of numerical probabilities (e.g., Wallsten, Budescu, Rapoport, & Forsyth, 1986) and can accommodate disagreements between various sources and experts. However, verbal terms' imprecision is also their major weakness, as they induce an illusion of communication (Budescu & Wallsten, 1985): People assume that everyone interprets the terms consistently and similarly, and fail to appreciate the variance in the interpretations of these words. The high level of potential miscommunication has been widely documented in many contexts (Brun & Teigen, 1988; Budescu & Wallsten, 1990; Karelitz & Budescu, 2004; Wyden, 1979). [Patt and Schrag \(2003\)](#) showed that communicators and the audience of probability words interpret them differently, and that these interpretations vary as a function of the events' severity. These authors speculated that these differences in interpretation may cause the public to underestimate the probabilities communicated in the IPCC reports.

The current study measured the degree to which the public's interpretation of the forecasts in the fourth IPCC report matches the authors' intentions. We hypothesized that the IPCC's probabilistic pronouncements are systematically misinterpreted by the public in a regressive fashion that can potentially lead to severe consequences. We also examined whether communication of the information in the report could be improved by issuing general interpretational guidelines designed to override individuals' spontaneous use and comprehension of language or by adopting alternative communication modes that combine words with numerical ranges. Specifically, we tested the efficacy of appending a generic translation table to the report (e.g., [Beyth-Marom, 1982](#); [Hamm, 1991](#); [Mosteller & Youtz, 1990](#)) and of associating every probability term in the text with a specific range of numerical values to create, in effect, a dual (verbal and numerical) scale (e.g., [Wittman & Renoij, 2003](#); [Wittman, Renoij, & Koele, 2007](#)). We predicted that both presentation

modes would improve communication, but expected the dual scale to be more effective because it highlights the key uncertainties, provides a constant reminder of the translation scheme, provides more information, and is perceived as informative by people who have different levels of expertise and diverse preferences for communication modes (Budescu & Wallsten, 1995).

METHOD

Subjects

The subjects were 223 volunteers from the University of Illinois community who responded to a posting on a campuswide electronic newsletter that advertised the study and promised a \$10 payment for participation. The subjects included 139 women and 84 men ranging in age from 18 to 71 years ($M = 30$, $SD = 13$). Only 60% of the participants were students.

Procedure

The experiment was computerized and administered individually. Participants first completed questionnaires designed to measure their beliefs about, and attitudes toward, the environment and climate change. These measures included the Revised New Ecological Paradigm ([Dunlap, Van Liere, Mertig, & Jones, 2000](#)) and the following scales used by [Heath and Gifford \(2006\)](#): perception that climate change is occurring, perception of climate change causes, perception of climate change consequences, self-efficacy (in the context of climate change), intention to act (in the context of climate change), and belief in the free-market system.

Next, subjects read 13 sentences from the IPCC report that included probabilistic pronouncements regarding environmental and climatic events (in each case, the target term was highlighted). Each of four key terms—*very likely*, *likely*, *unlikely*, and *very unlikely*—was used in 3 sentences.¹ One sentence used the phrase *more likely than not*, which is actually not listed in the IPCC guidelines. Table 2 presents the 13 statements that subjects read and rated.

For each sentence, subjects provided their best estimate of the probability intended by the report's authors, and the lowest and highest possible values they thought were consistent with the authors' intentions. Responses were made by sliding a cursor along a slider that was 11.5 cm long. Figure 1 shows a typical display. Subjects could adjust their initial responses for a particular sentence, but could not return to previous displays. The computer program ensured that, for each sentence, the value of the best estimate was no lower than the lower bound and no higher than the upper bound. The presentation order of the sentences was randomized. Most participants completed the study in less than 45 min.

¹To achieve this balance, we altered 4 sentences (8, 9, 10, and 12 in Table 2) by replacing the terms *likely* and *very likely* with *unlikely* and *very unlikely*, respectively.

TABLE 2
Statements Used in the Experiment

Sentences with *very likely*

1. It is **very likely** that hot extremes, heat waves, and heavy precipitation events will continue to become more frequent.
2. Continued greenhouse gas emissions at or above current rates would cause further warming and induce many changes in the global climate system during the 21st century that would **very likely** be larger than those observed during the 20th century.
3. Average Northern Hemisphere temperatures during the second half of the 20th century were **very likely** higher than during any other 50-year period in the last 500 years and likely the highest in at least the past 1300 years.

Sentences with *likely*

4. Global average sea level in the last interglacial period (about 125,000 years ago) was **likely** 4 to 6 m higher than during the 20th century, mainly due to the retreat of polar ice.
5. The Greenland ice sheet and other Arctic ice fields **likely** contributed no more than 4 m of the observed sea level rise.
6. Temperatures of the most extreme hot nights, cold nights and cold days are **likely** to have increased due to anthropogenic forcing.

Sentence with *more likely than not*

7. It is **more likely than not** that anthropogenic forcing has increased the risk of heat waves.

Sentences with *unlikely*

8. It is **unlikely** that there has not been significant anthropogenic warming over the past 50 years averaged over each continent except Antarctica.
9. Based on a range of models, it is **unlikely** that future tropical cyclones (typhoons and hurricanes) will not become more intense, with larger peak wind speeds and more heavy precipitation associated with ongoing increases of tropical SSTs [sea surface temperatures].
10. Temperatures of the most extreme hot nights, cold nights and cold days are **unlikely** to have increased due to factors other than anthropogenic forcing.

