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Getting Lost In The "Realm Of Possibility": Common Phrases Used To Communicate Rare Events Have Substantially Different Effects On Decision-Making

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ABSTRACT

Communicating probabilities is challenging. Numbers are precise, but poorly understood by the public. Verbal phrases ("it is unlikely") can be misinterpreted. The current study used a binary decision task (total n = 3207) to compare how varieties of verbal and numerical phrases impact decision-making. We identified "realm of possibility" phrases from real-world risk communications. These produced substantially higher risk perceptions compared to other formats. Verbally-formatted phrases increased risk perceptions compared to numerically-formatted ones. Contrary to previous findings, the "1-in-X" format did not uniformly increase risk perceptions compared to when percentages were used. When using the "1-in-X" format, risk perceptions decreased monotonically with the increased probability of negative decision outcomes. With percentages, risk perceptions instead showed a curvilinear (and contradictory) trend.

KEYWORDS: risk perceptions, risk communication, public health, verbal probabilities, numeracy

Introduction

Communicators often prefer verbal phrases to communicate probabilities (Brun & Teigen, 1988), but the number of unexamined

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phrasing options can be problematic (Wallsten, 1990). Labels warn that smoking "causes lung cancer" or "may complicate pregnancy". Health organizations warn that receiving a vaccine "very rarely" causes adverse side effects or carries only a "small risk" of side effects. Communicators might instead use precise numerical information, but even highly educated audiences don't necessarily process numerical information accurately (Lipkus et al., 2001) and precise data aren't always available. If they are available, they can still be communicated in multiple, mathematically equivalent ways that substantially affect risk perceptions (Sirota et al., 2014).

The purpose of the current study is to examine how people incorporate various commonly used probability phrases into their decision-making. We examined diverse communication platforms such as news coverage of the COVID-19 pandemic, public health websites, and drug commercials. The phrases we selected are often used inter-changeably to refer to adverse decision outcomes that have similar probabilities of occurring. To examine whether these different phrases produce substantially different decisions from audiences, we asked survey participants to make a hypothetical, binary ("yes" or "no") decision. We randomly assigned people to see the same risky decision with different probability phrases. There was always a risk-averse option, which gave us the ability to directly compare the risk-averse decision rates between different experimental conditions.

Literature Review

Risk communication research can be divided into three areas of focus: Messenger attributes (e.g., trustworthiness of the source), message attributes (e.g., message framing), and individual differences among the message's audience (Balog-Way et al., 2020). Much recent work has also explored how emotional aspects of a message, particularly messaging that incorporates narrative (Margolis et al., 2019) and interactivity (Roozenbeck & Van Der Linden, 2019). The current study concerns itself in particular with communicating probabilistic information. This is a complex and urgent area of research, as there are few general principles or heuristics available to communicators (Bostrom et al., 2018). This leaves people

to use their intuition to form messages, which can be problematic (Hart & Nisbet, 2012). The present study first isolates the effects of using verbal ("unlikely") and numerical ("1% chance") probability phrases. Furthermore, we introduce a novel distinction between different kinds of verbal phrases that substantially impact audiences risk perceptions and decision-making. Specifically, we differentiate "realm of possibility" phrases from "magnitude of risk" ones. Further details are given below.

Common Phrases Used in Risk Communication

Small changes in how a message is worded can have substantial effects on how the message is received (Davis et al., 2017; Davis et al., 2020; LaCour et al., 2022). Even if numbers are used instead of words, different formats can lead to different levels of risk perception among audiences (Sirota et al., 2014). It is therefore important to examine the phrasing used across a variety of risk communication contexts. The Centers for Disease Control and Prevention (CDC) use a variety of phrases to communicate the likelihood of experiencing adverse side effects from vaccines (CDC, 2020). These run the gamut from "[this side effect occurs] very rarely" to "there is a very remote chance", "sometimes [the side effect occurs]", and "[this side effect] can happen". TV drug commercials use a range of phrases to communicate similar risks. These include "A common side effect is...", "[this drug] may cause allergic reactions", "risks include", "may cause", and "rare... side effects could occur". The actual probabilities of experiencing adverse side effects from vaccines vary widely. They can occur on the scale of 1-in-a million to 1-in-a hundred thousand. Relatively speaking, these probabilities are very different from one another, but in an absolute sense, they could all be described as "rare". Ideally, precise numerical information would be provided in addition to (or instead of) these vague, verbal phrases. However, experts don't always know the relevant probabilities with much precision and must still communicate potential risks to the public. Even if precise risk information is known, members of the public struggle to process numerical information accurately, even highly educated ones (Lipkus et al., 2001).

