Misbeliefs and Biases in Health-Related Searches

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ABSTRACT

Quality of search engine results returned to health-related questions is very critical, since a searcher may directly trust any suggestion in the top results. We analyze search questions that mention diseases / symptoms and remedies that are potential health-related misbeliefs. Using lists of medical and alternative medicine terms, we extract health-related search questions from 1.5 billion questions submitted to Yandex. As an initial study, we sample 30 frequent questions that contain a disease–remedy pair like "Can hepatitis be cured with milk thistle?". For each question, we carefully identify a ground truth answer in the medical literature and annotate the top-10 Yandex search result snippets as confirming the belief, rejecting it, or giving no answer. Our analysis shows that about 44% of the snippets (that users may simply interpret as definitive answers!) confirm some untrue beliefs and are wrong, and only few include health risk warnings about using toxic plants.

CCS CONCEPTS

• **Information systems** → **Query intent**; **Presentation of retrieval results**.

KEYWORDS

Health-related search; Misbeliefs; Search bias

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1 INTRODUCTION AND BACKGROUND

Misinformation and superstitions in the health domain like "Milk thistle can cure hepatitis" are widespread on the web [12, 49]. Moreover, people tend to believe wrongful assertions, especially with respect to statements about positive outcomes for alternative medicine treatments [9]. The danger of misconceptions and misinformation in the field of medicine and health has recently become very relevant during the COVID-19 outbreak. As Geldsetzer [15] showed, especially in the beginning of the pandemic, a lot of myths about the origins and ways of transmitting the disease were shared. In the COVID-19 context, but also in other health-related scenarios, the credibility and the correctness of online information as well as battling fakes on the web are crucial [12].

For about 70% of people with Internet access, search engines are the primary source of information about symptoms, diseases, and treatments—and only half of them would visit a medical professional after their searches [13, 14, 20, 41]. When searching for treatments, users tend to trust the top-ranked result, regardless whether it is a positive answer (treatment helps) or a negative one (does not help) [25, 38]. However, some years ago, more than half of the top answers of search engines to medical yes/no questions were incorrect [47, 48]. Fortunately, search engines have started addressing the credibility of health-related search results. For instance, Google recently introduced the COVID-19 Research Explorer[1] and the BioMed Explorer[2] that retrieve evidence from medical literature. However, most searchers might not know these services and might also favor "simpler" results than excerpts from medical literature.

In this work, we analyze 1.5 billion questions submitted to Yandex and find that 71 million questions (5% in the log) ask about diseases, symptoms, or health conditions. We also perform a qualitative analysis of health-related questions by identifying most frequently asked ones and by analyzing month-by-month trends of such questions. Such that the query log data might provide additional evidence support for medical research.

We also present a pilot study on health-related search questions mentioning disease–remedy pairs that potentially reflect a medical misbelief (e.g., `hepatitis` and `milk thistle`). For 15 such potential disease–remedy misbelief pairs, we sample two frequent questions—potential misbelief questions—from a year-long Yandex log that either (1) ask for confirming or rejecting the belief (e.g., "Can hepatitis be cured with milk thistle?"), or (2) ask for instructions of preparing or using the remedy (e.g., "How to drink milk thistle to cure hepatitis?"). For each question, we carefully identify a ground truth answer in the medical literature and annotate the snippets of the top-10 Yandex search results as confirming the belief, rejecting it, or giving no answer. Additionally, we annotate whether the snippets contain direct instructions of how to prepare / use a remedy and whether a health risk warning is indicated.

Overall, 44% of the snippets are misleading in that they suggest a remedy where the actual ground-truth answer is negative. We also found that 17% of the snippets contain direct instructions of how to use some remedy but only 13% warn about potential health risks or advice to visit a medical professional. These findings of our pilot study question the credibility of search results and emphasize the need of finding new ways of how search engines might treat requests with potential misbeliefs in health-related searches. Such questions could be identified by simple rules matching medical terms (diseases, specific remedies),[3] and the results should contain warnings about potential risks and harms.

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[1] https://covid19-research-explorer.appspot.com/
[2] https://sites.research.google/biomedexplorer/
[3] Our lists are available at https://github.com/webis-de/CIKM-21

2 RELATED WORK

Search logs are a valuable source of information that can be used for disease surveillance and epidemics monitoring. For example, Google introduced the Google Flu Trends in 2008 for predicting influenza cases in the United States [16]. Search logs were also used in various health-related studies such as analyzing seasonal variations in mental disorders [2], the restless legs syndrome [36], or symptoms associated with drugs misuse [34].

