



Exploring the Role of Chatbots in Tackling COVID-19 Vaccine Hesitancy among Pregnant and Breastfeeding Women in Rural Northern India

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Rapid and widespread vaccination played a major role in stemming the flow of Covid-19 spread. In India, the government enabled free and accessible vaccination for Covid-19. Although the general public responded positively, pregnant and breastfeeding women in rural areas hesitated about COVID-19 vaccination, leading to low vaccine uptake. In this work, we started with a formative study to understand pregnant and breastfeeding women's vaccine hesitancy. We found that the main barriers were poor knowledge about vaccines and limited agency around vaccination. We deployed a chatbot over WhatsApp to tackle their hesitancy through evidence-based vaccine education. We studied the chatbot engagement of 800+ participants over 23 days through chat logs, surveys, and interviews. We present participants' experiences and aspirations around chatbots. We found the chatbot to work well under a constrained network to build participants' vaccine-related knowledge and intentions. We further discuss the role of chatbots in healthcare beyond COVID-19 vaccination.

CCS Concepts: • **Human-centered computing** → **Empirical studies in HCI**.

Additional Key Words and Phrases: Chatbot, COVID-19, Vaccination, Rural Areas, Pregnant women, Postpartum women, HCI4D, India

ACM Reference Format:

Jasmeet Kaur, Preetika Sharma, Vijay Kumar, Mona Duggal, Nadia Diamond-Smith, Alison El Ayadi, Kathryn Vosburg, and Pushpendra Singh. 2024. Exploring the Role of Chatbots in Tackling COVID-19 Vaccine Hesitancy among Pregnant and Breastfeeding Women in Rural Northern India. *Proc. ACM Hum.-Comput. Interact.* 8, CSCW1, Article 55 (April 2024), 29 pages. <https://doi.org/10.1145/3637332>

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ACM 2573-0142/2024/4-ART55

<https://doi.org/10.1145/3637332>

1 INTRODUCTION

The COVID-19 vaccination was open for pregnant and breastfeeding women in India in July 2021. COVID-19 infection among pregnant and breastfeeding women has been associated with higher health risks such as fetal and neonatal complications, maternal mortality, and morbidity [17, 42]. While the official government data ¹ does not track vaccination status separately for pregnant and postpartum women, research studies have identified low vaccination rates and vaccine-related knowledge among this population. The Global Network for Women and Children's Health Research found only a small proportion of Indian pregnant women (12.9%) had been vaccinated by September 2021 [32]. During the COVID-19 waves in India, pregnant and postpartum women were severely affected, especially during the second wave, when the symptomatic cases and case fatality rate among them were found to be significantly higher, 28.7% and 5.7% respectively, as compared to the first wave [3]. With such low vaccination rates among pregnant and postpartum women and its severe consequences, it becomes important to understand the factors hindering COVID-19 vaccine administration.

In view of COVID-19, the Indian government introduced a WhatsApp-based chatbot called MyGov Corona Helpdesk to disseminate information about COVID-19 in English and Hindi in 2020 [40]. The Indian government chatbot covered information on coronavirus, symptoms of COVID-19, ways to reduce COVID-19 risk, and ways to improve immunity. However, regarding vaccination, the government chatbot offered help only regarding booking vaccination appointment and downloading vaccination certificate. Moreover, the chatbot requires a user to create a MyGov account to access its services. The chatbot has been reported to reach 30 million users in India, showing its high acceptance among the general public [37]. In addition to the MyGov chatbot, WHO has also launched a chatbot for disseminating information on COVID-19 on Facebook Messenger in English, French, Spanish, and Arabic languages [2].

Given low vaccination rates, higher health risks, greater attention towards vaccination booking, and limited to no attention towards concerns around vaccination among pregnant and breastfeeding women, there exists an opportunity to understand pregnant and breastfeeding women's concerns behind the COVID-19 vaccine hesitancy in greater detail and offer interventions tailored to address their concerns to facilitate vaccine uptake. This approach aligns with suggestions from prior work, which suggests understanding the root causes of the hesitancy before tackling vaccine hesitancy in population sub-groups [19].

