Excluding numeric side-effect information produces lower vaccine intentions

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Abstract

Encouraging vaccine uptake is important to reducing the impact of infectious disease. However, negative attitudes and vaccine hesitancy, due in part to worry about side effects, are obstacles to achieving high vaccination rates. Provided vaccine information sheets typically include a list of side effects without numeric information about their likelihoods, but providing such numbers may yield benefits. We investigated the effect of providing numeric information about side-effect likelihood (e.g., ‘‘1%”) and verbal labels (e.g., ‘‘uncommon”) on intentions to get a hypothetical vaccine, reasons for the vaccination decision, and risk overestimation. In a diverse, online, convenience sample (N = 595), providing numeric information increased vaccine intentions—70% of those who received numeric information were predicted to be moderately or extremely likely to vaccinate compared to only 54% of those who did not receive numeric information ($p<.001$), controlling for age, gender, race, education, and political ideology. Participants receiving numeric information also were less likely to overestimate side-effect likelihood. Verbal labels had additional benefits when included with numeric information, particularly among the vaccine hesitant. For these participants, verbal labels increased vaccine intentions when included with numeric information (but not in its absence). Among the vaccine-hesitant, 43% of those provided numeric information and verbal labels were predicted to be moderately or extremely likely to get vaccinated vs. only 24% of those given a list of side effects ($p<.001$). We conclude that the standard practice of not providing numeric information about side-effect likelihood leads to a less-informed public who is less likely to vaccinate.

Excluding numeric side-effect information produces lower vaccine intentions

Vaccine hesitancy in the United States (U.S.) is driving a health care crisis during the COVID-19 pandemic. Unvaccinated people have 11 times higher fatality risk than the vaccinated [1]. Nonetheless, nine months after vaccine rollout [2], 23% of eligible Americans remained unvaccinated [3], a higher proportion than other wealthy countries [4].

Many causes of vaccine hesitancy exist, including complacency about the risks posed by disease, lack of convenient access to vaccines, negative attitudes towards vaccines, and the risks of vaccination vs. infection [for a review, see 5]. In particular, people's perceptions of vaccine risks are a key predictor of vaccination uptake [e.g., 6,7]. The present paper focuses on numeric vs. non-numeric methods to present such risks and their effects on reported likelihood to get a hypothetical vaccine.

Standard of care for vaccination includes educating patients about the range of possible risks. Doing so can increase perceived risks of vaccination and lower vaccine intentions [8] but is consistent with the ethics of informed choice. However, effects may depend on what side-effect information is shown. Currently in the U.S., side effects generally are presented in list form and without their numeric likelihoods of occurrence. Instead and similar to the European Union, likelihoods could be communicated as probabilities (10%), with or without verbal labels ("common"). With medications, presenting numeric likelihoods reduces overestimation of risk likelihoods and increases willingness to take a prescribed medication as compared to presenting a list by itself or with verbal labels [for a meta-analytic review, see 9]. Thus, providing numeric-likelihood information may improve the accuracy of risk perceptions and reduce vaccine hesitancy, the focus of the present paper.

The research reviewed thus far suggests that numeric information about the likelihood of side effects will reduce vaccine hesitancy. However, numeric information is frequently misunderstood [10,11], and people differ in how well they can understand and apply

mathematical and probabilistic concepts (i.e., numeracy) [12–14]. Those lower in numeracy tend to overestimate risks, pay less attention to numbers, and have more difficulty understanding and using numeric information than the highly numerate [15–17]. Thus, providing numeric information may benefit only those higher in numeric ability [e.g., 18]. Indeed, Peters et al. [18] found that numeric (vs. non-numeric) risk information decreased risk overestimation and increased willingness to take a medication more for those higher than lower in numeracy. However, the size of the numeracy effect was much smaller than the effect size elicited from presenting numeric vs. nonnumeric information, indicating that numeric information was beneficial even for those lower in numeracy.

Vaccination, of course, involves additional challenges. First, some people have negative attitudes to vaccines [5]; others have little knowledge or are misinformed [19]. Second, political polarization has increasingly divided Americans' views on responses to COVID-19, including vaccination [e.g., 20–22]. For example, Republicans have become more vaccine hesitant to both COVID-19 vaccines and vaccines in general [23]. Thus, vaccine hesitancy may grow even more common and more entrenched if we do not quickly find ways to combat it.

