Predicates of opinion attribution in the vaccine safety debate: A pilot study on persuasion and prior belief

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Friday 12th June, 2020

> "News, to a remarkable degree, is what people say and how they say it."
>
> *The word, an Associated Press guide to good news writing*, Cappon (1982)

Abstract

Predicates of opinion attribution like *say, insist,* and *show* offer a range of options for reporting what people believe and are especially important in the press coverage of scientific issues, for which the lay public relies on journalists to relay the opinions of external sources. We conduct a pilot study to assess how different predicates of opinion attribution may shape people's perceptions of the embedded opinions, focusing on the interaction with people's prior attitudes. Contrary to our expectations, we do not find that predicates signaling higher speaker commitment lead to higher agreement with the opinion that they embed, nor do we find that this predicate effect is stronger among people with less fixed attitudes toward the embedded opinion.

1 Introduction

The media coverage of debated issues is a rich signal for understanding how opposing stances are argued and sustained. This coverage is particularly interesting with respect to scientific issues, as the starting point of an underlying, scientific consensus gets refracted through journalistic transmission into multiple differing views that can reinforce the controversy. In many scientific debates, such as anthropogenic global warming, the threat of the COVID-19 pandemic, or the safety of vaccinations, the differing views tend to align with one of two stances—acceptance vs. skepticism of the perceived scientific authority or consensus.

One powerful strategy used by both sides of such debates is opinion attribution: for example, a vaccine advocate might say, "Leading scientists believe that vaccines do not cause autism," presenting a clause expressing their own stance (***that vaccines do not cause autism***) as an opinion shared by a reputable source, via the verbal predicate ***believe***. Through such [ENTITY] [OPINION PREDICATE] [PROPOSITION]-type sentences, people can effectively put words in the mouths of other entities and lend external support to their own position. Moreover, people can also mark the embedded proposition as being more or less factual through the choice of opinion predicate. To affirm their position further, the vaccine advocate could instead say, "Leading scientists ***know*** that vaccine do not cause autism," whereas on the other side, an anti-vaccine activist could say the same utterance but substitute an opinion predicate connoting doubt: "Leading scientists ***claim*** [that ...]." We henceforth refer to the three opinion attribution components of 1) the proposition being attributed, 2) the entity to which the opinion is attributed, and 3) the verbal predicate syntactically embedding the proposition as "proposition," "opinion predicate," and "source," respectively.

Despite their power in argumentative discourse, opinion attribution and predicate choice have received relatively little attention as a persuasive strategy. Theoretical work in persuasion has focused on request-like settings and the importance of heuristics such as expressing reciprocity and authority (Cialdini and Garde, 1987). In the discourse analysis literature, small-scale studies have analyzed how the choice of opinion predicate (*say* vs. *assert*) can encode journalist stance (Caldas-Coulthard, 2002) and bias audience perception of the quoted entity (Gidengil and Everitt, 2003). A large body of work in linguistics has studied how certain cue words can trigger differing perceptions of factuality and speaker commitment (Saurí and Pustejovsky, 2009; de Marneffe et al., 2011; Soni et al., 2014; Werner et al., 2015; Tonhauser et al., 2018). These papers have shown how the presence

of certain cues (e.g., *know*) in an utterance may signal that the speaker is committed to syntactically embedded content, while at the same time, the strength of this commitment can vary greatly according to contextual factors such as at-issueness of the content.

In this paper, we build upon previous work by examining ten such cues (described further in Section 3) as opinion predicates in a persuasive context, namely the debate around vaccine safety. Extending these cues to the debate environment, we hypothesize that opinion predicates signaling a high degree of factuality or speaker commitment will bias readers to believe in the content of the embedded proposition, and similarly, that opinion predicates with low speaker commitment will bias readers to doubt the embedded proposition. At the same time, given that some people may have strong prior beliefs about the propositions being attributed as opinions, we hypothesize that the choice of opinion predicate may have very little effect on their perception of the proposition's factuality.