Thus, with this approach, we started with identifying the concerns of pregnant and breastfeeding women around COVID-19 vaccination through semi-structured interviews. With knowledge of their concerns, we moved on to offering an intervention to address their concerns. With WhatsApp being the world's most popular messaging application [1] and having high accessibility and familiarity among our target population [22, 44], we decided to leverage WhatsApp to build an intervention to deliver healthcare information while keeping the learning curve for the intervention to minimal. Since the general public in India showed high acceptance for the Indian government's COVID-19 WhatsApp chatbot [37] and prior literature also stating the chatbot's potential to deliver healthcare information [46], we decided to develop a WhatsApp-based chatbot for tackling COVID-19 vaccine hesitancy among pregnant and breastfeeding women. We based our chatbot on a rule-based model given its capability to avoid misinterpretation of user queries, which we discuss later, and also its application in the chatbots deployed over WhatsApp such as MyGov, and other banking ² and shopping chatbots.

¹<https://www.cowin.gov.in/>

²<https://www.hdfcbank.com/personal/resources/ways-to-bank/chat-banking>

Prior research has investigated the potential of chatbots in healthcare for offering informational support on topics such as sexual and reproductive health [35], breastfeeding [46], and managing mental health [41]. These chatbots were prototypes following question and answer-based chatting style and were deployed in controlled settings. These studies observed that chatbots have the potential to act as the first point of contact for seeking answers for healthcare-related queries [35, 46], particularly for maternal and child health-related queries in resource-constrained environments [46]. We leveraged this observation to develop a chatbot for disseminating COVID-19 vaccine-related information among pregnant and breastfeeding women in resource-constrained settings. Thus, with an understanding of the vaccine-related concerns among pregnant and breastfeeding women, we developed our chatbot and deployed it in the wild, with 800+ users engaging with the chatbot. Post-deployment, through chat logs, surveys, and interviews, we studied participants' experiences with the chatbot, the effect of the chatbot on participants' vaccine hesitancy, and their aspirations for the chatbot to support their healthcare needs in the future. Thus, we aim to address the following research questions:

- What factors contribute to COVID-19 vaccine hesitancy among pregnant and breastfeeding women in resource-constrained settings?
- What is the effect of a chatbot in tackling COVID-19 vaccine hesitancy among pregnant and breastfeeding women in resource-constrained settings?

Through our study, we intend to address the gaps in the literature on chatbots in healthcare. Firstly, the potential of healthcare chatbots, primarily prototypes based on question-and-answer chatting style, is investigated, however, the effect of an actual working chatbot in the wild is under-studied. Secondly, research on the application of rule-based chatbots for healthcare is limited. We aim to address these gaps in our study and intend to extend the understanding of the role of chatbots in healthcare among the population residing in resource-constrained areas.

2 RELATED WORK

In this section, we describe the prior research focused on investigating the role of chatbots in the healthcare domain, with a focus on chatbots in the context of COVID-19, along with describing the mobile-based interventions such as IVR, text messaging, and mobile applications, targeted at extending informational support during pregnancy and postpartum phase in resource-constrained areas.

2.1 Chatbots in Healthcare

In recent years, chatbots have been deployed for various purposes such as railway ticket reservation³, banking⁴, and as an empathetic AI friend⁵ to name a few. Among several categorisations, chatbots can be task-oriented or data-driven [5]. Task-oriented chatbots perform well-defined tasks and have structured conversations with users through automated responses [5]. Chatbots used for ordering food⁶ are examples of task-driven chatbots. On the other hand, data-driven chatbots interact with users by understanding and responding to their queries in a context-aware manner. These chatbots learn user behavior over time and offer personalization to users [5]. Alexa and Siri are examples of data-driven chatbots. Task-based chatbots do not offer support for unstructured conversations but keep the conversation focused on the designated task and avoid providing incorrect information using the pre-defined rules. While data-driven chatbots allow more free-form

³<https://www.irctc.co.in/nget/train-search>

⁴<https://v1.hdfcbank.com/htdocs/onChat/index.html>

⁵<https://replika.com/>

⁶<https://www.chatbotguide.org/dominospizza-bot>

conversations, they must be mindful of interpreting user queries correctly, which is of prime importance in healthcare. Chatbots can be deployed on platforms such as Facebook, Telegram, Slack, Twitch, and as stand-alone applications.

