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DO PICTOGRAPHS AFFECT PROBABILITY COMPREHENSION AND RISK PERCEPTION OF MULTIPLE-RISK COMMUNICATIONS?

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ABSTRACT

Pictographs can be used to visually present probabilistic information using a matrix of icons. Previous research on pictographs has focused on single rather than multiple-risk options. The present research conducts a behavioral experiment to assess the effects of pictographs on probability comprehension and risk perception for single and multiple-risk options. The creation of the experimental stimuli is informed by a review of the Centers for Disease Control and Prevention's vaccine information sheets. The results suggest that, in the context of childhood vaccines, the inclusion of pictographs alongside numeric (e.g. 1 in 5) probability information can result in higher probability comprehension and lower risk perception for multiple-risk options; however, these effects are not observed for single-risk options. These findings have implications for how health-related risks are communicated to the public.

Keywords: Pictograph, Risk Perception, Probability Comprehension

INTRODUCTION

The U.S. healthcare system regards improving risk communication as a top priority (Rimer et al. 2004). Pictographs may serve as a valuable tool for communicating health-related risks to the public (for reviews, see Ancker et al. 2006; Garcia-Retamero and Cokely 2017). Pictographs use a matrix of icons (e.g. 100) to illustrate the frequencies of occurrence and nonoccurrence of an event (Garcia-Retamero, Galesic, and Gigerenzer 2010). For example, a pictograph could illustrate that among 100 users of a medication, 20 users experienced drowsiness as a side-effect, while 80 users did not.

A limitation of previous research on pictographs is that it has focused on single rather than multiple-risk options (Ancker et al. 2006). A single-risk option has only one risk; for example, a medication with one possible side-effect (e.g. drowsiness). A multiple-risk option has more than one risk; for example, a medication with several possible side-effects (e.g. drowsiness, mild fever, and vomiting). Multiple-risk options are present in a variety of health contexts, including when considering childhood immunizations (Frederickson et al. 2004), invasive health screenings (Waters et al. 2006), insurance coverage (Hibbard and Peters 2003), participation in medical studies (Fuller, Dudley, and Blacktop 2002), and genetic counseling (Grimes and Snively 1999).

In the context of childhood vaccines, the present research tests whether the inclusion of pictographs affects probability comprehension and risk perception for single and multiple-risk options. Probability comprehension refers to the accurate understanding of probabilistic information (Miron-Shatz et al. 2009), and risk perception refers to affective feelings that arise from exposure to risk information (Slovic and Peters 2006). The present research finds that the presence (vs. absence) of pictographs, alongside numeric (e.g. 1 in 5) probability information, increases probability comprehension and lowers risk perception for multiple-risk options; however, these effects are not observed for single-risk options. The results have implications for how pictographs are used to communicate health-related risks to the public.

BACKGROUND

Multiple-risk options are common in health-related decision making and communications. Medications, immunizations, and medical treatments often entail multiple risks or side-effects (Frederickson et al. 2004; Waters et al. 2006). For example, the Centers for Disease Control and Prevention (CDC) reports that the Measles, Mumps, and Rubella (MMR) vaccine has the following possible side-effects: fever (1 in 6), mild rash (1 in 20), swelling of glands in the cheeks or neck (1 in 75), seizure (1 in 3,000), temporary pain or stiffness in the joints (1 in 4), temporary low platelet count (1 in 30,000), serious allergic reaction (1 in 1 million), and other possible side-effects including deafness, long-term seizures, and permanent brain damage that are reported as too rare to know whether they are caused by the vaccine. Given the ubiquity of multiple-risk options, research is needed on how pictographs affect consumer perceptions of multiple-risk options, in addition to single-risk options.

