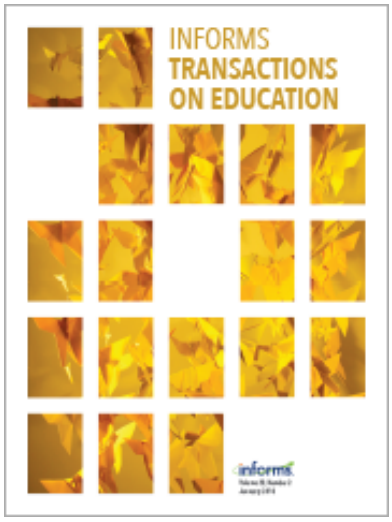

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Possible or Probable? An Experiential Approach to Probability Literacy

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This paper presents the design for and results from an experiential learning activity for beginning statistics or decision analysis students. University students in a required business statistics class are given the task of asking subjects to rank 10 commonly heard uncertainty phrases (words such as "possible" and "probable") in order from those that convey the most likelihood to those that indicate the least. The learning goals are communication, analysis of field results, and reflection upon the experience, and these are accomplished while exploring the concepts of subjective probability assessment as they are being learned in class. Students report their results and write a reflective report that covers their findings, the experience of working with participants, and, most importantly, their insights about language and the public's understanding of uncertainty. As students realize that those who assess probability are not always those who use the assessments for decision making, they become aware of the potential for confusion. The purpose of this article is not to conduct a statistical study of the rankings of the phrases, but rather to discuss the value of this experiential learning assignment for beginning students.

Keywords: subjective probability assessment; verbal probability; active learning; teaching probability; experiential learning
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1. Introduction and Motivation

Sir Arthur Conan Doyle raised a distinction in the use of verbal descriptions of uncertainty when Sherlock Holmes uttered, in *The Sign of Four* (Doyle 1890, p. 139), "How often have I said to you that when you have eliminated the impossible, whatever remains, however improbable, must be the truth?"

Holmes makes it clear that the word *impossible* conveys a smaller likelihood than the word *improbable*, a distinction that indicates that the word *probable* must convey a higher likelihood than the word *possible*. As clear as the ranking of these terms was to Sherlock Holmes, it is not always so clear to others. In everyday usage ranging from casual comments to official statements, words conveying a degree of uncertainty are prevalent in the English language. When an instructor says to the students that "we'll probably have a quiz on Wednesday," they are being asked to incorporate an implied probability assessment into their decision strategy to prepare (or not) for a quiz. When a TV meteorologist says there may be a bit of fog in the morning, or there is the chance of a few rain showers tomorrow evening, how should one prepare?

Over many years of introducing undergraduate business students to the basic concepts of probability and statistics, it has become clear that students prefer, and perform better during, units that cover descriptive statistics, inference, and regression than they do on units that deal solely with probability concepts. Garfield and Ahlgren (1988) noted three reasons that students of all ages have trouble with fundamental probability concepts: they have trouble with rational number concepts and proportional reasoning; probability ideas conflict with their view of the world; and they have negative bias based on previous classroom exposure. More recently, at the NRICH website, part of the Millennium Mathematics Project at the University of Cambridge, Spiegelhalter (2013) answered the question "Why do people find probability unintuitive and difficult?" with the pithy answer, "Because it is unintuitive and difficult."

A fundamental objective of an introductory statistics curriculum is to help students learn to think critically in order to make informed decisions. Therefore it is imperative that they realize how probability informs their decision making. To create an active learning environment, and hopefully to make probability concepts more palatable, we have incorporated the exercise described in this paper into sections of the required business statistics curriculum.

The students' task in the possible or probable exercise is to take a series of probability phrases to people of a variety of ages and backgrounds and learn how the subjects would rank the phrases on a likelihood scale. By doing so the students have an active field experience, they learn that their own interpretations are not universal, and they begin to understand how the complexities of language affect decision making when probability assessments are subjective and/or imprecise.

The goals of the exercise are to provide opportunities for the following:

(1) experiential learning, which is valued at our university and other universities;

(2) improved statistical literacy, through data collection and analysis;

(3) reinforcement of topics that are typically covered in business statistics courses, including collection of survey data, descriptive and inferential statistics for survey data, and the meaning of probability statements.

