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Vaccine information seeking on social Q&A services

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ABSTRACT

Experts are concerned about the spread and recalcitrance of vaccine misinformation and its contribution to vaccine hesitancy. Despite this risk, little research attention has been paid to understanding how individuals seek vaccine information online and evaluate its trustworthiness. Here, we hypothesized that when vaccine-hesitant parents seek information about vaccines, they prefer trustworthy sources based on their competence, integrity and benevolence. We explored this issue using 4910 questions and 2583 answers retrieved from two social question-and-answer (Q&A) platforms: "Yahoo! Answers" and the Facebook group "Talking about Vaccines." We examined what kinds of questions are asked about vaccines, to what extent they are explicitly directed at health professionals or parents, and what features of the answers predict perceived answer quality, based on the theory of epistemic trust. The findings indicate that on different platforms, vaccine-related questions focus on different topics; namely, questions on one platform focused on the risks and benefits of vaccination, whereas they dealt with vaccine schedules on the other. On both platforms, most questions did not specify that an answer should be based on professional expertise or parents' experience. Both pro-vaccine and anti-vaccine answers were proportionately represented among the "best answers". However, if an answer was written by a health professional, the askers and the community on "Yahoo! Answers" were twice as likely to choose it as the "best answer" to a vaccine-related question, irrespective of whether it encouraged or discouraged vaccination. By contrast, an online experiment revealed that both the identity of the respondent and the stance towards vaccination affected the perceived trustworthiness of the answers. These findings indicate that despite the proliferation of anti-vaccine messages, epistemic trust in mainstream science and medicine is robust. User responses to expert answers suggest that expert outreach in online environments may be an effective intervention to address vaccine hesitancy.

1. Introduction

Experts have repeatedly expressed concern about the ill effects of the internet on vaccination (e.g., [7,23,32]). Social media platforms such as Facebook facilitate the global spread of misinformation that may contribute to vaccine hesitancy, and thus lend themselves to the robustness and durability of the anti-vaccination movement [29]. The spread of health misinformation could end up reducing vaccine coverage and making preventable disease outbreaks more likely, but these media effects are still poorly understood [6]. Since vaccine hesitancy was cited as one of the top 10 threats to global health by the World Health Organization [33], social media companies such as Facebook have begun to limit the spread of anti-vaccination messages [1].

Nevertheless, little scholarly attention has been paid to understanding how individuals engage with vaccine information online. Similarly, researchers are only beginning to understand "how the online environment affects the communication of science information to the public" in general [2]. This article aims to achieve a better understanding by examining online information-seeking behaviors with respect to vaccines in the context of social question-and-answer platforms. Specifically, we examined what kinds of questions are asked about vaccines, and to what extent they are explicitly directed at health professionals or peers, such as other parents. We further explored what features of the answers predict perceived answer quality and trustworthiness, based on the theory of epistemic trust [14].

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2. Literature review

2.1. Vaccine hesitancy and epistemic trust

Vaccine hesitancy is defined in different ways: some define it as a set of beliefs or attitudes (e.g., [36], whereas others define it in terms of behavior (e.g., [11]. Here, we draw on the theoretical framework proposed by Peretti-Wattel et al. [20] which defines vaccine hesitancy as a "decision-making process" (Conclusion, para. 1) that varies across vaccines and can lead to different behavioral outcomes. These can include rejecting vaccination, postponing vaccination, or agreeing to vaccinate on schedule despite serious doubts. Peretti-Wattel et al. [20] identified two major determinants of vaccine hesitancy in individuals: the level of trust in health authorities and mainstream medicine, and the extent to which these individuals are committed to keeping abreast of health risks in everyday life.

To understand how people evaluate expert knowledge, we draw on the notion of "epistemic trust" in scientists, which is defined as "trust in knowledge that has been produced or provided by scientists" [14]. This construct entails both "dependen[ce] on the knowledge of others who are more knowledgeable" but also "a vigilance toward the risk to be misinformed" (p. 143).

Based on previous work in social epistemology and developmental psychology, Hendriks et al. [14] point to three factors which determine an expert's trustworthiness: (1) competence, i.e., pertinent knowledge of the topic at hand; (2) integrity, i.e., following a reliable belief-forming process and the rules of the profession; and (3) benevolence, i.e., offering "advice or positive applications for the trustor or (more generally) for the good of society," as opposed to some ulterior motive (p. 153). We hypothesized that when vaccine-hesitant parents seek information about vaccines, they would be interested in finding trustworthy sources based on these three criteria.

2.2. Vaccine hesitancy and information seeking

Evidence from several surveys suggests that information seeking is a common behavior among parents in developed countries, and that it usually involves engagement with multiple sources of information, which include both formal authorities, such as healthcare providers, as well as informal sources, such as friends and family. A 2004 U.K. survey found that 93.8% of all parents consulted one or more sources of information about the MMR vaccine, including nurses, physicians and anti-vaccination organizations [4]. Among U.S. parents surveyed in 2009, the most trusted source was their children's doctor, with 76% of all respondents reporting "a lot" of trust in this source [8]. Similarly, among U.K. parents surveyed in 2018, when asked to identify their most trusted sources of advice, 94% of parents mentioned doctors and 92% mentioned nurses. By comparison, only 10% claimed they would trust "people on social media or on online forums" [23].