Both single and multiple-risk options involve risks (e.g. side-effects), and risks have categorical (e.g. side-effect symptom) and incremental (side-effect probability) attributes. General evaluability theory describes how people evaluate categorical versus incremental attributes (Hsee 1996; Hsee and Zhang 2010). When evaluating a single-risk option, which has one risk with one categorical and one incremental attribute, the theory suggests that consumers will attend more to the option's categorical attribute and give less attention to the option's incremental attribute. This bias in attention is thought to be the result of categorical attributes being easier to evaluate in isolation than incremental attributes (Hsee et al. 1999). As a result, when evaluating a single-risk option, such as a vaccine with only one side-effect, the theory suggests that greater attention will be given to the side-effect symptom (e.g. fever) than its probability of occurrence (e.g. 1 in 5).

On the other hand, incremental (vs. categorical) attributes become easier to evaluate when presented with other incremental attributes (Hsee et al. 1999). As a result, when evaluating a multiple-risk option, having multiple categorical and incremental attributes, consumers will attend more to the option's incremental attributes and give less attention to the option's categorical attributes (Zikmund-Fisher, Fagerlin, and Ubel 2004). For example, when evaluating a vaccine with multiple side-effects, the theory suggests that greater attention will be given to the side-effect probabilities (e.g. 1 in 5, 1 in 10, 1 in 20) than their corresponding symptoms (e.g. fever, poor appetite, vomiting).

If consumers give greater attention to incremental (vs. categorical) attributes in the case of multiple (vs. single) risk options (Hsee and Zhang 2010), then pictographs should prove especially influential on consumer perceptions of multiple (vs. single) risk options. Previous research provides insight on how pictographs may influence consumer perception (Ancker et al. 2006). Garcia-Retamero and Galesic (2009) found that comprehension of a drug's ability to reduce the risk of heart attack increased when the probability of experiencing a heart attack, while taking the drug, was displayed using pictographs. Similarly, Petrova, Garcia-Retamero and Cokely (2015) found that comprehension of breast and prostate cancer screenings' ability to save lives through early detection increased when pictographs were used to represent the probability of dying from breast or prostate cancer with versus without the screenings.

Pictographs have also been found to decrease risk perception because of lessening denominator neglect (Ancker et al. 2006). Denominator neglect refers to a behavioral bias in which decision makers focus on the value of a probability ratio's numerator at the expense of its denominator (Denes-Raj, Epstein, and Cole 1995). Pictographs lessen this attentional bias by increasing the saliency of the denominator of a probability ratio (Garcia-Retamero, Galesic, and Gigerenzer 2010). When the denominator of a probability ratio is more salient, more attention is given to the denominator (e.g. the number of people treated) and less attention is given to the numerator (e.g. the number of people having a side-effect; Stone et al. 2003). Greater attention to the denominator (vs. numerator) of a probability ratio may lower risk perception by increasing consumers' focus on the number of instances in which a negative event did not occur (e.g. the number of people not having a side-effect; Garcia-Retamero, Galesic, and Gigerenzer 2010).

Such research suggests that pictographs may increase probability comprehension and lower risk perception. However, for pictographs to have such effects, consumers must focus on an option's incremental (vs. categorical) attribute(s). General evaluability theory (Hsee and Zhang 2010) suggests that consumers are more likely to focus on incremental attributes when several incremental attributes are presented together, as is the case with multiple-risk options. On the other hand, the theory suggests that consumers are less likely to focus on incremental attributes when incremental attributes are presented in isolation, as is the case with single-risk options. As a result, pictographs should increase probability comprehension and lessen risk perception for multiple-risk options; however, such effects are not expected for single-risk options. This discussion supports an empirical test of the following hypotheses:

H1. The presence (vs. absence) of pictographs, alongside numeric probability information, will increase probability comprehension for multiple-risk options but not for single-risk options.

H2. The presence (vs. absence) of pictographs, alongside numeric probability information, will lower risk perception for multiple-risk options but not for single-risk options.