Theoretical Perspectives on Verbal and Numerical Probability Phrases

Prospect Theory (PT, Kahneman & Tverskey, 1979) is one of the most prominent and influential models of decision-making. PT has received ample empirical support, including behavioral (Pachur et al., 2018), neuroscientific evidence (Tom et al., 2007), and large-scale replications of its basic predictions (Ruggeri et al., 2020). According to Prospect Theory (PT), people make decisions based on the potential outcomes of each option, weighted by the probability of those outcomes occurring. PT holds that these we assess the change in utility associated with decision outcomes (i.e., their "subjective utilities") and weight these by subjective probabilities. PT holds that subjective utilities and probabilities are non-linear functions of objective utilities and probabilities. Most relevant here, PT predicts that people treat improbable events as if they are more probable than they truly are and probable events as if they are less probable than they truly are. PT also predicts that people treat probabilities close to 1% (and approaching 0%) as if they are more or less the same. This leads to the first prediction for the present study:

> **H1:** There will be no substantive difference in the rate of risk-averse decision-making when the outcome probabilities lie between 1% and 0%.

It is important to test this prediction because many medical/health decisions (e.g., taking a medication, vaccinating) involve very low probability risks (i.e., side effects). These "microscopic" (<1%) probabilities are notoriously difficult to communicate to patients (Lipkus, 2007). Patients tend to treat <1% risks as if they are more likely to occur than they truly are (e.g., Shaheen et al., 2005). There have been conflicting results for this prediction, some showing no sensitivity for probabilities occupying different orders of magnitude, e.g., 1-in-1,000 versus 1-in-10,000 chance (Kaplan et al., 1985; Kunreuther et al., 2001). Other studies, though, have shown that using some formats (e.g., "1-in-X") increases risk perceptions compared to others (Sirota et al., 2014). Thus, it would appear as if PTs prediction about microscopic probabilities doesn't

always hold. A competing hypothesis based on the "1-in-X" studies runs as follows.

> **H2:** Using the 1-in-X format will result in more risk-averse decisions compared to when a probability format is used.

Verbal probability phrases

PT can only make predictions based on numerical inputs (e.g., dollars and probabilities). This is unfortunate because verbal phrases are ubiquitous in real-world risk communications, and they impact important decision-making processes. In a medical context, verbal probabilities are associated with a greater fear of side effects (Young & Oppenheimer, 2006), greater perceived probability of experiencing side effects (Knapp et al., 2004), and a lower probability of complying with medical treatment plans (Berry et al., 2003).

While PT can't directly make predictions based on verbally-presented information, the model does allow for people to change how they weight probability information into their decisions. Specifically, people can simply weight probability information into their decision to a lesser degree. If verbal probabilities are seen as vague – and they certainly are, compared to numerical information – this could bias people to change how much they weigh this information into their decision-making (Camerer & Weber, 1992). For instance, if someone is offered a 25% chance to win $100, a normative theory might say this offer is worth $25 (0.25 × 100). However, because prospect theory recognizes that subjective probabilities are not identical to objective ones, people might treat the 25% chance as if it's a 30% chance. They would value the offer at $30 (0.30 × 100). But, if the probability information is presented as if there is uncertainty associated with it (e.g., "thirty-ish percent"), people will change how much they weigh probability in their decision. They might treat "thirty-ish" as if it could denote a probability as low as 25% or as high as 35%. This kind of uncertainty tends to reduce how much people value an option (Camerer & Weber, 1992), which leads us to our third hypothesis:

> **H3:** Using verbal phrases will result in more risk-averse decisions compared to when numerical phrases are used.

