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Article

Percentages are a better format for conveying medical risk than frequencies

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SUMMARY

For patients to make informed decisions about their health care, it is essential that they understand the risks associated with various treatments. However, risks can be framed in different ways, and past research has yielded conflicting results about which format is easiest for people to comprehend. Frequencies (e.g., 1 out of 4) and percentages (e.g., 25%) are common ways to communicate risk, and the goal of this study was to explore how these formats affected the comprehension of different numerical values. A sample of American adults (N = 141) was recruited via Amazon's Mechanical Turk to take a survey on Qualtrics. Participants indicated their preference for frequencies or percentages and then answered a set of questions to evaluate their skill at working with the two formats when the values were small, large, complex, or simple. Participants reported equivalent comfort levels with risks framed as percentages and frequencies, but interestingly, they performed significantly better on questions asked using percentages than frequencies. These findings indicate that percentages should be used instead of frequencies when presenting risk information to patients, regardless of the size and complexity of the numerical value represented.

INTRODUCTION

Medicine has made incredible progress over the last few decades. Unfortunately, due to many people's poor numerical skills, understanding of these advances and their health-related options lags behind (1). The risks of various medicines or procedures are typically conveyed using numbers, which can be difficult for people to comprehend (2). For people to be able to make informed decisions, they must be presented with information in a format that is as easy for them to understand as possible (3). The purpose of this study was to gain insight into which numerical formats are best understood when conveying medical risk.

Shared decision making, where doctors and patients work together to decide on the best treatment option, is becoming increasingly common (4). When done well, shared decision making combines a doctor's knowledge of the best treatment options with the patient's knowledge of themselves (4). However, the effectiveness of the shared decision-making process relies heavily on patients' ability to understand the numbers used to present medical information. Numerical format may have a significant influence on patients' ability to understand the potential risks and benefits involved with different treatment options.

Two common formats used to convey risk are frequencies, such as 1 in 2, and percentages, like 50%. One goal of this study was to assess which of these formats is typically preferred and whether that preference reflects how well people can use the formats. A recent study which examined the feelings of both children and adults towards fractions, whole numbers, and math in general, found that both adults and children preferred working with whole numbers rather than fractions or percentages (5). Given that accurate levels of risk generally cannot be expressed in whole numbers, the present study will extend this comparison to frequencies versus percentages.

It remains unclear whether people have a better understanding of values presented as frequencies or percentages. One study recruited people who were visiting a health-related website and asked them to perform a number of operations (e.g., halve, triple) on numbers presented as either percentages or frequencies and found that, overall, people were equally good at working with frequency and percent formats (6). Conversely, another study showed that American adults comprehended risk better when it was expressed as a percentage than when it was a frequency (7). However, a meta-analysis of 35 studies showed that the use of frequencies (as opposed to percentages) increased risk comprehension in both people working in healthcare and consumers looking at medication (8). Given these conflicting conclusions, clearly, this is a topic that requires further examination.

It is likely that a person's understanding of frequencies and percentages depends upon the specific tasks and/or numbers presented. For instance, research with conditional probabilities has shown an advantage of using frequencies (9). Some research also suggested that using frequencies is more helpful than using percentages when numbers are small. For instance, a previous study showed that people tend not to use percentages less than one, even if they are explicitly told that they may do so (10). This is further supported by a study that demonstrated that participants had difficulty understanding values less than 1% when presented as percentages (11). These findings indicate that people may struggle with percentages less than one and that frequencies may be a better format to use when expressing such small numbers.

Conversely, when numbers are complex, expressing them as percentages may lead to better understanding compared to frequencies. Frequencies become increasingly complex and difficult to understand the greater the number of significant figures that are involved. It has been shown that smaller, whole numbers are significantly easier for people to understand than larger ones (14). Therefore, it may also be

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true that frequencies expressed using numbers with fewer significant figures will lead to increased comprehension. While percentages can also involve different numbers of significant figures, frequencies need to be written using two numbers (a numerator and a denominator) whereas percentages need only one. This difference may make it easier for people to grasp complex percentages rather than complex frequencies (12). For instance, someone presented with the frequency 3 out of 8 (which equates to 37.5%) might have difficulty seeing how close it is to 4 out of 10 - a simpler frequency. However, a person presented with the value of 37.5% would likely have an easier time rounding it to 40%. In scenarios where numbers are complex, using a percent instead of a frequency may make the probability easier to understand.