Sentences with *very unlikely*

11. It is **very unlikely** that the MOC (the meridional overturning circulation) will undergo a large abrupt transition during the 21st century.
 12. It is **very unlikely** that hot extremes, heat waves, and heavy precipitation events will not continue to become more frequent.
 13. It is **very unlikely** that climate changes of at least the seven centuries prior to 1950 were due to variability generated within the climate system alone.
-
-

Subjects were assigned to one of four conditions. Subjects in the *control* group were not given any instructions on the interpretation of the phrases. This group simulated the experience of a reader who is not aware of the report's guidelines regarding interpretation of uncertainty. Subjects in the *translation* group were shown the guidelines given by the IPCC, and could revisit this table at any time by clicking a button (see Fig. 1). This group simulated the experience of a conscientious reader who has studied the report's guidelines and turns back to the translation table whenever he or she needs a reminder. Subjects in the *verbal-numerical* conditions saw a range of numerical values next to each verbal term.² To test readers' sensitivity to the widths of the intervals, we ran two groups: The *wide* group was shown the numerical ranges recommended by the IPCC translation in every sentence with a probabilistic term. The *narrow* group was shown subsets of the original ranges conveying a higher level of precision (the ranges for *likely*, *more likely than not*, and *unlikely* had a length of 10%, and those of *very unlikely* and *very likely* were set at 5%).

RESULTS

We conducted multivariate analyses of variance comparing the three kinds of responses (lower bounds, upper bounds, and best

guesses) to each word across the four groups. We did not find systematic differences among the various sentences using the same terms, so we average the judgments across replications. These analyses were all significant, indicating that the presentation format affected interpretation. In discussing the sources of these differences, we first focus on the control and translation groups, which represent the current presentation mode. Next, we compare these two groups with the verbal-numerical groups to examine the efficacy of supplementing verbal terms with their numerical counterparts, and then we compare the two verbal-numerical groups to examine the respondents' sensitivity to the precision of the numerical information. Finally, we consider individual differences in the interpretation of the various phrases.

Control and Translation Groups

Because the IPCC guidelines involve ranges, we first analyzed the ranges implied by our subjects' responses. We classified a range (the mean of the lower bounds and the mean of the upper bounds across all sentences using a given term) as consistent with the IPCC guidelines if both its upper bound and its lower bound were within the range indicated by the guidelines, as inconsistent if these bounds were outside the range indicated by the guidelines, and as partially consistent otherwise. For example, Table 1 suggests that *likely* should describe probabilities greater than 66%. Consequently, responses to *likely* were considered to be consistent if the lower bound for this word was 66% or higher, incon-

²The first 79 subjects were randomly assigned to the control or translation group. The remaining 144 were assigned randomly to the four groups.

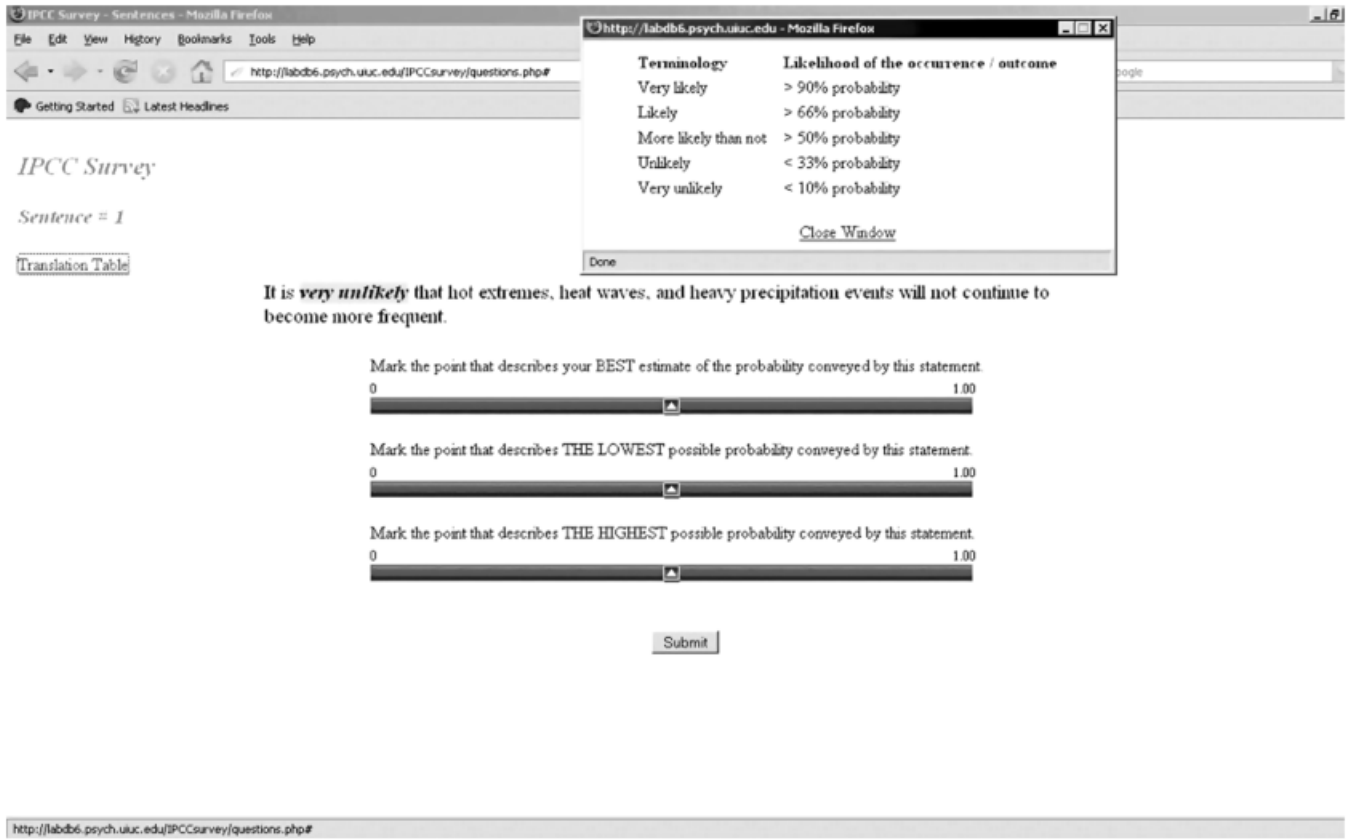


Fig. 1. Example of the displays presented to subjects. This particular display illustrates the information presented to the translation group.

