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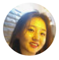
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The Effects of Numerical Evidence and Message Framing in Communicating Vaccine Efficacy

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To examine the effects of numerical evidence and message framing in communicating vaccine efficacy information about infectious diseases, an online experiment presented to U.S. adults different versions of a vaccination promotional message that vary by numerical vaccine efficacy evidence: (low efficacy rate: 60% vs. high efficacy rate: 95%), outcome framing (preventing disease-related infection vs. preventing disease-related severe illness), and gain vs. loss framing, using a factorial between-subjects design. While there was no significant interaction between numerical vaccine efficacy evidence and message framing, findings showed that a higher vaccine efficacy rate increased positive beliefs about vaccination and outcome framing emphasizing infection prevention increased message processing fluency. Given that infectious diseases pose higher risks for severe illness among older adults, follow-up analyses by age showed that only younger adults were sensitive to message framing where outcome framing emphasizing infection prevention increased processing fluency.

KEYWORDS

Vaccine efficacy, gain-loss framing, numerical evidence, message processing, infectious disease

During the COVID-19 pandemic, health professionals emphasized the efficacy of vaccination regimes as means to build up defenses against the coronavirus (World Health Organization [WHO], 2021). Although the efficacy in reducing virus infection may fluctuate with different variants of the virus, vaccines can effectively boost the immune system guarding the human body against severe illness that leads to hospitalizations and deaths (Katella, 2021). Promoting people's perceived effectiveness of the vaccines through communication campaigns may increase vaccine uptake and accelerate the process of ending the pandemic.

Promoting vaccination requires using evidence communication that conveys accurate disease and vaccination information (Yale Institute of Global Health, 2020). Numerical information, such as vaccine efficacy rates, is an important type of evidence. News stories and vaccination campaigns typically include numerical information about vaccine efficacy. However, while past research typically focused on numerical information about disease risks (Fagerlin et al., 2011; Peters et al., 2007; Reyna et al., 2009; Visschers et al., 2009), the effects of vaccine efficacy rates information on readers in the context of highly infectious diseases have largely been overlooked.

Moreover, such numerical information about vaccine efficacy may also interact with message framing. Framing effects research centers on how message formulation may affect readers' issue interpretation (McLeod et al., 2022). Specifically, when communicating vaccine efficacy, a message may emphasize different outcomes of vaccination (e.g., preventing disease infection versus severe illness), and the information may be formulated to highlight either the potential gains from getting vaccinated (e.g., gaining an opportunity of being protected against the disease) or losses by not getting vaccinated (e.g., losing an opportunity of being protected against the disease) (Tversky & Kahneman, 1981). While people are generally more sensitive to losses than gains (Kahneman & Tversky, 1979), the effects are not universal (Gallagher & Updegraff, 2012; O'Keefe & Jensen, 2007) and scholars argued for examining

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under what conditions gain or loss framed appeals may be more effective (Latimer et al., 2007; Shah et al., 2004). Specifically, studies found that when the losses appeared to be larger and more severe, it enhanced the persuasiveness of loss framing over gain framing (Hull, 2012; Latimer et al., 2007). Thus, in the case of vaccine communication, we may expect that communicating a high vaccine efficacy rate (e.g., 95%) should be accompanied by loss framing because the high efficacy rate will make the losses (from not getting vaccinated) seem larger and more unaffordable. Similarly, emphasizing severe illness (i.e., hospitalizations or deaths) as the outcome of infectious disease (such as COVID-19) features larger and more severe harm from the disease to one's health/well-being compared to virus infection (a less severe outcome). Therefore, we may also expect that communicating a high vaccine efficacy rate in preventing severe illness (i.e., hospitalizations and deaths) may be more effective in accentuating the importance of vaccination than talking about infection prevention.

Given that little is known to date about how vaccine efficacy rates information affects the readers, this study examines the effects of vaccine efficacy rates information and its potential interplay with different message framing elements (gain/loss framing and outcome framing in particular) on the general adult population in the U.S. to better promote vaccination against infectious disease.