That said, while survey research suggests that most parents rely primarily on their health care providers for health information, focus groups and in-depth interviews reveal a more complex picture with respect to vaccines. Some parents mistrust their doctors on this issue because they perceive them as being "unduly influenced by the authorities" [12]. Hence, vaccine-hesitant parents tend to consult peers, significant others, and online sources in addition to their doctors [12,21], since peers are perceived to have no conflicts of interest [15].

2.3. Vaccine information online

There is only sparse evidence on the extent to which parents are exposed to online sources about vaccines and their reliance on them. The data mostly derive from self-reported surveys and vary over time and between countries. In France, in 2012–2014, approximately 10–12% of mothers reported consulting the internet (in general) to seek information about vaccines [30], and in the Netherlands, 41% of parents with at least one child under 4 reported that they had consulted the internet to seek information about vaccines [13].

Previous work has also focused on the specific information needs of individuals with respect to vaccines on online platforms. For example, one study analyzed vaccine questions sent to a Spanish vaccine information website, *vacunas.org*, between 2008 and 2010, and found that 30% of the questions were related to vaccine safety. Other common topics identified in this study included indications (the conditions which make a vaccine advisable) and the schedule and method of vaccination (oral, injection, etc.); in total, the latter topics accounted for 47.8% of questions [10].

A relatively unsystematic body of work has also characterized the vaccine controversy on social media platforms such as Facebook. These discussions tend to occur in highly segregated communities that are either pro- or anti-vaccination, and which became more polarized between 2010 and 2017 [25]. The anti-vaccination community is sparsely interconnected on the whole, but it is also made up of many small, interconnected subgroups, a structure which allows information to flow quickly on a global scale and may contribute to the robustness of the movement [29]. Several studies have dealt with a Q&A Facebook group dedicated to a Polio vaccine catch-up campaign that took place in Israel, which emerged in response to a perceived need for personalized answers to parents' questions [18,19,24]. These studies showed that about half of all posts and comments addressed scientific and medical topics, but only 3.5% of the sample "presented a viewpoint or a comment by a researcher, or related to the results of a study or the use of a research method" [18].

2.4. Summary

Overall, previous studies have laid the theoretical foundations for investigating vaccine hesitancy in the context of online Q&A. However, there are still few fine-grained accounts of the ways people engage with online vaccine information and evaluate its trustworthiness. In this context, we explored how health information-seekers seek and evaluate vaccine-related information on the internet, and specifically on social question-and-answer (Q&A) platforms such as "Yahoo! Answers."

3. Research questions

Within the context of vaccine hesitancy and online information seeking, this series of related studies will examine three aspects of question asking and answer assessment on social Q&A platforms:

Study 1 – Askers' Information Needs: What questions are asked about vaccines on online Q&A platforms, and who are they directed at?

Study 2 – Predicting "Best Answers": What variables predict the likelihood that askers or the community will designate a given answer to a vaccine-related question as the "best answer"?

Study 3 – Perceived Trustworthiness of the Answers: What variables predict the perceived trustworthiness of these answers?

4. Research fields

This study examined two question and answer (Q&A) platforms that differed in terms of their characteristics: Yahoo! Answers (hereafter "YA") and a Facebook group called "Talking about Vaccines" (hereafter "TaV"). The main difference has to do with the sta-

tus of experts on the platform: YA is a platform designed for peer interaction, whereas TaV advertises itself as a place to interact with experts as well.

4.1. Yahoo! answers

YA is the world's largest question-and-answer platform, and the largest in the English language by a large margin, with over 120 million users and over 400 million answers cumulatively [5,16,22]. Askers are able to tag one of the answers as the "best answer" to their question [34]. If the asker did not select a best answer, other users were originally able to vote for one [16,22]; in 2014, however, the community vote feature was apparently discontinued. YA has a mix of both "pro-vaccine" and "anti-vaccine" participants, and thus stands out in comparison to other online communities, which tend to self-segregate to one of the stances [25].

"Talking about Vaccines" (*Medabbrim Al Hissunim,* hereafter TaV). This Hebrew-language *Facebook* group was founded in October 2013 explicitly as a space for experts and other community members to voluntarily answer questions about vaccine-related questions, as an outreach effort promoting the scientific and medical consensus, meaning that it probably attracts askers who have a high level of trust in health authorities, a key predictor of vaccine hesitancy [20]. The group had over 46,000 members by August 2019; approximately 150 were listed as experts including physicians, nurses and scientists, as well as physicians-in-training and scientists-in-training. The rest were mostly parents and other people interested in vaccines. Sharon and Baram-Tsabari [27] described the experts' participation patterns in TaV, and showed that they were based on diverse considerations, including those pertaining the establishment of epistemic trustworthiness. This group took over from a previous Facebook group called "Parents Talk about the Polio Vaccination," described elsewhere [18,19,24].

5. Study 1 – Patterns of questions about vaccines recur across websites and cultures, but standards for answers are seldom specified

Study 1 examined what askers wanted to know about vaccines and how often they specified whether they wanted an answer from a health professional or a parent, using a quantitative content analysis across both platforms: YA and TaV.

