Vaccination hesitancy: agreement between WHO and ChatGPT-4.0 or Gemini Advanced

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Abstract

Background. *An increasing number of individuals use online Artificial Intelligence (AI) - based chatbots to retrieve information on health-related topics. This study aims to evaluate the accuracy in answering vaccine-related answers of the currently most commonly used, advanced chatbots - ChatGPT-4.0 and Google Gemini Advanced.*

Methods. *We compared the answers provided by the World Health Organization (WHO) to 38 open questions on vaccination myths and misconception, with the answers created by ChatGPT-4.0 and Gemini Advanced. Responses were considered as "appropriate", if the information provided was coherent and not in contrast to current WHO recommendations or to drug regulatory indications.*

Results and Conclusions. *The rate of agreement between WHO answers and Chat-GPT-4.0 or Gemini Advanced was very high, as both provided 36 (94.7%) appropriate responses. The few discrepancies between WHO and AI-chatbots answers could not be considered "harmful", and both chatbots often invited the user to check reliable sources, such as CDC or the WHO websites, or to contact a local healthcare professional. In their current versions, both AI-chatbots may already be powerful instrument to support the traditional communication tools in primary prevention, with the potential to improve health literacy, medication adherence, and vaccine hesitancy and concerns. Given the rapid evolution of AI-based systems, further studies are strongly needed to monitor their accuracy and reliability over time.*

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Introduction

In the last decades, an increasing number of individuals have been using internet to retrieve information on health-related topics, with relevant implications on citizen's decisions and, in turn, public health (1,2). Search engines or social media were primarily used to access health-related contents, with serious concerns on the quality of online health information (3,4).

In the last few years, Artificial Intelligence (AI), and in particular AI Large Language Models (LLMs), has generated interest in the medical and academic communities, as they may become one of the main sources of health information seeking (5-7), and provide several Digital Health potential applications (8-10). Considering the gaining popularity of this technology, which can reproduce human language processing skills, generating realistic and coherent texts, several studies are evaluating their reliability and coherence with the best evidence available (11-15).

A few studies compared the reliability of different LLMs on vaccination-related topics (11,12,15): AI responses were not always fully accurate (15), and might even exacerbate vaccine hesitancy by spreading incorrect or misleading information (12).

This study aims to evaluate the accuracy of the currently most commonly used, advanced chatbots developed by OpenAI (ChatGPT-4.0) and Google (Gemini Advanced), comparing AI and World Health Organization (WHO) answers to the frequently asked questions (FAQs) about vaccines from WHO website (16-18). Given the substantial impact of these sources on the decision making of millions of individuals, it is crucial to verify that patients are informed according to the best available evidence.

Methods

Currently, two different versions of both ChatGPT and Gemini are publicly available: an open version (ChatGPT-3.5 and Gemini), and a more advanced version, which requires a monthly payment for access (ChatGPT-4.0 and Gemini Advanced) (19,20). This study collected the answers provided by ChatGPT-4.0 and Gemini Advanced to 38 open questions (Table 1), selected from the FAQs sections of WHO website (17-19). In particular, 13 questions pertain to the general topic of "Vaccines and immunization" (16); 11 questions focus on "Myths and misconceptions" related to vaccines, originally written by the U.S.

Centers for Disease Control and Prevention (CDC) to support practitioners involved in vaccinations for children (17); and 14 questions regards "COVID-19: Vaccines and vaccine safety" (18). These questions were posed by a single user to ChatGPT-4.0 and Gemini Advanced on February 13, 2024. Chatbots' answers were then independently and blindly evaluated by two authors (MF and AB), who compared AI answers with those answers provided by the WHO. AI responses were considered as "appropriate", if the information provided was:

(a) coherent with the information provided by the WHO;

(b) not related to a geographical area or other specific contexts only;

(c) not in contrast to current WHO recommendations on vaccination;

(d) not in contrast to drug regulatory agency indications about vaccines (21).