EXPERIMENT

This experiment tests whether the presence (vs. absence) of pictographs, alongside numeric probability information, results in higher probability comprehension and lower risk perception in the case of multiple-risk options but not in the case of single-risk options. To align the present research with current public policy needs, the experiment used the context of childhood vaccines.

Method

Design

The experiment used a between-participants 2 (pictograph: present vs. absent) by 2 (risk option: single-risk vs. multiple-risk) design. Participants were randomly assigned to one of four conditions in which they viewed stimuli resembling actual risk information provided to the public on childhood vaccines.

Experimental Stimuli

The creation of the experimental stimuli was informed by a review of vaccine information sheets (VIS) from the Centers for Disease Control and Prevention (CDC). Federal law requires that VIS are provided to a patient or parent prior to vaccine administration. A VIS was collected for each recommended child vaccine (*N* = 12) and their side effect symptom and probability descriptions were recorded. Side effect probabilities were reported for 46 (77%) of the 60 listed side-effects. Side-effect probabilities were only reported numerically and not graphically. 91% of side-effect probabilities were reported using the numeric 1-in-X format (e.g. 1 in 5). On average, the vaccines had about four side-effects with reported probabilities of occurrence (*M* = 4.27, *SD* = 1.96; Table 1).

[Insert Table 1 about here]

Experimental stimuli were created to mimic the CDC's VIS. To control against participants' possible experience with an actual vaccine, the stimuli described an ostensible vaccine using the acronym "WE". This acronym was chosen because it has not been used to describe an existing vaccine. A VIS stimulus was created for each of the four conditions. In the single-risk option condition, only one possible side-effect was reported -- a 20% chance of mild fever. Mild fever was the most common side-effect in our review of the CDC's VIS, being listed as a possible side-effect for the following nine vaccines: VAR, DTap, PCV13, HPV-Gardasil, HPV-Cervarix, HepB, MMRV, Hib, and MMR. In the multiple-risk option condition, four possible side-effects were reported -- a 20% chance of mild fever (as in the single-risk option condition), a 10% chance of poor appetite (e.g. PCV13 and HepA), a 5% chance of vomiting (e.g. RV and DTap), and a 2% chance of high fever (e.g. HPV-Gardasil, PCV13, Hib, and DTap). The multiple-risk option included four side-effects because our VIS review found the average number of side-effects with reported probabilities per vaccine was 4.27.[1] Pictographs were created using the web-based "Picto-Generator" created by the Center for Bioethics and Social Sciences in Medicine (CBSSM; cbssm.org/research_tools/pictographsz).

Participants

A total of 282 adults (*M(age)* = 34.42, *SD* = 9.74, 54.6% female) participated for payment and were recruited using Amazon Mechanical Turk (Casler, Bickel, and Hackett 2013). Participation was limited to participants located in the United States, fluent in English, and who had at least one child. 91.5% of participants had one or more children under the age of 18. Their demographics were like those of the U.S. population (www.census.gov): 79.8% were "Caucasian", 7.1% "Hispanic", 5.3% "Asian", and 2.8% "Other"; 31.6% had "less than a college degree", 59.2% had "a college degree", and 9.2% had "a graduate degree".

Procedure

All participants began by reading the following: "Imagine that health officials are recommending that all children get the WE vaccine to avoid contracting pertussis, a potentially life-threatening disease. Please review the provided information on the WE vaccine and then answer the questions that follow." Participants were then presented a VIS specific to their condition (Figure 1).