5.1. Methodology

5.1.1. Data source and Sampling

A total of 4540 questions were retrieved from YA using a list of keywords derived from the English Wikipedia article about "Vaccine Controversies" and the Vaccination Guidelines of the Israel Ministry of Health (Supplementary Material S1). Separately, a total of 7996 posts from 2017 were retrieved from Talking about Vaccines and a simple random sample of 370 posts was drawn from the population for further analysis. Both in YA and TaV, many of the askers self-identified as parents, but whether they were indeed parents is unknown. These questions were then manually classified by topic, using a coding scheme that demarcated vaccine-related questions from other questions, and then by several sub-topics of vaccine-related questions (Table 1).

5.2. Findings and discussion

5.2.1. Question topics

The distribution of question topics varied significantly in terms of the platform, $\chi^2(5) = 985.58$, $p < 0.001$. The largest difference stemmed from the proportion of non-vaccine topics, such as requests for diagnoses. On YA, these comprised 70% of the questions sampled, whereas these questions were much rarer on TaV, at 10% of the sample (Fig. 1a). Many of these questions matched keywords such as "HPV" and "papillomavirus," and requested advice on gynecological and sexual issues which were unrelated to the HPV vaccine. By contrast, such non-vaccine-related questions were less common in the TaV group, probably due to its laxer privacy settings.

On both platforms, questions about the risks and benefits of vaccines made up sizable proportions of vaccine-related questions: 53% on YA and 38% on TaV. Examples of questions from this category included requests for "reasons for and against giving the MMR (Measles, Mumps and Rubella) vaccine" and concerns about the pain involved in vaccination. A sizable minority of vaccine-related questions referred to the vaccine schedule (i.e., which vaccines are indicated for which population) and the extent to which the schedule can be adapted to local preferences and constraints, e.g., delaying, splitting or skipping vaccines (13% on YA, 49% on TaV). These differences may have derived from the way the Talking about Vaccines group advertised itself and the population of askers that it attracted. While on both platforms most vaccine-related questions were related to routine childhood and pregnancy vacci-

Table 1
Coding Book for Question Topic. Examples retrieved from TaV.

Codes	Category	Examples
11, 13, 14	*Vaccine Questions.*	Risks vs. Benefits (Code 11): • "Measles-mumps-rubella vaccine for one-year-olds, for or against. Why?" (Post #2016-252); • "How long does it take from the time I get the flu shot until the body develops antibodies?" (Post #2016-168)Schedule & Adaptation (Code 13): • "Hi, how many parts should I split the shots into for 6-month-olds, and which should I do first, I'd appreciate an answer (having all the shots done at once is completely out of the question)" (Post #2016-19)Other (Code 14): • "I'm about to vaccinate my two-month-old twin girls. Is there anything important I should know?" (Post #2016-63)
20	*Other Questions.* Posts containing questions about non-vaccine topics.	Infectious diseases: • "Can the kissing disease be a complication of the flu?" (Post #2016-259)
30	*Multiple.* All posts containing two or more questions spanning different categories or sub-categories.	Infectious disease & vaccine questions: • "A question about Hepatitis B.. Can you get it from swimming in a pool? How long does it take from the first dose until you can say that the child is immunized? [. . .]" (Post #2016-116)
40	*Not a Question.* All posts that did not contain questions, e.g., administrative announcements and health-related news and analysis.	• "You are all invited to a talk about Edward Jenner on May 17th [. . .]" (Post #2016-362); • "I just wanted to say I'm so happy I came across this group [. . .]" (Post #2017-62)