If an answer did not comply with the above-mentioned criteria, it was considered "inappropriate". Any discrepancy in the categorization was discussed by the pair, in order to achieve a consensus. If consensus was not achieved, the disagreement was reviewed and solved by a third author (LM). A precise description of the decision process was provided each time an answer was labeled as "inappropriate". Moreover, it was recorded when the chatbot invited the user to contact a healthcare professional or check reliable sources of information to have personalized and updated answers.

Data was managed with Google Sheets (Alphabet, San Francisco, CA, USA, 2024), and the overall accuracy rate of both chatbots was summarized using descriptive statistics. The transcription of all the 38 pairs of answers provided by the chatbots are available in the Supplementary Material, which can be requested to the corresponding author.

To ensure transparency, the screenshots of the entire chats with ChatGPT-4.0 and Gemini Advanced, and the html text of the WHO web pages' versions checked for this study (17-19) are available by request to the corresponding author.

Results

Overall, the rate of agreement between WHO answers and Chat-GPT-4.0 or Gemini Advanced was very high, as both provided 36 (94.7%) appropriate responses (Table 2).

Both chatbots reported a partially inappropriate

Table 1 - WHO's list of questions concerning (A) "Vaccines and immunization: What is vaccination?"; (B) "Vaccines and immunization: Myths and misconceptions"; (C) "Coronavirus disease (COVID-19): Vaccines and vaccine safety".

(A)

What is vaccination?

How does a vaccine work?

When should I get vaccinated (or vaccinate my child)?

Why should I get vaccinated?

What diseases do vaccines prevent?

Who can get vaccinated?

What is in a vaccine?

Are vaccines safe?

Are there side effects from vaccines?

Can a child be given more than one vaccine at a time?

Is there a link between vaccines and autism?

Should my daughter get vaccinated against human papillomavirus (HPV)?

I still have questions about vaccination. What should I do?

(B)

Weren't diseases already disappearing before vaccines were introduced because of better hygiene and sanitation?

Which disease show the impact of vaccines the best?

What about hepatitis B? Does that mean the vaccine didn't work?

What happens if countries don't immunize against diseases?

Can vaccines cause the disease? I've heard that the majority of people who get disease have been vaccinated.

Will vaccines cause harmful side effects, illnesses or even death?

Could there be long term effects we don't know about yet?

Is it true that there is a link between the diphtheria-tetanus-pertussis (DTP) vaccine and sudden infant death syndrome (SIDS)?

Isn't even a small risk too much to justify vaccination?

Vaccine-preventable diseases have been virtually eliminated from my country. Why should I still vaccinate my child?

Is it true that giving a child multiple vaccinations for different diseases at the same time increases the risk of harmful side effects and can overload the immune system?

Why are some vaccines grouped together, such as those for measles, mumps and rubella?

(C)

What vaccines protect against COVID-19?

Who should get vaccinated against COVID-19?

Who should not be vaccinated against COVID-19?

Do I need to be revaccinated with the COVID-19 vaccine?

Can children and adolescents get vaccinated against COVID-19?

Do all COVID-19 vaccines protect against virus variants?

Should I be vaccinated if I have had COVID-19?

Can I be revaccinated with a vaccine different from my previous dose?

Can I still get COVID-19 after I have been vaccinated?

How do we know that COVID-19 vaccines are safe and effective?

What are the side effects of COVID-19 vaccines?

Can I get vaccinated against COVID-19 if I am pregnant?

Should I get vaccinated against COVID-19 if I am breastfeeding?

Should I get vaccinated if I want to have a baby in the future?