[Insert Figure 1 about here]

Measures

Probability comprehension was measured following previous research (Garcia-Retamero and Galesic 2009; Galesic, Garcia-Retamero, and Gigerenzer 2009; Schwartz et al. 1997). In the single-risk option condition, probability comprehension was measured using one item: "If 1,000 children got this vaccine, approximately how many would experience mild fever?" Bergkvist and Rossiter (2007) provide support for the use of a single-item measure in consumer research. In the

11. Since CDC VIS do not contain information on whether the side effect probabilities are independent or not, we did not provide any information in our stimuli on independence. So, participants could make their own assumptions about whether and how often two or more side effects might be experienced by their child.

multiple-risk option condition, probability comprehension was measured using four items: “If 1,000 children got this vaccine, approximately how many would experience mild fever/poor appetite/vomiting/high fever?” In each condition, participants responded to each item by entering a whole number between 0 and 1000 (Garcia-Retamero and Galesic 2009). Risk perception was measured using the following two items (*alpha* = .91): “In your opinion, this vaccine is” (0 = Not at all risky, 100 = Extremely risky), and “In your opinion, the risk of side-effects is” (0 = Extremely low, 100 = Extremely high). Participants also reported their familiarity with vaccines (1 = Not at all familiar, 9 = Very familiar), education, gender, ethnicity, age, fluency in English, and country of residence. Participants were then debriefed and directed to the CDC website.

Results and Discussion

Probability Comprehension

Probability comprehension was assessed by creating a percentage correct score for each participant (Schwartz et al. 1997). Probability comprehension was assessed independently for the single-risk condition and the multiple-risk condition since the number of comprehension questions was not constant across the conditions (1 vs. 4). In the single-risk option condition, participants answered one comprehension question pertaining to the single side-effect probability on their condition-specific VIS. Thus, their percentage correct scores were either 0% or 100%. In the multiple-risk option condition, participants answered four comprehension questions pertaining to the side-effect probabilities reported on their condition-specific VIS. Thus, their percentage correct scores corresponded to their number of correct responses out of their four responses. Table 2 reports these estimates (0 to 1000) and the percentage correct for each comprehension question across conditions.

[Insert Table 2 about here]

In the single-risk condition, ANCOVA was used to assess the effect of pictographs on probability comprehension. The model included age, gender, education, and familiarity with vaccines as possible covariates; however, only education reached significance (F(1, 134) =

4.67, p = .032) and was positively associated with probability comprehension (*Beta* = .121, *SE* = .056). The presence (vs. absence) of a pictograph did not have a significant effect on probability comprehension, $F(1, 134) = .024$, $p = .876$. Probability comprehension in the presence of a pictograph (*M(correct)* = 83.82%, *SD* = 37.01%) was not significantly different than in the absence of a pictograph (*M(correct)* = 80.56%, *SD* = 39.86%). The mean estimates were nearer the correct response (of 200) to the comprehension question in the presence (*M* = 186.28, *SD* = 71.96) versus absence (*M* = 179.79, *SD* = 86.58) of pictographs; however, this difference is not significant (p = .63; Table 2).

In the multiple-risk condition, ANCOVA was used to assess the effect of pictographs on probability comprehension. The model included age, gender, education, and familiarity with vaccines as possible covariates; however, none reached significance (p's > .11). The presence (vs. absence) of pictographs had a significant effect on probability comprehension, $F(1, 136) = 4.75$, $p = .031$. Probability comprehension was higher in the presence of pictographs (*M(correct)* = 86.43%, *SD* = 39.08%) than in their absence (*M(correct)* = 73.61%, *SD* = 37.73%). Figure 2 illustrates the percentage of participants that correctly comprehended the probability of the side-effects reported in the single and multiple-risk conditions in the presence (vs. absence) of pictographs.

[Insert Figure 2 about here]

The results provide support for H1 and suggest that the presence (vs. absence) of pictographs increases probability comprehension for multiple-risk options but not for single-risk options. Post-hoc comparisons suggest that pictographs were especially helpful in increasing comprehension of the smaller probabilities (Table 2); in the multiple-risk condition, the probability of correctly comprehending the “1 in 20” probability of vomiting was 87.1% in the presence of pictographs and 73.6% in their absence, $\chi^2(1, N = 142) = 4.11$, $p = .034$; and the probability of correctly comprehending the “1 in 50” probability of high fever was 78.6% in the presence of pictographs and 63.9% in their absence, $\chi^2(1, N = 142) = 3.73$, $p = .054$. Though beyond the scope of the present research, there is an opportunity for future research to compare the effect of pictographs on probability comprehension for smaller versus larger probabilities.