In Section 2, we briefly review past work studying the vaccine safety debate. In Section 3, we formalize the hypotheses we use to test our predictions. We describe the experimental methods used in a pilot study to test these predictions in Section 4. In Section 5, we present the results, finding that our hypotheses are not borne out. Section 6 discusses possible interpretations of these findings and directions that we might take for follow-up studies. All materials for this paper are available at `https://github.com/yiweiluo/245bproject`.

2 Background on vaccines

The past decade has seen a proliferation of vaccine-hesitancy and anti-vaccine sentiment in the US public and US media, along with a general mistrust of mainstream scientific evidence and authorities (Petersen et al., 2019; Mitra et al., 2016).[1] Previous work has qualitatively studied vaccine-skeptical discourse in social media, finding recurring tactics such as censoring or criticizing advocates, arguing that vaccines are unsafe (Kata, 2012), and sharing of personal stories of children harmed by vaccines (O'Dell and Brownlow, 2005). Computational work has also built NLP systems to automatically detect anti-vaccine sentiment in social media (Skeppstedt et al., 2017).

Other work has studied the psychological roots of anti-vaccine attitudes, finding that demographic variables such as political affiliation and education account for insignificant levels of variance compared to variables such as level of conspiratorial thinking, disgust toward blood and needles, and an individualistic worldview (Hornsey et al., 2018).

3 Hypotheses

We now present our hypotheses concerning ten high frequency opinion predicates (*think, say, believe, show, find, point out, argue, insist, claim*) found in a corpus of vaccine advocacy and anti-vaccine blogs (see Section 4.1 for details).

H1: Speaker commitment is persuasive We hypothesize that opinion predicates signaling high speaker commitment will be more likely to persuade readers to agree with the embedded proposition relative to predicates signaling low speaker commitment. Specifically, we predict that the opinion predicates "show," "find," "suspect," and "point out" from our 10-predicate sample will bias readers to agree with the embedded proposition, as these predicates have been described in previous work as high commitment factive and semi-factive verbs. We also predict that the opinion predicates "claim," "argue," and "insist" will bias readers to disagree with the embedded proposition, as these predicates have been described in previous work as low commitment neg-factive verbs. Thirdly, we predict that the opinion predicates "think," "believe," and "say", which are relatively neutral ways of attributing an opinion, will fall somewhere between the high and low commitment predicates in their biasing effect.

H2: Prior belief dampens predicate effect Since some readers may have strong prior beliefs toward propositions concerning the topic of vaccines and thus may not be sensitive to the choice of opinion predicate, we predict that the effect of predicate choice will be smaller for people with a strong prior belief toward vaccines compared to people with a weak prior belief.

4 Methods

4.1 Selecting opinion predicates to test

We test the top 10 most frequent predicates of opinion attribution from a dataset of N blog articles on vaccines across pro- and anti-vaccine blogs. We

[1] As many as 50% of tweets about vaccination from 2009-2015 were found to contain anti-vax beliefs in Tomeny et al. (2017).

scrape the text of these articles using the BeautifulSoup library[2] and use the syntactic dependency parser from the spaCy library[3] to annotate each sentence for the sub-components of embedded proposition, source, and opinion predicate. The distribution of blog articles is shown in Tab. 1.

Stance	Blog	N
pro	Voices for Vaccines	341
	Shot of Prevention	136
	Immunization Evidence	15
	Families Fighting Flu	28
	Adult Vaccines Now	209
anti	Children's Health Defense	469
	I Can Decide	146
	Parents for Informed Consent	36
	Vaccine Safety Commission	59

Table 1. Number of blog articles from different pro- and anti-vaccine blogs.

4.2 Crowd-sourcing predicate judgments using Amazon Mechanical Turk (AMT)

We recruited 25 participants for our pilot study through AMT, limiting participants to US residents with a HIT approval percentage of at least 98% and with a minimum of 1,000 previous HITs approved. Responses from participants were processed with the aid of the Supersubmiterator tool.[4] We divided the HIT into two main phases: a prior belief elicitation phase (during which we asked participants about their own attitudes toward vaccines) and a sentence evaluation phase (during which we showed participants stimuli with different opinion predicates). The ordering between these two phases was assigned randomly for each participant.

