# “100% OF ANYTHING LOOKS GOOD”—THE APPEAL OF ONE HUNDRED PERCENT AND THE PSYCHOLOGY OF VACCINATION

by

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ABSTRACT OF THE THESIS

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People overweight certainty, even when it is just an illusion. In study 1, participants ($N$ = 470) preferred a vaccine that was 100% effective against viral infections that cause 70% of cancer cases to a vaccine that was 70% effective against infections that cause 100% of cancer cases. Study 2 ($N$ = 129) illustrated the appeal of 100%, even if it does not refer to probability: vaccines with either 100% effectiveness or 100% target range were preferred to other vaccines that were less than 100% effective towards less than 100% target. The preference for 100% effectiveness towards a subset of targets was unaffected by framing the vaccine in a broader target scope. We propose that people overweight 100% in general when they make decisions involving percentage, be it probability, proportion of population, or subset, despite the fact that almost anything can be described as 100% of something.

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# "100% of Anything Looks Good"

## The Appeal of Hundred Percent and the Psychology of Vaccination

"Not to be absolutely certain is, I think, one of the essential things in rationality", says the great English philosopher Bertrand Russell (Russell, 1949). Every day, human beings face decisions about uncertain events: whether to put an extra quarter in the meter, whether to buy an extended warranty for the computer, or whether to get into a marriage that statistics say may not last. Normative expected utility theory states that choice under uncertainty should be based on the utility of an outcome multiplied by its probability (Savage, 1954; von Neumann & Morgenstern, 1947). One way in which people violate this rational formula in their choices is to overweight certainty relative to other probabilities (Kahneman & Tversky 1979). In the current paper we explore the conditions under which people give special status to 100%.

The perception of certainty is sometimes misleading. For example, Kahneman and Tversky (1979) showed that people are unwilling to buy insurance that only covers odd days of the year, even if the insurance costs half the usual price. This dislike for probabilistic insurance presumably occurs because it only reduces risk, in contrast to regular insurance, which completely eliminates a defined subset of risks, and therefore gives a sense of certainty that probabilistic insurance cannot provide. However, any insurance only targets a portion of all risks (i.e., homeowner's insurance does not cover auto accidents), yet people do not reject regular insurance because it only reduces the combined risk in life. This phenomenon illustrates that people treat conditional certainty within a subset of risk like real certainty and overweight it—even when the definition of the subset is arbitrary.

Vaccination serves as an interesting example of this conditional certainty. Vaccination provides uncertain protection from pathogens because vaccinated people can sometimes still contract the pathogens the vaccine is made to prevent. Even when a vaccine provides 100% protection against a specific pathogen, that certainty is conditional because the vaccine targets only specific disease agents, but not others that may cause the same disease. For example, the flu vaccine protects against some strains of influenza but not others. Slovic, Fischhoff and Lichtenstein (1982) demonstrated a pseudo-certainty effect with a hypothetical vaccine scenario: people were more attracted to a vaccine that was described as eliminating a 10% risk for one of two equiprobable diseases, than if it was described as reducing the risk for one disease from 20% to 10%. Elimination of a subset of risk was more appealing to these participants than reduction of total risk, although the net risk reduction was held constant across conditions.

The pseudo-certainty effect has real world implications for how the effectiveness of certain vaccines is interpreted. In June 2006, the Food and Drug Administration approved the first cancer vaccine. It prevents cervical cancer by preventing Human Papilloma Virus (HPV) infection, a sexually transmitted infection that can cause cervical cancer. Clinical studies have found the vaccine to be 100% effective against the two strains of HPV that cause 70% of cervical cancer cases (Centers for Disease Control and Prevention, 2006). From the responses to the hypothetical vaccine in

Slovic et al.'s study (1982), we predict that decisions to vaccinate against HPV may be swayed by how information about the vaccine is presented. Study 1 replicated the pseudo-certainty effect using a vaccination scenario that mimicked the actual HPV vaccine. Study 2 tested whether the pseudo-certainty effect can be reduced by a reminder of the conditional nature of certainty, and whether people overweight 100% more generally, not just when it refers to probability.