Prior research has investigated chatbots in different directions, such as chatbot for facilitating group discussions [24, 25], chatbot for encouraging self-disclosure in users with a special focus on sensitive questions [28], chatbot for offering informational and emotional support to survivors of image-based sexual abuse [30]. Research has also attempted to understand the social roles of chatbots beyond dyadic interactions [38], and the adaptive behavior of chatbots in online communities [39]. In healthcare, chatbots play varied roles, such as psychotherapists, nurses, and medicine consultants. For example, Comendador et al. [16] designed a medicine consultant chatbot to offer information on generic medicines for children. Chatbots have also been developed to assist people with mental health issues, such as chatbots offering cognitive behavioral therapy for depression⁷, and chatbots for building resilience and reducing stress in adolescent and young cancer survivors⁸. Chatbots have been investigated to deliver information on healthcare topics such as obstetric and mental health care, breastfeeding, and sexual and reproductive health. Chung et al. [15] studied the efficacy of a text-based chatbot in delivering information to perinatal women and their partners on obstetric and mental health care. The results suggested updating datasets with user queries over time for user retention and building comprehensive datasets inclusive of males' perspectives on health conditions for higher usage and impact. However, the study pilot tested the chatbot with a small sample with an uneven sex ratio. Yadav et al. [46] followed a wizard-of-oz approach to study the potential of chatbots in providing breastfeeding-related information to postpartum women residing in urban slum areas in northern India. A doctor as a wizard provided answers to queries of postpartum women on behalf of the chatbot. Another study by Rahman et al. [35] prototyped a chatbot for answering sexual and reproductive health-related queries of adolescents in Bangladesh. Both studies were conducted in controlled settings and showed positive results towards feasibility and acceptance of the chatbot and discussed the ethical concerns related to the chatbots around user trust in the chatbot and privacy around shared phones. We build on this observation of chatbot prototypes' positive feasibility and acceptability to deploy an actual chatbot, thereby understanding how an actual chatbot performs in real-world settings.

In the context of COVID-19, studies have been conducted around the development of chatbots for delivering information on COVID-19, addressing queries related to COVID-19 vaccines, and offering insights into designing chatbots in the context of COVID-19. Baal et al. developed a chatbot, CORY, to offer information on COVID, tackle misconceptions around its growth rate, and deliver behavioral intervention to encourage people to practice COVID-related safety guidelines [31]. The chatbot targets population groups comfortable with English and Vietnamese but has not been tested for its efficacy. Altay et al. conducted a randomized-controlled trial to explore the potential of chatbots in answering COVID-related concerns of French people recruited through a crowdsourced platform [7]. The authors evaluated the impact of the chatbot through surveys, mainly the potential of the chatbot in building participants' intention to get vaccinated. The study results suggested a positive change in participants' attitudes and intentions toward COVID vaccines through informational support provided by the chatbot. Luk et al. conducted a pilot study to test the efficacy of a chatbot for promoting vaccination among unvaccinated and booster hesitant among 46 young adults in Hong Kong [29]. The chatbot interacted in Chinese using a model. The authors did a four-month follow-up with the participants and found an increase in the vaccination rates among the participants. However, these studies did not evaluate the chatbot in the wild with the actual

⁷<https://woebothealth.com/>

⁸<https://hopelab.org/product/vivibot/>

population. We aim to address this limitation through our study. Another study involving chatbot for tackling COVID-19 vaccine hesitancy showed reduction in hesitancy among 574 COVID-19 patients in Japan. The authors developed a chatbot, deployed over a messaging platform, providing answers to frequently asked COVID-19 vaccine questions. The results show a reduction in vaccine hesitancy and an increment in inclination towards vaccine uptake in the target population [26]

On the other hand, Amiri and Karahanna did a literature survey to identify the use cases and design of chatbots developed for public health situations against the backdrop of COVID-19 [8]. The survey details the chatbot's different use cases, such as risk assessment, surveillance, and information dissemination. The authors highlighted the importance of making the platforms where chatbots are deployed highly accessible to widen the reach of chatbots while acknowledging the benefits of chatbots' voice-based support in bridging the digital-skill divide. We modeled our chatbot on the information dissemination use case and deployed it on the WhatsApp platform, due to it being highly accessible to our target population, to ensure wider reach.

Thus, prior studies have investigated the potential and acceptability of chatbot prototypes for delivering healthcare information in controlled settings. However, the effect of actual chatbots, which can be rapidly deployed in the wild for specific purposes is under-studied, which we aim to study in our work. Moreover, the focus is primarily on question-and-answer-based chatbots in which the task of interpreting user queries in Indian regional languages could be challenging and lead to query misinterpretation given the limited natural language processing support available. Such chatbots require human involvement to moderate query interpretation tasks to avoid health risks [35, 46]. Since human involvement is not scalable, these chatbots face limitations for deployment at scale. Thus, in our work, we deploy a rule-based chatbot that surpasses the need for human involvement and hence, can be deployed at scale with minimal risks.