Vaccine Efficacy Rates Information

The efficacy of a vaccine refers to the extent to which the vaccine can reduce people's risk of getting sick (WHO, 2021). For example, a vaccine with a 90% efficacy rate means that those who were vaccinated were at a 90% lower risk of developing disease compared to people who got the placebo. In other words, if 10 out of 100 people were infected with COVID-19 virus in the placebo group, only 1 out of 100 people were infected in the vaccination group. People without sufficient vaccine knowledge may lack information about vaccine efficacy or may misestimate the efficacy of a vaccine. When people encounter vaccine efficacy information, they may form/alter their beliefs about vaccination through evaluating the given information.

A COVID-19 vaccine must have an efficacy rate of 50% or above in preventing infection in order to be approved by the U.S. Food and Drug Administration [FDA] (2022) and World Health Organization (2021). For COVID-19, vaccine efficacy rates based on the results of clinical trials (e.g., Pfizer-BioNTech, Moderna, and Johnson & Johnson vaccines) are reported in terms of either preventing infection or severe illness (Centers for Disease Control and Prevention, 2022). Accordingly, news stories and health messages about COVID-19 vaccines may either depict the efficacy of the vaccine in guarding against infection or severe illness (i.e., hospitalizations or deaths).

Effects of Vaccine Efficacy Rates and Message Framing

People tend to utilize the information they encounter to form their subsequent beliefs and judgments, known as the anchoring effects (Tversky & Kahneman, 1974; Wilson et al., 1996). While the anchoring mechanism, in its original conceptualization, centered more on perceptions shaped by largely irrelevant information, the anchoring effects may play a more important role when the beliefs measured are directly relevant to the information in focus. For example, past research suggests that numerical information may serve as an anchor when it is easy to understand and internalize (Lee et al., 2021; Liu & Niederdeppe, 2021; Liu et al., 2019). Communicating the prevalence rates of impaired driving and endangered species in percentage formats not only shaped/altered perceived prevalence of impaired driving and endangered species but also affected perceived severity of the issues (Lee et al., 2021). Applying this line of reasoning to the context of vaccine efficacy, people may rely on the given vaccine efficacy rate to derive their subsequent vaccination-related beliefs (Wilson et al., 1996). For example, as vaccine efficacy rates indicate the level of benefits that can be acquired by receiving the vaccination, it may shape beliefs about vaccination among message recipients where a high vaccine efficacy rate may trigger more positive beliefs. Similarly, message recipients may be more likely to argue in favor of vaccination when communicating with others if the vaccine efficacy rate is relatively high, another indicator of their positive beliefs which may have societal implications by creating a favorable opinion climate surrounding vaccination. Whereas people's beliefs/perceptions about vaccination and their likelihoods of advocacy for it may be more directly influenced by vaccine efficacy rates, vaccination intention/behavior is more complex and may be shaped by factors beyond vaccine efficacy which may also include perceived disease risks, self-efficacy, and perceived individual- and societal-level resources/barriers (Rosenstock, 1974; Witte, 1992). Thus, we focus on positive beliefs and advocacy here and pose the hypothesis below.

A high vaccination rate will increase (a) positive beliefs about vaccination and (b) likelihoods of arguing in favor of vaccination compared to a low vaccine efficacy rate.

Moreover, the effects of vaccine efficacy information might also interact with message framing. Vaccination promotional messages may use either loss-framed appeals (e.g., you will fail to protect yourself by not getting vaccinated) or gain-framed appeals (e.g., you will be able to protect yourself by getting vaccinated) (Levin et al., 1998) and may selectively feature the efficacy of the vaccine in preventing infection or severe illness (Katella, 2021). While Prospect Theory argues that people are generally more reactive to losses than gains (Kahneman & Tversky, 1979), scholars have also noted that the effectiveness of gain versus loss framing may be dependent upon the type of behaviors in focus (Rothman et al., 2006): loss framing may be more effective for disease detection behaviors such as cancer screening (Meyerowitz & Chaiken, 1987), and gain framing may work better for disease prevention behaviors such as wearing sunscreens to prevent skin cancer (Rothman et al., 1993). This is because disease detection behaviors are more risk related (the risk of finding that one has a health condition, for example) than disease prevention behaviors such as diet and exercise that involve little risks. Along these lines, as vaccination is a disease prevention behavior, it may benefit from gain framed messages. However, meta-analysis studies do not show the advantage of gain framing in promoting disease prevention behaviors (Gallagher & Updegraff, 2012; O'Keefe & Jensen, 2007) and vaccination in particular (O'Keefe & Nan, 2012).