"Realm of possibility" and "Magnitude of risk" phrases

While examining real-world risk communications, we were surprised by the variety of phrases being used for the same probabilities, and how much these different phrases could impact audience's decision-making. For instance, there is roughly a 0.00015% chance of contracting Guillain-Barré syndrome after receiving a flu vaccine. The Mayo Clinic's website (2020a) translates this number verbally into "rarely". A self-described "alterative news site" labels this same probability as "common" and "possible" (Reizer, 2019). The case-mortality rate of COVID-19 is estimated to be 0.09%, as of this writing (Worldometer, 2020). Former Fox News pundit Tucker Carlson translated this number verbally to "virtually zero" (McCarthy, 2020). Other news outlets stressed that it is possible for people to die from COVID-19. For example, a Reuters article (Banerjee & Nebehay, 2020) noted that younger people "can die" from the virus. The Mayo Clinic website (2020b) says contracting COVID-19 at "can…lead to death". New York City mayor Bill De Blasio said people were "not impervious" to COVID-19 (Durkin, 2020).

When analyzing the verbal phrases used to convey risk in real-world settings, we noticed a potentially important distinction. On the one hand, there are phrases that merely convey that an adverse decision outcome is possible (e.g., it "could happen", "there is a chance"). On the other hand, there are phrases that naturally imply that an adverse event is possible but also attempt to describe the (small) magnitude of the probability associated with the event occurring (e.g., "very rarely", "remote chance"). We refer to the former as a "realm of possibility" (ROP) phrase and the latter as a "magnitude of risk" (MOR) phrase.

From a strictly logical perspective, ROP phrases only convey that an event has some non-zero probability of occurring. Indicating that an event is "possible" only entails that it is not impossible for it to occur. ROP phrases therefore imply that the probability being referenced can fall anywhere within the interval $0\% < x \leq 100\%$. The fact that the communicator doesn't intend for x to approach 100% is left for the listener to infer from context. MOR phrases make such inferences less necessary. Rather than conveying "this event is possible" MOR phrases convey that

"this event is unlikely" (which implies that the event is also possible). ROP phrases are also similar, in a way, to using the 1-in-X format because they both emphasize the possibility of an event (Zikmund-Fisher, 2011). When a probability is expressed as a percentage (e.g., "1%"), it is possible that the magnitude of the probability (rather than the mere fact that an event is possible) becomes more salient. For these reasons, we formed the following prediction.

> **H4:** Using ROP phrases will result in more risk-averse decisions compared to when MOR phrases are used.

This outcome could be problematic if ROP and MOR phrases are used interchangeably but covey different subjective probabilities of risk to audiences. Afterall, several verbal phrases could be accurate representations of the same "underlying" numerical probability. For instance, the ROP phrases "It is possible to become infected" and "some people have become infected" as well as the MOR phrases "you are unlikely to become infected" and "it is very rare to become infected" could all convey a numerical probability of 1%, 0.01%, or even 0.0001%. The exact choice of wording, though, could result in very different decisions from audiences. Good faith actors, such as public health officials, could influence risk perceptions in an unintended direction (by using ROP phrases instead of MOR ones) while bad faith actors can use the perceived equivalence of different phrases to exaggerate (or downplay) a risk while simultaneously avoiding the appearance of misrepresenting the facts.

Method

Overview of Methods

This study examined how commonly used probability phrases affect recipients' decision-making. We used convenience sampling, recruiting participants in two waves, from Amazon's Mechanical Turk platform and Prolific. Both populations were U.S. citizens. No special qualifications or screeners were used. All participants were given a binary decision task, i.e., a single hypothetical decision to

make. Participants responded "yes" or "no" to whether they would make a given choice under the conditions described. We used a variety of decision contexts to test the robustness of any phrasing effects. For instance, some participants decided whether to receive a new vaccine (despite the risk of adverse side effects) or buy an extended warranty for a new TV (despite the risk of never needing to claim the warranty). The dependent variable in this study was whether participants selected an option whose potential negative outcomes were described by the prompt, thus favoring the less risky status quo.