2.2 Interventions for Informational Support during Pregnancy and Postpartum Phase in Resource-constrained Settings

Prior research has focused on interventions that offer informational support to pregnant and postpartum women through IVR (Interactive voice response), SMS, videos, and messaging platforms. Interventions compatible with feature phones have been developed to offer information on maternal and child health topics, such as family planning through SMS. These interventions targeted improving health behaviors such as adopting medicines and family planning practices, frequency of antenatal clinic visits, and immunization rates [34, 36]. Other interventions involving health-related information dissemination through messages include Wazazi Nipendeni in Tanzania [21], MomConnect in South Africa [9], and Aponjon in Bangladesh [6]. These interventions attempted to bridge the healthcare access gap by offering maternal and child-related health information and have shown positive results towards behavioral change in pregnant and postpartum women around antenatal visits, institutional deliveries, and HIV testing. However, SMS-based systems face the limitation of drafting messages with a certain word limit and put the cost of the service on both the implementation team and the end users. A hybrid model has also been tested to understand its effectiveness in imparting informational support to pregnant women [34]. SMS model with a human in the loop has been evaluated to address the health queries of pregnant women in Kenya. SMS was used to provide health information, while human support in the form of a nurse addressed pregnant women's queries which were either unstructured or used a mix of languages. Such hybrid systems face scalability issues due to human involvement. Further, IVR systems have also been developed to disseminate healthcare information. Studies have studied the impact of IVR-based automated calls on medical adherence among pregnant women by providing weekly reminders encouraging women to take iron supplements [33]. These IVR-based systems disseminate information on topics such as diet, antenatal visits, complementary feeding, and ultrasound tests [4, 14]. These studies

describe user experience and the slow adoption process of such interventions in low-resource areas. Radio chat shows based on IVR have been found to have the potential to offer information on maternal health-related topics in resource-constrained areas [23]. Moreover, community-led interventions have also been investigated to disseminate locally relevant and locally generated content to pregnant and postpartum women in the form of videos [27]. These community-led interventions were found to integrate well into the social constructs and state-supported health infrastructure. These interventions work well with feature phones and limited network connectivity in resource-constrained areas. However, with the penetration of smartphones in these areas, it makes sense to take the next step and utilize smartphones to deliver better healthcare interventions that, at the same time, fit well into their network infrastructure. Smartphone-based interventions such as WhatsApp-based support groups, moderated by healthcare professionals, to offer informational and emotional support to pregnant and postpartum women residing in low-resources areas have also been studied [22, 44]. The study sheds light on the healthcare needs of women during pregnancy and postpartum phases and the benefits of digital support groups in delivering healthcare information and suggests further exploring the unplatformed design model for extending healthcare support in low-resource settings. We adopted the unplatformed design approach by using WhatsApp to deploy our chatbot. We further developed the chatbot to operate without human involvement, put no cost on the end user, and could be scalable. We aim to contribute to this pool of interventions that offer healthcare support in resource-constrained settings by developing and testing interventions beyond the traditional IVR and SMS-based systems.

3 METHODOLOGY

We started with a formative study in which we conducted 15 semi-structured interviews to understand the concerns of pregnant and breastfeeding women around COVID-19 vaccination. We then developed a chatbot to tackle COVID-19 vaccine-related concerns. We followed the development phase with a user study involving chatbot deployment and assessment among pregnant and postpartum women, with the help of our collaborator NGO (Non-Governmental Organization). Post-deployment, we assessed user experiences with the chatbot and its impact through surveys and semi-structured interviews with participants and staff of our collaborator NGO.

3.1 Positionality

Our team consists of authors residing in India and the United States. All the authors have experience researching in the maternal and child healthcare domain in resource-constrained regions in India. Two of the authors identify as male, and the rest as female. One male and one female author have an education background in computer science and HCI, and the rest have a background in healthcare. The authors' experiences in conducting fieldwork related to maternal and child health have shaped the collection and analysis of data.