sistent if the upper bound was below 66%, and partially consistent if the upper bound was above 66% and the lower bound below 66%. Table 3 summarizes the consistency of subjects' range estimates in the control and translation conditions. As the table indicates, consistency with the IPCC conversion table was low, especially for phrases that convey more extreme probabilities. Consistency was higher in the translation group than in the control group, but still low in absolute terms. The difference between the groups was significant, $\chi^2(2, N = 132) = 7.89, p < .05$, when the term *more likely than not* was excluded.

Next, we analyzed the respondents' best estimates of *very likely*, *likely*, *unlikely*, and *very unlikely*, averaged across the various sentences. Figure 2 displays the central 90% of the distributions of the best estimates (with the highest and the lowest 5% Winsorized) in the two conditions. (We excluded the term *more likely than not* to facilitate interpretation of the display.) As the figure illustrates, the meanings assigned to the probability terms varied widely across individuals, and the terms were not well differentiated. These patterns were more pronounced in the control group than in the translation group.

TABLE 3
Percentage of Subjects' Range Estimates Consistent, Inconsistent, and Partially Consistent With the Guidelines of the Intergovernmental Panel on Climate Change

Probability phrase	Translation group (n = 67)			Control group (n = 65)		
	Consistent	Partially consistent	Inconsistent	Consistent	Partially consistent	Inconsistent
Very likely (> 90%)	6.0	67.2	26.9	3.1	64.6	32.3
Likely (> 66%)	16.4	70.1	13.4	7.7	73.8	18.5
More likely than not (> 50%)	41.8	49.3	9.0	40.0	56.9	3.1
Unlikely (< 33%)	23.9	59.7	16.4	9.2	72.3	18.5
Very unlikely (< 10%)	7.5	40.3	52.2	4.6	44.6	50.8
Five terms overall	19.1	57.3	23.6	12.9	62.5	24.6
Overall excluding <i>more likely than not</i>	13.5	59.3	27.2	6.1	63.9	30.0