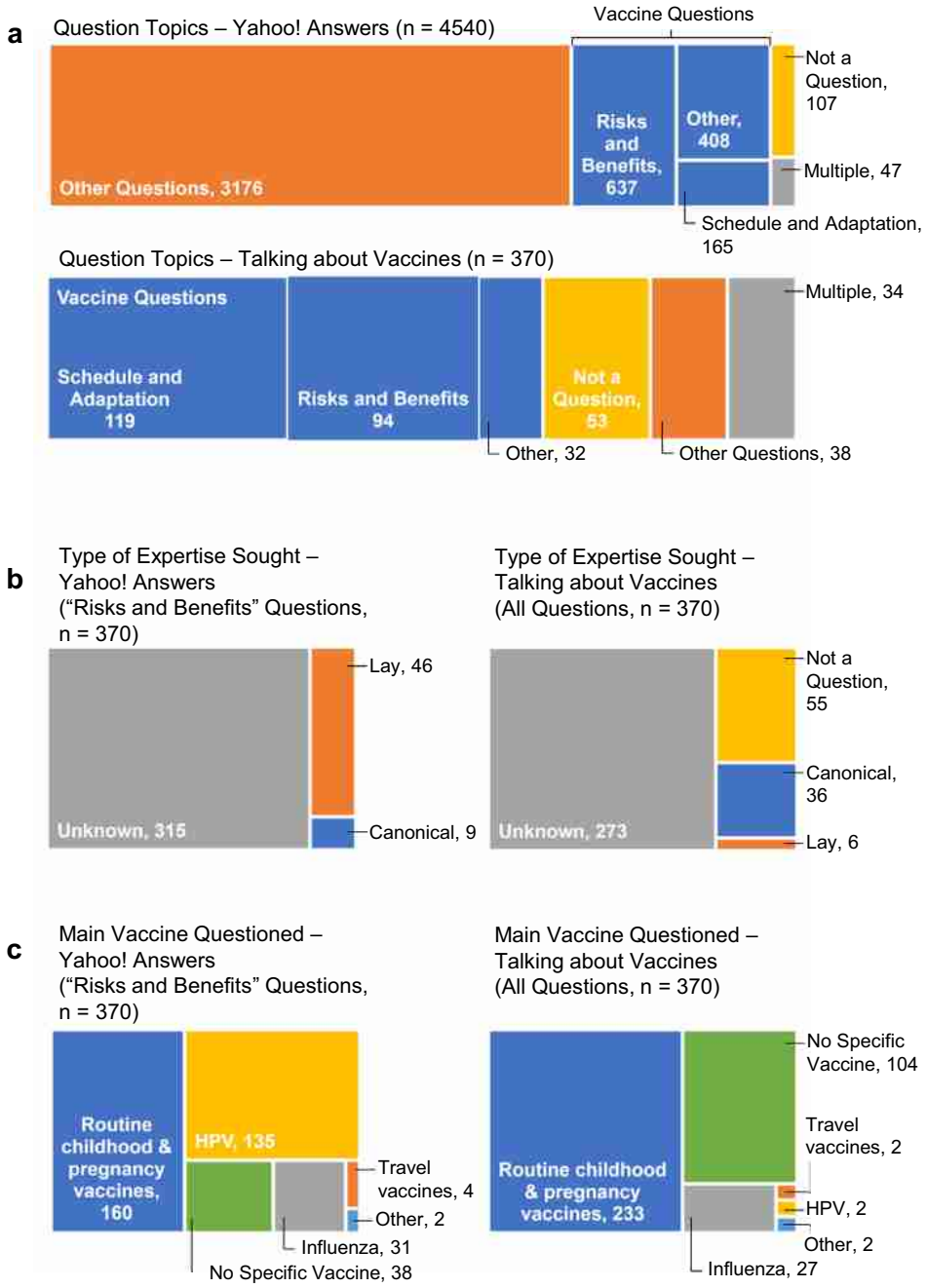

Fig. 1. Characteristics of questions on the two platforms: Yahoo! Answers and Talking about Vaccines. (a) Frequencies of question topics. (b) Frequencies of Type of Expertise Sought. (c) Frequencies of Main Vaccine Questioned.

nes (43% of the "Risks and Benefits" questions on YA and 63% on TaV), HPV came as a close second on YA, but not on TaV (36% of the "Risks and Benefits" questions on YA and 1% on TaV, Supplementary Material S1).

These findings are similar to those reported in García-Basteiro et al. [10], who studied questions sent to the Spanish vaccine information website *vacunas.org*, and found that 30% were related to vaccine safety. Both on TaV and on *vacunas.org*, large proportions of questions were asked about vaccines' indications and the schedule and route of vaccination: 32% on TaV ("Schedule and adaptation") and 30% on *vacunas.org*. These findings indicate that while overall, similar concerns about vaccines recur across different cultures and websites and over time, the specific distributions of questions depend on the context studied.

5.2.2. Type of expertise sought

Across both platforms, only a small fraction of the questions explicitly requested answers based on the testimony of medical and scientific experts such as physicians, or explicitly requested answers based on scientific findings such as journal papers: 2% of the "Risks and Benefits" questions on YA and 10% on TaV. Similarly, across both platforms, only small percentages of the posts explicitly requested information based on the experience of parents: 12% of the "Risks and Benefits" questions on YA and 2% on TaV (Fig. 1b).

These findings cohere with results from the "Parents talk about the Polio vaccine" Facebook group, in which very few questions and answers explicitly referred to research findings or methods, or to a researcher's viewpoint [18]. It is not clear from these find-

ings whether online Q&A services such as TaV are perceived as an appropriate venue to ask other parents to state their experience. Further research is needed on this issue.

5.2.3. Main vaccine questioned

On both platforms, routine childhood and pregnancy vaccines attracted large proportions of questions (43% of all the "Risks and Benefits" questions on YA and 63% of all questions on TaV; Fig. 1c). Questions pertaining the HPV vaccine were fairly frequent on YA, with 36% of all "Risks and Benefits" questions addressing it, compared with 1% of all questions on TaV. This probably derives from the numerous questions about the pain associated with the HPV vaccination. These findings strengthen the conclusion that the distributions of question topics depend on the context.

6. Study 2 – Health professionals' answers were twice more likely to be selected as the "best answers

Study 2 examined what features, if any, predicted the likelihood of the askers or the community to select a given answer to a vaccine-related question as the "best answer" on YA. Answers labelled the "best answer" on this platform were either selected by the asker or, if the asker did not choose one, selected by a community vote[1].

6.1. Methodology

6.1.1. Data source and sampling

The answers to all vaccine "Risks and Benefits" questions on YA were retrieved and analyzed. In total, 2583 answers were subjected to a content analysis and automated linguistic tagging (see "Independent Variables").

6.1.2. Dependent variable

The dependent variable (d_best) represented whether the answer appeared as the "Best Answer" to the question. It was manually coded as 0 or 1 to signify "no" and "yes," respectively. Just under a quarter of answers appeared as "best answers" (613 answers, or 23.7% of the total). It is likely that some of these were selected by the asker and others were selected by community vote.