The current study

The current research investigated risk overestimation and vaccine intentions towards a hypothetical vaccination modeled on COVID-19 vaccines. We compared the standard vaccine side-effect lists with lists that also included numeric likelihoods (e.g., "1%"), verbal-likelihood labels (e.g., "rare"), or both. We reasoned that providing such information can correct people who have the wrong facts and/or inappropriate interpretations by highlighting the context of low-likelihood serious consequences and higher-likelihood less serious consequences. In a diverse online convenience sample (N=595), we tested the (preregistered) hypothesis that presenting numeric side-effect information, whether with or without risk labels, would result in greater

willingness to receive the vaccine as compared to presenting only nonnumeric side effect information.

We further documented potential mechanisms for any differences. We measured overestimation of the likelihood of three side effects and asked participants the most important reason for their decision (e.g., side effects being unlikely, the possibility of a serious side effect).

Additionally, we conducted an exploratory analysis examining whether vaccine hesitancy moderated any effects of how side effects were presented. We reasoned that effects may be stronger for participants with positive intentions to vaccinate, who might therefore pay more attention to provided information. Such an effect would be similar to prior findings that people elaborate more on messages that are personally relevant [e.g., 24]. On the other hand, how vaccine information is presented may not influence those who are already pro-vaccine because they are already inclined to vaccinate. Instead, those who are hesitant, but not opposed to vaccination, may demonstrate stronger effects of our manipulations for two reasons. First, vaccine hesitancy may motivate more information processing to reduce ambivalence and uncertainty about vaccination [e.g., 25–27]. Second, at least some of the vaccine hesitant may not have strong feelings either way; thus, they may be more receptive to the benefits of providing numbers and verbal labels outlined above due to these same reasons of ambivalence and uncertainty [e.g., 28,29].

Method

Participants and procedure

We conducted an online survey of 601 adults in the United States who were recruited from a cohort of 1,226 Amazon Mechanical Turk workers (see **Supplemental Text 1**) who had previously completed baseline measures of objective numeracy, vaccine hesitancy, vaccine beliefs, political ideology, and demographics. Approximately two weeks after the baseline, the

entire cohort was invited to complete the present 10-15-minute study for a $2.50 payment. Data collection was stopped once 601 participants completed the survey. Of those participants, six gave nonsense responses to open-ended questions (e.g., responding "yes" to "What do you think the survey was about?"). The remaining 595 participants had a mean age of 40.91 years old (*SD*=12.17), 44% were female, and 75% were non-Hispanic white (**Table 1**). Participants were randomly assigned to read information about a hypothetical vaccine in a 2 (numeric information: absent vs. present) × 2 (verbal labels: absent vs. present) between-participants design. After viewing one of four versions of the vaccine information, participants indicated their intentions to receive the vaccine, the reason for their choice, and estimates of the numeric likelihoods for three provided side effects on the next page. Methods were reviewed and approved by the Institutional Review Board at the University of Oregon. All participants gave their informed consent to participate. Data, materials, and code are available at https://osf.io/4xg5e/.

Table 1. Descriptive statistics overall and within condition. Percentages or means with standard deviations in parentheses are reported.

Descriptive	Overall (n=595)	List only (n=146)	Verbal label (n=158)	Numeric (n=152)	Label+ numeric (n=139)	Test for differences between conditions
Age (SD)	40.91 (12.17)	41.35 (12.41)	42.27 (12.79)	41.64 (12.42)	38.13 (10.52)	$F(1,590)=3.35$, $p=.019$
Ethnicity, % white	75.0%	72.6%	79.5%	73.5%	74.1%	$\chi^2(3)=2.36$, $p=.50$
Gender, % female	43.9%	47.6%	40.4%	39.5%	48.9%	$\chi^2(3)=4.16$, $p=.25$
Education, % high school degree or more	74.6%	80.8%	70.9%	69.7%	77.7%	$\chi^2(3)=6.74$, $p=.08$
Mean ONS (SD)	5.15 (1.36)	5.15 (1.31)	5.32 (1.38)	5.10 (1.33)	5.01 (1.43)	$F(1,591)=1.37$, $p=.25$

Received Covid Vaccine, % yes	71.9%	68.5%	69.4%	70.4%	79.9%	$\chi^2(3)=5.84$, $p=.12$
Political Ideology (Liberal)	56.6%	57.5%	55.1%	54.6%	59.4%	$\chi^2(6)=4.91$, $p=.56$
Political Ideology (Moderate)	17.5%	18.5%	15.8%	15.8%	20.3%	
Political Ideology (Conservative)	25.9%	24.0%	29.1%	29.6%	20.3%	