2. Review of Literature

2.1. Active and Experiential Learning

As Kotteman and Salimian (2008, p. 247) note when discussing the need to engage students with data they understand, "The challenge is to make the topic come alive, to make its relevance consistently salient, and to inculcate students' personal investment in the materials covered." Active and experiential learning is key to student understanding. At our university, the second goal of the six-goal strategic plan is to advance experiential learning. The university strongly encourages faculty to incorporate experiential learning whenever appropriate and touts experiential learning in its recruiting efforts.

Active learning was noted as third of the seven principles developed during the 1980s that describe successful undergraduate institutions (Chickering and Gamson 1987). Active learning is defined by Bonwell and Eison (1991, p. 2) as any strategy "that involves students in doing things and thinking about the things they are doing." Prince (2004) compared forms of active learning in engineering education and noted that there is not one universally consistent definition of the term. In general, he describes active learning as "any instructional method that engages students in the learning process" (p. 223). He notes that the differing descriptions add to the complexity of measuring results and concludes that "Some of the findings, such as the benefits of student engagement, are unlikely to be controversial although the magnitude of improvements resulting from active-engagement methods may come as a surprise" (p. 229).

The concept of experiential learning was formalized by Kolb and Fry (1975) and by Kolb (1984) using a four-stage process that includes experience, reflection, generalization, and application. This model has spawned a large body of pedagogical research over the years; a bibliography of work related to the Kolb model can be found at Kolb's website (Kolb 2013). In a presentation posted on this site, Kolb describes experiential learning, explaining "the center of learning is experience—your own subjective experience."

Many authors have studied the effectiveness of experiential or active learning in college statistics classes. Conferences and workshops at professional meetings, such as the Making Statistics More Effective in Schools of Business (MSMESB) series begun in 1986, have addressed the call to improve learning in statistics, and one common conclusion is that students need to interact with real, relevant data. Westbrook (2011) attributed improvement in statistics self-efficacy and in statistical numeracy and reasoning skills to the use of real data, reflections on data representations, and applications of models for prediction in a combined college algebra/statistics course. Garfield and Ben-Zvi (2007, p. 388) concluded that

> students learn by active involvement in learning activities . . . it is easy to underestimate the difficulty students have in understanding basic concepts of probability and statistics . . . learning is enhanced by having students become aware of and confront their errors in reasoning.

As the *Guidelines for Assessment and Instruction in Statistics Education* (*GAISE*) *College Report* (Aliaga et al. 2010, p. 16) notes in its second recommendation,

> It is important to use real data in teaching statistics to be authentic, to consider issues related to how and why the data were produced or collected, and to relate the analysis to the problem context.

2.2. Statistical Literacy

Students and the general public come upon both verbal and quantitative expressions of probability through a wide range of sources. Students usually list the probability of weather events when asked where they encounter probabilities, quickly adding gambling and lotteries to the list when pressed for more examples. Fulton et al. (2012) documented that even those in charge of running such organizations as lotteries do not always correctly distinguish between odds, chances, and probability. By helping students realize that many important decisions are based on subjective assessments, inaccurate language, or both, instructors can help students improve decision making.

The *process* of gathering data and reflecting upon the results fits well within the five-point description of statistical competency noted by Rumsey (2002) including data awareness, an understanding of concepts and terminology, knowledge of data collection and descriptive statistics, the ability to describe what the results mean, and being able explain the results to someone else. The *results* from the exercise match Rumsey's conclusions

about data awareness, noting that students should understand that "data are often misused, leading to misinformation, and decisions made based on data can have a strong impact on our lives." Students' reflections from the activity (see §3.4) make it clear that they have realized how verbal assessments of subjective probability are fraught with misinformation and can lead to poor decisions.

2.3. Verbal Probability

The literature related to verbal probability comes from a wide variety of sources ranging from linguistics and psychology to decision analysis. Karelitz and Budescu (2004) provide an excellent overview.

Many authors provide examples that showcase the difficulty that arises when the probability assessor, who reports findings using verbal expressions, is not the person or group making the operational decisions that rely on the assessments. As several authors note, such was the case in the assessment of problems with the *O*-rings in the space shuttle *Challenger*. The overriding conclusion from all of these studies is confirmation that variation in meaning is prevalent. Although the activity we describe is focused on social conversation, the evidence from all of this work is that no matter the criticality of the consequences, verbal probability assessments are imprecise at best.