Today's extensive use of web content for self-informing on health-related topics like causes of diseases, searching for treatments, or self-diagnosing has motivated research in identifying medical misinformation on the web and studying whether searchers trust such misinformation. For instance, Bhattacharya et al. [9] mined tweets containing health-related statements like "Marijuana treats PTSD" and labeled them as true, false, or debatable. Their study showed that Twitter users demonstrated higher levels of belief in the false and debatable statements compared to the true ones. Similarly, the study by Bal et al. [4] found that tweets with misinformation about cures and causes of cancer tended to attract more attention. Several studies also analyzed questions asking about treatments and remedies on a Russian community question answering platform and found that almost all answers tend to recommend alternative medicine for treatment [7, 8].

A study closely related to ours was presented by White [47] who analyzed Bing users' beliefs and biases in health-related searches like "Can tea tree oil treat canker sores?". The study found that more than half of the Bing answers to such yes/no questions were incorrect, and that the search engine tended to rank 'yes' answers higher. These findings closely correlate with our analysis of the answers returned by Yandex. Differently to White [47] who also studied a wide range of generic medical search questions like "Do food allergies make you tired?", we focus on questions that mention disease–remedy pairs that may represent potential misbeliefs.

A motivation for our study is that people quite often purposefully search for wrongful health-related information [49], that they often fail to find the correct answer for questions about remedies, tend to overestimate treatment effectiveness [18], and that search engines tend to confirm their users' beliefs, be they correct or wrong [47]. We study how search engines specifically respond to questions asking about instructions of taking alternative remedies and if search engine results contain warnings about health risks.

A recent comprehensive review by Azzopardi [3] summarized different types of cognitive biases in search. Examples are projection bias (i.e., the way searchers formulate queries indicates their prior beliefs), confirmation bias (i.e., searchers select results that conform their beliefs), and content bias (i.e., web content returned by search engines is biased to positively framed 'yes' answers) that is especially relevant in the case of health search.

3 DATA

As our basis, we use all the questions submitted to the Russian search engine Yandex in the year 2012. The questions are extracted from the whole log by matching against a list of question words and phrases, see [45]. After removing entries that are not real questions and that do not reflect genuine askers' information needs (e.g., movie and book titles that are formulated as questions, crossword questions, or questions from TV quiz shows), a total of 1.5 billion questions remain (about 730 million unique ones).

Table 1: The ten most frequently mentioned diseases, symptoms, and conditions in questions from the Yandex log. Ambiguous terms for which we cleaned the frequencies from non-medical mention variants are marked with (⋆).

Frequ.	Disease	Frequ.	Symptom	Frequ.	Condition
1,124,402	Vaginal thrush	2,675,642	Fever⋆	11,406,708	Pregnancy
900,845	Cancer⋆	1,646,372	Pressure⋆	1,457,167	Pimple
566,079	Allergy	1,345,203	Pain / ache	896,097	Virus⋆
551,672	Cold / flu	814,583	Cough	556,700	Abortion
444,797	Hepatitis	520,182	Delay⋆	412,830	Bruise
432,548	Quinsy	505,529	Runny nose	366,441	Immunity
428,525	Hemorrhoids	353,502	Inflammation	338,112	Burn
424,871	Cyst	336,160	Oedema	309,114	Wart
405,355	Cellulite	326,507	Diarrhea	301,974	Miscarriage
395,747	Herpes	218,207	Vomiting	291,874	Intoxication

To identify health-related questions with potential misbeliefs from this year-long question log, we create a list of diseases, symptoms, and medical conditions, and a list of medicinal plants and other alternative remedies. The idea is to match the questions against these lists and further analyze only those questions that contain a disease / symptom / condition and a medicinal plant or alternative remedy (i.e., the trigger terms for potential misbeliefs).

As for the diseases, symptoms, and conditions, we collect a list from the ICD codes[4] and retrieve all Wikidata entities[5] that are subordinate to *disease* (Q12136) either as *instance_of* (P31) or *subclass_of* (P279). This often also helps to add more colloquial terms besides the official disease names (e.g., *cancer* for *malignant neoplasm*). Removing redundant terms (e.g., *caries* instead of *caries of dentine*) and duplicates yields a final list of 4,398 disease / symptom / condition names. As for the medicinal plants and alternative remedies, we again collect a list by retrieving *instance_of* (P31) *medicinal plants* (Q188840) from Wikidata and extending it with the Wikipedia list of medicinal plants using the PetScan tool.[6] From the resulting list, we manually removed terms such as "usual", "medicinal", or "Asian" (e.g., Celandine Asian) yielding 1,007 unique plant names. Additionally, we added another 49 common alternative remedies like honey, leeches, kerosene, etc. following the links from the Wikipedia article on alternative medicine.[7]