Experimental Materials

Respondents were told, ‘‘You have been recommended to receive Vaccine A to protect you against Disease A. This disease is infectious and caused by a virus. It can be passed from person to person. This disease can cause complications including a runny nose, red eyes, fever, wheezing, skin rash, and extreme fatigue.’’ All participants viewed a list of possible side effects in a table similar to the standard list of side effects generally presented to the public [e.g., 30]. The list of side effects and their corresponding likelihoods that were shown to participants were consistent with CDC-provided information for the first dose of the COVID-19 Pfizer vaccine [31]. We decided not to explicitly cue participants to the COVID-19 because at the time of the study, many people had already made a COVID-19 vaccine decision [e.g., 20–22]. Because our interest here is in how information about vaccine side effects influences intentions to receive a specific vaccine rather than how existing/prior attitudes towards COVID-19 vaccination influences intentions to receive a COVID-19 vaccination, we made the decision to frame the vaccine as a hypothetical vaccination.

Because we wanted to include a low likelihood, very serious side effect, however, we also included an additional side effect, thrombocytopenia syndrome, that has been recorded in

response to AstraZeneca and Johnson & Johnson vaccines; in the numeric conditions, we showed a likelihood in the general adult population similar to those vaccines.

Participants in the verbal label conditions viewed this list of side effects accompanied by descriptive labels used by the European Commission (e.g., 21% = very common) [32]. Participants in the numeric information conditions were provided percentage information. Thus, we tested four vaccine conditions: list only, verbal label without numeric information, numeric information without verbal label, and verbal label plus numeric information (see **Figure 1** for a depiction of the latter condition).

Possible Side Effects:

Likelihood		Description
71%	Very common	Injection site pain
47%	Very common	Tiredness
42%	Very common	Headache
21%	Very common	Muscle pain
14%	Very common	Chills
7%	Common	Injection site swelling
5%	Common	Injection site redness
4%	Common	Fever
1%	Uncommon	Nausea
0.0001%	Very rare	Blood clotting leading to a very serious condition called thrombocytopenia syndrome

Figure 1. Full information (verbal label and numeric information) provided to participants. All participants viewed the list of side effects (right-most column); participants in the verbal-label conditions also received the verbal-likelihood labels (middle column); participants in the numeric-information conditions received the percentages (left-most column). Participants in the list-only condition had text for the last risk changed to "very

rare blood clotting leading to a very serious condition called thrombocytopenia syndrome."

Measures

Vaccine intentions

Vaccine intentions were assessed using a single item (i.e., ''If the vaccine were available, how likely is it that you would receive it?"). Participants responded using a 6-point scale (1= not likely; 6 = extremely likely).

Reasons for decision

Participants then indicated the most important reason for their intentions: a) most of the side effects are not very serious; b) any serious side effects are very unlikely; c) prefer to avoid receiving vaccines and will do something else; d) there are too many possible side effects; e) a lot of people will experience at least one of the side effects, and I don't want to be one of them; f) the possibility of very serious blood clotting; g) other.

Risk overestimation

We selected three side effects that varied widely in their likelihood (71%, 4%, and .0001%, respectively, for injection site pain, clotting, and fever). Participants estimated (or recalled, if in the numeric condition) the likelihood of injection site pain, blood clotting, and a fever as a percentage (e.g., "What is the likelihood of having injection site pain as a side effect of getting Vaccine A? Please write your answer as a percentage."). These responses were coded for overestimation (1=percentage higher than actual likelihood; 0=percentage less than or equal to actual likelihood).

Individual differences

Vaccine hesitancy

In the baseline, we used a single item to assess vaccine hesitancy. We asked, "In thinking about a new vaccine that your doctor recommends for you, what are your thoughts about getting it?" The answer options were: a) I have never thought about getting a recommended vaccine; b) I'm usually undecided about getting a recommended vaccine; c) I've decided I don't want to get recommended vaccine; d) I've decided I do want to get a recommended vaccine. Most participants (64%, N=378) indicated they would get a recommended vaccine. However, 140 (24%) reported usually being undecided about getting vaccinated, 45 (8%) participants reported they had decided not to get a recommended vaccine, and 32 (5%) had not thought about it. Because of the small numbers, we combined these three vaccine-hesitant groups, leaving us with a binary measure of willing (N=378) vs. hesitant (N=217) participants (see **Table S1** for demographics by vaccine willingness).