The literature includes many studies where the authors asked subjects to rank verbal probability phrases. Researchers used students (Lichtenstein and Newman 1967; Wallsten et al. 1986, 1993; Teigen and Brun 2003; Budescu et al. 2003; Karelitz and Budescu 2004; and Dhami and Wallsten 2005), professionals (Beyth-Marom 1982), and the general public (Budescu et al. 2009) to develop their comparisons. Some provided the list of phrases for the participants and others let the participants select their own phrases. Instructors who wish to add to the possible or probable assignment or to understand the design of similar activities are directed to these studies, as are students who are curious about the results of similar experiments.

3. Methods

The possible or probable learning exercise fits well at several different points of an introductory statistics, probability, or decision analysis class. Most widely adopted business statistics texts provide an early chapter on concepts of probability, devoting much of the chapter coverage to contingency tables, probability rules, and conditional probability (sample information) problems. See such texts as Black (2011), Lind et al. (2010), Sharpe et al. (2011), Anderson et al. (2013), Bowerman et al. (2013), Groebner et al. (2014), and Levine et al. (2013). Although subjective probability is mentioned along with classical and relative frequency methods, exercises focus on the application of probability rules. To provide motivation for realistic decision making, it is instructive for students to consider the source of probabilities for outcomes. There are many important decisions—such as those surrounding the launch of a new product or implementation of public policy such as the Affordable Care Act—for which pertinent classical or relative frequency probabilities either do not exist or do not make sense. In these cases, decision makers are left to search for a similar historic event or rely on the subjective, and perhaps biased, opinions of experts. Uncertainty affects not only the eventual outcome but also the assessment of probability. Students should understand that most operating decisions are made in a climate of uncertainty where probabilities must be developed.

3.1. Learning Objectives

The possible or probable exercise has four purposes that support statistical literacy through active learning.

- *Application*. Expand a curricular topic (subjective probability assessment) by experiencing how subjects understand it and use its language.
- *Communication skills*. Rather than simply observe and record, students are required to use communication skills to explain the task to their subjects. By selecting participants from a variety of age and educational levels, interviewers must alter their communication strategy appropriately.
- *Analysis and presentation*. Students must determine the best way to present their results. Instructions for the final report are purposely vague. We are interested to see what analytical tools students will use to present their results and how those tools will be incorporated into a professional report.
- *Reflection*. Finally, students reflect on the differences revealed by their participants' conclusions. This is the primary learning objective for the exercise and leads them to think critically about the challenges inherent in using subjective assessment for decisions.

3.2. The Possible or Probable Exercise

Each student is asked to take a list of phrases to at least 10 different people of a variety of ages and backgrounds. The student asks each subject to first arrange the phrases in order from the one that conveys the highest likelihood to the one that conveys the least. Once this is done, each subject is asked to draw a line separating those that convey a likelihood greater than 50% versus smaller than 50%. The students compile their results and reflect on the experience. This assignment has been used for both individuals and teams. The assignment instructions are provided in the appendix.

The first time we used the exercise, we provided a list of phrases, such as "I think," that did not mention an event. Students commented that subjects found it easier to parse a phrase if it mentioned an event, such as "I think our football team will win this weekend."

Table 1 Phrases to Be Ranked by Survey Participants

Code	Phrase
A	I *think* I will be at the party
B	I *could* be at the party
C	I am *likely* to be at the party
D	I *might* be at the party
E	I am *more likely than not* to be at the party
F	*Odds are* that I will be at the party
G	It is *possible* that will be at the party
H	I will *probably* be at the party
I	There is a *chance* that I will be at the party
J	It is *unlikely* that I will be at the party

The danger with mentioning a specific event (such as the next football game played by the school's team) is that subjects will assess the probability of that specific event instead of ranking the probability phrases. To counteract this tendency, we now add "at the party" to all of the phrases (shown in Table 1) and we caution students to remind their subjects that this is a general statement and they are not providing the likelihood that they will come to any particular party, but instead are simply putting in order of decreasing likelihood what they would mean by phrasing their response this way.