4 QUERY AND SEARCH RESULT ANALYSIS

To gain a general overview, we first analyze the frequency of the diseases, symptoms, and conditions in the logged Yandex questions. For ambiguous terms like cancer (also an astrological sign) or virus (also a computer virus), we exclude non-relevant questions based on simple patterns (e.g., cancer questions must not include the terms 'horoscope' or 'sign', virus questions must not include 'computer', 'windows', etc.). In total, about 71 million questions (5% of the log) mention some entry from our list of medical terms. Table 1 shows the 10 medical terms appearing in the most questions—manually grouped into diseases (e.g., thrush), symptoms (e.g., fever), and conditions / states (e.g., pregnancy). Not too surprisingly, 'pregnancy'

[4] International Classification of Diseases adopted in Russia: https://mkb-10.com/
[5] Using Wikidata Query Service https://query.wikidata.org
[6] https://petscan.wmflabs.org
[7] https://en.wikipedia.org/wiki/Alternative_medicine

Table 2: The ten most frequent questions in the Yandex log that mention a disease, a symptom, or a condition.

Frequency	Question
190,918	What is a vaginal thrush?
143,731	Why does one dream of pregnancy?
142,297	How to get rid of pimples?
70,123	How to get rid of pimples at home?
62,726	How to get rid of cellulite?
57,402	How to get rid of cellulite at home?
54,059	How to induce delayed periods?
52,153	How to boost immunity?
47,688	Can one make love during pregnancy?
46,749	How to get rid of dandruff?

is the most frequently mentioned medical term in the questions, but it is interesting that people seem to ask more often about pimples than cancer. The 10 most frequently asked questions containing a disease, symptom, or condition are shown in Table 2. Most often, people seem to ask about how to get rid of some medical condition but also ask for descriptions (e.g., "What is a vaginal thrush?").

We also analyze the temporal trends of mentions of the most frequent diseases / symptoms / conditions—omitting the dominating questions about pregnancy that are equally distributed through the year (about 1 million every month). Not surprisingly, Figure 1 shows a drop in the number of questions about fever in summer with a large growth towards December, while questions about vaginal thrush are peaking in spring and autumn.[8] Questions mentioning pimples show the least deviation in monthly distribution with an overall trend of increasing towards the end of the year.

To analyze how search engines answer potential health-related misbelief questions, we extract those questions that contain pairs of diseases, symptoms, or conditions and medicinal plants or alternative remedies (1.2 million questions in total). By manually inspecting the most frequent questions, we observe two major groups: (1) questions asking whether a remedy helps like "Can hepatitis be cured with milk thistle?" (asking for a belief confirmation) and (2) questions asking for instructions how to prepare or take the remedy like "How to drink milk thistle to cure hepatitis?" (representing an established belief). We view as misbelief questions exactly those with no scientific evidence that the remedy helps, or where clinical trials even showed the opposite.

We selected 30 frequent questions (15 yes/no questions and 15 asking about instructions) that contain pairs of diseases (symptoms, conditions) and remedies (medicinal plants or alternative remedy). Using Cochrane,[9] PubMed,[10] and BioMed Explorer[11] we searched for publications that contain medical studies and trials, and asked a medical professional to assess the true evidence (cf. columns 'True' and 'Evidence' in Table 3). For instance, for the question "Does garlic kill viruses?" we found that garlic prevents a widespread of viral infections through boosting the immune response, and thus the true answer is 'yes' [42], while the question "Can hepatitis be cured with milk thistle?" should be answered 'no'

[8]There are some studies investigating seasonal fluctuation in vaginal infections (e.g., [23, 31, 50, 53]). The results vary: some studies report seasonal variation, others do not. Moreover, climate and cultural norms can impact the frequency of the disease. Query log data might be an additional evidence for such studies.
[9]https://www.cochrane.org
[10]https://pubmed.ncbi.nlm.nih.gov
[11]https://sites.research.google/biomedexplorer/

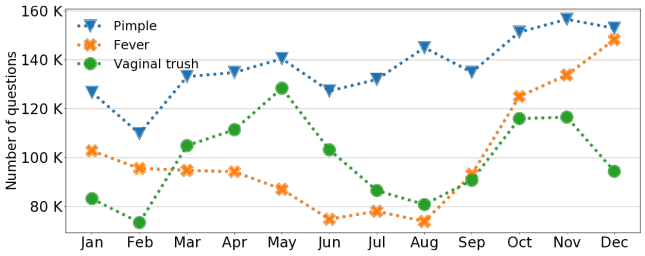

Figure 1: Yearly trends in the Yandex log for questions mentioning one most frequent disease, symptom, or condition.

based on the clinical trials that showed not enough strong evidence for beneficial effects of milk thistle in patients with hepatitis [39]. Some evidence suggests promising positive effects of photosensitive agents extracted from greater celandine in cancer therapy [46]. These are, however, just preliminary laboratory experimental results by applying the extract directly to cancerous cells such that for the 'celandine–cancer' questions a potential health risk should be indicated since celandine is a toxic plant that can lead to a toxic hepatitis with several reported fatalities [37].