6.1.3. Independent variables

Answers were coded manually and automatically for 21 features of the answer. These included textual features, such as the number of links in the answer, as well as content features, such as whether the answerer self-identified as a health professional (n_prof), whether the answerer self-identified as a parent (n_parent), and the answer's stance towards vaccination (n_recc). (Whether the answerers were actually health professionals or parents was unknown, both to the casual users and to the researchers in this study.) A simple random sample of health professionals' answers (n = 235) revealed that most answers in this category were contributed by nurses (39%) and other professionals, such as microbiologists (43%), with physicians contributing just 18% of the answers. Answers were considered to encourage vaccination if they either argued in favor of it or positively reflected on their own experience. Answers were considered to discourage vaccination if they argued against it, argued for delaying or splitting vaccines, or negatively related to their own experience. Automatic coding was performed using the GNU "Style and Diction" software package following Fu & Oh [9] for features such as answer length, but the automatically generated data were ultimately not used in this analysis (see details in Supplementary Material S2).

6.1.4. Statistical analysis

We conducted a binary logistic regression analysis to determine whether any of four independent variables predicted the chances of being the "Best Answer" (d_best); i.e., the two variables representing the answerer's self-identification (n_prof and n_parent) and the two dummy variables representing the answer's stance towards vaccines (n_recc_en and n_recc_dis). We also tested for five interactions between these variables, to assess the effects of combinations of the values of these variables; namely, the combined effect of identifying as health professionals *and* as parents (n_prof * n_parent), and the combined effects of answerer identities with different stances toward vaccination (i.e., the answerer identified as a health professional *and* encouraged vaccination, etc.).

6.2. Findings and discussion

Most answers were written by individuals who identified neither as parents nor as health professionals (80.5%, n = 2079); Only 9.2% (n = 237) were written by self-identified health professionals and 11.11% (n = 287) were written by self-identified parents. Among the "best answers," 14.84% (n = 91) were written by self-identified health professionals and 10.76% (n = 66) by self-identified parents. With respect to the stance towards vaccination, for each answer that discouraged vaccination, more than two answers encouraged vaccination (18.5% discouraging answers vs. 44.5% encouraging answers), with the remainder neither encouraging vaccination nor discouraging it (n = 955, 36.97%) (Supplementary Material S1). These three stances toward vaccination were proportionately represented among "best answers," with 22% discouraging "best answers" (n = 133), 44% encouraging "best answers" (n = 268) and 35% neither here nor there (n = 212).

In addition, the findings suggested a relatively level playing field for anti-vaccination messages and pro-vaccine messages on YA. Twice as many answers took the pro-vaccine side than the anti-vaccine side, but these proportions were observed within the "best answers" as well. Whether this finding is indicative of a tie between vaccine promoters and deniers or a de-facto loss for vaccine promotion is unclear.

Next, a logistic regression analysis revealed that answers written by self-identified health professionals were 2.365 times more likely to appear as the "best answer" than other answers, when all other variables were kept equal ($p < 0.001$). No significant effects were observed for answers written by self-identified parents, or for the stance of the answer towards vaccination. Likewise, no significant effects were found for the interactions we tested between the four variables (Table 2). This means that in our dataset, when an answer was written by a self-identified health professional, it was more than twice as likely to be chosen as the "best answer," all else equal, including whether the answer contained a pro- or anti-vaccine message

To evaluate the model, we conducted several tests. The Omnibus Test of Model Coefficients indicated that the accuracy of the model exceeded that of the baseline model when adding the predictors ($\chi^2(9) = 41.701$, $p < 0.001$). The Hosmer & Lemeshow test of goodness of fit suggested the model was a good fit to the data ($p = 0.983$) (Table 2). However, the value of Nagelkerke's R^2 was 0.024, suggesting that the model explains only a small amount of the variation in the outcome.

These findings suggest that while self-identified health professionals' answers about vaccines are in the minority, askers or community members tend to reward these answers as the "best answers," due to the sense of competence that they convey.

[1] The website provides no information as to which of the "best answers" were put up for a vote and how voting was conducted.

Table 2
Logistic regression predicting the likelihood of appearing as "Best Answer". This logistic regression predicts the probability that an answer will appear as the "best answer" to a vaccine-related question based on four characteristics of that answer and five interactions between them. Each variable is attributed an odds ratio which is equal to the probability of this outcome given that the characteristic is present, divided by the probability of this outcome when this characteristic is absent. The only variable that significantly predicted "best answers" was whether the answerer identifies as a health professional.

Predictor	Description	β	S.E. β	Wald's χ^2	*df*	*p*	e^{β} (odds ratio)
Constant		−1.345	0.085	248.305	1	**0.000**	**0.261**
n_prof	Answerer identified as a health professional	0.861	0.248	12.014	1	**0.001**	**2.365**
n_parent	Answerer identified as a parent	0.098	0.362	0.073	1	0.787	1.103
n_recc_en	Answer encouraged vaccination	0.116	0.116	0.997	1	0.318	1.123
n_recc_dis	Answer discouraged vaccination	0.278	0.152	3.363	1	0.067	1.320
n_prof by n_parent	Answerer identified as a health professional and as a parent	0.257	0.536	0.229	1	0.632	1.292
n_prof by n_recc_en	Answerer identified as a health professional and encouraged vaccination	−0.183	0.317	0.332	1	0.564	0.833
n_prof by n_recc_dis	Answerer identified as a parent	0.120	0.475	0.064	1	0.801	1.127
n_parent by n_recc_en	Answerer identified as a parent and encouraged vaccination	−0.728	0.453	2.587	1	0.108	0.483
n_parent by n_recc_dis	Answerer identified as a parent and discouraged vaccination	0.051	0.426	0.014	1	0.905	1.052
Overall model evaluation				**χ^2**	**df**	**p**	
Omnibus Test of Model Coefficients				41.701	9	<0.001	
Goodness-of-fit Test				**χ^2**	**df**	**p**	
Hosmer & Lemeshow				0.4	4	0.983	