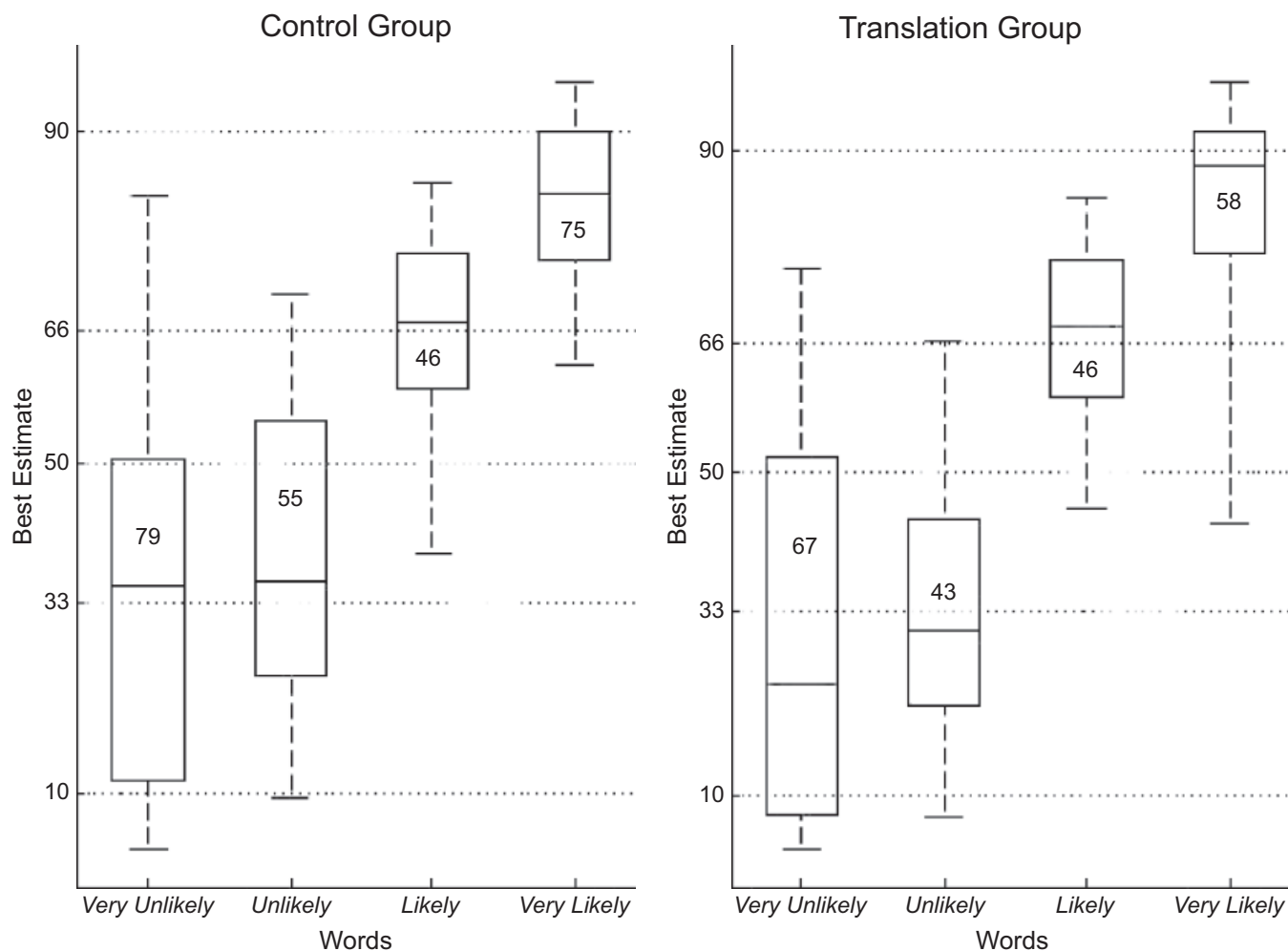


Fig. 2. The central 90% of the distributions of subjects' best estimates of the meanings of four probability terms (*very likely*, *likely*, *unlikely*, and *very unlikely*) in the control (left panel) and translation (right panel) conditions (i.e., the two conditions in which numerical information was not presented in the text). Each box includes the central 50% of judgments, and the solid lines in the boxes mark the medians. The horizontal dotted lines represent the category boundaries in the guidelines of the fourth report of the Intergovernmental Panel on Climate Change (IPCC). The numbers in the boxes indicate the percentage of judgments inconsistent with the IPCC guidelines, and their placement above or below the medians indicates the direction of the misinterpretation.

We considered a best estimate (the mean across all sentences involving a given term) to be inconsistent with the IPCC guidelines if it was outside the prescribed range. Inconsistency with the IPCC guidelines was very high, and it worsened for the more extreme terms (see Fig. 2). Invariably, interpretations were regressive. Inconsistency was reduced by the availability of the conversion table, both across all words, $\chi^2(1, N = 132) = 5.57$, $p < .05$, and for the term *very likely*, $\chi^2(1, N = 132) = 4.38$, $p < .05$.

The terms selected by the IPCC imply a particular order, but most subjects displayed some order reversals (on average, 1.8 reversals per subject in the control group and 1.7 reversals per subject in the translation group).

The Effect of Adding Numerical Information

Given the similarity of the analyses of the implied ranges and the best guesses for the control and translation groups, we focus only

on the best estimates in our comparison of those groups with the verbal-numerical groups. Figure 3 displays the distribution of the subjects' best estimates of the four terms when presented with and without numerical information in the text. The presence of numerical ranges in the text reduced the overall level of inconsistency from 53% to 41%. The proportion of consistent responses increased across all the terms combined, $\chi^2(1, N = 223) = 12.50$, $p < .05$, and for the term *very likely*, $\chi^2(1, N = 223) = 4.39$, $p < .05$.

For all the terms, the median responses were more extreme (less regressive) when numerical information was included than when it was not (.90 vs. .86 for *very likely*, Mann-Whitney U test, $z = -2.10$, $p < .05$; .70 vs. .67 for *likely*; .24 vs. .33 for *unlikely*, $z = -2.38$, $p < .05$; and .17 vs. .33 for *very unlikely*, $z = -2.41$, $p < .05$).

A similar pattern held for the ranges of values associated with the four terms, which were significantly narrower in the condi-