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answer to the question "Can children and adolescents get vaccinated against COVID-19?", as they reported that COVID-19 vaccination is recommended for all children, while the WHO reported the following answer: "Healthy children and adolescents aged 6 months to 17 years belong to the low priority group for COVID-19 vaccination. Vaccinating them at this stage of the pandemic has limited public health impact […]. Children and adolescents at higher risk of severe COVID-19 (those who are immunocompromised, with severe obesity or with comorbidities) and never received COVID-19 vaccination, should get one dose" (22). Chat-GPT-4.0 also reported a partially incorrect answer to the question "When should I get vaccinated (or vaccinate my child)?", as it stated that the hepatitis B vaccine is commonly administered within 24 hours after birth. However, this is not a routine practice in many geographical contexts (*e.g.*, some European countries) (23). Finally, Gemini Advanced wrongly answered the question "What vaccines protect against COVID-19?", as it reported that the Moderna COVID-19 vaccine is authorized for adults only. However, according to the Food and Drug Administration, this vaccine may be administered to all individuals aged 6 months or older (24).

As regards the FAQs sections, both chatbots correctly answered to all the questions listed in the section "Vaccines and immunization: Myths and misconceptions". Finally, ChatGPT-4.0 and Gemini Advanced suggested to check reliable sources of information, or to contact a physician or a healthcare professional in 25 (65.8%) and 31 (81.5%) of the answers, respectively (Table 2).

Table 2 - Assessment of the answers of ChatGPT-4.0 and Gemini Advanced to WHO' FAQs.

	ChatGPT-4.0	Gemini Advanced
Vaccines and immunization: What is vaccination?		
What is vaccination?	1	1[†]
How does a vaccine work?	1	1
When should I get vaccinated (or vaccinate my child)?	0[†a]	1[†]
Why should I get vaccinated?	1	1[†]
What diseases do vaccines prevent?	1[†]	1[†]
Who can get vaccinated?	1[†]	1[†]
What is in a vaccine?	1[†]	1[†]
Are vaccines safe?	1[†]	1[†]
Are there side effects from vaccines?	1[†]	1[†]
Can a child be given more than one vaccine at a time?	1[†]	1[†]
Is there a link between vaccines and autism?	1[†]	1[†]
Should my daughter get vaccinated against human papillomavirus (HPV)?	1[†]	1[†]
I still have questions about vaccination. What should I do?	1[†]	1[†]
Agreement rate to WHO' FAQs	12/13 (92.3%)	13/13 (100%)
Vaccines and immunization: Myths and misconceptions.		
Weren't diseases already disappearing before vaccines were introduced because of better hygiene and sanitation?	1	1
Which disease show the impact of vaccines the best?	1	1
What about hepatitis B? Does that mean the vaccine didn't work?	1	1
What happens if countries don't immunize against diseases?	1	1
Can vaccines cause the disease? I've heard that the majority of people who get disease have been vaccinated.	1	1
Will vaccines cause harmful side effects, illnesses or even death? Could there be long term effects we don't know about yet?	1	1[†]
Is it true that there is a link between the diphtheria-tetanus-pertussis (DTP) vaccine and sudden infant death syndrome (SIDS)?	1[†]	1[†]
Isn't even a small risk too much to justify vaccination?	1[†]	1[†]
Vaccine-preventable diseases have been virtually eliminated from my country. Why should I still vaccinate my child?	1	1[†]
Is it true that giving a child multiple vaccinations for different diseases at the same time increases the risk of harmful side effects and can overload the immune system?	1[†]	1[†]
Why are some vaccines grouped together, such as those for measles, mumps and rubella?	1	1
Agreement rate to WHO' FAQs	11/11 (100%)	11/11 (100%)
Coronavirus disease (COVID-19): Vaccines and vaccine safety.		
What vaccines protect against COVID-19?	1[†]	0[†b]
Who should get vaccinated against COVID-19?	1[†]	1[†]
Who should not be vaccinated against COVID-19?	1[†]	1[†]
Do I need to be revaccinated with the COVID-19 vaccine?	1[†]	1[†]
Can children and adolescents get vaccinated against COVID-19?	0[†c]	0[†c]
Do all COVID-19 vaccines protect against virus variants?	1[†]	1[†]
Should I be vaccinated if I have had COVID-19?	1[†]	1[†]
Can I be revaccinated with a vaccine different from my previous dose?	1[†]	1[†]
Can I still get COVID-19 after I have been vaccinated?	1	1[†]
How do we know that COVID-19 vaccines are safe and effective?	1	1[†]
What are the side effects of COVID-19 vaccines?	1[†]	1[†]
Can I get vaccinated against COVID-19 if I am pregnant?	1[†]	1[†]
Should I get vaccinated against COVID-19 if I am breastfeeding?	1[†]	1[†]
Should I get vaccinated if I want to have a baby in the future?	1[†]	1[†]
Agreement rate to WHO' FAQs	13/14 (92.9%)	12/14 (85.7%)
Overall agreement rate to WHO' FAQs	36/38 (94.7%)	36/38 (94.7%)