## Study 1

We constructed two descriptions of a cancer vaccine based on features of the HPV vaccine. The descriptions were equivalent in terms of the net effectiveness of the vaccine—both were 0.70—but differed in whether the vaccine was 100% effective against a subset (70%) of cancer risks, or 70% effective against the entire set of cancer risks. The first version involves risk elimination, while the second involves risk reduction. If people overweight apparent certainty, the first description should make the vaccine seem more appealing. In order to exclude the influence from existing attitudes towards the HPV vaccine per se, we specified that the vaccines were hypothetical.

### Methods

470 Rutgers college students completed an internet survey appended to a larger questionnaire on HPV and cervical cancer. 333 students completed the survey in one semester, and 137 students completed it in the following semester.

Students were instructed that some hypothetical scenarios about possible future vaccines would be presented. Then, they randomly received one of two versions of the question presented in Table 1 and indicated their intentions to vaccinate on a 0% (definitely would not vaccinate) to 100% (definitely would vaccinate) scale, with 10% intervals.

Results and discussion

[ Table 1]

As shown in Table 1, students who received version 1 (M = 77.32, SD = 25.61) indicated higher intentions to vaccinate than students who received version 2 (M = 66.28, SD = 27.23), $t(468) = 4.53$, $p < .0001$, $d = .41$. This result is consistent with findings reported by Slovic et al. (1982) and shows a pseudo-certainty phenomenon: people overweight the apparent certainty (100% effective) associated with a subset (70%) of targets in version 1.

Study 1 had some limitations. Noticeably, 100% effective in …70% of known cases in version 1 contained two percentage numbers, while 70% effective in… all the known cases in version 2 contained only one. It is possible that the number 100% was more easily registered than the word all. In addition, the first number that appeared in the description was 100% in version 1, but 70% in version 2. The higher vaccination intention in version 1 could be due to a primacy effect, where the impression of the vaccine was determined by whichever number people first encountered in the description. These limitations were addressed in the next study.

## Study 2

Study 1 replicated the pseudo-certainty effect with a hypothetical vaccine that described the actual HPV vaccine, illustrating how vaccination intention is influenced by certainty. Previous research indicates that people not only overweight 100% probability of risk protection (certainty effect), but also overweight 100% coverage of the population when allocating screening tests. Ubel, Dekay, Baron, & Asch (1996) demonstrated a preference for offering a less effective screening test to 100% of a population rather than offering a more effective test to 50% of the population, even though the latter would result in more lives saved. This preference for equity over efficiency was drastically reduced when neither tests covered 100% of the population (Ubel, Baron, Nash & Asch, 2000), demonstrating a special effect of 100% coverage. This overweighting of 100% coverage is further demonstrated by the fact that preference for equity was reduced when the tests were described in a broad frame of two states (with equal populations), so that the coverage was 50% or 25% of the population of two states, in contrast to the narrow frame of one state, where the coverage was 100% or 50% of the population of the state (Ubel, Baron, & Asch, 2001). The preference for 100% coverage represents a bias that is parallel to the preference for certainty within a subset, because population and subset are both arbitrarily defined concepts. When the scope of the problem is expanded to include additional risks or targets, the protection measure no longer provides certain protection.

Thus, the pseudo-certainty effect and the preference for equity both illustrate the overweighting of 100% of something, either probability or population coverage. Although Study 1 illustrated a preference for 100% effectiveness, it is possible that

100% is also overweighted concerning target range of the vaccine. In Study 2 we examined whether people overweight 100% relative to other percentages in general, whether or not the 100% refers to effectiveness or target range. To do this, in addition to the two vaccines from Study 1, we also presented 4 other vaccines that were less than 100% effective towards less than 100% of targets, holding the net effectiveness constant at 0.70 (e.g., 74% effective against 95% of all viruse strains that cause a certain cancer, see methods section). Theses vaccines were presented within-subject, to make the equivalent net effectiveness transparent. If people indeed overweight 100% in general, the medium range vaccines should be less preferred than the two vaccines with 100% as either effectiveness or target range.