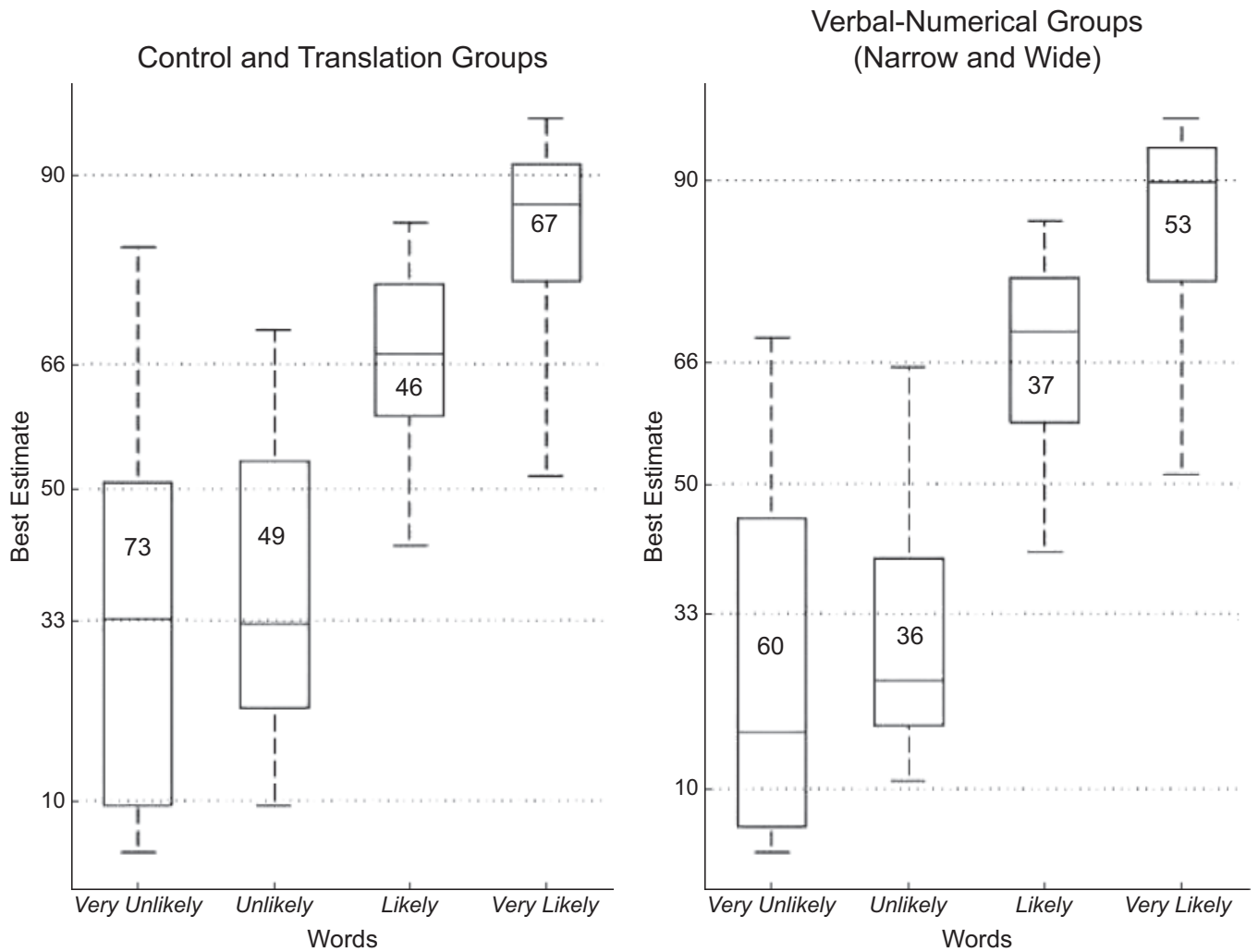


Fig. 3. The central 90% of the distributions of subjects’ best estimates of the meanings of four probability terms (*very likely*, *likely*, *unlikely*, and *very unlikely*) when numerical information was given in the text (i.e., the numerical-verbal conditions; right panel) and when numerical information was not given in the text (i.e., the control and translation conditions; left panel). Each box includes the central 50% of judgments, and the solid lines in the boxes mark the medians. The horizontal dotted lines represent the category boundaries in the guidelines of the fourth report of the Intergovernmental Panel on Climate Change (IPCC). The numbers in the boxes indicate the percentage of judgments inconsistent with the IPCC guidelines, and their placement above or below the medians indicates the direction of the misinterpretation.

tions with numerical ranges given in the text (.16 vs. .26 for *very likely*, Mann-Whitney *U* test, $z = -4.07, p < .05$; .23 vs. .30 for *likely*, $z = -2.37, p < .05$; .21 vs. .29 for *unlikely*, $z = -2.68, p < .05$; and .16 vs. .23 for *very unlikely*, $z = -3.05, p < .05$). The proportion of subjects with order reversals was also reduced significantly (from .64 to .50) by the presence of the numerical ranges, $\chi^2(1, N = 223) = 3.79, p < .05$.

Sensitivity to the Range of Numerical Values

Figure 4 compares the distributions of the subjects’ best estimates when wide versus narrow numerical ranges were included in the text. The overall consistency with the IPCC guidelines was slightly higher in the narrow group (55%) than in its wide counterpart (53%), but this difference was not significant.

The most interesting pattern in Figure 4 is the clear reduction in the range of values associated with these terms in the narrow condition across respondents: The range in this group was reduced for three of the terms and on average (by 7%). This reflects, in part, the fact that individuals’ ranges of the four terms were significantly narrower in the narrow group than in the wide group (.11 vs. .23 for *very likely*, Mann-Whitney *U* test, $z = -3.49, p < .05$; .19 vs. .32 for *likely*, $z = -3.85, p < .05$; .16 vs. .25 for *unlikely*, $z = -3.22, p < .05$; and .12 vs. .20 for *very unlikely*, $z = -2.67, p < .05$). Consequently, individuals’ ranges were consistent with the IPCC guidelines significantly more often for respondents in the narrow group than for respondents in the wide group; this was true not only across all terms (39% vs. 22%), $\chi^2(2, N = 91) = 13.84, p < .05$, but also specifically for the terms *very likely*, $\chi^2(2, N = 91) = 11.22, p < .05$, and *likely*, $\chi^2(2, N = 91) = 9.02, p < .05$.