The overarching goal of this study was to learn more about how best to communicate medical risk to a cross section of American adults. Participants were first asked about their preference between percentages and frequencies. Then participants were asked a series of multiple-choice questions which asked them to identify the largest of three values; the goal of these questions was to assess how well participants understood each format. We hypothesized that when looking at numbers less than 1%, participants would score higher on measures of numeracy using frequencies rather than using percentages; however, when looking at frequencies expressed using more complex numbers, we hypothesized participants would score higher on measures of numeracy when percentages were used as opposed to frequencies. Lastly, when looking at numbers in general, we expected participants would score differently on measures of numeracy using percentages than using frequencies, but the conflicting nature of past research made it difficult to make a directional hypothesis. The main finding of the study was that presenting numbers as percentages resulted in better performance across all types of numbers, although the differences were greatest when the numbers were large and/or complex.

RESULTS

Number Format Preference

Adult participants were asked six questions about their preference for data in the form of frequencies or percentages; an example of this type of question was “How important is understanding math with frequencies/percentages in them?”. Responses for the three frequency and three percentage questions were averaged separately, and we found that participants did not report a preference for either format (p = 0.73, d = 0.02). Participants felt comfortable with both formats, as they rated their feelings towards frequencies on average as a 4.76 out of 6 and their feelings towards percentages as a 4.79 out of 6. There was only a 0.03 difference in score between the conditions (**Figure 1**).

Percentages versus Frequency

We gave participants 12 multiple choice questions in which they were asked to identify the largest of three values. Half of the questions presented sets of frequencies, and the other six presented sets of percentages. Participants scored significantly better when numbers were phrased as percentages than when they were phrased as frequencies (p < .001, d = 0.79). Participants scored an average of 3.64 out of 6 on the frequency formatted questions while they scored 4.94 out of 6 on the equivalent percentage format questions (**Figure 2**).

The questions in both formats included sets of simple numbers (e.g. 1 out of 4 or 25%), complex numbers (e.g., 9 out of 23 or 39%), large numbers (greater than 1%), and small numbers (less than 1%), and we contrasted participant performance based on these specific types of numbers. The advantage of using a percent format was markedly greater when handling large numbers as opposed to small numbers (**Figure 3**). Participants were on average correct on 1.03 more questions when working with large percentages rather than frequencies and only 0.45 more questions when working with small percentages rather than frequencies (**Figure 4**).

Our hypothesis that when percentages were less than 1, participants would score better on equivalent frequency questions was not supported. Participants still scored significantly higher on the percent questions, 2.26 vs 1.81 questions correct (p < .001, d = 0.49) (**Figure 3**). However, even though participants scored better on the percent phrased questions for small values, this difference had the smallest effect size of any of the conditions (**Figure 4**).

As hypothesized, when looking at complex frequencies, the equivalent percentages were easier for people to understand, 1.71 vs 1.04 questions correct (p < .001, d = 1.11). Not only did participants score higher with percentages than frequencies, but the effect size of this relationship was the greatest of all the conditions (**Figure 4**).

Relationships between Preference and Performance

We used Pearson product moment correlations to determine if number preference and number performance were related. People who reported liking frequencies also had a tendency to like percentages (r = .73, p <.01). Similarly, participants’ skill in working with frequencies had a moderate positive relationship with their skill in working with percentages (r = .46, p < .01) (**Table 1**).