Data analysis strategy

To test for preregistered effects of condition, we conducted ANOVAs using SPSS on vaccine intentions with verbal likelihood (absent=0, present=1) and numeric information (absent=0, present=1) as factors and age, gender, race, education, and political ideology as covariates (effects of covariates on outcomes are reported in **Table S2**). We conducted parallel analyses on participants' most important reason and overestimation (the latter was also preregistered). We added vaccine hesitancy and an interaction with each factor and a three-way interaction of both factors and hesitancy to test for moderation by hesitancy. We conducted similar analyses replacing hesitancy with numeracy (preregistered) as well as ideology and vaccine beliefs (**Supplemental Text 2, 3, and 4**).

Results

Numeric side effect information increased vaccine intentions

Providing numeric-likelihood information increased vaccine intentions (M=4.67, se= 0.09; 95%CI: 4.50, 4.84) relative to not providing it (M=4.12, se=0.09; 95%CI= [3.95, 4.23]), $F(1,574)=19.80$, $p<.001$, $\eta_p^2=.03$, confirming our hypothesis (demographic covariate effects in **Table S2**). No main effect existed of verbal-label provision nor its interaction with providing numbers (p's>.20). To illustrate the power of providing numbers, we conducted a logistic regression of those who were moderately to extremely likely to vaccinate (vs. had lower intentions) using the same predictor variables. Controlling for covariates, 70% of those who received numeric information were predicted to be moderately to extremely likely to vaccinate compared to only 54% of those who did not receive numeric information. Vaccine intentions were also higher for people with more education, liberals, and men (**Table S2**).

Exploratory analyses: vaccine hesitancy as a moderator of condition effects

We conducted the same analysis as above but included vaccine hesitancy as a moderator of our conditions and their interaction. The main effect of numeric information remained significant, $F(1,570)=13.77$, $p<.001$, $\eta_p^2=.02$. There was also a main effect of verbal label, $F(1,570)=6.00$, $p=.015$, $\eta_p^2=.01$, and interaction of numeric and verbal label, $F(1,570)=10.42$, $p=.001$, $\eta_p^2=.02$. Moreover, non-hesitant participants were more likely to intend to be vaccinated given provided information (M=5.05, se=0.07; 95%CI= [4.93, 5.18]) than those who were hesitant (M=3.21, se=0.09; 95%CI= [3.04, 3.39]), $F(1,570)=257.16$, $p<.001$, $\eta_p^2=.31$.

In addition, a three-way interaction emerged of vaccine hesitancy, numeric condition, and verbal condition, $F(3,570)=17.22$, $p<.001$, $\eta_p^2=.03$ (**Figure 2**). Among those willing to get a recommended vaccine, only small differences emerged; the effect of numeric information to increase intentions occurred in the absence of verbal labels, $F(1,570)=5.50$, $p=.019$, $\eta_p^2=0.01$,

but not in their presence (p>.20). However, among the vaccine hesitant, presenting both verbal labels and numeric information produced the highest likelihoods to get vaccinated; verbal labels increased vaccine intentions with numeric information, $F(1,570)=26.06$, $p<.001$, $\eta_p^2=.04$, but not without (p>.20), and numeric information increased vaccine intentions with verbal labels, $F(1,570)=26.74$, $p<.001$, $\eta_p^2=.05$, but not without (p>.15) . Among the vaccine hesitant, 43% were predicted to be moderately or extremely likely to get the vaccine when provided numeric information and verbal labels compared to only 24% in the list only (i.e., standard-of-care) group, controlling for covariates. Thus, providing numeric plus verbal labels minimized the effects of vaccine hesitancy, $F(1,570)=22.97$, $p<.001$, $\eta_p^2=.04$, relative to the other three conditions (F's >65). Hesitancy did not moderate condition effects on other outcomes.