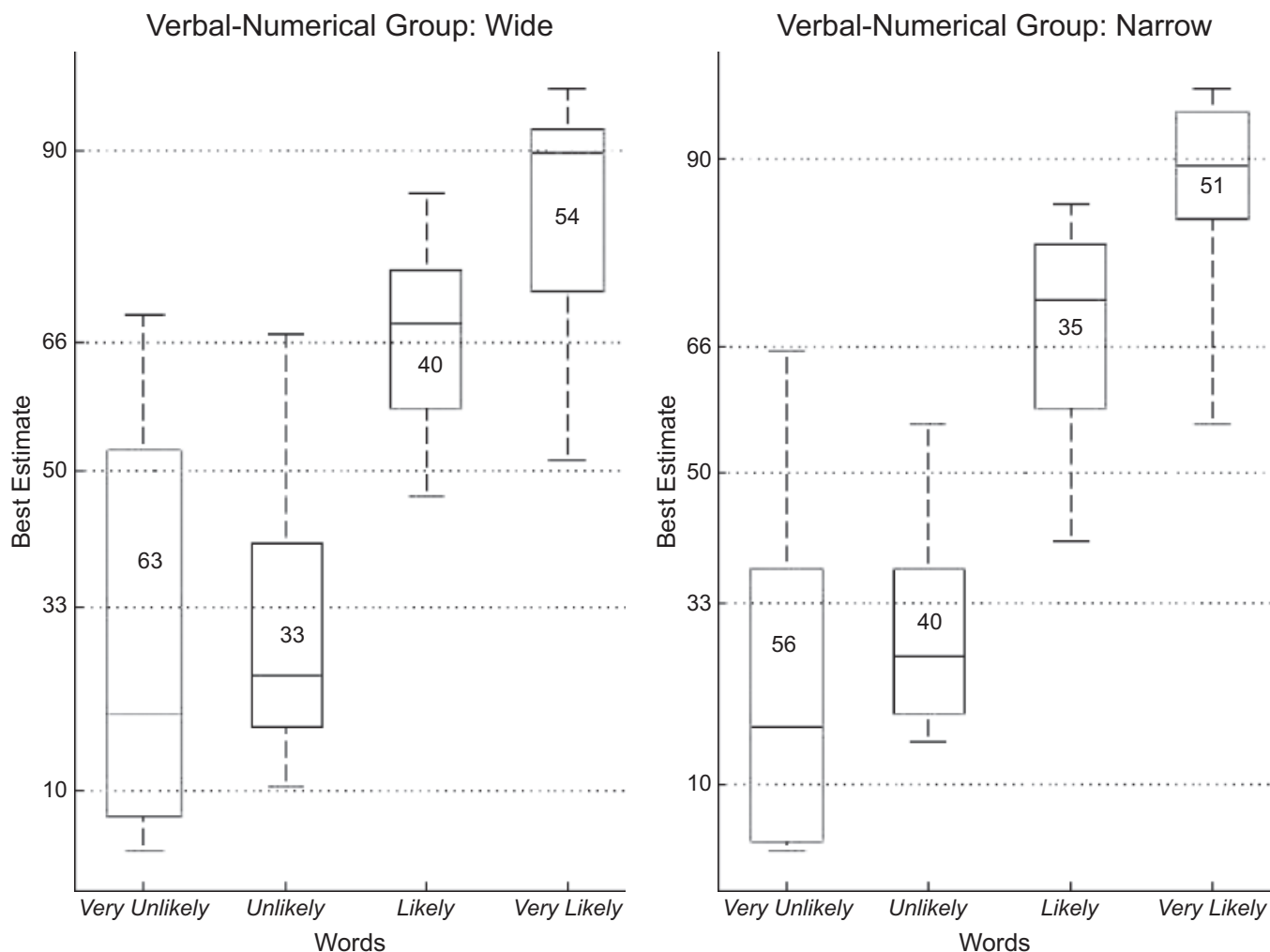


Fig. 4. The central 90% of the distributions of subjects' best estimates of the meanings of four probability terms (*very likely*, *likely*, *unlikely*, and *very unlikely*) when wide (left panel) and narrow (right panel) numerical ranges were included in the text. Each box includes the central 50% of judgments, and the solid lines in the boxes mark the medians. The horizontal dotted lines represent the category boundaries in the guidelines of the fourth report of the Intergovernmental Panel on Climate Change (IPCC). The numbers in the boxes indicate the percentage of judgments inconsistent with the IPCC guidelines, and their placement above or below the medians indicates the direction of the misinterpretation.

Individual Differences in the Interpretation of the Terms

We correlated various characteristics of the individual subjects' responses (their best guess, their estimate of the lower and upper bounds and of the range of each term, and overall consistency with the IPCC guidelines across all words) with demographic information (age, sex) and responses to the various questionnaires. Although some of these correlations were significant, no consistent, systematic pattern emerged. For example, most scales indicating higher concern with environmental issues and climate change were positively correlated with the best guess of *very likely*, but not with the mean (or the range) of the other terms.

SUMMARY AND RECOMMENDATIONS

Although the probability phrases taken from the IPCC report were embedded in meaningful, high-stakes contexts, our results replicate those of many previous, mostly context-free studies

(e.g., Budescu & Wallsten, 1995; Lipkus, 2007). The numerical estimates and their lower and upper bounds were stable within respondents across the various sentences, but they spanned wide ranges across individuals, and they were quite regressive. These differences were not related to the sex and age of the respondents, nor to their overall attitudes toward climate change. Thus, we conclude that the observed spread reflects the typical level of interpersonal variability in the interpretation and use of these probability expressions. Access to the translation table induced slightly higher, but imperfect, consistency with the IPCC guidelines. This suggests that although one cannot legislate language (Wallsten, Fillenbaum, & Cox, 1986), there may be ways to reduce interindividual differences in the interpretation of language. Indeed, the results of the two verbal-numerical groups confirm this point quite forcefully.

The IPCC opted to use words, rather than numbers, in the first place because some of the events referred to are ambiguous, and

the sources of their underlying uncertainties are hard to specify and measure. Consequently, scientists' assessed probabilities may vary considerably (for examples of this variability, see [Morgan & Keith, 1995](#); [Wallsten, Forsyth, & Budescu, 1983](#)). The verbal terms provide a way to bridge over the disagreements among the authors, and to signal to readers that the relevant uncertainties cannot be summarized neatly by a single value. However, we suspect that the variability in the interpretation of the forecasts exceeds the level of disagreement among the authors in many cases. Consider, for example, the statement that “average Northern Hemisphere temperatures during the second half of the 20th century were *very likely* higher than during any other 50-year period in the last 500 years” (IPCC, 2007, p. 8). It is hard to believe that the authors had in mind probabilities lower than 70%, yet this is how 25% of our subjects interpreted the term *very likely*!