Interestingly, there was a weak inverse relationship between how much participants reported liking working with frequencies and how good they actually were with the format (r = -.27, p = .002). Additionally, there was no significant

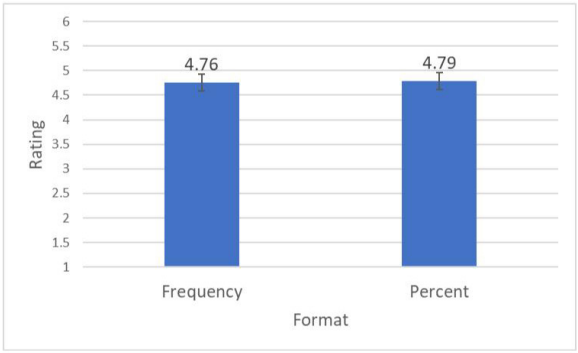

Figure 1. Participants expressed no preference for frequencies or percentages (N = 127). Mean rating of how much participants liked frequencies/percentages. All participants were given two scales: One that asked about how much they liked using frequencies and one that asked about how much they liked percentages; a paired t-test was used to determine statistical significance. Error bars represent 95% confidence intervals. There was no significant difference between how participants rated percentages and frequencies.

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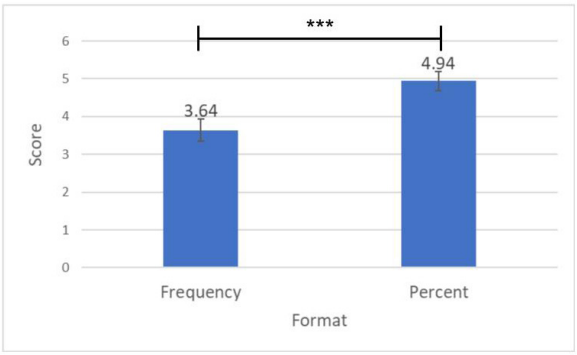

Figure 2. Participant performance overall was better when using percentages than frequencies (*N* = 141). Mean number of questions answered correctly using frequencies and using percentages. Participants were given 12 randomly ordered questions which asked them to select the largest frequency/percent from three choices; a paired t-test was used to determine statistical significance. Error bars represent 95% confidence intervals. *** = $p < 0.001$. Participants answered significantly more questions correctly on average when using percentages than when using frequencies.

relationship between how much people reported liking percentages and how good they actually were at using them ($r = -.06$, $p = .52$).

DISCUSSION

The purpose of this study was to determine whether percentages or frequencies are a more preferred and/or better understood format with which to communicate medical risk. Participants did not report a preference for either frequencies or percentages. Both formats were rated fairly high, which suggests that our study participants value and are comfortable with both formats.

Despite expressing no preference for one numerical format over the other, participants better understood the values presented using percentages rather than frequencies. Past findings on this subject are variable, which may be a result of the specific questions asked in different studies. For instance, one study found that frequencies are an easier format to use than percentages when solving problems that have to do with conditional probabilities, or the probability that an event will occur given that another event has already occurred (9). However, a different study that gave participants a risk stated as a simple, singular probability found that participants understood the risk better when it was phrased as a percentage than as a frequency (7).

The hypothesis that a frequency format would lead to superior performance when participants worked with values less than 1% was not supported. While participants still performed better with percentages in this condition, and previous studies (11,13) suggested this would be the case, our study's results show that people performed better when given the values in a percentage format even when the values were small. However, it is notable that the benefit of percentages over frequencies was the least when numbers were less than 1%. On the other hand, the fact that the benefit of percentages was greatest in the context of complex numbers indicates that frequencies are a particularly poor choice for communicating this kind of information.

The strong, direct relationship between a participant liking frequencies and liking percentages could be due to people's more general feelings towards numbers and math. Additionally, people who were good at working with one of the formats were usually good at working with both of them. Unfortunately, this relationship also means that some people are not good at working with either format. Alternative methods of presenting risk (ones that do not involve numbers) could be helpful to these people. One alternative method of presenting risk is the European Union's system of verbal descriptors, which describes the risk of adverse effects using terms like common and rare (14). However, studies have shown that these verbal descriptors often lead to dramatic overestimation of risk (14, 15).