3.2 Participants

For our study, we recruited pregnant and breastfeeding women as participants. We connected with participants through collaboration with an NGO located in northern India. The NGO runs WhatsApp-based groups of pregnant and postpartum women, primarily residing in low-resource areas of Northern India, to deliver information and address queries on maternal and child health-related topics. Participants for the formative study and user study belonged to these WhatsApp groups and had varying COVID-19 vaccination statuses - no vaccine dose, one vaccine dose, and two vaccine doses. We circulated messages in these WhatsApp groups seeking participation from members and finally recruited those who volunteered to participate in our study. Moreover, we also interviewed members of the NGO staff to understand their experiences with deploying chatbots

Table 1. Demographics of post-intervention interview participants

Demographic	Interviews (16)
Category	Pregnant(8), Breastfeeding(8)
Age	18-24 (3), 25-34 (12), 35-44 (1)
Highest Education	Class 12th and below (3), Graduation (8), Post-graduation (3), Nursing (2)
Employment	Employed (4), Unemployed (12)
Smartphone ownership	Personal (14), Shared (2)
Vaccine status before deployment	No dose (2), Single dose (8), Both doses (6)
Vaccine status after deployment	No dose (2), Single dose (3), Both doses (11)

Table 2. Demographics of the NGO staff

Moderator ID	Age	Gender	Education	Experience of working in maternal and child health domain
Moderator1	31	Female	Bachelors in Arts	6 months
Moderator2	29	Female	Masters in Sociology	3 years
Moderator3	43	Female	Masters in Arts	2 years
Moderator4	35	Female	Double Masters in Arts	3 years
Moderator5	39	Female	MBA & Masters in Social Work	6 months
Moderator6	82	Male	MBBS & MD	>40 years

in WhatsApp groups. The demographics of the participants and the NGO staff involved in the semi-structured interviews conducted post-deployment of the chatbot are listed in tables 1 and 2, respectively. The paper mentions the formative study participants as F1, F2, and so on and, similarly, mentions the post-intervention interview participants as P1, P2, and so on.

3.3 Formative Study - Understanding COVID-19 vaccine related concerns

We first examined the concerns that contributed to hesitancy around COVID-19 vaccination. To identify the concerns, we conducted 15 semi-structured telephonic interviews with pregnant (2) and breastfeeding (13) women participants in the age ranges 18-24 (5), 25-34 (8), and 35-44 (2). Among the participants, 10 were graduates, two had completed 10th standard, two had completed 12th standard, and one had completed post-graduation. During the formative study, we tried recruiting

pregnant and breastfeeding women in similar proportions, however, we ended up interviewing more breastfeeding women, given their availability and consent. These interviews were telephonic in nature and were conducted in Hindi and later manually translated and transcribed into English for analysis using a mix of deductive and inductive thematic approach [13]. Upon analysis, we identified pregnant and breastfeeding women's concerns about COVID-19 vaccination, which hindered their vaccine uptake. We found that the women had a lack of proper knowledge along with a lack of agency around vaccine administration. The women were unsure if it was safe to get vaccinated against COVID-19 during the pregnancy/breastfeeding phase and if they should delay the vaccination. Moreover, if it is safe, what is the right time during pregnancy/breastfeeding to get vaccinated. They had concerns about whether it was safe to get vaccinated in the late stages of pregnancy or early stages of breastfeeding. The women expressed having insufficient information on the effects of COVID-19 vaccines on other health conditions, such as high blood pressure or diabetes. They were unsure if it would be safe to get the vaccine while having other health conditions; hence, they developed hesitancy due to a lack of such information. Moreover, women were also doubtful about the impact of COVID-19 vaccines on their bodies beyond developing immunity against COVID-19. They had doubts if the vaccines could result in any allergies which could adversely impact their health during pregnancy and breastfeeding. A woman shared her concern,

"I was scared of the fact that how will they inject, how is it going to react in my body. We had heard a lot of things like fever, skin issues after vaccination, so that is what I was scared of." (F10)

They wished to avoid such health risks and hence hesitated to get vaccinated. Further, the women were unsure of the effectiveness of the vaccines. They sought information on how the vaccines could improve their immunity against COVID-19. They feared the vaccine's side effects, which further contributed to their hesitancy. They had concerns such as the fear of the adverse impact of vaccination on their fertility and fetal development and also feared that the vaccine could lead to miscarriage. A woman shared avoiding any risk due to vaccination,

"I would not take the vaccine as I feel that if I had a fever my baby will have fever too. Many people had fever after the vaccine and why take all this risk during pregnancy? People are conceiving through medicines these days, and there is no reason behind risking all this for a vaccination." (F14)

Breastfeeding women were doubtful that the vaccine would have side effects on their children and could adversely impact their breast milk production. A breastfeeding woman shared how she decided against vaccination due to her concern that the vaccine would induce excess heat in her child's body, which would be harmful,

"The child was breastfeeding, so I did not take the vaccine as it was said that it can produce warmth in the child's body." (F5)

Further, the pregnant and breastfeeding women lacked knowledge on how to get vaccinated, like information on the nearest vaccination center, the cost of vaccination, and registration required for vaccination, and also lacked knowledge about post-vaccination care. A few women have had bad experiences with the first dose of the COVID-19 vaccine and were skeptical about whether they should get the second dose. They experienced post-vaccine effects such as fever and body aches after the first dose and needed clarity if they should still go ahead with the second dose and how they could avoid these effects.