Risk Perception

The two items used to assess the perceived risk of the WE vaccine were averaged to create a measure of risk perception; performing the following analysis on each item individually does not appreciably change the results. A 2 (pictograph: present vs. absent) x 2 (risk option: single-risk vs. multiple-risk) ANCOVA was estimated on risk perception. The model included age, gender, education, and familiarity with vaccines as possible covariates; however, none reached significance (*p*'s > .11).

There was a significant effect of risk option (single-risk vs. multiple-risk) on risk perception, $F(1, 273) = 12.83$, $p < .001$. As would be expected, risk perception was higher in the multiple-risk condition ($M = 29.23$, $SD = 27.28$) than in the single-risk condition ($M = 19.11$, $SD = 19.32$). The presence (vs. absence) of pictographs did not have a main effect on risk perception. Risk perception was lower in the presence ($M = 22.03$, $SD = 23.16$) versus absence ($M = 26.29$, $SD = 24.99$) of pictographs; however, this difference is not significant ($p = .11$). This lack of significance is explained by an interaction between pictograph (present vs. absent) and risk option (single-risk vs. multiple-risk), $F(1, 273) = 5.15$, $p = .024$; in the single-risk condition, risk perception was not affected by the presence ($M = 20.02$, $SD = 20.13$) versus absence ($M = 18.26$, $SD = 18.63$) of pictographs, $t(138) = .537$, $p = .59$; however, in the multiple-risk condition, risk perception was lower in the presence ($M = 23.98$, $SD = 25.76$) versus absence ($M = 34.33$, $SD = 27.92$) of pictographs, $t(140) = 2.29$, $p = .023$ (Figure 3).

[Insert Figure 3 about here]

The results provide support for H2; risk perception was significantly lower in the presence (vs. absence) of pictographs in the multiple-risk condition, but this did not occur in the single-risk condition (Figure 3). The lack of an effect in the single-risk condition may be the result of participants, in this condition, focusing on the side-effect symptom (mild fever) more than its probability (1 in 5). The idea that participants gave less attention to side-effect probability in the single-risk condition aligns with the previous finding that probability comprehension was unaffected by the presence (vs. absence) of pictographs in the single-risk condition.

On the other hand, when presented with multiple incremental attributes, as in the multiple-risk condition, participants may have focused on the side-effect probabilities (i.e. incremental attributes) more than on the symptoms (i.e. categorical attributes; Hsee et al. 1999). As suggested by previous work on denominator neglect (Garcia-Retamero, Galesic, and Gigerenzer 2010), this increased focus on side-effect probabilities (vs. symptoms), may have resulted in pictographs lessening risk perception by encouraging participants to consider the number of people that did not experience a side-effect from the vaccine.

In addition, when considered with the previous finding on probability comprehension, pictographs may have lowered risk perception for the multiple-risk option because they were especially helpful in increasing comprehension of the smaller probabilities. As is the case with the CDC’s VIS, less probable side-effects are often associated with more severe side-effect symptoms. As a result, pictographs may have lessened risk perception in the multiple-risk condition by allowing participants to more accurately assess the likelihood of the more severe side-effects.

CONCLUSION

Consumers are likely to encounter multiple-risk options in many health contexts such as when choosing health insurance, medical treatments, and medications (Frederickson et al. 2004; Waters et al. 2006). Based on the present findings, policy makers are encouraged to consider incorporating pictographs when communicating multiple-risk options. The present research suggests that pictographs may increase probability comprehension and lower risk perception for multiple-risk options; however, given that pictographs can result in lower risk perception, the desired result of the communication deserves consideration. Regarding childhood vaccines, lower perceived risk may result in higher vaccination rates, which is desirable. However, there are situations, such as when promoting the health risks of risky behaviors (unprotected sex) or products (cigarettes), where lower risk perceptions are not desirable.