Aside from this primary decision task, participants answered decision-relevant questions specific to each context. For instance, when deciding whether they would vaccinate, participants were asked about their general vaccine skepticism (LaCour & Davis, 2020). The study was conducted in two waves. In the first wave, there were three decision contexts: vaccination, buying a warranty, and an abstract decision task with no concrete details. Within each of these contexts, one of 5 probability phrases were used. Two of these were verbal MOR phrases ("there is a very remote chance", "there is virtually zero chance"), another two were verbal ROP phrases ("there is a risk...", "some people [have experienced the outcome]"). The remaining three were numerical phrases: 0.1%, 0.01%, or 0.001% chance. For the second wave of the study, two new decision contexts were used: deciding whether to make an investment and deciding whether to adhere to a prescribed medication. Within these contexts, one of ten probability phrases were used: two of these were a MOR phrases ("in some rare cases", "...will occasionally..."), two of them were ROP phrases ("people have experienced", "[the outcome] may [occur]"). The remaining six were numerical phrases that presented probabilities either in a percentage format (1%, 0.1%, 0.00001%) or a mathematically equivalent 1-in-X format (1-in-100, 1-in-1,000, 1-in-1,000,000). We used general linear modeling to estimate differences in the rates of risk-averse decision-making between different phrasing conditions while statistically adjusting for variables related to the decision contexts at hand (e.g., vaccine attitudes for vaccine decisions).

Participants

For the first wave, we recruited 1,675 participants from Amazon's Mechanical Turk platform and paid them $0.30 for their time. We planned on having 80 participants per condition (3 contexts x 5 phrases). Five participants were removed because they skipped the primary decision task. Thus, the final participant count is 1,675 rather than 1,680. Each participant had to pass a CAPTCHA test to proceed with the survey and enter a uniquely generated completion code to be included in the study. The majority of the participants in the first wave were male (52% male, 46.39% female, 0.24% Non-binary / third gender, 0.48% Prefer not to say). The average age was 40.60 ($SD = 12.32$). 15.28% identified as Hispanic and 83.46% as non-Hispanic. 1.25% did not specify. 1.01% identified as American Indian or Alaskan Native, 7.58% as Asian, 5.79% as African American, 1.79% as Native Hawaiian or Other Pacific Islander, and 81.91% as White.

For the second wave, we recruited 1,532 participants from Prolific and paid each of them $6.68 an hour for their time. We planned on having 75 participants per condition (2 contexts x 10 phrases). We ended up overrecruiting due to issues with the platform (on our part) and dropping participants who did not answer the primary decision task. This resulted in a net "gain" of 32 participants. This is why the final sample size is 1,532 rather than 1,500. Participants were 55.34% female, 42.27% male, 2.39% Non-binary / third gender, or "Prefer not to say". The average age was 38.21 ($SD = 13.11$). 6.60% of participants were Hispanic, 91.07 % non-Hispanic, and 2.33% did not specify. 0.19% of participants were American Indian or Alaskan Native, 11.39% Asian, 5.31% Black, 3.24% chose multiple races, 3.82% chose not to specify, and 75.79% were white.

Overall, these convenience samples of online survey takers were fairly representative of the U.S. population (see Table 1). The present sample is slightly older than the general U.S. population. Women are slightly overrepresented compared to men, and white participants were slightly overrepresented compared to non-white participants. In each case, however, the deviations from U.S. Census data are negligible.

TABLE 1 Sample demographics from both surveys

Demographic variable	Current sample	U.S. Census
Age	39.46 (12.76)	38.8
Sex		
Male	1524 (48.29%%)	49.5
Female	1632 (51.71%%)	50.5
Ethnicity		
White	2543 (78.98%)	75.8
Non-White	677 (21.02%)	24.2

Measures & Procedure

At the beginning of either survey, participants were informed on how they would be compensated, approximately how long it would take to complete the survey, and the possible risks and benefits of completing it. If they proceeded, participants first completed the primary decision task, followed by short questionnaires about decision-relevant attitudes (e.g., vaccine attitudes for decisions about vaccinating), followed by a demographic questionnaire. Within each primary decision task, participants were asked whether they would commit (or omit) a behavior that, relative the status quo, would require taking some risk. After participants were randomly assigned to a decision context, the risk information within that context was randomly assigned to one of several different phrasing conditions (see Table 2 for example stimuli).