The paradoxical, and unintended, consequences of the “one size fits all” solution adopted by the IPCC are that the report may convey levels of imprecision that are too high, and that many probabilities may be interpreted less extremely than intended by the authors (see [Budescu & Wallsten, 1990](#)), which may lead to underestimation of the magnitude of the problems being discussed.

So far, the IPCC assessments have emphasized the consensus opinions. Oppenheimer et al. (2007) suggested that future assessments should focus more on the structural uncertainties that permeate the models and their projections, and should highlight the sources and magnitude of these uncertainties. We conclude with four recommendations about the communication of information regarding uncertainty. They apply to the IPCC reports, as well as other similar efforts. The first two pertain to the target events:

- *Make every possible effort to differentiate between the ambiguity of a target event and its underlying uncertainty.* Consider the statement, “It is *very unlikely* that the MOC [meridional overturning circulation] will undergo a large abrupt transition during the 21st century.” People may disagree in their interpretation of this statement because they assign different meanings to *very unlikely*, but they may also disagree in their interpretation because they do not agree on what type of change should be considered *large* and *abrupt*. Such ambiguity may affect interpretations of the probability terms. For example, in our survey, the word *likely* was assigned significantly higher values (and lower bounds) in the context of a statement referring to the ambiguous event of the most extreme hot nights, cold nights, and cold days than in the context of a statement referring to the precise event of a 4-m rise in sea level.³ To avoid possible confounds between the ambiguity of an event and its underlying uncertainty, authors should define

³Note that the interpretation of the probability terms in these statements could also be affected by other differences between these events, such as their severity ([Weber & Hilton, 1990](#)), as well as by other contextual effects ([Windschitl & Weber, 1999](#)).

target events as precisely as possible and use probabilistic pronouncements primarily for unambiguous events ([Budescu & Wallsten, 1995](#); [Fischhoff, 1994](#)).

- *Specify the various sources of uncertainty underlying key events and outline their nature and magnitude, to the degree that this is possible* ([Budescu & Wallsten, 1995](#); [Morgan & Keith, 1995](#)). For example, authors should clarify whether uncertainty is due to incomplete understanding of a process, imperfect information about its parameters, unreliability of measurements, insufficient data, or other sources. When appropriate, a report should communicate the extent to which these uncertainties could be reduced by future research.

Our final two recommendations follow directly from our results and pertain to the mode and format for communicating uncertainty. They are guided by the principle that decision makers are best served when the precision of the communication matches the precision of the evidence ([Budescu & Wallsten, 1987](#)).

- *Use both verbal terms and numerical values to communicate uncertainty.* IPCC reports should maintain a coarse classification system with seven category labels and include general guidelines for interpretation of these terms, but, in addition, every term should be accompanied by a range of probabilities. The terms should rely on a common stem (*likely*) accompanied by modifiers that determine the terms' ordering ([Lipkus, 2007](#)). The numerical boundaries of the terms should be based on the numerous published scaling studies ([Budescu & Wallsten, 1995](#); [Mosteller & Youtz, 1990](#)), and should be presented as percentages. This dual approach would provide more information, facilitate agreement in interpretation of the phrases, and cater to a broad and heterogeneous audience with various levels of expertise and preferences (see [Witteman & Renooij, 2003](#); [Witteman, Renooij, & Koele, 2007](#)). Indeed, in our study, supplementing verbal terms with numerical boundaries improved the quality of communication considerably.
- *Adjust the width of the numerical ranges to match the uncertainty of the target events.* The numerical bounds accompanying a probability term should be consistent with the IPCC's general guidelines, but do not have to be uniform. Communication of uncertainty should be refined by conveying differential levels of uncertainty that reflect the degree of consensus (or lack thereof) about the reliability and quality of the available scientific evidence (see [Risbey & Kandlikar, 2007](#), for a similar approach). For example, a report could say, “The Greenland ice sheet and other Arctic ice fields likely (66%–85%) contributed no more than 4 m of the observed rise in sea level,” and “Temperatures of the most extreme hot nights, cold nights, and cold days are likely (80%–90%) to have increased because of anthropogenic forcing.” Although these two sentences use the same term, the distinct ranges signal that the likelihood of the second event is slightly higher, and more precise, than the likelihood of the first,

because there is less disagreement. Our results show that readers are highly sensitive, and respond appropriately, to such differential information. We recognize that it would be impractical to generate a different range for each occurrence of a probability term, and, indeed, the boundaries in the translation table should serve as default values. Nevertheless, narrowing down the intended meaning of a given term whenever possible would increase the precision and efficiency of the communication. It would also remind readers that not all events are equally uncertain and that some of the uncertainties can be reduced through future research.

We believe that these simple recommendations, which are based on well-documented results regarding individual judgment and communication of uncertainty, could go a long way toward improving the communication of uncertainty in the IPCC reports, refining the reported conclusions, improving understanding of the findings and assessments, and thereby enhancing the foundation for sound policy decisions.

Acknowledgments—This work was supported by the National Science Foundation under Grant No. 0345925. We thank Jeremy Turinetti for programming the survey.