We also examined whether the pseudo-certainty effect would be reduced if people had a broader perspective of other disease risks not protected by the vaccine. Such a manipulation may trigger people to realize that full effectiveness is relative, depending on the scope of protection targets in consideration. This manipulation was similar to that used by Ubel et al. (2001) except that we did not explicitly present the net risk reduction in both scope frame as they did (they specified that 100% coverage of 1 of 2 states means 50% coverage overall). Instead, we wanted to examine the effect of scope without a transparent indication that changes in scope affect relative risk reduction. Therefore, we simply reminded people of another cancer risk unprotected by the vaccine to see if this would reduce overweighting of full-effectiveness.

Thus, Study 2 examined whether the pseudo-certainty effect was modified by scope of cancer risks in which the vaccine was described, and whether the mere appearance of 100%, not just certainty, could make the vaccine seem more appealing. In order to exclude alternative explanations mentioned in discussion of Study 1, we made the two alternative vaccine descriptions more equivalent by replacing the word "all" with the number "100%" (see methods section, vaccine a and f) and counterbalanced the order in which effectiveness and target range appeared in the sentence, so that 100% did not always precede 70%.

Methods

180 Rutgers college students completed an internet survey. Students all read a description of cancer X, which affects about 5% of the population and is caused solely by certain strains of viruses. They were told that various vaccines have been developed to prevent these virus infections, and they were asked to rate 6 vaccines on a 1 (extremely appealing) to 7 (extremely unappealing) scale. Ratings were reversed to 1= extremely unappealing, 7 = extremely appealing in the analysis. Participants were also asked which vaccine was the most appealing, and the likelihood they would vaccinate if the vaccine they picked as the most appealing was the only vaccine available. The 6 vaccines presented were as follows:

a: It is 70% effective against 100% of all virus strains that cause cancer X.

b: It is 74% effective against 95% of all virus strains that cause cancer X.

c: It is 82% effective against 85% of all virus strains that cause cancer X.

d: It is 68% effective against 68% of all virus strains that cause cancer X.

e: It is 95% effective against 74% of all virus strains that cause cancer X.

f: It is 100% effective against 70% of all virus strains that cause cancer X.

The wording was slightly modified from Study 1(e.g. "…virus infections that cause xx% of known cases of a specific type of cancer") to make the description more straightforward. The order of the 6 vaccines was randomized, and vaccine d was included as a comprehension check: Since vaccine d was dominated by all the other vaccines in both effectiveness and target range, participants who rated this vaccine as more appealing than any other vaccines were excluded from the analysis. The net effectiveness for all 5 other vaccines were 0.70, rounded up to the second decimal place.

In addition to the 5-level within-subject variable of vaccine type, there were 2 fully crossed between-subject variables: phrasing and scope. Students were randomly assigned to either the effectiveness preceding target condition, as vaccine descriptions presented above, or the target preceding effectiveness condition, e.g.:

a: Against 100% of all virus strains that cause cancer X, it is 70% effective.

……

f: Against 70% of all virus strains that cause cancer Y, it is 100% effective.

The phrasing variable was fully crossed with the 2-level scope variable. In the broad scope condition, students were told that cancer Y also affects about 5% of the population and is caused by viral infections, but the virus strains causing cancer X and those causing cancer Y are different; all vaccines were described as "not effective in preventing cancer Y" in addition to the descriptions in terms of cancer X presented above. In the narrow scope condition, students did not read information about cancer Y and all vaccines were described only in terms of cancer X.