The lack of main effects of gain-loss framing does not signal that message framing does not matter (Shah et al., 2004). Rather, some scholars have suggested that research should focus on the conditions in which gain-loss framing would be more effective by examining its interactions with other personal- or message-level factors (Latimer et al., 2007). For example, Bartels et al. (2010) found that loss framing was more persuasive than gain framing only when people faced high-risk outcomes but not when the risks involved were low. Similarly, Hull (2012) found that loss framed appeals were more powerful than gain framing only among people who perceived higher disease risks. As a high vaccine efficacy rate (e.g., 95% compared to 60%) suggests that the probability of losing the benefit of vaccination is larger by not getting vaccinated (i.e., the disease risk is higher without vaccination), we may expect that the difference between communicating a high vaccine efficacy rate vs. a low efficacy rate on beliefs about vaccination and advocacy in favor of it will be larger under loss framing than gain framing.

Along this line, as loss framing and a high vaccine efficacy rate (when combined together) indicate effectively preventing a high-risk loss from happening, this combination highlighted both the potential loss people may face in the future and the effective way to avoid it, which may echo people's risk averse tendencies and their expectations for an effective vaccine. As a result, people might be able to process vaccination messages showing such a combination of features more fluently whereas other possible combinations (e.g., using loss framing but featuring that the vaccine is not very effective in protecting people) may not significantly differ in their effects on processing fluency. Thus, we pose the hypothesis below.

Interaction between *vaccine efficacy rates* and *gain/loss framing*: the difference between communicating a high vaccine efficacy rate vs. a low efficacy rate on (a) message processing fluency, (b) positive beliefs about vaccination, and (c) advocacy in favor of vaccination will be larger when paired with loss framing than gain framing.

The vaccine efficacy rates information may also interact with outcome framing. Emphasizing preventing disease related severe illness (i.e., hospitalizations and deaths) highlights both the high severity of the outcome and the utility of the vaccine to guard people against it, which may more effectively augment the difference between communicating a high vaccine efficacy rate vs. a low one on vaccination beliefs and advocacy than featuring infection prevention (i.e., the prevention of a less severe outcome). Also, given that vaccines for infectious diseases such as COVID-19 are indeed typically more effective in preventing severe illness than infections (Wu et al., 2023), emphasizing the prevention of severe illness as the outcome might also meet people's expectations and produce better message processing fluency (whereas the processing fluency of other combinations might not differ significantly), making the vaccination promotional message easier to read and comprehend. Therefore, we pose the hypothesis below.

Interaction between *vaccine efficacy rates* and *outcome framing*: the difference between communicating a high vaccine efficacy rate vs. a low efficacy rate on (a) message processing fluency, (b) positive beliefs about vaccination, and (c) advocacy in favor of vaccination will be larger when emphasizing severe illness prevention than infection prevention.

Finally, following the reasoning of H2 and H3, it might be possible that there will be a three-way interaction between efficacy rates information, outcome framing, and gain/loss framing where emphasizing severe illness prevention (vs. infection prevention) may enlarge the difference between communicating a high vaccine efficacy rate vs. a lower one and such augmenting effects will become even larger under loss framing than gain framing. It is because the two framing elements may create a synergy when combined producing greater augmenting effects to the high vaccine efficacy rate information than the sum of what each could do separately. However, it is also possible that as both outcome framing and loss framing serve to augment the role of high vaccine efficacy, there might be no additional benefits when combining the two message framing elements because they have similar/overlapping functions or because too much emphasis on risks/outcome severity may incur message resistance/reactance instead. Given the complexities, we pose the research question below.

Is there a three-way interaction between vaccine efficacy rates information, outcome framing, and gain/loss framing?