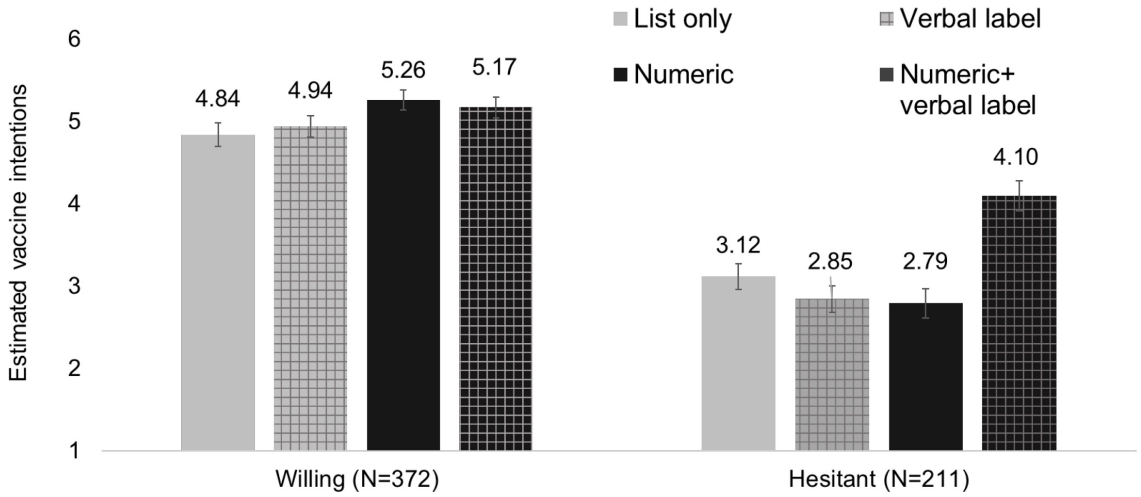

Figure 2. Estimated marginal means of vaccine intentions by numeric information, verbal label, and vaccine uncertainty. Age, gender, race, education, and ideology were included as covariates (Table S1). Error bars indicate ± standard error of the mean.

Numeric side effect information decreased risk overestimation

As expected, providing numeric information corrected misunderstandings; it reduced how often risks were overestimated. Participants without numeric information overestimated an average 2.5 out of 3 risks (se=0.04; 95%CI= [2.40, 2.57]), whereas those with numeric

information misremembered 1.0 (*se*=0.04; 95%CI= [0.94, 1.11]) out of the same 3 risks as higher than the information they were provided, $F(1,574)=557.11$, $p<.001$, $\eta_p^2 = .49$. Unexpectedly, overestimation was higher in the presence of a verbal label, $F(1,574)=15.35$, $p<.001$, $\eta_p^2=.03$. This effect was qualified by an interaction with numeric condition, $F(1,574)=4.95$, $p=.026$, $\eta_p^2=.01$ (**Figure 3**), such that overestimation was highest in the presence of a verbal label and without numeric information, $F(1,574)=19.53$, $p<.001$, $\eta_p^2=.03$, but verbal labels made little difference in the presence of numeric information ($p>.20$). Overestimation was also higher among women and conservatives (see **Table S2**). Thus, our expectation that numeric information would reduce overestimation was supported. Parallel analyses conducted on overestimation of individual side effects and numeric and verbal risk estimates for each side effect are reported in **Supplemental Text 5**.

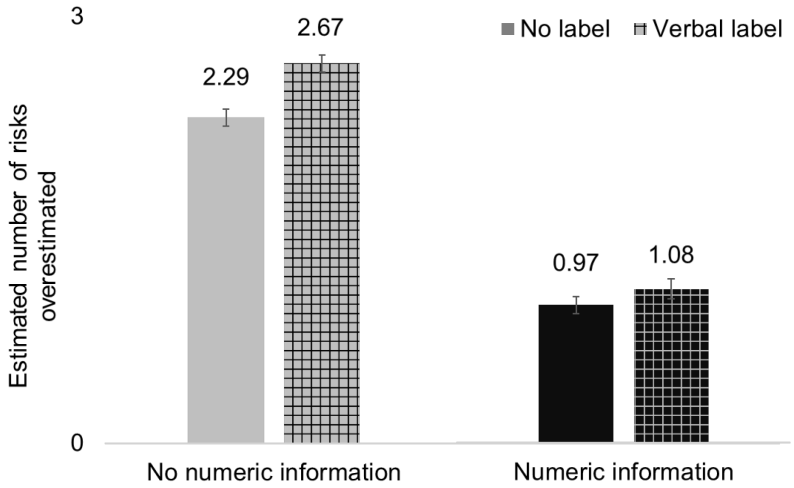

Figure 3. Estimated marginal means of overestimation (out of 3) of risks depending on numeric information and verbal label. Age, gender, race, education, and ideology were included as covariates (Table S1). Error bars indicate ± standard error of the mean.