Results

A total of 44 students rated vaccine d as more appealing than one or more other vaccines. An additional 7 gave inconsistent responses in vaccine ratings and choice of the most appealing vaccine, or chose more than one vaccines as the most appealing vaccine. These students were excluded from the final analysis; thus 129 out of 180 students were included in the analysis.

[ Figure 1]

To answer specific questions about the two vaccines derived from Study 1, the first analysis focused on vaccine a and vaccine f (see Figure 1). We conducted a 2 (vaccine) × 2 (scope) × 2 (phrasing) ANOVA using rating as the dependent measure. Although the within-subjects design made the normative equivalence of the two vaccines transparent to participants, the analysis still revealed significantly higher ratings for vaccine f (M = 6.27, SD = 0.90) than for vaccine a (M = 5.81, SD = 1.04), $F(1, 125) = 26.13$, $p < .0001$, $\eta^2_p = 0.17$ (Table 2). Scope did not have a significant main effect, although vaccine ratings were slightly lower in the broad scope (M = 5.92, SE = 0.11) than in the narrow scope (M = 6.16, SE = 0.10), $F(1, 125) = 2.60$, $p = .11$, ns. There was no interaction between scope and vaccine type. This means that reminding students of another cancer unprotected by the vaccines did not reduce the pseudo-certainty effect. There was a significant main effect of phrasing. When vaccines were phrased with target before effectiveness, as in towards virus infections that cause 70% (100%) cases of cancer, it is 100% (70%) effective X, students rated the vaccines less appealing (M = 5.87, SE = 0.10) than when they were phrased with effectiveness before target (M = 6.22, SE = 0.11 ), $F(1,125) = 5.63$, $p < .05$, $\eta^2_p = 0.04$ (Table 2). However, of more interest there was no interaction between phrasing and vaccine type, suggesting that people did not prefer vaccine f over vaccine a because 100% appeared before 70% in vaccine f and made a lasting first impression. The main effect of phrasing is likely due to the unusual structure of the sentence when target was mentioned first.

[ Table 2]

Next, we performed a 5 (vaccine) x 2 (scope) x 2 (phrasing) ANOVA for ratings among all 5 vaccines (excluding vaccine d). The purpose was to test whether 100% was overweighted over other percentages, either as 100% probability—in vaccine f—or as 100% target range—in vaccine a. Figure 2a shows mean ratings of the 5 vaccines. A planned contrast showed that vaccine f was rated as more appealing than the mean of the other four vaccines, $F(1, 128) = 83.13$, $p < .0001$. A second contrast showed that vaccine a was rated as more appealing than the mean of vaccines b, c, and e— the medium range vaccines, $F(1, 128) = 8.67$, $p < .01$. A third contrast between two medium range vaccines—vaccine b and vaccine e—did not show significant difference in ratings, $F(1, 128) = 1.59$, $p = .21$. There was no significant main effect of scope on vaccine ratings, nor was there an interaction between scope and vaccine type. The main effect of phrasing was not significant in the overall omnibus analysis.

[Figure 2]

Some students gave a same rating to multiple vaccines. The choice of the most appealing vaccine served as a tie-breaker because only one vaccine could be picked. Students' choice of the most appealing vaccine confirmed the high preference for vaccine f and vaccine a (Figure 2b). Out of 129 students, more than 1/5 (n = 62 or 48%) indicated vaccine f as the most appealing among the five vaccines, $\chi^2(1, N = 129) = 82.24$, $p < .0001$. Among the remaining 67 students, more than 1/4 indicated vaccine a as the most appealing (n = 27 or 40%), as opposed to vaccine b, c, e, $\chi^2(1, N = 67) = 8.36$, $p < .01$, consistent with the contrast of ratings between vaccine a and vaccine b, c, e. Apparently, the 100% target range in vaccine a had a special appeal compared to the less-than-100% target range in vaccine b, c, and e.