1: Appropriate; 0: Inappropriate; †: the chatbot, in the answer, invited the user to check reliable sources of information to contact a healthcare professionals;
a: the answer provided by ChatGPT-4.0 stated that the hepatitis B vaccine is commonly administered within 24 hours after birth; however, this is not a routine practice in many geographical contexts (*e.g.*, some European countries) [23];
b: the answer provided by Gemini Advanced stated that the Moderna COVID-19 vaccine is authorized for adults only; however, this vaccine may be administered to all individuals aged 6 months or older according to the Food and Drug Administration [24];
c: the answer provided by both chatbots suggested that COVID-19 vaccination is recommended for all children; on the other hand, the WHO answer described children and adolescents as low priority categories and vaccination recommendations may vary by different geographical contexts, and specified that is recommended particularly for children with comorbidities that may expose them to higher COVID-19 related risks [22].

Discussion

In this study, focused on the list of FAQs about vaccines reported by the WHO, we observed a very high level of agreement between the answers provided by the same WHO and both ChatGPT-4.0 and Gemini Advanced. To date, no study explored the performance of Gemini Advance on vaccines-related topics to date, and only two studies previously evaluated the clarity, correctness and exhaustiveness of ChatGPT-3.5 and -4.0 in responding to vaccination misconceptions (13) or vaccine concerns and hesitancy (12). Our findings are in agreement with those from both of the above studies: Deiana et al. showed an accuracy higher than 85% for both versions of ChatGPT, with the more advanced 4.0 performing slightly better (13); and Torun et al. observed that ChatGPT-3.5 was a valuable source of information for guiding patients with vaccine hesitancy, boosting patient confidence in primary prevention (12). When other health-related topics are considered, the results have been similarly positive: as an example, according to Johnson et al. (25), ChatGPT-3.5 was capable of providing 96.9% correct answers to FAQs about cancer myths and misconceptions.

Given that digital resources should not replace the doctor-patient relationship, and even though a negative AI performance has been reported in some fields, such as parasitology (26), the available body of literature suggest that these AI-chatbots may already be powerful instrument to support the traditional communication tools in primary prevention, with the potential to improve vaccine literacy (27), medication adherence, and vaccine hesitancy and concerns (28), especially in developing countries (29). Clearly, it will be essential that the accuracy and reliability of AI-chatbots will be maintained over time, otherwise these technologies could facilitate the spread of misinformation that may be dangerously detrimental for patients (30,31). Importantly, however, in the present study the few discrepancies between WHO and AI-chatbots answers could not be considered "harmful", are simple to revise, and both chatbots often invited the user to check reliable sources, *e.g.,* the CDC or the WHO websites, or to contact a healthcare professional to seek out updated and additional information, finally to consult the Local Health Authorities for geographically-specific information. In any case, further studies should keep analyzing these and other AI-chatbots performances, compare them in different settings, and assess potential errors and biases (32,33).