Prior belief elicitation In this phase, participants were shown a series of 3 statements (see Table 2) about vaccines from a 2017 Pew public opinion poll on childhood vaccines,[5] with minor edits to reduce length and enhance clarity. For each statement, participants were asked to indicate their personal level of agreement using a continuous slider with endpoints labeled as "completely disagree" and "completely agree."

"Vaccines have high preventive health benefits and low risks of side effects"
"Healthy children should be required to be vaccinated to attend school because of potential health risk to others"
"Medical scientists understand the health risks and benefits of vaccines"

Table 2. Statements shown to participants during the prior belief elicitation phase.

Sentence evaluation In each trial of this phase, participants were shown sentences representing instances of opinion attribution, e.g. "Researchers insist that vaccinating children is a crucial measure for public health." After a time delay of 6 seconds, participants were then shown the prompt, "After reading the excerpt, how much do you agree or disagree with the following statement?" along with the embedded proposition. Agreement was measured through their response indicated on a continuous slider (with endpoints labeled as "completely disagree" and "completely agree.") Such trials were repeated a total of 30 times in this phase.

The opinion attribution stimuli for this phase consisted of an opinion source, opinion predicate, and embedded proposition. The opinion source for each stimulus was randomly chosen from the set {"Researchers", "Scientists", "Doctors"}. The opinion predicates were a shuffled array of the ten predicates in our hypotheses, with each predicate repeated three times. The embedded propositions were a shuffled array of 30 manually written, distinct sentences, with 15 expressing a pro-vaccine attitude and 15 expressing an anti-vaccine attitude.

5 Results

In this section, we present the results of analyses that we conduct to test our hypotheses. In accordance with our pre-registered exclusion criteria,[6] we exclude the response from one participant who responded "no" to the question "Do you think you did this HIT correctly?" in a demographic questionnaire administered at the end of the HIT. To preview our findings, we obtain a null result: choice of

[2] https://www.crummy.com/software/BeautifulSoup/bs4/doc/

[3] https://spacy.io/api/dependencyparser

[4] https://github.com/sebschu/Submiterator

[5] https://www.pewresearch.org/science/2017/02/02/public-opinion-about-childhood-vaccines-for-measles-mumps-and-rubella/

[6] https://osf.io/mux73

opinion predicate does not seem to have an effect on participant agreement with embedded propositions, across both weak and strong prior-belief participants.

5.1 Participant demographics

In the remaining sample of 24 participants, all self-report as being native speakers of English; 10 self-identify as female and the remaining 14 as male; 79% have received some extent of college education; and most are between 20 and 40 years of age (Fig. 3). We are primarily interested in participants' prior belief toward vaccines: we obtain an "index" of this belief by transforming their responses to the three Pew survey statements to a [0, 1] scale and then summing these responses. The distribution of participant prior belief is shown in Figure 1, indicating that most participants have a pro-vaccine attitude. Participants with the lowest prior belief indices tended to disagree with the second survey statement ("Healthy children should be required to be vaccinated to attend school because of the potential health risk to others") more so than the first or third, suggesting that they may not be anti-vaccine per se but against imposing strict rules.

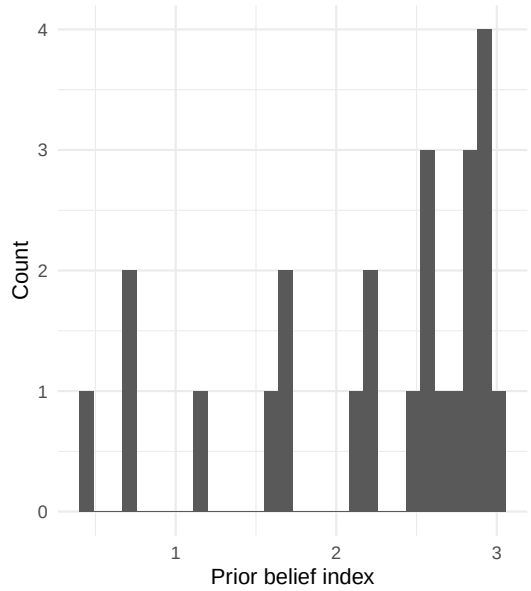

Figure 1. Distribution of participant attitudes toward vaccines. "Prior belief index" is computed as the sum of participants' responses (transformed to a [0, 1] scale) to the three Pew survey questions during the prior belief elicitation phase.