The last analysis examined intentions to vaccinate if one's favorite vaccine was the only vaccine available. This is a different question compared to the vaccination intention question from Study 1. In Study 1, only one vaccine was presented to each person, who did not have the chance to compare it with other vaccines; In Study 2, subjects selected the most appealing vaccine among all vaccines. Thus, the intention to vaccinate concerns the vaccine they had chosen on their own as the most appealing. Vaccination intentions in Study 1 reflect people's attitudes towards a given vaccine, while that in Study 2 reflect more about people's satisfaction towards their own choice of vaccines. Table 3 shows mean vaccination intentions for one's choice of the most appealing vaccine. A planned contrast on vaccination intention with choice of vaccine as a between-subject variable showed that people had higher intentions to vaccinate if they indicated that vaccine a or f was the most appealing vaccine, than if they indicated vaccine b, c, or e as the most appealing vaccine, $t(124) = 2.56$, $p = .01$.

[ Table 3]

Discussion

Study 2 replicated the pseudo-certainty effect in a more transparent within-subjects design. When two equally effective vaccines were presented at the same time, people were attracted by a vaccine that was 100% effective towards 70% of virus strains causing a certain cancer, compared to a vaccine that was 70% effective towards 100% of virus strains causing this cancer, despite the equivalence in net effectiveness. And the slight modification of wording from Study 1 did not change the preference. This phenomenon is not an effect of the primacy of 100% in a sentence, but rather a true preference for full effectiveness within a subset. In contrast to the Ubel et al. study (2001), where participants were presented with the relative percentage of population in the broad scope condition, participants in the broad scope condition of the current study were just informed of another disease against which the vaccine was ineffective, hinting to the arbitrary nature of target range and the illusionary nature of certainty. Unlike the reduction of preference for equity in the broad scopes in the Ubel study, the tendency to overweight 100% effectiveness was unaffected by the scope manipulation in the current study: people tended to like both vaccines less when they were reminded of a broader scope of cancer targets, but they still preferred the vaccine with full effectiveness within a subset—the illusion of certainty remained attractive. It suggests that interventions that are fully effective are attractive almost regardless of what they are effective about.

The appeal of 100% effectiveness may be due to two reasons: overweighting of 100% relative other percentages, and overweighting of effectiveness relative to target range. The results from Study 2 suggest that people overweight 100% in general, but they do not overweight effectiveness in general, except that 100% effectiveness is given more weight than 100% target range. This special effect of 100% was demonstrated in the ratings for 5 vaccines that had equivalent net effectiveness. Although vaccine a through f increased in effectiveness, vaccine rating was not a linear function of effectiveness; in contrast, it showed an asymmetric U shape function: Most appealing was the vaccine on one end—with 100% effectiveness; next appealing was the vaccine on the other end—with 100% target coverage; least appealing were 3 medium range vaccines in the center—partially effective with partial target coverage.

The fact that people's intention to vaccinate was higher if they had chosen the "100%" vaccines as the most appealing is a further demonstration of the strong appeal of 100%. Unless people who tend to vaccinate in general also tend to find the "100%" vaccines most appealing, or vise versa, this result would indicate that people were more satisfied with their choice of the most appealing vaccine if it was 100% in either effectiveness or target range, than if it was less than 100% in both aspects.

General Discussion

The decision weighting function of Prospect theory (Kahneman, D., Tversky A., 1979) predicts people's tendency to overweight certainty. Tendency to overweight 100% effectiveness demonstrated in both studies is consistent with this prediction. However, Study 2 demonstrates that people also overweight 100% relative to other percentages when the percentage refers to target range, indicating that the appeal of 100% is more general that previously thought. The weighting function of Prospect Theory may comprise a specific case of a more general principle of overweighting differences that are close to a reference point. The value of 100% is a salient reference point that cannot be exceeded in various contexts (probability, subset, etc.). It is possible that 100% is a more salient reference point for effectiveness (because probability can never exceed 100%) than for target range (where in some contexts range could exceed 100%, e.g., the viruses covered by this vaccine are 150% of that covered by the previous vaccine). This would explain why the preference for 100% is stronger for effectiveness than for target range.