We submitted each of the 30 disease–remedy questions as a query to Yandex and manually labeled the top-10 snippets (a) with 'yes' if the question is answered positively (e.g., "The best way to treat hepatitis C is to use the seeds' powder of milk thistle or make a tincture in alcohol.") or 'no' otherwise (cf. column 'A' in Table 3), (b) whether a snippet contains instructions on how to prepare and take the remedy (e.g., "Milk thistle oil for hepatitis should be taken 1 tsp. twice or three times a day. The course of treatment is 4-8 weeks."; cf. column 'I' in Table 3), and (c) whether a warning about potential health risks is included (e.g., "Silymarin in the plant is unsafe and it cannot be taken in uncontrolled courses."; cf. column 'W' in Table 3). We labeled the snippets with 'no answer' if there is no explicit answer given (e.g., "There is a popular belief that milk thistle helps to treat hepatitis C. But is it true?").

Our annotations show that most snippets tend to positively answer the health-related questions from our set—even 44% positive answers on questions with untrue assumptions (i.e., misbeliefs) while only 6% give a correct 'no' answer in such cases. About 17% of all snippets also contain recipes and instructions on how to prepare, take, or apply medicinal plants or alternative remedies (for 'yes' but also for 'no' answers!), while only 13% of the snippets contain warnings about health risks (e.g., side effects, careful use, or recommending professional advice). To generalize our observations, we translated the questions into English and submitted them to Google, again annotating the top-10 snippets. On the 'yes' questions, the results are very similar to Yandex, while on the 'no' questions, contrary to Yandex, Google snippets in a relative majority of 47% actually correctly say 'no'. Still, also on Google, 32% of the snippets actually answer 'yes' when the correct answer is 'no'.

Even though looking a bit better on Google, our results are still worrisome, since we found evidence of potential health risks for all questions in our study. Our findings suggest that the snippets for health-related misbelief questions too often confirm the misbeliefs. This is a problem, since searchers may simply believe untrue statements and misuse alternative remedies causing self-harm. For

Table 3: Analysis of the top-10 Yandex result snippets for potential health-related misbelief questions. For each question, a true answer is given with the medical sources of the found evidence and possible risk. Column C (category): disease (d), symptom (s), or condition (c); column A (answers in the snippets): yes (y), no (n), or no answer (?); column I: number of instructions or recipes in the snippets; column W: number of health risk warnings in the 'yes', 'no', or 'no answer' snippets, respectively.