Based on our inspection of this distribution, we code participants as having a pro-vaccine prior belief if the value of their prior belief index is greater than 2, and we code participants as having a strong prior belief if their prior belief index falls outside of the range around the middle, [1, 2.33]. The resulting distribution of participant belief and belief strength is shown in Fig. 2.

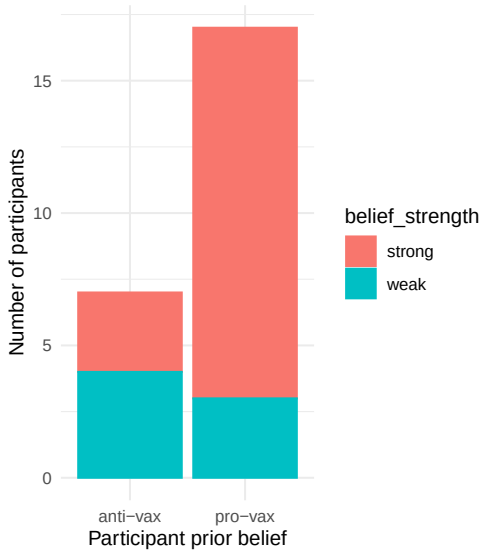

Figure 2. Distribution of coded participant prior belief stance and prior belief strength.

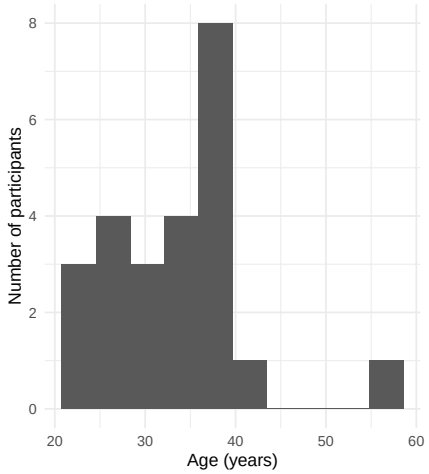

Figure 3. Distribution of participant age.

5.2 Testing opinion predicate hypotheses

We first plot participant levels of agreement with the embedded propositions in our stimuli set over the three different opinion predicate categories of interest: those that we predict will bias participants toward lower levels of agreement (neg), those we predict to bias participants toward higher levels of agreement (pos), and those we predict to fall in between neg and pos predicates in their bias-

ing effect (neut). We additionally group levels of agreement by whether the participant has a pro- or anti-vaccine prior belief, whether that prior belief is strong or weak, and the stance expressed by the embedded proposition (anti- or pro-vaccine) (Fig. 4).

We first of all notice some broad patterns that likely reflect intuitive differences between participants with pro- vs. anti-vaccine prior beliefs: participants with a strong pro-vaccine prior belief show uniformly high levels of agreement with pro-vaccine propositions and uniformly low levels of agreement with anti-vaccine propositions, whereas participants with strong anti-vaccine prior beliefs show the opposite (though the difference in levels of agreement is much smaller for anti-vaccine participants and there is some overlap in agreement with pro- and anti-vaccine propositions). For participants with a weaker pro-vaccine prior belief, the levels of agreement with both pro- and anti-vaccine embedded propositions are less uniform, and the values of agreement are also relatively closer (though still non-overlapping). Interestingly, participants with a weak anti-vaccine prior belief also show higher agreement with pro-vaccine propositions and lower agreement with anti-vaccine propositions, suggesting that the weak-prior belief participants might be better grouped under a single bin.