When the interviews are complete, each individual or team is to develop a summary, analyze the results, and write a description of the findings. Students address these questions:

- How consistent were the rankings?
- Did people have trouble with the task?
- What implications do you think this has for the way we communicate uncertainty?
- How do you think the rankings might change if you were to modify the statements with words like "very" or "really?" As an example, consider this question: If *probable* conveys a higher likelihood than *possible*, what happens when you modify possible so that it becomes *very possible*? Does including the word very change their order?

Students are given about 10 days to work on the exercise. They are instructed to compile their results and present them effectively. We encourage the use of Microsoft Excel in this class, so most create some sort of table or chart to aid in their analysis. Grades on the final report reflect an evaluation of their analysis and the professionalism of their written communication.

3.3. Student Submissions

The reports that students have submitted through the years frequently incorporate a large Excel table that shows the ranked list of phrases for each of their subjects. Table 2 shows information from a typical individual student's 10 interviews, using the phrase codes from Table 1. Cells that are shaded are those that the respondent said indicated a likelihood higher than 50%. Respondent 1, for example, ranked the phrases as *think, likely, probably, odds are, more likely than not, possible, might, could, a chance, and unlikely*, drawing the line between *more likely than not* and *possible*.

Table 2 Typical Results Report with Shading for Responses Conveying Probability > 0.50

	Respondent									
Rank	1	2	3	4	5	6	7	8	9	10
1 (most likely)	A	C	H	A	C	E	A	F	A	E
2	C	A	D	H	A	C	G	A	F	F
3	H	F	E	C	B	F	H	C	B	C
4	F	H	C	E	E	G	B	E	C	H
5	E	E	F	F	F	H	C	G	D	G
6	G	B	A	D	D	A	E	B	E	B
7	D	G	B	G	H	B	F	A	H	D
8	B	D	G	I	G	D	D	I	G	A
9	I	I	I	B	I	I	I	D	I	I
10 (least likely)	J	J	J	J	J	J	J	J	J	J

It is interesting to see how students present their results, and it would be possible to pool information from all students to explore rankings from a larger sample. However, the more pertinent part of this assignment for the instructor is to review students' reflections on the experience. These reflections, on both the challenges of working with the general public and the awareness that there are large discrepancies among people's understanding of the language of uncertainty, confirm that the primary learning objectives of the assignment have been achieved.

3.4. Student Reflections

Most students realize that there is more variability in the middle rankings than in the phrases that are ranked at the top or at the bottom. Students also find that working with the public—even if they include friends, family members, or colleagues—is not always easy. Table 3 provides examples of student reflections that address the learning objectives.

4. Refinements and Extensions

Having used the exercise for eight years, we have made several adjustments to it in order to make it more effective. We have also contemplated how we might extend it for situations other than the traditional in-class setting.

4.1. Motivating the Exercise

Although the general assignment has retained essentially the same form, we have adjusted the phrase list over the years and experimented with the assignment instructions. We have replaced words (for example, the first survey included the phrase "believe strongly that") and tied the words to an event.

One semester, when there was a bit of extra time, we had the students themselves first answer the interview questions in class. We thought it would be useful