Intriguingly, there was a weak, inverse relationship between how much participants liked working with frequencies

	1. Like Frequency Scale	2. Like Percent Scale	3. Frequency Score	4. Percent Score
1. Like Frequency Scale	1			
2. Like Percent Scale	.73**	1		
3. Frequency Score	-.27**	-.25**	1	
4. Percent Score	-.16	-.06	0.46**	1

Table 1. Correlations Between Preference Scales and Number Skill Scales (*N* = 130). Shows correlations between scores on preference and performance scales for frequencies and percentages. Scales determined how much participants like frequencies and percentages and the 12 questions determined how well participants performed with percentages and frequencies; Two-tailed Pearson's product moment correlations were run to determine the strength and significance of the correlations amongst these four variables. ** = $p < 0.01$. Correlations between liking frequencies and liking percents, liking frequencies and performance using frequencies, liking percentages and performance using frequencies, and performance with frequencies and percentages were significant.

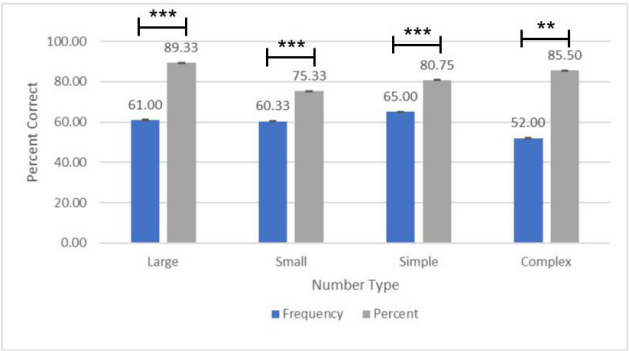

Figure 3. Participant performance was better when using percentages than frequencies across the four types of numbers examined: large, small, simple, and complex (*N* = 141). Results are presented using percentages because the number of items differed across the types of numbers. Paired t-tests were used to determine statistical significance. Error bars represent 95% confidence intervals. ** = $p < 0.01$, *** = $p < 0.001$. Participants performed significantly better using percentages than using frequencies for each number type.

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	Simple		Complex
	Large (over 1%)	Small (under 1%)	Mixed (over & under 1%)
Percent	(25% v. 17% v. 10%) (1% v. 10% v. 50%)	(0.1% v. 0.05% v. 0.02%) (0.01% v. 0.1% v. 0.5%)	(0.38%, v. 0.74%, v. 0.58%) (58% v. 39% v. 63%)
Frequency	(1/4 v. 1/6 v. 1/10) (1/100 v. 10/100 v. 50/100)	(1/1000 v. 1/2000 v. 1/5000) (1/10000 v. 10/10000 v. 50/10000)	(12/3146 v. 72/9672 v. 37/6429) (7/12 v. 9/23 v. 5/8)

Table 2. Comprehension Questions Divided by Type. Questions asked to determine participants ability to work with frequencies and percents. Question format was based off of a widely used numeracy scale (16).

and how accurate they actually were when using that format. In addition, there was no relationship between how much participants liked using percentages and how good they were at working with them. Therefore, it is possible that a person's preference for a particular numerical format should not be a major factor in deciding which format to use when presenting risk.

By examining people's understanding of frequencies and percentages using many different types and values of numbers, the present study makes a valuable contribution to the research on this topic. However, all of the questions used the same format by asking participants to select the largest of three risks. A useful extension of the project would be to replicate the study using a variety of question formats and to evaluate the participants' ability to utilize numbers when presented as frequencies and percentages to make more complex decisions. Additionally, it would be valuable to test a larger set of the different kinds of performance questions (i.e., large, small, simple, complex) in order to ensure that the same patterns hold true. Another limitation of the study is that the way people respond when answering questions on a survey may differ from how they respond when making important medical decisions. The participants that were surveyed were not looking for treatment and so their behavior may not reflect how they would react in a real-life situation. Even when making decisions related to their health, the severity of the problem (e.g., cancer versus a rash) might affect how people respond. Finally, it would be helpful to look at other factors that may be related to people's understanding of medical risk