Assuming these are indeed experts in health, these findings are consistent with previous work on of another social Q&A service, Stack Overflow, which has indicated that only a minority of answerers provide good answers [31,35]. These findings are also in line with surveys indicating parents' high level of trust in health professionals (e.g., [23]). However, in this context, no support was found for the claim that "parents trust other parents" [12]; at least, our data did not show that self-identified parents are trusted more than answerers who did not identify as parents. Whether the askers and the user community had a directional bias towards answers that conformed with their stance towards vaccines is an open question. We explore this issue in Study 3.

7. Study 3 – Answerers' perceived trustworthiness correlates primarily with their stance towards vaccination

Study 3 tested whether the self-identification of the answerer (health professionals, parents or unknown) and the answerer's stance towards vaccines (pro- or anti-vaccination) affected their perceived trustworthiness. This was tested using an online experiment in which volunteer participants were asked to rate the trustworthiness of different answerers, using Amazon Mechanical Turk (MTurk) [3].

7.1. Experimental design

We employed a 2x3 between-subjects experimental design, using 600 answers sub-sampled from the 2583 vaccine-related answers analyzed in Study 2 (see Table 3). These answers differed by two independent variables: the answer's stance towards vaccination (with two levels: pro- and anti-vaccination; these correspond to n_recc_en and n_recc_dis from Study 2) and the answerer's self-identification (with three levels: health professional, parent or unknown; these correspond to n_prof and n_parent from Study 2). Each of the answers was rated by between one and seven different respondents (M = 3.3), yielding a total of 1,981 ratings. Respondents could participate in the study more than once, but could only rate each answer once. Each respondent was compensated at a fixed rate of $0.30 per rating.

7.2. Research tools

The participants were asked to fill out a three-part questionnaire. The first part measured participants' evaluations of the epistemic trustworthiness of answerers, the second part was an attention check, and the third part was a short survey of attitudes towards vaccines, generating a vaccine confidence score between 1 and 5. Each part is described in Supplementary Material S3 and is attached as Supplementary Material S4.

7.3. Ethics

A notice at the beginning of the questionnaire informed respondents that their participation was voluntary and that they could withdraw at any time without suffering from any negative consequences. Ethics approval was sought and obtained from the authors' institutional review board (approval number 2019-037).

7.4. Data analysis

After preparing the data for analysis (as detailed in Supplementary Material S3), we conducted a moderation process analysis to examine the relationship between answerer self-identification and perceived epistemic trustworthiness. The answerer's stance towards vaccination was included as a moderator variable and three additional variables were included as covariates (the answer's length, in sentences, whether the answer appeared as a "best answer", and the rater's vaccination confidence).

Overall, the raters were characterized by a very high confidence in vaccines, based on the mean response to the vaccine confidence scale (M = 4.55 out of 5, SD = 0.74). Additionally, only 5.1% of the raters disagreed that vaccines are safe, compared to 14.3% in the general U.S. population (Table 4). To focus on the vaccine-hesitant raters, we repeated the moderation process analysis separately for raters with below-average vaccine confidence scores (the bottom 37% of ratings) and those with above-average scores (the top 63%). The raters' own vaccination confidence was not included as a covariate in these two analyses.

7.5. Findings and discussion

For the average rater, the effect of the answerer's self-identification on the perceived trustworthiness of an answer was moderated by the answer's stance towards vaccination ($\beta = -0.05$, $p < 0.01$, Fig. 2). Namely, the greater the expertise of the answerer, the more trustworthy the answer was perceived to be, but this effect was stronger among answers that encouraged vaccination than among answers that discouraged it ($\beta_{encouraging} = -0.16$, $p < 0.001$; $\beta_{discouraging} = -0.05$, $p < 0.05$) (Supplementary Material S3). Answer length had a small, positive, and significant effect on perceived trustworthiness ($\beta = 0.1$, $p < 0.001$), consistent with previous studies, which found that answer length predicted perceived

Table 3
Experimental design for Study 3. Each participant was asked to rate one or more answers as either pro- or anti-vaccination, and written by a health professional, a parent, or neither.

	Answerer identified as...	Stance towards Vaccination		Subtotal	Sampling method	Examples
		n (Pro-vaccine)	n (Anti-vaccine)			
1.	Health professional	120	22	142	All retrieved answers	"*As a nurse* I can tell you without a doubt there is NO WAY you can get HPV from the shot." (Answer #1932, pro-vaccine)
2.	Parent	103	121	**224**	All retrieved answers	"I am definitly [sic] not letting *my child* get the h1n1 vaccine" (Answer #2175, anti-vaccine)
3.	Neither	117	117	**234**	Simple random samples	"yes, the meningitis shot has been around for a long time and is very safe." (Answer #815, pro-vaccine)
	Subtotal	**340**	**260**			
	Total			**600**		

Note: Italics added for clarity.

Table 4
Proportion of vaccine hesitancy in the Study 3 rater sample and in the U.S. population, as measured by the percentage of respondents replying "Strongly disagree" or "Tend to disagree" with statements pertaining to vaccine confidence.