Table 3 Examples of Student Reflections Matched to Learning Objectives

Learning objective	Student reflections (verbatim, with emphasis added by the authors)
Application to probability concepts	• I had added one more question in my interview. I asked if they would rather prefer using numbers or percentage to actually convey their view on the certainty of an event. The feedback was unanimous. *They would prefer using percentage to actually convey their message.* • Not only were the older and younger subjects' answers different but people in the same family had different answers. *I interviewed a set of twins that grew up together and even graduated from college with degrees in the same fields and their answers were even different.* • I analyzed some of the individual results and found them quite interesting. A few people actually ranked "likely" after "more than likely." I found this to be quite amusing, but this reiterates the idea that *words are very relative. They mean different things depending on what context they are in.*
Communication	• I was surprised that a number of people commented that they found the survey difficult, or [were] unsure of the directions. In fact, one survey was rejected, as I was unable to determine the results. • A number of people would ask how they performed on the survey, and were given the response that *there were no right or wrong answers.* • This task looked like it should be easy, putting just 10 phrases in order. However it ended up being quite a difficult task for many of the individuals.... *The interview really made people think about the way they would say. I actually had a couple of the people I interviewed ask me if the sentences were worded wrong, like they would never use that phrasing or had actually never heard anyone use those phrases in conversation before.* • One of the things I found most interesting in giving the survey was observing how different people took it and worked through it. *The instructions I gave were all the same, however everyone heard them differently.* The men that I interviewed all wrote down numbers—instead of the letters A through J—in the rank area. The women all marked out the phrases as they used them. And everyone asked what the event was that the phrases were talking about.
Analysis and presentation	• The rankings for the words to be used were generally the same with the first three ranks and the last three ranks. However, there was an inconsistency with the ranks from four to seven. People generally could not decide on whether the word in that rank would be suitable for more than 50% probability. The confusion just fades as we go to the very top and the bottom as the words become more certain and convey a strong feeling of either the event will occur or not. The implications of this would be, if the words you use are in the range of those ranked from four–seven then, it would create confusion in the minds of the listener as the certainty of event happening would be ambiguous in their minds. • Young people did not find any difficulty in ranking these as compared to middle aged people. The reason I could notice is that *the young people did not really weigh the words against each other as much as the mature people of the lot did.* • *I have always been taught the English language was one of the hardest languages to learn and now I understand why.* Although I had 10 people do the task for me, I also tried to rank the phrases and words myself, and it is quite a task. At one point in time I thought one way, and later my opinion changed.
Reflection	• The last issue I contemplated was the implications of my findings on the way people communicate uncertainty. This project made it clear to me that descriptive words are not necessarily precise words. *Probability words have different meanings to different people because of their different backgrounds*, which is easily displayed by the results. The implications of these different meanings would most definitely be confusion and misunderstandings between people. Using imprecise probability words while attempting to convey a message to someone forces speculation from both sides as to what percentage of likeliness "I might" really has. • *The implications in the way uncertainty is communicated vary with the level of the consequence. If consequences or risk is at a high level then expressions should not be used.* This will cause a big variation in the way people place value on an event happening and if the risk is high, accuracy should be sought. *But for events that are small in risk, expressions might be used because of the minimal risk involved if wrong.* • This project was interesting because everyone wanted to see how others had done their rankings. I would not let them until after they gave me their choices. After everyone at work completed their rankings there was a debate as to what the difference was between *more likely than not* and *odds are*, along with *possible* and *might*. After explaining why they chose one way over another, everyone understood, but did not necessarily agree. We then discussed how sometimes this can happen when sending or receiving text messages from a cell phone. We have all misinterpreted what someone has sent us via text message. The person reading the message understands what they think the message said but it is not always what the sender meant. The discussion is what I found to be the most interesting and also the most fun about this project. • I think what this indicates is that we do not put any degree on uncertainty. I think that we all know that some words mean more hot or cold but we do not attach percents or whatever to the phrases or words we use. *This may be a problem especially in the world of business where so many things are based off of risks and how likely something is to happen.* I think this was a good eye-opening exercise.

for the students to be given the task of ranking the words prior to their being given the assignment and that by having done this "cold" they should have a better appreciation for how to present the task to their subjects. They reported that they did not find this to be particularly helpful, so in the interest of time we decided not to do it again.

One fall semester the exercise was used in a team environment with classroom students and the timing was such that most of them did their interviews with family members over Thanksgiving break. Many of the group reports indicated that the phrases did not match the way people speak and the subjects balked at ranking words they did not use regularly. Accordingly, the next semester groups were instructed to determine their own list of phrases, with the stipulation that the list had to include the words possible and probable. Their phrase choices were fairly similar, with likely, might, and certainly appearing on the lists of most groups. Students were also advised to tie the phrase

to a neutral event, such as attending a party. It is interesting that, disregarding the instructions, one group used a different event for each phrase, providing a teaching moment when the reports were returned.

Media references may be used prior to the exercise for motivation or following the exercise to confirm the prevalence of probability phrases. In addition to asking students to share examples they find, instructors might also refer them to videos of Valvoline motor oil commercials entitled "When Probably Doesn't Cut It" from the late 2000s. The commercials featured people in everyday situations who needed assurance that an uncertain situation was safe. The commercials, plus some spoofs, are readily available on YouTube (see, for example, the parachute commercial at http://www.youtube.com/watch?v=YwCX-ArPu34) and could be good resources to use in the classroom.

4.2. Extensions to the Exercise

Special conditions require that accommodations sometimes be made for the exercise.