Participants answered a number of decision-relevant questions, usually via a 7-point Likert scale anchored at "Strongly disagree" and "Strongly agree." The vaccine attitude questions used in this study (Cronbach's $\alpha = 0.94$) were a subset of the ones used by LaCour and Davis (2020). We selected the five items from this questionnaire that could be adapted most easily to the warranty context with similar wording (Cronbach's $\alpha = 0.79$). We also used questionnaires measuring the constructs from the theory of planned behavior (TPB, Ajzen, 1991). TPB seeks to account for how attitudes (), familiarity ($\alpha_{vaccine} = 0.78$, $\alpha_{warranty} = 0.82$), perceived norms ($\alpha_{vaccine} = 0.85$, $\alpha_{warranty} = 0.91$), past behavior ($\alpha_{vaccine} = 0.54$, $\alpha_{warranty} = 0.43$), and perceived behavioral control ($\alpha_{vaccine} = 0.64$, $\alpha_{warranty} = 0.72$) jointly influence behavior intentions.

TABLE 2 Example stimuli from the vaccination context, with randomly assigned phrases in bold.

MOR	ROP	Numerical
According to the CDC, **there is a very remote chance** of contracting Guillain–Barré syndrome after receiving this vaccine.	According to the CDC, **there is a risk** of contracting Guillain–Barré syndrome after receiving this vaccine.	According to the CDC, there is a **[0.1%, 0.01%, or 0.001%]** risk of contracting Guillain–Barré syndrome after receiving this vaccine.
According to the CDC, **there is virtually zero chance** of contracting Guillain–Barré syndrome after receiving this vaccine.	According to the CDC, **some people** have contracted Guillain–Barré syndrome after receiving this vaccine.	

Reliability was high for most of these measures, but quite low for others. The numeracy measure created by Lipkus and colleagues (2001) is widely used to measure people's proficiency with interpreting quantitative information. Its reliability in the first wave of the study was moderate ($\alpha = 0.68$), but lower in the second wave ($\alpha = 0.58$). For the first wave of the study, we asked participants a number of questions about their political affiliation and attitudes towards the COVID-19 pandemic. To reduce the number of redundant covariates in the model, we created a factor analysis for these questions, and chose a two-factor solution. There was a very clean factor structure. We estimated factor scores for each participant and used these as covariates in our primary analyses (for further information, see https://osf.io/zjpyg/). We asked participants in the medication condition about their familiarity (or experience) with migraines. These questions showed relatively strong reliability ($\alpha = 0.72$). Upon completing the survey, participants were thanked for their time and given a completion code to use as verification and payment.

Results

For all analyses, the dependent variable was whether participants chose the risk-averse response. We used a general linear model (GLM) with group membership dummy coded (for discussion of this method, see Hellevik, 2009). We also reproduced each analysis as logistic regressions and other methods (https://osf.io/zjpyg/). The results were virtually identical. The only exception due to a

set of groups in wave 2 where risk averse decisions were extremely low. As a result, the standard errors associated with the logistic regression coefficients for these groups were very large, so some of the results were not statistically significant. In the vast majority of cases, differences in decision context uniformly raised (or lowered) the proportions of risk-averse decisions. In other words, there were no substantial context by phrasing interactions. Each phrase's ranking in terms of producing the most risk averse responses were highly consistent across decision contexts. The only exception to this trend was in the migraine context, where risk-averse decisions were extremely low overall and less consistent compared to how phrases affected decision-making within other contexts. See the online supplementary materials for further details (https://osf.io/zjpyg/).

Overall, averaging across contexts, 58.47% of participants made a risk-averse decision when risk information was presented with an ROP phrase. By contrast, 34.37% participants made risk-averse decisions when MOR phrases were used. This 24.10 percentage point difference was statistically significant, $SE = 0.02$, $p < .001$. This result is consistent with H4. Overall, averaging across contexts, 46.06% of participants made a risk-averse decision when a verbal phrase (ROP or MOR) was used. By contrast, 17.66% of participants made a risk-averse decision when one of the numerical phrases were used. This 28.40 percentage point difference was statistically significant, $SE = .01$, $p < .001$. This result is consistent with H3.