Reasons for willingness to take or refuse the vaccine

The most common reason selected by participants for their willingness to take the vaccine was that most side effects were not serious (selected by 43% of the sample). However, differences existed by condition (**Figure 4**; interaction of numeric information condition and verbal label condition, *b(se)*=0.90 (0.35), *p*=.011, OR=2.47; 95%CI= [1.23; 4.93]). The presence of verbal labels mattered in the numeric condition, *b(se)*=0.63 (0.25), Wald $\chi^2(1)=6.25$, *p*=.012, OR=1.87; 95%CI= [1.14, 3.05], but not in the non-numeric condition (*p*>.20). Only 36% of those in the list only condition indicated that most side effects were not serious compared to 61% in the verbal-label-plus-numeric-likelihood condition.

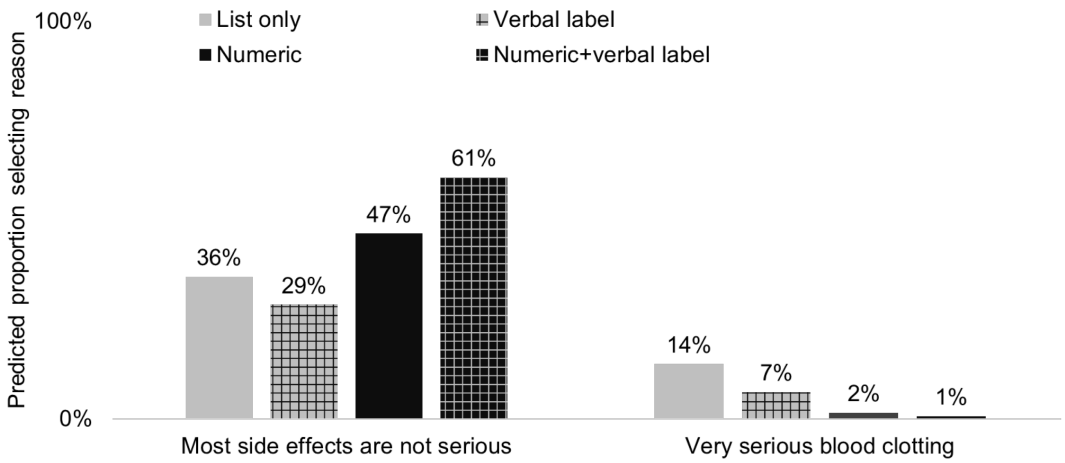

Figure 4. Predicted proportions of people selecting each reason by condition, controlling for age, gender, race, education, and political ideology.

On the other hand, only 2% of participants in the numeric conditions selected serious blood clotting as the most important reason for their choice compared to 11% in the non-numeric conditions, *b(se)* = −2.26 (0.63), Wald $\chi^2(1)=12.69$, $p<.001$, OR=0.10; 95%CI= [0.03,.36]. Also, only 5% of participants who viewed verbal labels selected serious blood clotting as the most important reason for their choice compared to 8% of those who did not see verbal labels, *b(se)*=−0.78 (0.39), Wald $\chi^2(1)=3.98$, $p=.046$, OR=0.46; 95%CI= [0.21, 0.99]; no interaction emerged between conditions ($p>.90$).

The remaining reasons (avoiding vaccines, too many side effects, and avoiding side effects) did not differ by condition (p's>.15), except for "serious side effects are unlikely" (**Table S2**).

Discussion

The current study advances prior research by demonstrating that providing numeric information about vaccine side effects increased likelihoods of getting vaccinated compared to not providing it, similar to findings communicating side effects of medications [9,18]. Furthermore, we investigated the psychological mechanisms underlying the effects of providing

numeric information on vaccination intentions, namely the reduction in overestimation of severe side effects and changes to reasons for wanting to get vaccinated. Finally, our results suggest that a change from the status quo of providing only a list of side effects could be helpful. Specifically, providing both numeric and verbal information is superior to providing either one alone or neither one at all (the latter being the current status quo in the United States). The reasons people selected for their intentions underscored the importance of correcting misinterpretations and putting serious side effects in context as well. With the combination of numeric likelihoods and their verbal interpretations, a very simple communication change, participants were much more likely to indicate that most side effects were not serious and less likely to be concerned about the rare but serious blood clotting. Thus, providing *both* numeric and verbal information may better meet the needs of the informed consumer and facilitate vaccination uptake. As others have concluded [33,34], the use of verbal labels, such as the European Commission labels, appears to be problematic when presented without numeric information. Unclear is whether this combination also may reduce perceptions of unknown side effects or those that have been repeated but are not real (e.g., autism), a possible future research direction.