To test whether the type of opinion predicate does or does not have an effect on participant agreement with the embedded proposition, we fit a linear mixed effects model using the lme4 package in R (Bates et al., 2015) with fixed effects for the predicate type (neg, neut, or pos), opinion source ("Researchers," "Scientists," or "Doctors"), proposition type (pro- or anti-vaccine), prior belief type (pro- or anti-vaccine) and strength of prior belief (strong or weak), and random effects for participant and stimulus (Eq. 1). Other than participant agreement, which is a continuous variable ranging from 0 to 1, all other variables are coded as leveled factors, then centered. The equation we use to fit the linear mixed effects model is given by

$$y = \mathbf{X}\boldsymbol{\beta} + \mathbf{Z}\mathbf{b} + \epsilon, \tag{1}$$

where y is participant level of agreement, $\mathbf{X}$ is the vector of fixed effect terms, $\boldsymbol{\beta}$ is the vector of fixed effect coefficients, $\mathbf{Z}$ is the vector of random effect terms, $\mathbf{b}$ is the vector of random effect coefficients, and ϵ is the error term.

We find that the only significant ($t > 2$) terms are the fixed effect of embedded proposition type (with pro-vaccine propositions correlated with higher levels of participant agreement overall), the interaction of prior belief and embedded proposition type (pro-vaccine participants show higher agreement with pro-vaccine propositions and anti-vaccine participants show higher agreement with anti-vaccine propositions, regardless of the predicate category), and the 3-way interaction between prior belief, prior belief strength, and proposition type (participants with a weak, pro-vaccine prior belief show lower agreement with pro-vaccine propositions compared to participants with a strong, pro-vaccine prior belief, and vice versa for anti-vaccine participants, again regardless of predicate type).

In fact, none of the terms involving predicate type have a significant effect on participant agreement, indicating that we cannot reject the null hypothesis for **H1** (that predicates with higher speaker commitment elicit greater agreement). Nor can we reject the null hypothesis for **H2**, that the strength of participants' belief dampens the effect of predicate type, as we have found no evidence for a predicate effect regardless of prior belief strength.

6 Discussion

In this paper, we ran a pilot study to test the persuasive effects of 10 opinion-embedding predicates spanning different levels of speaker (or writer) commitment and across audiences with varying strengths of prior belief. We expected predicates signaling high speaker commitment to elicit higher levels of agreement, but for this effect to be dampened for participants who have a strong prior belief and who may thus be less sensitive to the choice of opinion predicate. After crowd-sourcing judgments with stimuli containing embedded propositions about vaccines, we did not find either hypothesis to be borne out.

One potential limiting factor could be that our participant sample was rather skewed—the majority of our limited number of participants have strong pro-vaccine attitudes. Our stimuli also had the drawback of being very generic: when eliciting participant agreement with embedded propositions, the opinions being expressed were about vaccines more generally, and reading a single new opinion about vaccines may not do anything to affect participants' beliefs toward vaccines as a whole. In a follow-up study, we would consider creating stim-