As can be seen from Figure 1, there was a substantial difference in risk-averse decision rates between the two verbal phrase types as well as a difference between verbally-formatted phrases in general versus numerically-formatted phrases. It is equally clear, however, that using the 1-in-X format did not uniformly cause higher risk-averse decision rates compared to the percentage format. In fact, the 18.30% of participants chose the risk-averse decision when risk information was presented with a percentage versus 16.02% of participants when the 1-in-X format was used. This 2.28% difference was not statistically significant, $SE = .02$, $p = .985$.

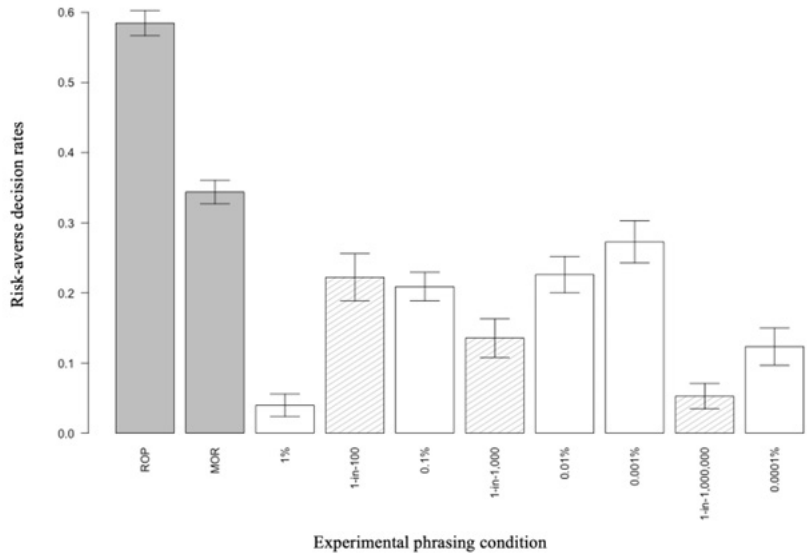

FIGURE 1 Average risk-averse decision rate for each phrasing condition (with standard errors)

At first glance, this result appears to confirm H1, and thus conflict with H2, but it's worth the 1-in-X format appears to result in risk-averse decision rates that decrease monotonically with the objective probabilities of adverse decision outcomes. With the percentage format there is a curvilinear relationship between risk-averse decision rates and the probability of adverse decision outcomes. As can be seen in Figure 2, people's risk perceptions appear to increase as the likelihood of adverse decision outcomes decreases. This makes no logical sense, as people should be less risk averse as the negative consequences of a decision become less likely.

Discussion

Ideally, communicators will use precise, numerical data to inform the public. This unfortunately can't always the case. There is often too much uncertainty for this level of precision. Besides, the general public tends to misinterpret numerical information, regardless of education levels (Lipkus et al., 2001). The present results