In addition to a lack of proper knowledge, fear of side effects, and doubt about vaccine effectiveness, women faced a lack of agency around vaccination. They shared being denied COVID-19

vaccination by community health workers and their family members. One of the women shared her lack of agency regarding decision-making around her vaccination,

"Mam, I told you earlier that I wanted to get vaccinated, but my in-laws told me not to as the baby feeds, so I did not say much as all of them are older to me." (F8)

Given their family's disapproval of the vaccine, women could not get vaccinated despite their wish. A woman shared how her husband experienced fever, severe body aches, and heavy breathing problems post-vaccination, hence, objected to her vaccination. Thus, participants did not have the sole agency, and their decision around vaccination was influenced by the COVID-19 vaccine-related perceptions of their families and health workers. Given the objective of our study to understand vaccine hesitancy among pregnant and breastfeeding women, understanding the perception of family members and health workers due to which they advised against vaccination was beyond the scope of our current study and hence, it wasn't further investigated. Hence, women also sought help with ways of convincing their husbands/family members and health workers regarding COVID-19 vaccination. Overall, a lack of knowledge and a lack of agency contributed to vaccine hesitancy in pregnant and breastfeeding women.

3.4 Chatbot Development

Chatbot architecture: The chatbot's purpose is to deliver information on COVID-19 vaccines in Hindi to address the participants' concerns. We surveyed the WhatsApp groups to identify the language most used by our participants and observed the group members interacting with each other in Hindi and Hinglish, Hindi words written using English alphabets. Being a standard language, Hindi was chosen. Moreover, we presented numeric options for users to choose from while interacting with the chatbot. However, participants were free to type text messages in any language while interacting with the chatbot. Yadav et al. indicated getting a word error rate of 67% using state-of-the-art NLP tools in trying to understand such mixed-language messages [45]. Since the natural language understanding algorithms are not yet advanced for regional Indian languages and given that we were tackling a critical health topic, we decided to limit the abilities of the chatbot in favor of making sure that no misinterpretation of queries happens and thus no misinformation is communicated. Thus, we adopted a model to disseminate information with minimal health risks. It involves the chatbot offering a pre-defined set of options to a user and providing responses based on the chosen option. The interviews conducted during the formative study to understand COVID-19 vaccine concerns yielded codes and themes that constructed the chatbot's options which we discuss in data analysis. The options were in the form of questions, and the answers to these questions were formulated by the authors having medical background. The chatbot options were kept static and were not updated over time. Though the chatbot options could appear similar to Frequently Asked Questions (FAQs), interaction with the chatbot could offer a two-way interaction style for users to seek health information. Moreover, providing FAQs with a search function would also be challenging for users to access health information as it has been found that low-literate users have difficulty in generating search terms without any guidance that give desired results [12].

Further, the chatbot was developed over WhatsApp using WhatsApp business API purchased through a third-party vendor. We used the WhatsApp platform because of its popularity and ease of use. Our users are very familiar with WhatsApp. Moreover, building chatbots over WhatsApp is also a scalable option. It offers the provision of developing multiple chatbots and reaching out to a huge population using a single WhatsApp API. WhatsApp-based bots can spread quickly in the community as only a contact number has to be shared. The API cost was around \$100 USD monthly and was borne by the implementation team. The API provides a contact number to be associated with the chatbot, and it supports integrating a programming script with WhatsApp to