Methods

Procedure and Participants

An online survey delivered different vaccination promotion messages (see Appendix for the message stimuli) concerning a hypothetical virus *Sebarisus* (with information modeled after COVID-19 vaccines) to a sample of U.S. adult respondents in the United States. The stimuli were developed based on a previous study by the authors (Lu et al., 2023). Respondents were recruited through Qualtrics and were compensated by Qualtrics. Participants were randomly assigned to a treatment group using a 2 (vaccine efficacy rate: 95% vs. 60%) by 2 (vaccination outcome framing: preventing infection vs. preventing severe illness) by 2 (gain vs. loss framing) between-subjects design plus a no-message control condition. Eight hundred and forty-five respondents read the message stimuli (reading time ≥10 s) and completed the questions related to our target variables. This study was approved by the Institutional Review Board of the University of Wisconsin-Madison.

In the gain framing condition, the message presented the outcome of getting vaccinated as, “If you make an appointment to get vaccinated now, you will gain an opportunity to protect yourself against” the *Sebarisus* virus. By comparison, in the loss framing condition, the message presented the consequence of not getting vaccinated as, “If you do not make an appointment to get vaccinated now, you will lose an opportunity to protect yourself against” the *Sebarisus* virus. Given that COVID-19 vaccines have different efficacy rates, the message portrayed the vaccine as having an efficacy rate of either 60% or 95%, mirroring the reported clinical trial tests for COVID-19 vaccines from Pfizer-BioNTech, Moderna, and Johnson & Johnson. Also, the message emphasized either the efficacy of the vaccine in preventing *Sebarisus* infections or preventing severe illness from Sebarisus (e.g., hospitalization or death). Full message stimuli are shown in the Appendix.

The average age of respondents was 47.46 (SD = 17.46, range: 18–87). 55.1% were aged between 18 and 49 and 44.9% were aged 50 or over. 46.9% were male and 52.0% were female. About 75.4% of respondents were White adults, followed by Black adults (12.0%), Asian (5.2%), and 7.5% were of other racial groups or had more than one racial identity. 26.2% did not attend college, and 73.8% received some college education or had a bachelor’s degree or higher. 47.8% had an annual household income of less than $50,000, and 52.2% were with an income of $50,000 or above. After reading the message stimuli, respondents then answered questions about message processing fluency, beliefs about vaccination, and advocacy intention for vaccination. Demographics information was also collected.

Measures

Processing fluency

Measures for message processing fluency were derived based on Kostyk et al. (2021). By using semantic differential scales, respondents were asked the extent to which the message was (a) difficult to read/easy to read, (b) unclear/clear, (c) incomprehensible/comprehensible, and their processing was (d) unsmooth/smooth; (e) effortful/effortless, and (f) difficult/easy, each on a scale 7-point scale where higher values indicate higher processing fluency. These six items were then averaged to form the processing fluency index ($\alpha = .94$, $M = 5.96$, SD = 1.32).

Beliefs about vaccination

Beliefs about vaccination measurements were adapted from past research (Brewer & Fazekas, 2007; Gerend & Shepherd, 2012). Respondents were asked to indicate their agreement with five statements depicting the benefits of vaccination against the *Sebarisus* virus, including “I could rely on the vaccine to prevent me from getting the Sebarisus disease;” “I would feel protected after getting vaccinated against Sebarisus;” “I would feel safe after being vaccinated against Sebarisus;” “Vaccination of an individual against Sebarisus is very important for the protection of the community;” “By vaccination against Sebarisus, I significantly contribute to the protection of others who can’t be vaccinated,” each on a 7-point scale from 1 (strongly disagree) to 7 (strongly agree). Responses were averaged as the beliefs about vaccination index ($\alpha = .95$, $M = 4.68$, $SD = 1.76$).

Arguing in favor of vaccination

Respondents were asked about their likelihoods of arguing in favor of vaccination by indicating how likely they would (a) post information on social media arguing for vaccination; (b) argue against family member who intend to *not* get vaccinated; and (c) argue against friends who intend to *not* get vaccinated, each on a scale from 1 = very unlikely to 7 = very likely. Responses to the three items above were then averaged to form the arguing in favor of vaccination index ($\alpha = .87$, $M = 3.56$, $SD = 1.94$).

Demographics

Demographic information was also collected, including age, gender, race, education, income, and political ideology.