Importantly, providing numeric information increased intentions to take a hypothetical vaccine modeled on current COVID-19 vaccines similar to findings communicating side effects of medications [9,18]. According to October 2020 rates of vaccine hesitancy in a nationally representative sample of Americans [23], approximately 120 million people were unsure or unwilling to vaccinate in response to a question similar to the one we posed. A switch at that point in time to describing vaccines with both verbal labels and numeric information might have convinced an additional 11 million Americans (3% of the U.S. population) to vaccinate, assuming an effect on actual vaccination half the size observed here (and based on reports of being moderately to extremely likely to vaccinate).

The benefits of numeric information appear due to them playing an overlooked educational role, correcting the near ubiquitous overestimation of the likelihood of side effects. Indeed, reduced overestimation mediated the effect of numeric information on increased intentions **(Supplemental Text 6).** Additional exploratory results (**Supplemental Text 6**) suggest that overestimation of very severe blood clotting, in particular, may have driven the effect of numeric information on increased intentions. This finding is consistent with prior research demonstrating that people given numeric information about the likelihood of side effects were not influenced by changes in minor side-effect likelihood, but were more likely to choose vaccination when rare, serious side effects were presented as rarer [34]. Future research could examine when or for whom very rare, very serious side effects influence vaccination behavior and/or whether consideration of such rare effects are rational or not. [35]

The combination of numeric and verbal information appeared particularly beneficial for vaccine-hesitant individuals, providing helpful evidence for policy makers and others working to increase vaccine uptake. For those participants, the combination of verbal and numeric information produced the highest level of vaccine intentions. The results that the vaccine hesitant showed stronger effects of information is consistent with the possibility that those who are hesitant are uncertain or ambivalent [e.g., 28,29,36,37]; they may be paying more attention in order to reduce that uncertainty or ambivalence. However, this past research does not explain why combined verbal label and numeric information in particular was more effective than numeric information alone [18]. One possibility is that participants in the prior research had the information available for answering questions about risk perceptions and intentions whereas information and questions were separate in the current information. Here, the presence of numeric information (but not verbal labels) reduced overestimation, but perhaps their combination helped emphasize the fact that even “common” side effects are fairly unlikely, which decreased hesitancy. It may also be that their combination gave the impression of more

298 complete information and reduced doubts about vaccination [for a similar argument related to
299 attitude certainty, see 38]. Alternatively, the labels may have helped participants to evaluate not
300 just what the number is, but how it feels, thus increasing the use of the numbers [39]. Future
301 research should explore these effects further, including the metacognitions (e.g., certainty and
302 ambivalence) of those hesitant to vaccinate and the effects of pro-vaccine messaging on these
303 metacognitions. Greater certainty and lower ambivalence increase the correspondence between
304 belief and behavior [29,37,40,41]. The vaccine-hesitant being less certain and more ambivalent
305 about their beliefs could explain why attempts to change thoughts and feelings about vaccines
306 have not had large effects on vaccine behavior [for review, see 42]. Specifically, encouraging
307 people to have more positive beliefs about vaccination may be insufficient if they remain
308 uncertain and/or ambivalent in those beliefs.

309 Although health professionals and policy makers may believe that giving numeric
310 information will overwhelm, our results instead strongly indicate that numeric information
311 increased vaccine intentions and reduced risk overestimation even among those lower in math
312 ability (**Supplemental Text 2**), consistent with prior research [18]. Although overestimation
313 results pointed towards the highly numerate benefiting more from numeric information [as in 18],
314 the same was not true for vaccine intentions where, if anything, the less numerate may benefit
315 more (**Figure S1**). This finding alleviates concerns that those lower in numeracy may not be
316 able to handle such information. Nonetheless, because the highly numerate remember numeric
317 information better, those lower in numeracy may particularly benefit from being given numeric
318 side effect information at the time of choice. Other researchers have found that the effects of
319 knowledge on vaccine intentions are stronger immediately vs. over time. For example, a leaflet
320 about disease risks increased knowledge and produced greater vaccine intentions immediately,
321 but not 3 months later [43]; thus, we would expect these effects to be most impactful in

situations most proximal to vaccination (e.g., in doctor's offices). Alternatively, information needs to be clear [44], simple, and repeated from a variety of trusted sources [45].