User: Hello
Saheli: Hello! 🙌 I'm Saheli, an informational chatbot. Please ask me questions if you want to get COVID-19 vaccine information for pregnant and breastfeeding women 🤰👶
Keep in mind that since I'm a chatbot, this information is not intended as a substitute for medical advice.
Thanks for Joining! What brought you here today?
1. I came to find information about COVID-19 vaccine for pregnant women 🤰
2. I came to find information about COVID-19 vaccine for breastfeeding women 👶
3. I have other questions about the vaccine 🤔
Please choose the digit corresponding to the option you want to choose.
User: 1
Saheli: Thanks for sharing that. 🙌
To help me get you the correct information, please tell me if you are
1. I am pregnant 🤰
2. I am breastfeeding my baby 👶
3. I am looking for resources to share with my family, friends, community 🤝👶👶
Please choose the digit corresponding to the option you want to choose.
User: 1
Saheli: 1. I am pregnant. Can I take Covid Vaccine?
2. How can I get the Covid Vaccine dose?
3. I am worried that COVID vaccine might harm me and my baby, I want to know what are the side-effects of COVID vaccine?
4. I am pregnant, what special care should I take post taking COVID vaccine?
5. My family/doctors do not allow me to take vaccine dose during pregnancy, what should I do?
6. When should I get my second dose of COVID vaccine?
7. Where can I get reliable information about COVID vaccine?
User: 1
Saheli: 1. I am pregnant, which COVID-19 vaccine should I get and when?
2. How can vaccine improve my protection against COVID?
User: 1
Saheli: Pregnant women may take any one of the two Covid-19 vaccines (Covishield and Covaxin) at any time before and after delivery. Two doses are needed for full protection. Two tetanus toxoid vaccines are also given during pregnancy, by the ANM at the subcenters.
Saheli: To help me get you the correct information, please tell me if you are
1. I am pregnant 🤰
2. I am breastfeeding my baby 👶
3. I am looking for resources to share with my family, friends, community 🤝👶👶
Please choose the digit corresponding to the option you want to choose.

Fig. 2. Example of a chat session

a friend in English, and informs the user about its purpose of providing information on COVID-19 vaccines and also informs users that it is not a replacement for a doctor. At the same time, it presents menu options enquiring whether the user is looking for information on the COVID-19 vaccine related to pregnancy or breastfeeding or in general. For either option, the chatbot follows up with a set of menu options for the user. Fig 1 represents our chatbot's workflow. Fig 2 represents an example of a chat session between a user and our chatbot, Saheli. The chatbot also sends a three-question feedback survey to the users once a week after any one conversation. The survey provides an overview of chatbot engagement. The survey included questions - "How did you find chatting with the chatbot?", "Did you find the information provided by the chatbot useful?", and "Would you like to get the COVID-19 vaccination after talking with the chatbot?". These survey responses contributed to understanding participants' experience with the chatbot. Fig 3 and Fig. 4 show snapshots of chatbot interaction.

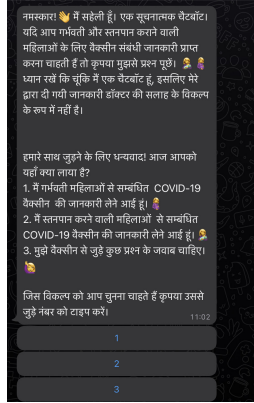


Fig. 3. Introductory message sent by the chatbot

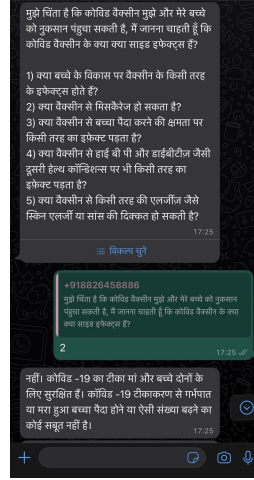


Fig. 4. A snapshot of message exchange between a user and the chatbot

3.5 Data Collection

We followed up the formative study and chatbot development with a user study to understand user engagement with the chatbot. For this, we deployed the chatbot over WhatsApp on February 15, 2022. The NGO's staff advertised the chatbot's WhatsApp link in 12 WhatsApp groups run by our collaborator NGO. Along with the chatbot link, a message was sent to the groups seeking participation from the members. Through the message, participants were informed about the study objective and, further, about the collection of their chat logs with the chatbot, which will be analyzed by the research team for research purposes and will not be shared outside the research team. We collected participants' chat logs to understand the nature of message exchange between the participants and the chatbot. The chatbot has been discontinued due to no user participation. For analysis, we considered chat logs collected till March 9, 2022. We initially observed a high participation rate, with the number of users interacting with the chatbot reaching 288 in a day. However, when the participation rate dropped to only four or six users interacting with the chatbot per day over consecutive days, we stopped considering chat logs for analysis. Overall, we observed participation from a total of 829 users till March 9.