Results

To address the effects of vaccine efficacy information and its potential interactions with outcome framing (preventing infection versus severe illness) and gain-loss framing, factorial ANOVA tests were conducted (mean values and standard deviations by experimental conditions are depicted in Table 1). Demographic variables were not controlled in the analyses as the randomization check showed that respondents’ demographics did not significantly differ between conditions. Findings showed that vaccine efficacy rates information had a significant main effect on beliefs about vaccination, $F(1, 741) = 9.81$, $p = .002$, and arguing for vaccination, $F(1, 741) = 4.31$, $p = .04$. Specifically, compared to those exposed to a low vaccine efficacy rate (60%) ($M = 4.50$, $SD = 1.70$ for beliefs about vaccination and $M = 3.41$, $SD = 1.92$ for arguing in favor of vaccination), respondents exposed to a high vaccine efficacy rate (95%) showed significantly more positive beliefs ($M = 4.89$, $SD = 1.81$) as well as higher intentions to argue for vaccination ($M = 3.70$, $SD = 1.96$). Thus, H1 was supported.

For the interaction effects (H2, H3, and RQ1), vaccine efficacy rates information did not significantly interact with gain/loss framing to affect processing fluency, $F(1, 741) = 0.11$, $p = .74$, beliefs about vaccination, $F(1, 741) = 1.21$, $p = .27$, or arguing in favor of vaccination, $F(1, 741) = 0.83$, $p = .36$. Vaccine efficacy rates information also did not significantly interact with outcome framing: $F(1, 741) = 0.00$, $p = .99$ for processing fluency, $F(1, 741) = 0.39$, $p = .54$ for beliefs about vaccination, and $F(1, 741) = 3.02$, $p = .08$ for arguing in favor of vaccination. Therefore, H2 and H3 failed to receive support. For RQ1, there was no significant three-way

Table 1. Descriptive statistics by experimental conditions ($N = 749$)

	60% efficacy in preventing infection (gain framing)	60% efficacy in preventing severe illness (gain framing)	60% efficacy in preventing infection (loss framing)	60% efficacy in preventing severe illness (loss framing)	95% efficacy in preventing infection (gain framing)	95% efficacy in preventing severe illness (gain framing)	95% efficacy in preventing infection (loss framing)	95% efficacy in preventing severe illness (loss framing)
Processing fluency	6.07 (1.22)	5.75 (1.42)	5.97 (1.30)	5.79 (1.31)	6.13 (1.14)	5.96 (1.49)	6.24 (1.11)	5.91 (1.37)
Beliefs about vaccination	4.41 (1.66)	4.36 (1.75)	4.59 (1.67)	4.62 (1.71)	4.88 (1.82)	4.98 (1.86)	5.09 (1.59)	4.65 (1.94)
Arguing in favor of vaccination	3.53 (2.07)	3.33 (1.88)	3.37 (1.88)	3.41 (1.87)	3.35 (1.94)	3.85 (1.86)	3.66 (2.04)	3.98 (1.97)

Cell entries represent mean values with standard deviations in parentheses.

interaction, $F(1, 741) = .68$, $p = .41$ for processing fluency, $F(1, 741) = 1.45$, $p = .23$ for beliefs about vaccination, and $F(1, 741) = .55$, $p = .46$ for arguing in favor of vaccination, respectively.

Although not hypothesized, outcome framing had a significant main effect on processing fluency, $F(1, 741) = 6.93$, $p = .009$. Compared to respondents who were exposed messages highlighting vaccine efficacy in preventing severe illness ($M = 5.85$, $SD = 1.40$), respondents who read messages emphasizing vaccine efficacy in preventing infections showed higher processing fluency ($M = 6.10$, $SD = 1.19$).

Follow-Up Analysis by Age

To better understand the lack of interaction between vaccine efficacy rates information and message framing, follow-up analyses by age were conducted to test age as a moderator: the interaction between vaccine efficacy and message framing may be rather based on age. For infectious diseases like COVID-19, the mortality rates are much higher for older adults (Centers for Disease Control and Prevention, 2023; Statista, 2023). The fact that elderly people are at greater risks of severe illness from infectious diseases might make them more risk averse and respond to vaccination promotional messages differently than younger adults who are much less likely to suffer from severe health consequences. Thus, it is possible that the moderating effects of message framing techniques (either loss framing or emphasizing the prevention of severe illness) to accentuate the role of high vaccine efficacy rates may only appear among older adults. However, it is also possible that older adults may be immune to message framing because their elevated risks have made their beliefs more stable over time and thus less responsive to the alternative ways the efficacy information is presented (i.e., message framing) (Luo et al., 2021). Similar reasoning may also be applied to younger adults. On the one hand, their lower mortality risks might make them not attentive/sensitive to message framing, and thus gain/loss framing or outcome framing may not interact with vaccine efficacy rates information. On the other hand, the fact that they are at less risk might also make their beliefs less rigid (and more movable) and thus more easily shifted by message framing (cues in the presentation apart from numerical evidence) (McLeod et al., 2022).