The salience of 100% may stem from its frequent use in language. Synonyms of 100% include "all", "complete", "entire", " whole", " perfect", and so on; synonyms of other percentages are often vague and do not represent exact numerical values, e.g. "most" "some" and "a little", with the rare exception of "half" , "quarter" and "none". Note "none" is the compliment of 100%.  More importantly, 100% often has the connotation of "unsurpassable" in daily language, e.g., "one hundred percent satisfaction", "one hundred percent effort" etc. Overtime, 100% may have acquired special status beyond its numerical value: it becomes more easily encoded and more likely to be interpreted as "unsurpassable" because of its frequent use and the typical contexts it is used in.

Such properties of 100% can lead to the use of 100% as a cue in judging how good an alternative is. Gigerenzer and Goldstein (1996) suggest that people do not incorporate all the information relevant to a decision, but use fast and frugal rules—heuristics in reasoning about the world under limited time and knowledge. One of these rules is the priority heuristic (Brandstatter, Gigerenzer & Hertwig, 2006): instead of weighting and summing the utility and probability of all alternatives, people examine alternatives against one reason at a time, until there is a good-enough reason to prefer one alternative over another. As demonstrated by Brandstatter et.al. (2006), priority heuristic can achieve near perfect accuracy in prediction of gamble choices. In our studies, participants who preferred the vaccine with a "100%" attribute may have followed a priority heuristic with "100%" as the first reason for preference, which would explain the preference for the two vaccines with "100%" in either effectiveness or target range over other vaccines without "100%" attribute; when both vaccines have a '100%" attribute, a second reason could be was used (for example, whether the 100% attribute has truly a maximum), which determines the preference for the "100% effective" vaccine over the "100% target range" vaccine.

The appeal of 100% has important implications for health promotion, consumer decision and public policy. Interpretations of situations can change based on the scope within which the issue is framed. The preference for 100% is non-normative, because it is subject to a framing effect: a proportion of a whole set is 100% of a subset; mere probability is certainty with contingencies; and risk reduction is elimination of specific risks. The appeal of 100% is another cognitive bias that can unknowingly or knowingly sway decisions. After all, anything can be described as “100% of something”.

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**Table 1**

Intentions to Vaccinate in Study 1

| Version of vaccine description | Mean | *SD* | *N* |
|---|---|---|---|
| *Version 1: Imagine there is a vaccine available; it's very safe, and 100% effective in preventing virus infections that cause 70% of known cases of a specific type of cancer. In people who aren't vaccinated, about 4% get this type of cancer. How likely would you be to get vaccinated?* | 77.32 | 25.61 | 239 |
| *Version 2: Imagine there is a vaccine available; it's very safe, and 70% effective in preventing virus infections that cause all known cases of a specific type of cancer. In people who aren't vaccinated, about 4% get this type of cancer. How likely would you be to get vaccinated?* | 66.28 | 27.23 | 231 |

**Table 2**

Analysis of Variance for Ratings of Vaccine *a* and Vaccine *f*

| Source | $F(1, 125)$ | $\eta^2_p$ |
|---|---|---|
| Between subjects | | |
| Scope | 2.60 | 0.02 |
| Phrasing | 5.63* | 0.04 |
| Scope × Phrasing | 1.41 | 0.01 |
| Error | (1.36) | |
| Within subjects | | |
| Vaccine | 26.13** | 0.17 |
| Vaccine × Scope | 0.03 | 0.00 |
| Vaccine × Phrasing | 1.22 | 0.01 |
| Vaccine × Scope × Phrasing | 0.23 | 0.00 |
| Error | (0.47) | |

Note. Values enclosed in parentheses represent mean square errors.
* $p < .05$ ** $p < .0001$.