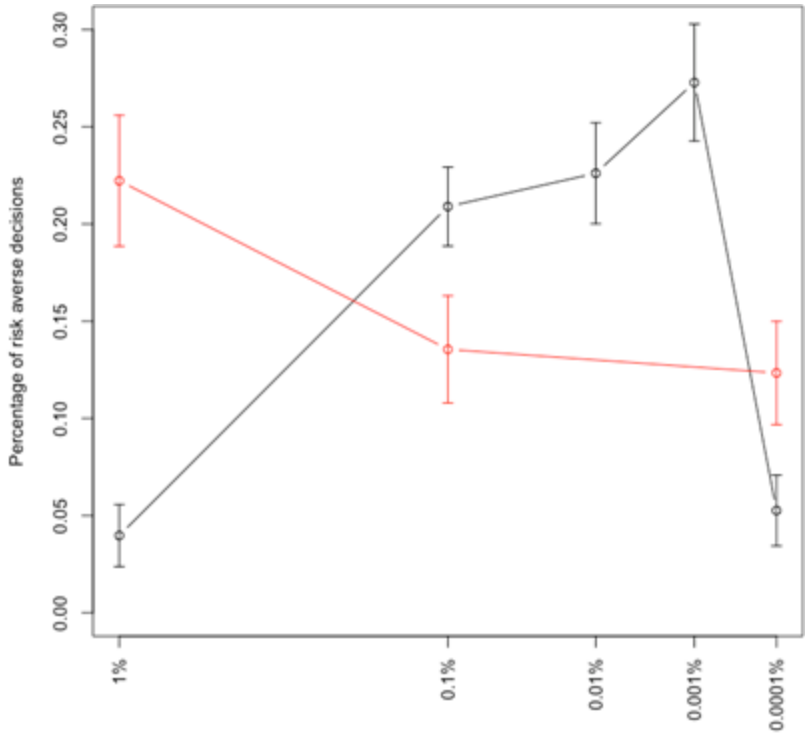

FIGURE 2 **Average risk-averse decision rate for "1-in-X" conditions (red) and probability conditions (black), with standard errors**

show that people's risk perceptions are lowered when numerical information is used compared to verbal information (consistent with H3) by about 28.4 percentage points. Numerical phrases could occasionally lower risk perceptions to perhaps inappropriate levels. For example, approximately 0.57% of adults in the US are HIV positive (HIV.gov, 2022). In light of the present results, "0.57%" might seem miniscule. People might risk practicing unsafe sex or skip opportunities for HIV screenings. Sometimes it will be necessary to use verbal phrases, but these are vague. The word "rarely" could refer to a "0.0001% chance" or a "5% chance", depending on context. This is why we sought to identify much-needed (Bostrom et al., 2018) categories of phrases that have substantial impacts on audience's decision-making. We've shown (consistent with H4) that using ROP and MOR phrases

can result in a nearly 25 percentage point increase in risk-averse decisions.

Theoretical Perspectives on Verbal and Numerical Probability Phrases

The present study makes a number of theoretical contributions. PT predicts that people treat "microscopic" probabilities as if they are roughly equal, which was the basis of H1. This is a non-trivial prediction because many risks occupy this "microscopic" scale—not wearing seatbelts, not buying flood insurance). PT's prediction had support (Kaplan et al., 1985; Kunreuther et al., 2001), but other studies (e.g., Sirota et al., 2014) appeared to conflict with it, suggesting the prediction only held with specific formats, which formed the basis for H2. Participants in these previous studies rated perceived risks on a Likert scale. Here, they incorporated risk information into a decision. This alternative methodology showed no overall effect of using the "1-in-X" format (going against H2), but did show some distinct, non-linear relationships between risk perceptions and objective probability. It would therefore be useful to explore alternative probability weighting functions based on differently formatted information and revising PT in the future. Another avenue for extending PT is incorporating verbal probability phrases. We found that using verbal probability phrase raised risk perceptions (consistent with H3). This is likely due to verbal information being less precise, thus lowering the valuation of the option its associated with (Camerer & Weber, 1992). However, we that some verbal phrases impact risk perceptions much more than others.

Practical Implications

The present study has a number of practical implications. We showed that a small change in phrasing can lead to substantial differences in decision-making. For instance, we observed a large shift in risk-averse decision rates between verbal communications (46.06%) and numerically-formatted information (17.66%), consistent with H3. While verbal probability phrases aren't as precise as numerical ones, communicators will often find themselves

trying to communicate about complex, unfolding crises, where new data are constantly arriving, and there is much uncertainty about important aspects of the crisis. With the COVID-19 pandemic, there was a constant influx of new data created a lot of uncertainty about characteristics of the virus and how best to curtail infections. Recall that COVID-19 was preceded by a series of other outbreaks such as Zika and Ebola. In each instance, communicators tried to create an appropriate response from the public (disease mitigation behaviors) while still conveying a level of uncertainty about such quantities as the infectiousness of the disease or its case mortality rate. Communicators will continue to need verbal (i.e., non-numeric) phrases to accomplish this task. Thus, it is important to choose verbal phrases wisely, based on empirical studies such as this one, where we identified a category of phrasing options (ROP versus MOR) that result in a nearly 25 percentage point swing in people's decisions.