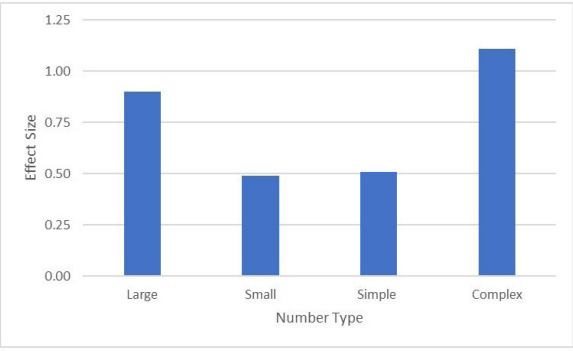

Figure 4. Effect sizes (Cohen's d) for t-tests on all types of numbers (*N* = 141). Effect size was the greatest when numbers were complex or large and smaller when numbers were simple or small.

such as education level and socioeconomic status.

Overall, our findings indicate that percentages are a better format than frequencies for presenting medical risk to patients. Therefore, when describing risks to patients, doctors should be advised to use percentages rather than frequencies, especially when numbers are complex. With the increase of medical information available on the internet, patients are playing a growing role in making their own medical decisions. One of the most important challenges facing health professionals today is how best to convey medical information to their patients so that the patients can then make the best decisions for themselves.

MATERIALS AND METHODS

Participants

A power analysis indicated that with power set at 0.8 and alpha value of 0.05, a sample of 128 people was necessary to show a small-moderate effect. In order to gain access to a cross section of the U.S. population, participants were recruited via Amazon's Mechanical Turk, a service which pays people to complete minor tasks, including online surveys. After the study received IRB approval, participants were invited to take a "short survey about medication safety". Participants who consented were presented with a link to a survey on Qualtrics. 141 people completed the performance questions, but only 127 completed all the preference questions. Participants who only completed the performance questions were included in the analysis for those parts. The 141 people who completed enough of the survey to be used in the data analyses ranged in age from 18 to 69 with a mean of 38.11 ± 11.29 years. Just over half of participants (53.9%) identified as male while the rest of the participants (46.1%) identified as female. Additionally, over 80% of participants said that they were White; the rest of the sample identified as Black, Latinx, Asian American, or Native American.

Number Format Preference

After completing a consent form, the first thing that participants saw was a set of six randomly ordered questions from a study by Sidney, et al. (5). These questions were used to determine which number format (frequencies or percentages) was preferred by participants. Three of the questions asked about participants' feelings towards frequencies (e.g., "How much do you like thinking about problems with frequencies in them?"), which they rated on a 6-point scale while the other three asked the same things about percentages; higher numbers indicated greater liking. The average of participants' responses to each of the sets of the three questions was calculated and used in the data analysis. The questions about participants' feelings towards frequencies and percentages were placed before the questions which asked participants to work with the two formats so that participants' performance with either format would not influence their answers about how they felt about either format.

Comprehension of Percentages vs. Frequencies

After the number format preference questions, participants were shown a randomly ordered set of 12 questions to test their comprehension of numbers presented as frequencies and percentages. Each item asked participants to select the largest value from three options. This format was based on a widely used numeracy scale (16). Half of the questions were

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in a percent format while the other half were in a frequency format. The types of questions were further divided into ones that dealt with both simple and complex values as well as values that were both greater than and less than 1%. The 12 items are divided by type and shown in **Table 2**.

Data Analysis

We used paired t-tests to compare participants' attitudes toward frequencies and percentages as well as their performance on the numeracy questions presented in the two formats. Pearson product moment correlations were used to look at the relationships among the variables.

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Appendix

Number Format Preference Scale

- How much do you like thinking about problems with frequencies/percentages in them?
- How much do you like solving problems with frequencies/percentages in them?
- How important is understanding math with frequencies/percentages in them?