Online students. We have found that the exercise is particularly useful as a team project to engage students who are taking an online version of the class.

As Hrastinski (2009, p. 79) noted, participation in online class work is essential to learning in this environment. "It is a complex process that includes, for example, doing, talking, thinking, feeling and belonging. In short, participation involves everything we do and feel when being part of engaging experiences." Because it is easier for online students to hide, assigning their participation to a group activity connects them to their classmates and the subject matter. Even students who are not doing well with the course material can participate fully in this exercise.

During a compressed summer session online class, the exercise was abbreviated to a discussion board posting. The Sherlock Holmes quote was posted and the students were asked to discuss their personal rankings of only four words: impossible, improbable, possible, and probable. This generated by far the lengthiest discussion of all the questions posted during the summer course. Among the student comments were these:

- I agree with (other student's) third and fourth words, but I had a difference in the first two words. I think something [that] is possible does not necessarily happen (or has a chance to happen), but something probable has a higher chance. Still, it's somehow hard to explain!
- This is too profound for me to understand. I have never really paid attention to these words until I took this class.
- My justification for ordering these words in this sequence is that I do not believe that anything in this world is impossible. This may not be 100% true but how would we know what is possible or impossible if someone didn't test the limits of what is truly possible or impossible.

Advanced students. If the exercise is used in a more advanced statistics or decision analysis class, several extensions are appropriate. At a minimum, the exercise could support work in sensitivity analysis. Assigning a series of exercises that state probabilities in words rather than numbers would provide a challenging yet realistic environment for students. As an experiential activity, students could be asked to keep a journal of their own and public examples of probability phrases and write a reflection paper about their findings. Their consolidated data could also be used for nonparametric analysis.

The instructor who wishes to use the results of the possible or probable exercise to introduce nonparametric topics or to conduct research on the subject is encouraged to read further. Readers who are interested in schemes to convert phrases to a numerical scale or to otherwise calibrate meaning should refer to Beyth-Marom (1982), Wallsten et al. (1993), and Karelitz and Budescu (2004). In addition, much work has been done with membership functions, where $f(\text{phrase}) = 1$ if this phrase belongs to this group of values/meanings; $f(\text{phrase}) = 0$ if not. Intermediate values of the membership function indicate the strength of membership. For more information on membership functions, the reader is directed to Wallsten et al. (1986, 1993), Budescu et al. (2003), Karelitz and Budescu (2004), and Dhami and Wallsten (2005).

Recall, however, that the purposes of the possible or probable exercise are to provide a field experience for the students and help them think critically about communication between probability assessors and operational decision makers. Introductory statistics courses customarily do not include sufficient coverage of ranking analysis, so those concepts are not included in the basic exercise.

International students. The results of the assignment and the work of multitudes of researchers make it clear that there is little agreement on the meaning of probability phrases among English speakers. How, then, should we handle the assignment for those international students who have not yet mastered the nuances of English? To address this issue, we offered an alternative assignment to nonnative English speakers asking them to write an essay explaining to their classmates how uncertainty is conveyed in their language. Our international student population led to reports focused on usage in Arabic and in Mandarin, and it was interesting to the domestic students to learn that adjectives, tone of voice, the relationships between speakers, and etiquette all influence the understanding of the speakers' intentions in these languages.

A Chinese student wrote "In China, we hardly reject others' invitations directly, which means all the probability words could actually mean a rejection. In other words, it is more likely that I will not be at the party unless I say 'I will definitely be there,' no matter how theoretically high the likelihood should be by using a particular possibility word. That would make it hard to reflect the use of possibility words in this scenario." An Arabic speaker wrote that "In Arabic we always say there is a possible [*sic*] that I will be in the party and this means 50%. So most people say there is small or big possibility that I will be in the party. When we say there is a big possibility, it means I will be in the party unless something unusual, in other word, a miracle that stops me. But if I say small possibility it means I'm not going to the party, but if something happen don't be surprised if I show up."

5. Limitations

The possible or probable exercise focuses on verbal descriptions of subjective probability assessments, but it does not provide practice in assessing probabilities. It would be interesting to have a group of students develop a group ranking of the words and then match them with numerical probabilities. Alternatively, the instructor could devise an experiment to ask students to assign a number to a phrase. For example, the instructor places a covered box on a table and tells the students that it contains 100 red and white balls, of which at least one is red and one is white. The instructor might then say, "If I say that it is *likely* that the ball I draw out of the box is red, and there are 100 balls in the box, then how many red balls do you think are in the box?" This exercise would be particularly useful in a large class with a personal response system. Results could be compiled to develop a frequency distribution for each phrase.