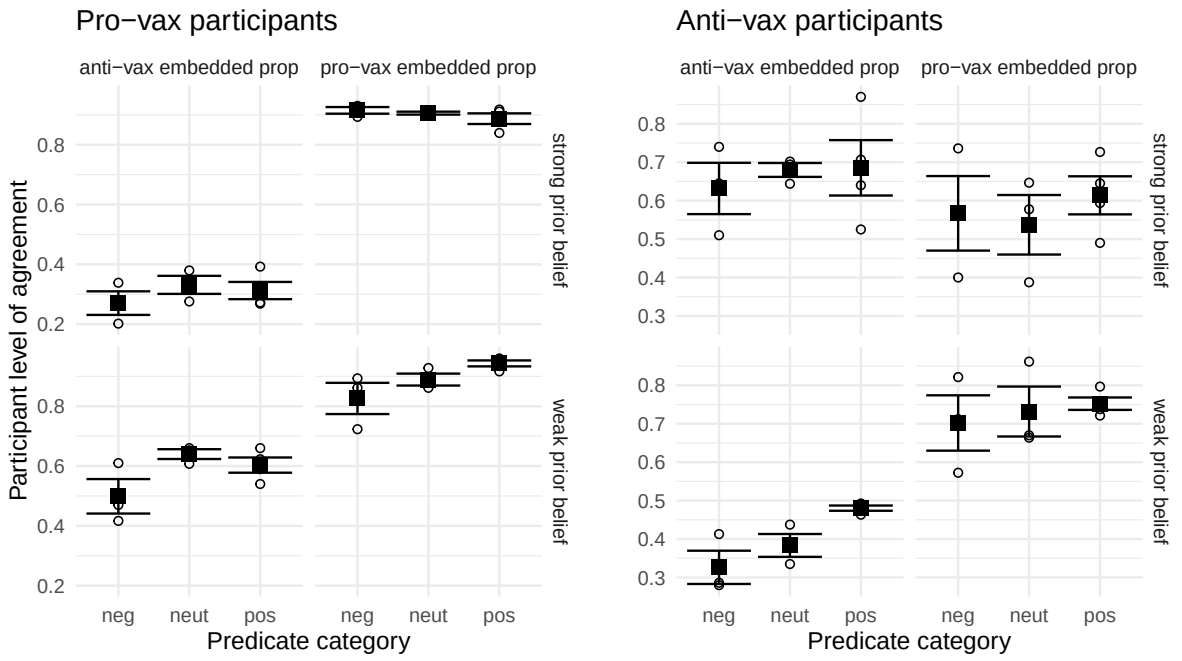

Figure 4. Participant levels of agreement for different opinion predicate types (neg, neut, pos), for pro- and anti-vax participants, grouped according to strength of participant prior belief and stance expressed by the embedded proposition. Black squares show means with a 95% confidence interval.

uli with embedded propositions about unfamiliar or made-up vaccines.

In addition, our pilot set-up was lacking in a form of baseline that would offer some indication of whether participants are sensitive to varying the opinion predicate at all. In future pilots, we would include stimuli on some topics unrelated to vaccines and toward which we would not expect participants to have any prior stance one way or the other, potentially borrowing from resources such as FactBank (Saurí and Pustejovsky, 2009). For such stimuli, we would expect the choice of opinion predicate to be a strong heuristic by which participants judge their personal agreement.

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Supplemental Material

Stimuli embedded opinions "the benefits of getting vaccinated far outweigh the risks" (**pro**), "many diseases can be contained with vaccines" (**pro**), "vaccines are a safe and effective way to save lives" (**pro**), "vaccines are effective at preventing diseases like measles" (**pro**), "there is no link between vaccines and autism" (**pro**), "the link between vaccines and autism is unfounded" (**pro**), "vaccines do not cause autism" (**pro**), "without the vaccine, the epidemic would have been far more widespread" (**pro**), "vaccines have saved countless lives" (**pro**), "we have basically eradicated measles" (**pro**), "children should be required to get vaccinated" (**pro**), "vaccinating children is a crucial measure for public health" (**pro**), "concerns over vaccine injuries are generally unfounded" (**pro**), "the vaccine-autism link is entirely a myth" (**pro**), "the study linking vaccines to autism has been debunked" (**pro**), "vaccines were responsible for some cases of autism in children" (**anti**), "thimerosol, an active ingredient in the measles vaccine, can cause seizures" (**anti**), "the mercury contained in vaccines is linked to autism risk" (**anti**), "vaccines are not as effective as people think" (**anti**), "vaccines pose non-trivial risks" (**anti**), "parents should have a choice in whether they vaccinate their children"(**anti**), "vaccine benefits are exaggerated and vaccine risks are downplayed by pharmaceutical companies" (**anti**), "many children have shown adverse reactions to vaccines" (**anti**), "getting vaccinated can pose serious risks" (**anti**), "vaccines are not as safe as many people imagine" (**anti**), "the campaign to get children vaccinated is driven in large part by drug companies" (**anti**), "people have sometimes still gotten sick, even after being vaccinated against the illness" (**anti**), "vaccines do not guarantee immunity" (**anti**), "the absolute safety of vaccines is a misconception" (**anti**), "we need to be more aware of the risks posed by vaccines" (**anti**)