The present research does not directly bear on vaccination intentions or behavior as they are likely the result of many factors in addition to probability format. For example, age and education (Shui, Weintraub, and Gust 2006), trust in the government or medical profession (Raithatha et al. 2003), and peer and primary care provider opinions (Chapman and Coups 1999) can affect vaccination intentions. In addition, risk judgments often depend not only on the perceived probabilities of outcomes and the perceived severity of outcomes, but also on other factors such as perceived control, dread, novelty, and voluntariness (Slovic et al. 2004; Slovic 1987). Future work could examine how such factors interact with the presence (vs. absence) of pictographs when judging perceived risk.

The present research only assessed probability comprehension and risk perception within a specific context involving a hypothetical vaccine. Future work could test whether the observed effects extend to contexts involving multiple-risk options having different numbers of risks or probability ratios than those tested. Future research could also address whether the observed effects are limited to pictographs. It may be the case that providing more information on probabilities using other graphical or numerical formats may also prove effective.

To help generalize the present results to additional contexts, theoretically oriented research is needed to compare the effect of probability format on probability comprehension and risk perception of multiple-risk options in generic contexts such as those offered in gambling-task paradigms. Such paradigms may help us understand how laypersons combine the individual probabilities of multiple possible outcomes to come up with an estimate of the probability of at least one of a set of outcomes occurring, in the absence of information on any probabilistic dependencies between the possible outcomes offered by an option.

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TABLE 1

Summary of CDC VIS Review of Side-Effect Probabilities and Formats

Vaccine	Num. of Side-Effects	Num. of Side-Effect Prob. in 1-in-X Format	Mean Side-Effect Prob. (%)	*SD* (%)
DTap	9	8	8.8	12.4
HepA	4	3	9.7	5.3
HepB	4	3	10.6	10.6
Hib	3	2	15.0	10.0
HPV-Cervarix	6	6	46.3	24.3
HPV-Gardasil	5	5	30.0	27.4
MMR	8	6	7.8	9.7
MMRV	6	4	5.0	7.7
PCV13	5	4	40.3	24.6
RV	3	1	>0.0	n/a
IPV	2	0	n/a	n/a
VAR	5	3	11.3	6.6
Average	4.3	3.8	16.8	12.6

TABLE 2

Mean Estimates and Percentage of Correct Responses to Comprehension Questions in

the Single and Multiple-Risk Conditions in the Presence Versus Absence of Pictographs						
			Pictograph Absent		Pictograph Present	
	Question	Correct Response	Mean Estimate	Percent Correct	Mean Estimate	Percent Correct
Single-Risk Condition	Mild Fever	200	179.79	80.60%	186.28	83.8%
Multiple-Risk Condition	Mild Fever	200	198.31	75.0%	201.43	87.1%
	Poor Appetite	100	98.94	81.9%	111.29	92.9%
	Vomiting	50	65.67	73.6%	65.79	87.1%
	High Fever	20	44.93	63.9%	39.44	78.6%

FIGURE 1
Example of the Experimental VIS Stimuli Used in the Multiple-Risk Pictograph Present Condition