Depending on the student population and the time available, additional preparation for the exercise could be made. Instructors might ask students to listen for several days and compile a list of the phrases they hear, then use that list for the survey. If participants have trouble ranking the words, students might first ask them to separate those that indicate a higher likelihood than getting heads while flipping a coin. Students might also want to provide something other than a list for their subjects to use. Beyth-Marom (1982) used a more tactile approach, having subjects arrange a set of cards, each containing one of the probability phrases, rather than simply listing the phrases in order.

6. Conclusion

In the aftermath of the 2011 Japanese earthquake, tsunami, and radiation fears, uncertainty phrases were common in one news report after another. The New York Times (Wald 2011) quoted Nuclear Regulatory Commission chair Gregory Jaczko, who noted before a congressional panel that, "We believe that radiation levels are extremely high, which could possibly impact the ability to take corrective measures." Although scientists and engineers certainly calculated probability distributions of catastrophic outcomes, most of the reports for the general public used words rather than numbers to convey likelihoods. Given differences in individuals' understanding, is communicating "the probability of an aftershock is 80%" more or less useful than communicating "there is a high likelihood of an aftershock?" This query was posed to Washington Post reporter Steven Pearlstein, author of a piece on low probability, high impact events (Pearlstein 2011a). His reply (Pearlstein 2011b) certainly provides fodder for classroom discussion, as well as reopening a question to pursue: "None of us is that precise in our language, including journalists. But better to use the words we do than to engage in false precision."

It is incumbent on instructors to introduce statistics students to considerations of uncertainty and help them understand the vagaries of interpretation that can come from using language to convey uncertainty. Students, and those who write exercises, should remember that in real applications, subjective probability assessment is almost always required. Students have to know how to conduct the appropriate analyses. They also need to realize that many of their decisions will be based on subjective assessments that are not always clearly communicated. Assignments such as this that encourage students to listen to the language they use and contemplate its meaning will raise their awareness of how challenging it is to assess and convey subjective probability.

Appendix. Typical Probable or Possible Exercise Instructions

The words we use to describe potential outcomes of our decisions are descriptive but often imprecise. We all understand that the probability of heads on a coin toss is 50%, but the likelihood you convey when you say "I am probably going to come" may not be the same as the likelihood the listener assumes. Yet we often use expressions rather than numbers to describe our assessment that an uncertain event will happen, and this can sometimes lead to communication problems, even for people who have the same native language. For example, shortly before Borders Books folded, the following sentence about the possibility of Borders Books going bankrupt was highlighted: *"In our exclusive interview, billionaire investor Bill Ackman told Fast Money a Borders bankruptcy was 'a low probability event.'"*

For this assignment you are to work with the 10 phrases listed below in alphabetical order. Your task is to interview 10 people and ask them to *rank* the phrases from the one that conveys the most likelihood to the one that conveys the least. It will be most useful if you interview people of a variety of ages and educational levels. This assignment works best

when all of your subjects are familiar with the nuances of the English language. If you are in a location where you cannot find 10 English speakers, feel free to send the information to others electronically. When they have made their lists, ask them to draw a line to separate those phrases that mean the event has at least a 50% chance of happening from those that convey a smaller likelihood. Develop a way to present the results in a table or chart that is part of your report.

When you have completed your interviews, analyze the results and write a summary of what you have found. How consistent were the rankings? Did people have trouble with the task? What implications do you think this has for the way we communicate uncertainty? Your report should be submitted as a single Word file. Please use your last name as part of the file name and include your name at the beginning of your written report. As before, you will be graded on your writing and professionalism as well as on the content of the report.

Words to use:

A I *think* that the event will happen
B I believe the event *could* happen
C I believe the event is *likely* to happen
D I believe the event *might* happen
E I believe the event is *more likely than not* to happen
F I believe the *odds are* that the event will happen
G I believe it is *possible* that the event will happen
H I believe the event will *probably* happen
I I believe there is *a chance* that the event will happen
J I believe it is *unlikely* that the event will happen

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