Percent who "strongly disagree" or "tend to disagree" that...	Raters in Study 3, 2019	U.S. Population, 2016
"Vaccines are important for children to have"	4.6	9.2
"Overall I think vaccines are safe"	5.1	14.3
"Overall I think vaccines are effective"	3.4	10.1
"Vaccines are compatible with my religious beliefs"	3.6	12.6

Note. U.S. population data retrieved from Larson et al. [17].

answer quality [9]. The designation of the answers as "best answers" had an even smaller, but still significant, positive effect ($\beta = 0.06$, $p < 0.01$). However, the rater's own vaccine confidence had no significant effect ($\beta = 0.01$, $p = 0.67$). Taken together, these findings suggest that most internet users look more favorably upon pro-vaccine messages online, especially when written by experts, and less favorably upon messages discouraging vaccination. Once a message is perceived to discourage vaccines, having a self-identified expert as the author does not improve its trustworthiness by much. Answer length and cues such as "best answer" make small but positive contributions to perceived trustworthiness. These findings appear to be valid at least among populations of mostly vaccine-confident users and when the stakes of the trustworthiness assessment are low.

By comparison, when vaccine-hesitant participants rated answers' trustworthiness, their ratings were significantly affected by answerers' self-identification ($\beta = -0.16$, $p < 0.001$) and by answer stance towards vaccinations ($\beta = 0.19$, $p < 0.001$), but not by the interaction between them ($\beta = -0.02$, $p = 0.50$). Among these raters, answer length had a particularly large effect on perceived trustworthiness ($\beta = 0.18$, $p < 0.001$). Furthermore, among these raters, cues such as "Best Answer" had no significant effect on perceived trustworthiness ($\beta = 0.06$, $p = 0.09$).

These findings should be treated with caution, since the R^2 values were between 0.23 and 0.34, suggesting that the models explained only part of the variation in the outcome. Further research should be conducted with more diverse samples of participants, especially with respect to vaccine hesitancy.

8. Discussion and conclusion

These three studies explored three aspects of online information seeking with respect to vaccines in the context of social Q&A platforms. Study 1 examined what kinds of questions are asked about vaccines, and to what extent they are explicitly directed at health professionals or parents. The results indicated that by and large, question topics tend to recur between different Q&A websites, although the distribution of topics depends on local context. The results also showed that most questions are neither directed towards health professionals nor towards parents.

Study 2 explored which features of answers predicted the likelihood that the users of YA would choose an answer as the "best answer." The findings show that askers and community members of this website were more likely to designate answers written by health professionals as the best answers, when all other variables were held equal. However, this likelihood was not associated with the stance the answerer took towards vaccines.

Study 3 extended Study 2 by asking external raters to assess the trustworthiness of answers. The findings showed that the answerers' self-identification and their stances toward vaccines both had significant effects on trustworthiness assessments, especially when the answerers encouraged vaccination. For this sample of raters, the length of the answer and its designation as a "best answer" seemed to have little effect on perceived trustworthiness. These differences in findings between Studies 2 and 3 may derive from the differences in the study designs: YA users may have had more of a stake in assessing the information than volunteer study participants, and therefore were more motivated to carefully evaluate the answers [28].

These findings should be considered with several limitations in mind. The main one is that the samples of Studies 2 and 3 are self-selected, and that it is not clear how well they represent the population of parents at large. It cannot be ruled out that these samples may be biased towards people who have a high level of trust in health authorities, a major determinant of vaccine hesitancy [20]. Indeed, in Study 3, the sample of external raters was less hesitant towards vaccines than the general U.S. population [17]. Hence, one cannot rule out the possibility that in Study 2, the sample of YA users who selected "best answers" shared the same characteristics as well.

Despite its limitations, this study's main strength lies in its description of authentic user behavior on social Q&A in the context of vaccines, and its description of trustworthiness assessments of authentic answers. It provides preliminary answers to two questions in the context of vaccine information seeking. The first question was what kinds of questions are asked about vaccines. According to the data, it depends on the platform. A generic Q&A service like YA, where askers and answers are anonymous, will have a different distribution of question topics than a Facebook group, where revealing real names and photos is the norm. Furthermore, some differences may have stemmed from the fact that TaV is operated by volunteer experts and is intended for parents. The second question addressed the issue of evaluating the trustworthiness of an answer. The findings here suggest that