Limitations

The present study has a number of limitations. For instance, some of the TPB scales had low reliability. Future researchers might consider using longer with higher reliabilities. While the two survey platforms (Mechanical Turk and Prolific) produced samples that were largely reflective of the general U.S. population, we did not ask people about level of formal educational. Past research sampling from the same platforms found these samples likely overrepresent people with higher levels of educational attainment compared to U.S. Census data (LaCour & Bell, 2023). Thus, future researchers should collect education data to assess the generalizability of our findings. It is also worth noting that some cultures tend to emphasize degrees of uncertainty in their print media more than others (Liu & Zhang, 2018). Combine this with how differently the U.S. responded to the COVID-19 pandemic compared to similar countries (LaCour & Bell, 2023), it is worthwhile to assess how generalizable these findings are across different countries.

We found that people process numerical information in inconsistent, even paradoxical ways. For instance, when probability formatting is used, people's risk perceptions appeared rise when

objective risks were decreasing in magnitude. This result is interesting, but further study is needed to explore potential counter-explanations. While we found negligible context by phrasing interactions, it is still possible that some of these peculiar trends are due to certain probability phrases appearing only in some decision contexts. Future studies should keep the underlying context and decision outcomes constant while systematically varying the probabilities associated with decision outcomes.

We used decision-making as a proxy measure of risk perception. The process of incorporating probability information into a decision certainly involves risk perception at some stage, but this method doesn't directly assess risk perception. Researchers might consider isolating people's subjective impressions of outcomes from their probabilities of occurring. Note, however, that the process of judging a stimulus in isolation (e.g., "what probability do you associate with the word 'rarely'?) is different from incorporating the same stimulus into a larger set of data (e.g., decision outcomes). The latter is more faithful to how people make decisions in real-life, which is why we chose to use a decision-based methodology in this study rather than a judgment-based one. The decisions participants made in this study were also hypothetical. While there are substantial correlations between self-reported behavior intentions and actual behavior in some contexts (e.g., vaccines; Brewer et al., 2007), there will still be instances where these don't align. Researchers could implement different messages in a field experiment (e.g., Milkman et al., 2021) to examine this possibility.

Future Directions

Moving forward, it would be useful to identify the psychological mechanism by which ROP phrases produce greater risk perceptions compared to MOR phrases. It might be the case that ROP phrases produce greater risk perceptions because they have a wider perceived range of applicable probabilities they could denote. However, ROP phrases don't appear to be interpreted any more widely than others (Ott, 2021). It's also possible that using ROP phrases imply to audiences that the messenger is less certain of the risks. It would be worthwhile to examine how the negation of an ROP phrase (e.g., "It is not impossible") affects decision-making.

The present study used survey questionnaires, randomly assigning participants to experimental conditions. We sketched a few follow-up studies using similar methods above, but other disciplines and methodologies would be useful too. A more sophisticated linguistic analysis would be useful. For instance, intensifiers, e.g., "very", "extremely", factor heavily in linguistic discourse (Sugimoto, 1998). We managed to discover a distinction used in real-world risk communications that creates a substantial difference in decision-making. We did this by carefully reading though prototypical communications. Further progress in this domain would benefit from corpus studies, which have been helpful in discovering shifts in how risks are discussed in news media (Zinn & McDonald, 2016) and how different sub-groups on social media discuss COVID-19 vaccines (Alkhammash, 2023).

Conclusion

It is important to accurately inform the public with precise information, while also taking into account the possibility that this information could be misinterpreted (Lipkus et al., 2001). This study examined how different verbal probability phrases affect audience's decision-making. The results help in building toward a much-needed (Bostrom et al., 2018) framework for making principled, evidence-based decisions about uncertain and probabilistic risk communication. We used PT as a theoretical framework to guide our hypotheses, but also designed the study to uncover avenues for expanding PT. Specifically, we found that probability weighting might function differently depending on what formats numerical risk information is presented in. Most importantly, we distinguished "realm of possibility" (ROP) phrases from "magnitude of risk" (MOR) phrases. The results suggest that communicators should be hesitant to use ROP phrases to describe risks if their intention is to make these risks seem improbable. Also, while numerical probability information might seem objective, unbiased, and transparent compared to verbally-presented information, the current results show that they potentially "under sell" the risks involved with decisions. Communicators should phrase their messages with caution because these phrasing choices can result in

substantially different decisions by their audiences. Together, the present study broadens our theoretical understanding of risk communication and decision-making and provides concrete strategies for risk communicators.

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