Terms	C	Question	True	Evidence	Risk	Top-10 snippets		
						A (y/n/?)	I	W (y/n/?)
Cancer / Celandine	d	Does celandine help with cancer? How to drink celandine for cancer?	No	Maybe promising in future [46].	Toxic [37].	7 / 1 / 2 3 / 2 / 5	3 4	0 / 0 / 0 1 / 1 / 1
Hemorrhoids / Leeches	d	Can hemorrhoids be cured with leeches? Where leeches should be applied for hemorrhoids treatment?	No	Relieve symptoms only [24].	Source of pathogens [29].	8 / 0 / 2 9 / 0 / 1	2 3	0 / 0 / 0 1 / 0 / 0
Hepatitis / Milk thistle	d	Can hepatitis be cured with milk thistle? How to drink milk thistle to cure hepatitis?	No	Not enough evidence [39].	Adverse effects [32].	2 / 0 / 8 8 / 0 / 2	1 3	0 / 0 / 1 0 / 0 / 2
Vaginal thrush / Camomile	d	Does chamomile help with thrush? How to heal thrush with chamomile?	No	No evidence found.	Anaphylaxis as allergic reaction [40].	2 / 0 / 8 2 / 1 / 7	2 1	1 / 0 / 0 0 / 0 / 0
Vaginal thrush / Garlic	d	Does garlic help with thrush? How to heal thrush with garlic?	No	Not enough evidence [27].	Allergy, bleeding, burns [10].	7 / 0 / 3 1 / 0 / 9	1 1	0 / 0 / 0 0 / 0 / 0
Runny nose / Aloe	s	Does aloe help for a runny nose? How to treat a runny nose with aloe?	No	Lack of robust studies [43].	Potentially toxic and carcinogenic [17].	2 / 0 / 8 2 / 0 / 8	0 2	0 / 0 / 0 0 / 0 / 0
Toothache / Garlic	s	Does garlic help with toothache? Where to apply garlic against toothache?	No	No evidence found.	Chemical burn [11].	6 / 0 / 4 6 / 1 / 3	0 5	1 / 0 / 0 1 / 0 / 0
Pregnant / Coffee	c	Can pregnant women drink coffee? How to drink coffee during pregnancy?	No	See risk.	Risk of miscarriage [26].	2 / 0 / 8 3 / 4 / 3	2 1	2 / 0 / 4 3 / 3 / 0
					Total in 'no', %	44 / 6 / 51	19	6 / 3 / 5
Blood pressure / Green tea	s	Can green tea reduce blood pressure? Which green tea reduces blood pressure?	Yes	Reduces blood pressure [51].	Toxic in large doses [19].	5 / 0 / 5 1 / 2 / 7	1 0	1 / 0 / 0 0 / 1 / 2
Cough / Ginger	s	Does ginger help with cough? How to prepare ginger for cough?	Yes	Antitussive activity [22].	Combining with DOACs[12] can be fatal [28].	6 / 0 / 4 7 / 0 / 3	0 5	2 / 0 / 0 2 / 0 / 1
Cough / Licorice root	s	Does licorice root help with cough? How to take licorice sirup for cough?	Yes	Anti-inflammatory properties [52].	Toxic side effects [33].	7 / 0 / 3 7 / 0 / 3	1 2	0 / 0 / 0 1 / 0 / 1
Immunity / Echinacea	c	Does echinacea boost immunity? How to boost immunity with echinacea?	Yes	Natural immunomodulator [5].	Leads to antiretroviral medication failure [44].	2 / 0 / 8 5 / 0 / 5	2 1	0 / 0 / 0 2 / 0 / 0
Immunity / Honey	c	Does honey boost immunity? How to boost immunity with honey?	Yes	Stimulate the immune response [30].	Can cause paralysis in infants [35].[13]	4 / 0 / 6 6 / 0 / 4	2 2	0 / 0 / 0 1 / 0 / 1
Virus / Garlic	c	Does garlic kill viruses? How does garlic kill virus?	Yes	Significant antiviral activity [42].	Allergy, bleeding, burns [10].	3 / 0 / 7 9 / 0 / 1	1 0	0 / 0 / 1 1 / 0 / 0
Virus / Onion	c	Does onion kill viruses? How does onion work against viruses?	Yes	Antiviral effects of quercetin [6].	Potential allergen [1].	6 / 0 / 4 8 / 0 / 2	2 2	0 / 0 / 0 0 / 0 / 0
					Total in 'yes', %	54 / 1 / 45	15	7 / 1 / 4

[12]Direct Oral Anticoagulants.

[13]https://www.cochrane.org/CD007094/ARI_honey-acute-cough-children

instance, Johnson et al. [21] showed that choosing cancer treatment with alternative medicine may lead to refusal or delay of conventional treatment increasing the mortality rate by a factor of 2.5. Thus, new ways of presenting answers to questions that contain disease–remedy pairs are needed. For instance, search engine results should prominently mention warnings for health risks of using alternative medicine or advice to visit a medical professional.

5 CONCLUSIONS

We have analyzed health-related search questions with potential misbeliefs from a year-long Yandex log. About 5% of the 1.5 billion questions mention a disease, a symptom, or a medical condition. People ask about cancer quite often, yet questions about pimples are more frequent. In the yearly trends of the distributions of questions mentioning diseases / symptoms / conditions, pregnancy dominates and is almost equally distributed over the year.

In our study of questions with potential misbeliefs, we use a simple approach that matches the questions against lists of medical terms (diseases, symptoms, and conditions) and alternative remedies (medicinal plants, alternative remedies). We have sampled 30 frequent questions that contain disease–remedy pairs with potential misbeliefs from the questions submitted to Yandex and studied how the answers tackle the potential misbeliefs. Our analysis of the top-10 Yandex snippets showed a bias towards returning 'yes' answers to the misbelief questions, and thus confirming untrue beliefs. Not as pronounced, but still also on Google a substantial number of snippets tend to confirm misbeliefs. Moreover, only few snippets on both search engines include warnings of using alternative remedies. These findings suggest that for potential misbelief questions more attention should be put to the credibility of the retrieved answers, and that warnings about potential health risks may need to be shown more prominently.

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