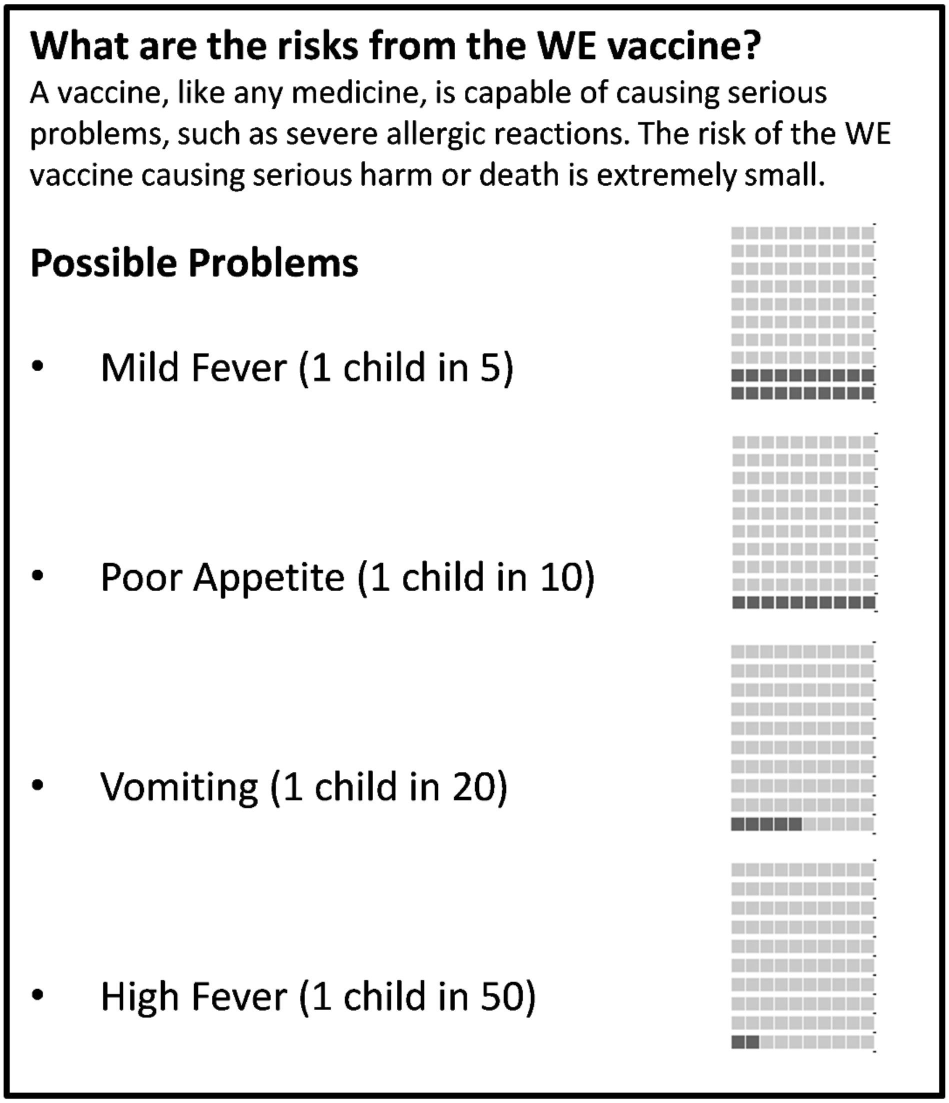


FIGURE 2
Probability Comprehension (Percent Correct) in the Single and Multiple-Risk Conditions in the Presence Versus Absence of Pictographs.