Our results (and others' [18]) suggest that providing numeric risk information to a complete list of possible side effects helps people more accurately assess risks of side effects. Others' research has raised concerns about diluting the impact of serious side effects by presenting them along with common, but less serious side effects [46]. Future research could vary the number of side effects with and without numeric information to determine whether adding numeric information affects this dilution process. On the one hand, adding numeric information could enhance the influence of a side effect if it were perceived as atypical (i.e., an enhancement effect with atypicality, Peters & Rothbart, 2000). On the other hand, if the risks are overestimated, as they are here, adding numeric information may lead to positive feelings of relief and less worry (Fagerlin, Zikmund-Fisher, & Ubel, 2005) and dilute the impact of the serious side effect even further. It is currently unclear which result is more likely; more research is needed.

Methods to increase vaccine intentions and overcome vaccine hesitancy may become increasingly important if political polarization about COVID-19 vaccines generalizes to other vaccines. Our exploratory analyses (**Supplemental Text 4**) demonstrate the same trends others have found [21,23]. Specifically, conservatives were less likely to have received a COVID vaccine, had more negative beliefs about vaccination in general, and were more vaccine-hesitant. They also had lower intentions to our hypothetical vaccine. However, our manipulations reduced this effect—the combination of verbal labels and numeric information increased vaccine intentions of conservatives the most of any condition and minimized the effect of ideology relative to the other conditions.

Limitations

Although we used a large, diverse convenience sample (see **Table S3**), our sample was more highly educated than the general population; it was also more numerate. It is possible that the least numerate people may not benefit from numeric information, although our reported results were more consistent with increased effects of condition on vaccine intentions for those lower in numeracy. At some point, however, this effect may asymptote or reverse, a possibility that could be examined by recruiting less-educated and less-numerate samples.

Second, there was a failure of random assignment—our label + numeric condition was significantly younger than the other conditions (**Table 1**). However, we controlled for this and other demographic variables in our analyses. Furthermore, as older age related to greater vaccine intentions (**Table S2**), it is unlikely that the higher intentions in the label + numeric condition could be explained by those in that condition being *younger* on average than the remaining conditions.

Third, we used a hypothetical vaccine. A primary intention of this manuscript is to encourage study of the effect in a more ecologically valid setting. Future research ideally would occur within provider-patient dyads or with public health departments to determine whether numeric information increases real-world vaccine uptake. Intentions to vaccinate strongly predict vaccination behavior [47,48], as can more general positive beliefs towards vaccination [49]. Nonetheless, our choice to test the effects of numeric and verbal likelihoods distanced from the politically polarized context of COVID-19 vaccines means that their effects on COVID-19 vaccine uptake will likely be smaller than the effects found here. Because of this, when estimating impact on this vaccine uptake, we estimated an effect size that was half of what we found. Therefore, implications of our findings for policy and practice would benefit from confirmation using actual vaccine behavior. It is also likely that numeric information was helpful in the present study because participants overestimated risk; in situations where participants

underestimate their risks (or benefits), numeric information may hurt vaccine intentions. This possibility could be examined in future research.

A final limitation is that our sample included more individuals who were in favor of vaccination than hesitant. Future research could recruit greater numbers of vaccine-hesitant and vaccine-opposed participants to verify the robustness of effects.

Conclusions

The use of standard lists to convey vaccine side-effect information reduced vaccine intentions. Without numeric information about the likelihood of side effects, people likely overestimate these risks. In the case of very rare, serious side effects, this overestimation was ubiquitous (98% of our sample not given numeric information overestimated the risk of serious blood clots vs. 32% who were given numeric information) and likely a key contributor to lower intentions to vaccinate. The combination of verbal labels (e.g., “very rare”) with numeric information (e.g., 0.0001%) showed the most promise in convincing vaccine-hesitant people (i.e., politically conservative, those who reported uncertainty about vaccination in general) to vaccinate. Simply providing numeric and verbal likelihood information may be an overlooked method to overcome vaccine hesitancy and increase vaccination.

All authors attest they meet the ICMJE criteria for authorship.

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