This study has some limitations that must be considered in interpreting the results. First, although we adopted a strongly validated reference to identify the correct answers (WHO), and two investigators independently assessed every question, a certain level of subjectivity in evaluating the agreement of the responses could not be avoided. Also, the answers presented by ChatGPT-4.0 and Gemini Advanced were appropriate for the proposed questions, but in a real-case scenario, it cannot be excluded that an incoherently-written question about vaccines may lead to a misleading or incorrect answer. Third, ChatGPT-4.0 and Gemini Advanced are available for paying users only, which poses the problem of digital inequity, representing a recognized aspect of health disparity (34). Fourth, although we included a relatively long list of relevant questions, it cannot be considered a comprehensive list of the doubts faced by patients about vaccination. Finally, all the chats were conducted in English, so the performance of the chatbots in other languages may be different, and should be properly assessed.

Conclusions

Both ChatGPT-4.0 and Gemini Advanced showed a very high level of agreement with 38 answers provided by the WHO on important vaccine-related topics, including vaccination effectiveness, safety, schedules, and others. The few, partial discrepancies could not be considered potentially harmful, and both AI-chatbots often advised the user to check other reliable sources and seek a doctor to obtain further information. These findings suggest that both AI-chatbots can already be powerful instrument to support the traditional communication tools in primary prevention, with the potential to improve vaccine hesitancy and concerns. As AI-chatbots are evolving rapidly, further studies are strongly needed to monitor their accuracy and reliability over time.

Riassunto

Esitazione Vaccinale: concordanza tra OMS e ChatGPT-4.0 o Gemini Advanced

Background. Un numero crescente di pazienti consulta chatbot basati sull'Intelligenza Artificiale (IA) per ottenere informazioni relative alla salute. Data la loro rilevanza, diffusione e le possibili applicazioni nella Digital Health, è fondamentale verificare che i pazienti siano informati da questi strumenti alla luce delle migliori evidenze disponibili. Tuttavia, in letteratura sono emerse inaccuratezze da parte dei chatbot-IA quando consultati su argomenti relativi alla salute. Tali imprecisioni potrebbero aggravare l'esitazione vaccinale diffondendo informazioni errate o fuorvianti. Pertanto, lo studio si propone di valutare l'accuratezza delle risposte fornite a domande sulla esitazione vaccinale da due dei chatbot più avanzati e comunemente utilizzati: ChatGPT-4.0 e Google Gemini Advanced.

Metodi. Le risposte fornite dall'Organizzazione Mondiale della Sanità (OMS) nel suo sito web a 38 domande frequenti (FAQs) su convinzioni errate riguardanti i vaccini sono state confrontate con quelle formulate da ChatGPT-4.0 e Gemini Advanced. Le risposte sono state considerate "appropriate" se le informazioni risultavano coerenti e non in contrasto con le attuali raccomandazioni dell'OMS o di altre autorità regolatorie internazionali. Inoltre, è stato registrato quando il chatbot invitava l'utente a consultare un professionista sanitario o fonti di informazione ufficiali per ottenere risposte personalizzate e aggiornate.

Risultati e Conclusioni. Il livello di concordanza tra le risposte dell'OMS e quelle di ChatGPT-4.0 o Gemini Advanced è risultato molto alto, con entrambi i chatbot-AI che hanno fornito 36 (94,7%) risposte appropriate. Le poche discrepanze tra le risposte dell'OMS e quelle dei chatbot-IA non sono state considerate pregiudizievoli per la salute pubblica. Entrambi i chatbot hanno consigliato spesso all'utente di verificare le fonti affidabili, come i siti web del CDC (Centro per la prevenzione e il controllo delle malattie) o dell'OMS, o di consultare un professionista sanitario. Pertanto, entrambe le versioni avanzate dei chatbot-IA, possono essere considerati alleati utili nelle strategie preventive, con la potenzialità di migliorare l'alfabetizzazione sanitaria riguardante i vaccini. Dato il rapido sviluppo della tecnologia IA, sono necessari ulteriori studi per monitorare costantemente l'accuratezza e l'affidabilità di questi strumenti.

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