REFERENCES

- Agrawala, S. (1998). Structural and process history of the Intergovernmental Panel on Climate Change. *Climatic Change*, *39*, 621–642.
- Begley, S. (2007, August 13). The truth about denial. *Newsweek*, *150*, 20–29.
- Beyth-Marom, R. (1982). How probable is probable? A numerical translation of verbal probability expressions. *Journal of Forecasting*, *1*, 257–269.
- Brun, W., & Teigen, K.H. (1988). Verbal probabilities: Ambiguous, context-dependent, or both. *Organizational Behavior and Human Decision Processes*, *41*, 390–404.
- Budescu, D.V., & Wallsten, T.S. (1985). Consistency in interpretation of probabilistic phrases. *Organizational Behavior and Human Decision Processes*, *36*, 391–405.
- Budescu, D.V., & Wallsten, T.S. (1987). Subjective estimation of precise and vague uncertainties. In G. Wright & P. Ayton (Eds.), *Judgmental forecasting* (pp. 63–81). Chichester, England: Wiley.
- Budescu, D.V., & Wallsten, T.S. (1990). Dyadic decisions with numerical and verbal probabilities. *Organizational Behavior and Human Decision Processes*, *46*, 240–263.
- Budescu, D.V., & Wallsten, T.S. (1995). Processing linguistic probabilities: General principles and empirical evidence. In J.R. Busemeyer, R. Hastie, & D. Medin (Eds.), *The psychology of learning and motivation: Decision making from the perspective of cognitive psychology* (pp. 275–318). New York: Academic Press.
- CBS News & New York Times. (2007). *Americans' views on the environment* [Press release]. Retrieved August 16, 2007, from <http://www.cbsnews.com/htdocs/pdf/042607environment.pdf>
- Dunlap, R.E., Van Liere, K.D., Mertig, A.G., & Jones, R.E. (2000). Measuring endorsement of the new ecological paradigm: A revised NEP scale. *Journal of Social Issues*, *56*, 425–442.
- Fischhoff, B. (1994). What forecasts (seem to) mean. *International Journal of Forecasting*, *10*, 387–403.
- Fox, C.R., & Irwin, J.R. (1998). The role of context in the communication of uncertain beliefs. *Basic and Applied Social Psychology*, *20*, 57–70.
- Hamm, R.M. (1991). Selection of verbal probabilities: A solution for some problems of verbal probability expression. *Organizational Behavior and Human Decision Processes*, *48*, 193–223.
- Heath, Y., & Gifford, R. (2006). Free-market ideology and environmental degradation: The case of belief in global climate change. *Environment and Behavior*, *38*, 48–71.
- Intergovernmental Panel on Climate Change. (2005). *Guidance notes for lead authors of the IPCC Fourth Assessment Report on Addressing Uncertainties*. Retrieved February 2007 from http://ipcc-wg1.ucar.edu/wg1/Report/AR4_UncertaintyGuidanceNote.pdf
- Intergovernmental Panel on Climate Change. (2007). *Summary for policymakers: Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Retrieved February 2007 from <http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-spm.pdf>
- Karelitz, T.M., & Budescu, D.V. (2004). You say “probable” and I say “likely”: Improving interpersonal communication with verbal probability phrases. *Journal of Experimental Psychology: Applied*, *10*, 25–41.
- Lipkus, I.M. (2007). Communicating the uncertainty of harms and benefits of medical interventions. *Medical Decision Making*, *27*, 681–695.
- Morgan, G.M., & Keith, D.W. (1995). Subjective judgments by climate experts. *Environmental Science and Technology*, *29*, 468–476.
- Mosteller, F., & Youtz, C. (1990). Quantifying probabilistic expressions. *Statistical Science*, *5*, 2–16.
- Nobelprize.org. (2008). *The Nobel Peace Prize 2007*. Retrieved November 2007 from http://nobelprize.org/nobel_prizes/peace/laureates/2007/press.html
- Oppenheimer, M., O'Neill, B.C., Webster, M., & Agrawala, S. (2007). The limits of consensus. *Science*, *317*, 1505–1506.
- Oreskes, N. (2004). Beyond the ivory tower: The scientific consensus on climate change. *Science*, *306*, 1686.
- Patt, A.G., & Schrag, D.P. (2003). Using specific language to describe risk and probability. *Climatic Change*, *61*, 17–30.
- Risbey, J.S., & Kandlikar, M. (2007). Expressions of likelihood and confidence in the IPCC uncertainty assessment process. *Climatic Change*, *85*, 19–31.
- Wallsten, T.S., Budescu, D.V., Rapoport, R.Z., & Forsyth, B. (1986). Measuring the vague meanings of probability terms. *Journal of Experimental Psychology: General*, *115*, 348–365.
- Wallsten, T.S., Fillenbaum, S., & Cox, J.A. (1986). Base rate effects on the interpretations of probability and frequency expressions. *Journal of Memory and Language*, *25*, 571–587.
- Wallsten, T.S., Forsyth, B., & Budescu, D.V. (1983). Stability and coherence of health experts' upper and lower subjective probabilities about dose-response curves. *Organizational Behavior and Human Decision Processes*, *31*, 277–302.
- Weber, E.U., & Hilton, D.J. (1990). Contextual effects in the interpretation of probability words: Perceived base rate and severity of effects. *Journal of Experimental Psychology: Human Perception and Performance*, *16*, 781–789.
- Windschitl, P., & Weber, E.U. (1999). The interpretation of “likely” depends on the context, but 70% is 70%—right? The influence of associative processes on perceived certainty. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *25*, 1514–1533.

- Witteman, C., & Renooij, S. (2003). Evaluation of a verbal–numerical probability scale. *International Journal of Approximate Reasoning*, 33, 117–131.
- Witteman, C., Renooij, S., & Koele, P.M. (2007). Medicine in words and numbers: A cross-sectional survey comparing probability assessment scales. *BMC Medical Informatics and Decision Making*, 7,

- Article 13. Retrieved January 2008 from <http://www.biomedcentral.com/1472-6947/7/13>
- Wyden, P. (1979). *Bay of pigs*. New York: Simon & Schuster.

(RECEIVED 5/14/08; REVISION ACCEPTED 7/16/08)