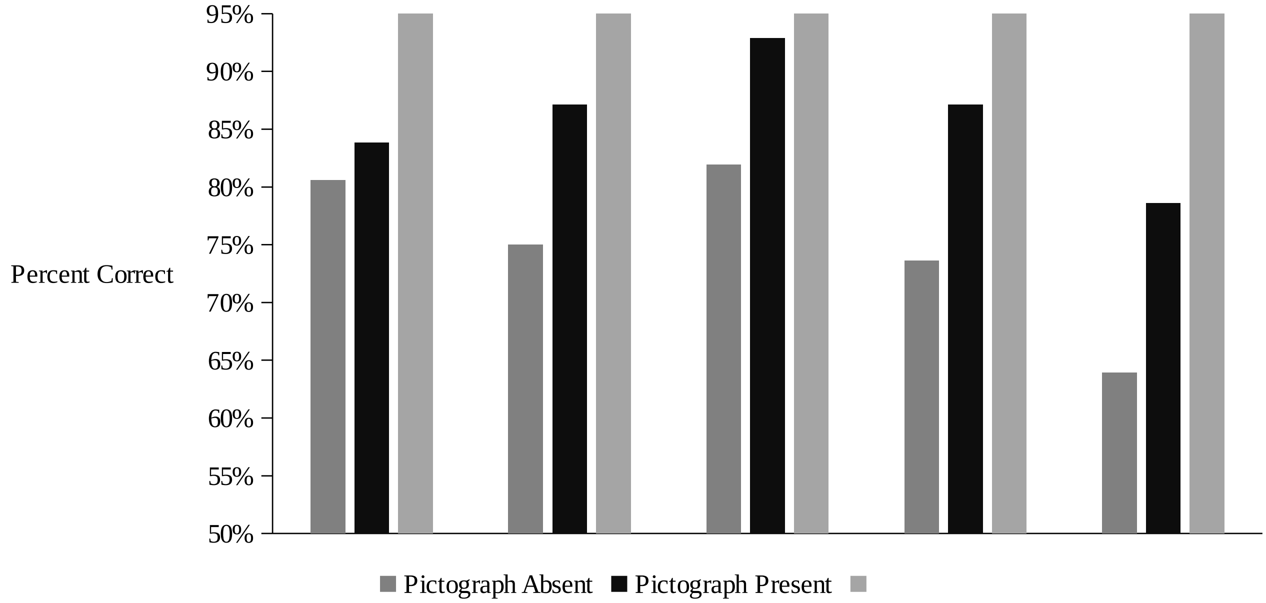
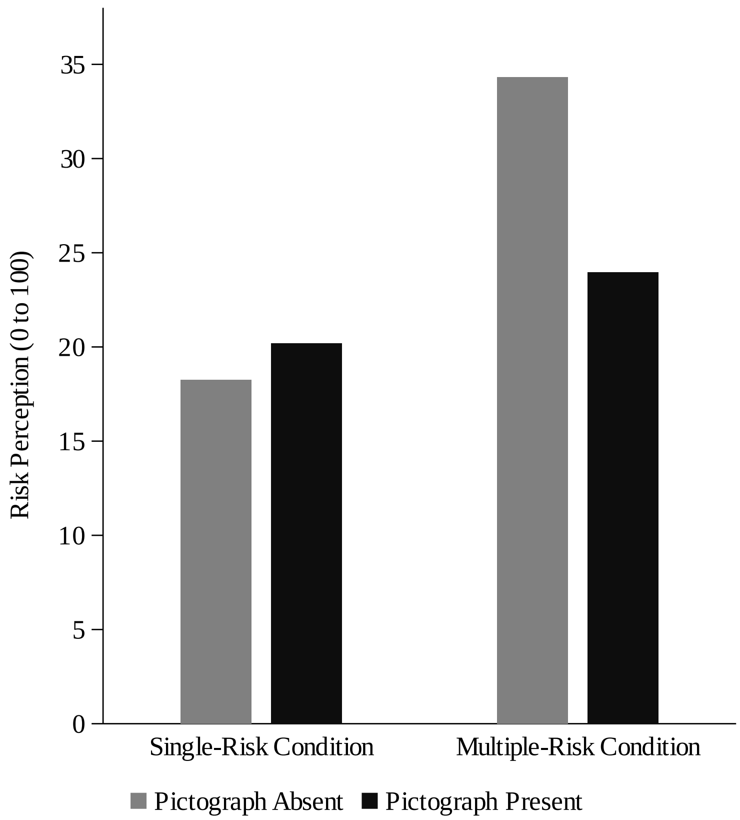


FIGURE 3
Risk Perception in the Single and Multiple-Risk Conditions in the Presence Versus Absence of Pictographs


Risk Perception (0 to 100)
35
30
25
20
15
10
5
0
Single-Risk Condition
Multiple-Risk Condition
Pictograph Absent
Pictograph Present