Based on this reasoning, we explored the three-way interaction (a) between vaccine efficacy information, gain/loss framing, and age; and (b) between vaccine efficacy information, outcome framing, and age, using the PROCESS macro in SPSS (Hayes, 2018) which treated age as a continuous variable in the analyses and used the Johnson–Neyman test to explain the moderating effect of age if it occurs (Darlington & Hayes, 2016; Hayes, 2018). Findings revealed that there was no significant three-way interaction (all ps > .05), echoing results from the overall sample. However, there was a significant two-way interaction between outcome framing and age ($p = .01$) on processing fluency. The Johnson–Neyman test showed that for younger respondents aged between 18 and 52, emphasizing the prevention of severe illness (vs. infection prevention) reduced processing fluency. By comparison, among older respondents (aged 53 or above), outcome framing did not have significant impact on processing fluency.

Discussion

This study helps to create effective campaigns by examining the effects of vaccine efficacy rates information and its interaction with message framing in the context of infectious disease. Findings revealed no significant interaction effect between vaccine efficacy rates information and message framing. While we found that vaccine efficacy rates affected beliefs about vaccination and outcome framing influenced message processing fluency, follow-up analysis of data by age showed that only younger people were responsive to message framing where outcome framing emphasizing infection prevention (compared to severe illness prevention) boosted processing fluency. These findings have several important implications.

To begin with, we found main effects of vaccine efficacy rates information on beliefs about vaccination and advocacy for vaccination. A higher vaccine efficacy rate increased positive beliefs and likelihoods of arguing in favor of vaccination. These findings indicate the important role of numerical evidence in vaccination campaigns where readers utilize vaccine efficacy rates to form their subsequent beliefs/judgments. They echo the anchoring effects of numerical information (Lee et al., 2021; Liu et al., 2019) and extend past research examining disease risk related numerical information (Fagerlin et al., 2011; Visschers et al., 2009) to numerical vaccine efficacy information.

Moreover, while we hypothesized interaction effects where the difference between communicating a high vaccine efficacy rate vs. a low rate will be larger under loss framing (vs. gain framing) or emphasizing severe illness prevention (vs. infection prevention) based on the reasoning that highlighting a highly effective way of preventing a possible severe outcome or a high-risk loss may be more likely to evoke people's risk averse tendencies and maximize their expectancies for the utility of vaccination, the hypotheses did not receive support. Thus, although studies suggest that loss framing was more effective than gain framing when more risks were involved (Bartels et al., 2010; Hull, 2012), our results did not echo such findings in the context of communicating vaccine efficacy. Considering also the fact that we found main effects of vaccine efficacy rates information, these findings together suggest that people may largely focus on and prioritize numerical evidence than message framing (as framing only changes the way the information is presented but not the evidence being communicated) in vaccination messages, with higher efficacy rates being significantly more effective in vaccine promotion than lower efficacy rates. A possible explanation might be that when the numerical evidence is provided in an easy-to-understand format such as percentages, people who prioritize numerical evidentiary information do not need to rely on other message features (such as gain-loss framing) to help/facilitate their issue interpretation. As vaccine efficacy rates are typically communicated as percentages (Katella, 2021), they may be easier to understand and internalize than information with more complex number formats such as fractions or raw frequencies. Indeed, Lee et al. (2021) found that gain-loss framing only had differential effects when numerical information was presented in raw frequency formats, and such effects disappeared when numerical information took the form of percentages.