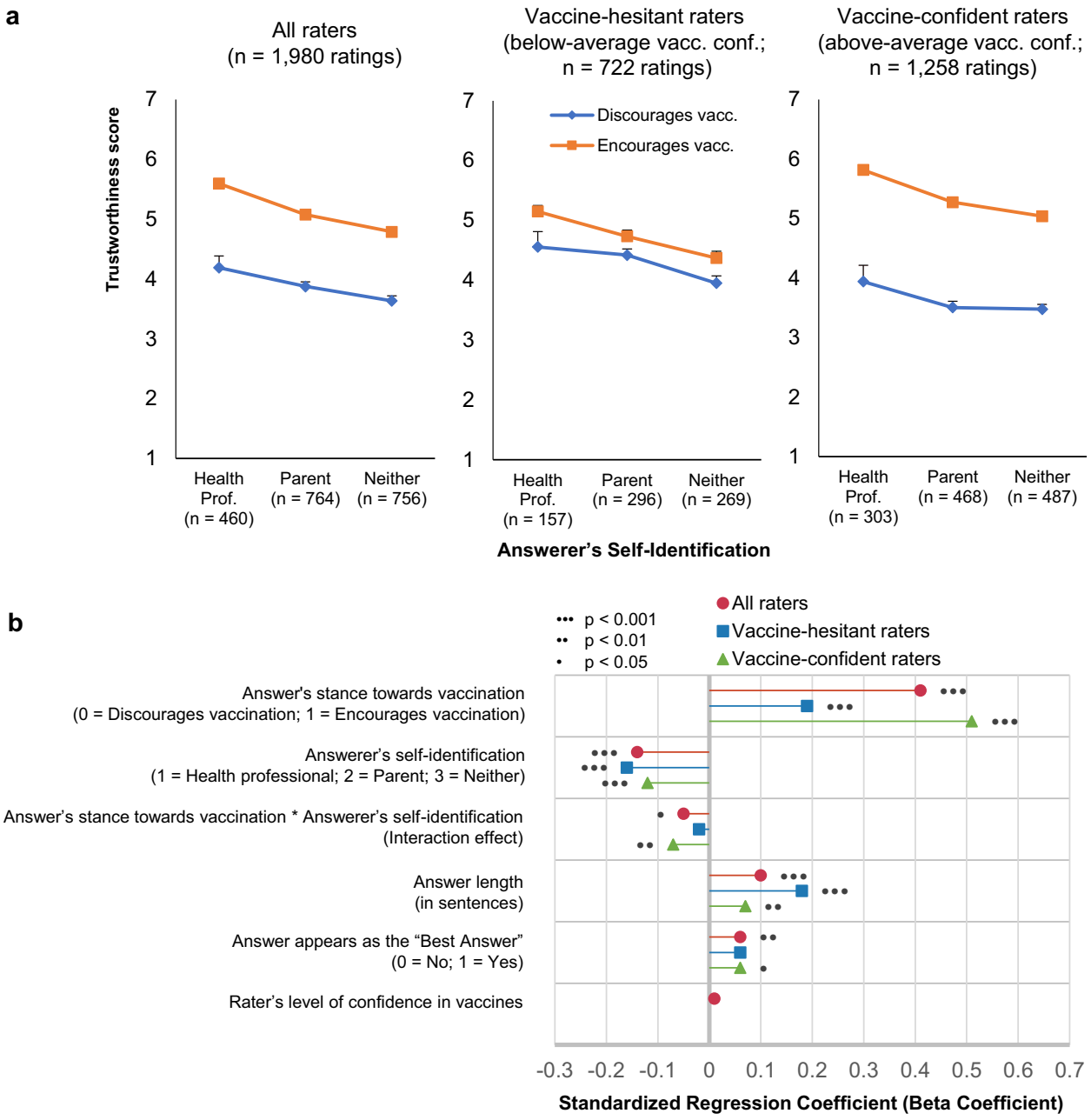

Fig. 2. Epistemic trustworthiness ratings by answer's stance towards vaccination and answerer self-identification. (a) Descriptive statistics of trustworthiness ratings for all raters, for vaccine-hesitant raters, and for vaccine-confident raters. Ratings are based on the mean of 14 questionnaire items on a 7-point Likert scale. Error bars denote the standard error of the mean. (b) Moderation analyses predicting epistemic trustworthiness ratings. These analyses examine whether different variables predict trustworthiness ratings, and if so, to what extent, and whether the relationship between answerer self-identification and trustworthiness depends on the answer's stance towards vaccines. One moderation analysis was performed for all raters, and one analysis each for vaccine-hesitant raters and vaccine-confident raters. Each independent variable was attributed a standardized regression coefficient (beta coefficient), which describes the extent to which changes in that variable are related to changes in trustworthiness ratings, when holding all other variables constant, where changes in variables are measured in standard deviations. One, two and three bullets (•, ••, •••) denote significance at the 0.05, 0.01 and 0.001 levels, respectively.

trustworthiness is in the eye of the beholder; if you look at user behaviors in a naturalistic setting, such as YA users selecting the "best answer," you will get a different picture than if you ask a sample of external raters in an experimental setting.

Taken together, however, these findings suggest that many internet users will not easily change their mind about vaccination, even though many of them report being exposed to negative messages about vaccinations on social media [23]. The findings also suggest that experts' outreach in online environments can be an effective tool within a larger toolbox of interventions aimed at addressing vaccine hesitancy.

Future research could focus on the askers' decisions to use social Q&A as an information source and their expectations regarding these answers, through the implementation of interviews and focus groups [26]. In addition, future research should explore settings where participants know more about the experts in question, such as their workplaces, experience and funding sources, and are therefore able to make more informed decisions about their benevolence. Finally, as recommended by Chou et al. [6], we reiterate the call to conduct research to determine "the threshold at which an intervention is needed to ameliorate the negative health consequences of misinformation" (p. 2418) in the context of online Q&A platforms.

9. Authorship

All authors attest they meet the ICMJE criteria for authorship.

CRediT authorship contribution statement

Aviv J. Sharon: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Writing - original draft, Visualization. **Elad Yom-Tov:** Conceptualization, Methodology, Data curation, Supervision, Writing - review & editing. **Ayelet Baram-Tsabari:** Conceptualization, Methodology, Supervision, Writing - review & editing, Project administration, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary material

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