**Table 3**

Likelihood to Vaccinate if the Most Appealing Vaccine Was the Only Vaccine Available.

| | Vaccine Selected as Favorite | | | | |
|---|---|---|---|---|---|
| **Descriptor** | vaccine *a* | vaccine *b* | vaccine *c* | vaccine *e* | vaccine *f* |
| **Mean** | 0.80 | 0.78 | 0.69 | 0.68 | 0.85 |
| ***SD*** | 0.26 | 0.15 | 0.27 | 0.25 | 0.16 |
| ***N*** | 27 | 13 | 19 | 8 | 62 |

# Figure Captions

*Figure 1*. Ratings for vaccine *a* and *f* on a 1 (most unappealing) to 7 (extremely appealing) scale. Number of students in each condition is shown at bottom. Error bars: +2 standard errors. * $p < .05$. ** $p < .001$.

*Figure 2. (a)* Mean rating of 5 vaccines on a 1 (most unappealing) to 7 (extremely appealing) scale. *(b)* Number of people indicating each vaccine as the most appealing vaccine. Error bars: ±2 standard errors.

Figure 1.

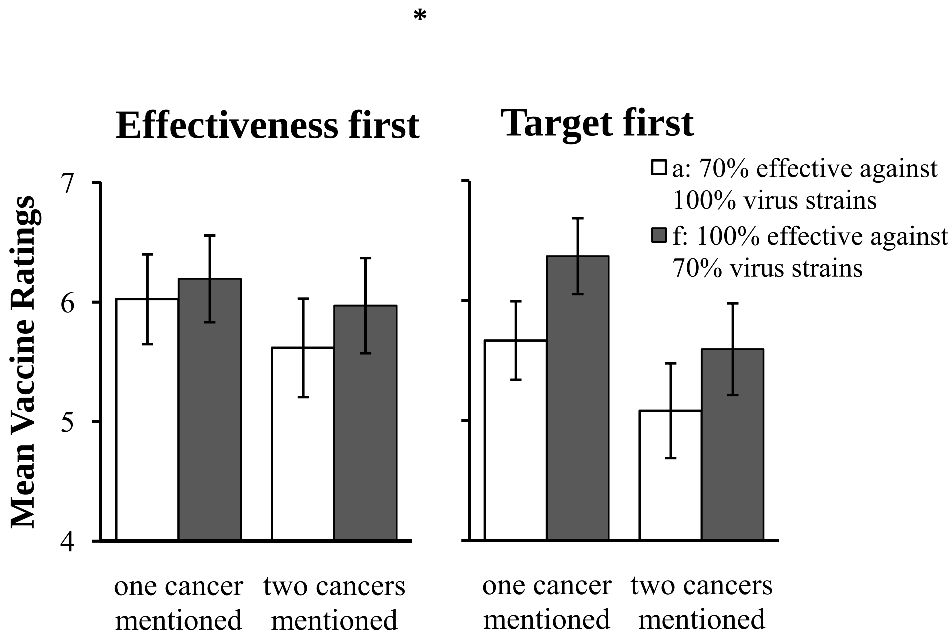
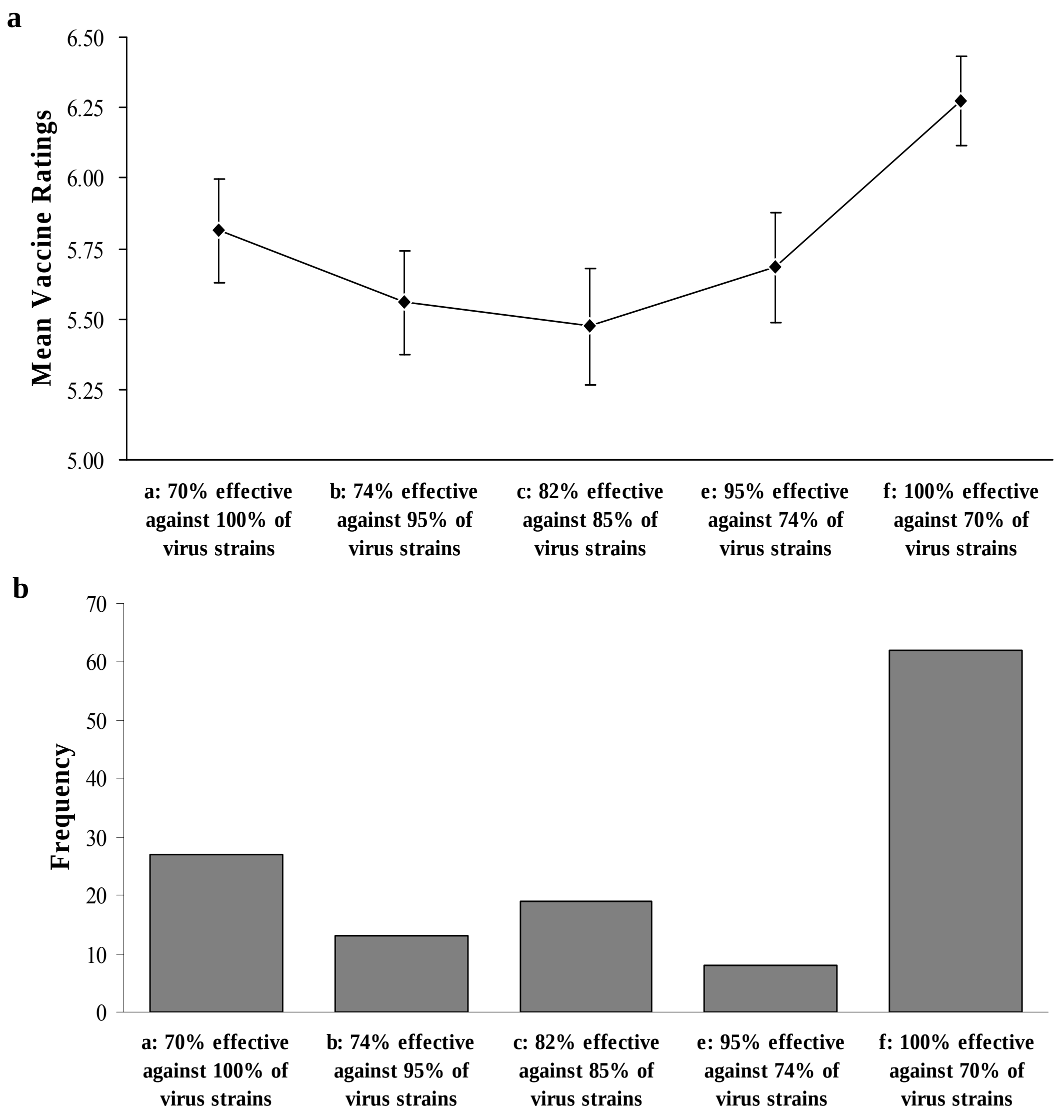

*
Effectiveness first
Target first
a: 70% effective against 100% virus strains
f: 100% effective against 70% virus strains
Mean Vaccine Ratings
7
6
5
4
one cancer mentioned
two cancers mentioned
one cancer mentioned
two cancers mentioned

Figure 2.


a
6.50
6.25
6.00
5.75
5.50
5.25
5.00
Mean Vaccine Ratings
a: 70% effective against 100% of virus strains
b: 74% effective against 95% of virus strains
c: 82% effective against 85% of virus strains
e: 95% effective against 74% of virus strains
f: 100% effective against 70% of virus strains
b
70
60
50
40
30
20
10
0
Frequency
a: 70% effective against 100% of virus strains
b: 74% effective against 95% of virus strains
c: 82% effective against 85% of virus strains
e: 95% effective against 74% of virus strains
f: 100% effective against 70% of virus strains