In addition, while past research on message framing largely overlooked processing fluency-related outcomes (McLeod et al., 2022) (possibly because being easier to read and comprehend does not necessarily mean that the message will be more persuasive to achieve the intended outcome), we found that numerical evidentiary information and message framing affected different types of outcomes, with vaccine efficacy rates information influencing beliefs about vaccination and outcome framing affecting message processing fluency. Surprisingly, emphasizing infection prevention as the outcome of vaccination increased processing fluency compared to highlighting severe illness prevention. However, only looking at the results from the overall sample may mask important individual differences and make the interpretations and practical implications unclear. Specifically, as older people are at much higher mortality risks for infectious diseases such as COVID-19 (Centers for Disease Control and Prevention, 2023; Statista, 2023), follow-up analyses by age showed that emphasizing infection prevention only increased processing fluency among younger adults aged between 18 and 52 but did not impact older adults. A possible explanation could be that older adults are immune to message framing because their vaccination-related beliefs are more stable (due to their long-term exposure to information about their elevated disease risks and need for preventive measures) and thus more difficult to be shifted by the difference in the presentation of the information beyond the numerical vaccine efficacy evidence being communicated (Luo et al., 2021). By comparison, as younger adults are at much lower risks for severe health consequences (e.g., hospitalizations or deaths) from infectious diseases than elderly people, their beliefs about vaccination may be more malleable and thus more susceptible to the framing technique that shifts their interpretations through changing the reference points they use to understand the issue (Tversky & Kahneman, 1974, 1981). Moreover, the fact that younger adults' risks for infections are much higher than severe illness might also make them more attentive/sensitive to infection prevention information, and as a result, outcome framing highlighting infection prevention led to higher processing fluency among this age group. However, given that infection is a less severe consequence, this increased message processing was not accompanied by changes in beliefs.

This study has limitations. Considering that many people in the U.S. have already been vaccinated against COVID-19, we used a fictitious disease with features similar to COVID-19. However, given that respondents knew that it was a fictitious disease when reading the message stimuli and answering the questionnaire, it remains a question whether their processing of the message and their responses might differ if the disease were real. Also, while featuring a fully crossed design increased the internal validity of the study so that effects observed can be more accurately attributed to specific message components, it may also sacrifice the ecological validity of the study as the efficacy rate in preventing severe illnesses is usually higher than 60% in the real word (e.g., in the context of COVID-19 vaccination). Also, the message stimuli in the study were featured as from CDC, but vaccine efficacy information might be widely discussed by diverse sources. Future research should investigate public responses to vaccine promotion messages from sources including the government, public health agencies, news media, and social media to see if the pattern of findings can be replicated.

Notwithstanding these limitations, this study contributes to our understanding of the central role of vaccine efficacy rates information in vaccination promotional messages regarding infectious disease. As U.S. adults are responsive to numerical vaccine efficacy evidentiary information, communicating higher vaccine efficacy rates by selectively highlighting vaccine efficacy rates in preventing severe illness (which are typically higher than efficacy rates in preventing infections, see Wu et al., 2023) should significantly boost their positive beliefs about vaccination and intentions to advocate for it. Although younger adults process messages emphasizing infection prevention more fluently, this increased fluency is not accompanied by more positive beliefs about vaccination.

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Appendix. Message Stimuli (adapted from Lu et al., 2023)

The *Sebarisus* virus is highly contagious and is transmitted in much the same way as the virus (SARS-CoV-2) that causes COVID-19. The symptoms of *Sebarisus* include congestion, runny nose, fever, chills, cough, and difficulty breathing. In some cases, the condition can worsen, resulting in severe lung problems that lead to hospitalization, and even death.

Fortunately, a *Sebarisus* vaccine has been developed and is now available. This vaccine has been shown to be [60% | 95%] effective at preventing [*Sebarisus* infection | severe illness from *Sebarisus* (e.g., hospitalization or death)] in people with no evidence of previous infection.

If you [make | do not make] an appointment to get vaccinated now, you will [gain | lose] an opportunity to protect yourself against [*Sebarisus* infection | severe illness from *Sebarisus*].

The CDC recommends that people get vaccinated for the *Sebarisus* virus. To make a vaccination appointment, register online to receive your first dose at a local vaccination site.

By [registering | not registering] for a vaccination appointment today, you will [gain | lose] an opportunity of being protected against [*Sebarisus* infection | severe illness from *Sebarisus*].