On March 10, we released our post-intervention survey using Google Forms to understand participants' experience with the chatbot. The NGO staff informed us that the group members are well-versed with Google Forms, hence, we decided to use Google Forms for our survey. The survey was open for all the WhatsApp group members irrespective of their chatbot usage, however, responses were filtered and considered of only those members who used the chatbot at least once. The survey was conducted in Hindi, considering the literacy levels of the pregnant and postpartum women connected with the NGO. The survey provided deeper insights into participants' engagement with the chatbot and how they perceived the chatbot in the future. The survey comprised 14 questions, including, "What did you like most while interacting with the chatbot?", "Did interaction with the chatbot help you to decide in favor of getting the COVID-19 vaccine?", and "Which other topics do you think the chatbot can provide you information on to support your pregnancy/postpartum phase?". The survey received 442 responses, with 109 responses from

pregnant women, 242 responses from breastfeeding women, and 84 responses from respondents who were neither pregnant nor breastfeeding and were family members/friends of the WhatsApp group members, while seven didn't mention whether they were pregnant or breastfeeding. The respondents lie in the age range 18-37 years, and most had either graduation or post-graduation as the highest educational qualifications.

The post-intervention survey was followed by post-intervention semi-structured interviews with 16 participants. All the interview participants were first-time chatbot users. Based on the chat log analysis, we selected interview participants with varied chatbot usage. We selected some participants who had used the chatbot for a day, some who had used it for two days, and so on. We made the selection keeping a balance between the number of pregnant and breastfeeding women. Interviews with participants provided deeper insights into their experiences with the chatbot, such as its affordances and perceived impact. Interviews with participants included questions such as "Do you find any advantage in the way the chatbot provides you information?", "Did you get the vaccine after talking with the chatbot?" and "If given a chance, how would you improve this chatbot?". To further understand how the chatbot impacted participants' inclination towards vaccination, participants were probed further on the question, "Did you get the vaccine after talking with the chatbot?" with questions such as "If you got the vaccine after talking with the chatbot, how did the chatbot help you to decide in favor of vaccination?", "If you did not get the vaccination after talking with the chatbot, then what was the reason behind not getting vaccinated?". "If you were double vaccinated before talking with the chatbot, then did the chatbot help you in any way?". Moreover, we also interviewed six NGO staff members responsible for circulating the chatbot link in the WhatsApp groups and managing participants' chatbot-related queries. NGO staff provided insights into the efforts required at the NGO's end to deploy the chatbot in the community of pregnant and postpartum women. Interviews with NGO staff included questions such as "What changes did you make in managing the groups due to the introduction of the chatbot?". We identified the strategies adopted by the staff and how they visualized chatbots for supporting the healthcare needs of pregnant and breastfeeding women in the future.

3.6 Data Analysis

The formative phase interviews were transcribed and translated into English and further analyzed. The codes emerging from the analysis were grouped into themes. For example, the theme 'How can I get the COVID vaccine dose?' had corresponding codes - 'Do I need to register to get the vaccine?', and 'Do I need to pay to get the vaccine?'. These themes and codes formed the chatbot menu options. The themes formed the first-level menu options, and the codes formed the second-level menu options.

The chat logs were analyzed using scripts written in the Python programming language to draw insights into users' engagement patterns, such as the time spent interacting with the chatbot and the chatbot options explored by the users. The post-intervention interviews and open-ended responses from the post-intervention survey were translated and transcribed in English for analysis using an inductive thematic approach [13]. The codes emerging from the analysis were discussed among the authors and finally grouped into themes. For instance, first-level codes include, 'Initially reluctant to use chatbot thinking that the number showing after opening the link is someone unknown' and 'Afraid that clicking link might result in annoying repeated calls about getting vaccine which might cause the family to react'. The corresponding second-level code is 'Misconceptions about chatbot link,' and the final theme emerged as 'Interaction challenges'. Further, the closed-ended responses from the post-intervention survey have been counted against the total number of responses received for that closed-ended question. The chat logs, surveys, and semi-structured interviews informed users' experiences with the chatbot, which we present in the following section.

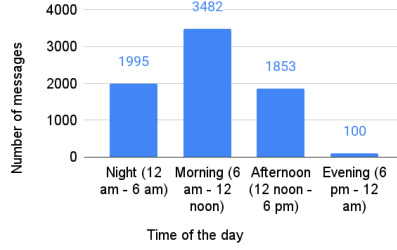


Fig. 5. Number of messages sent by participants across the day

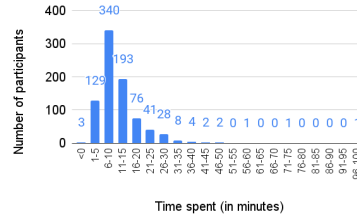
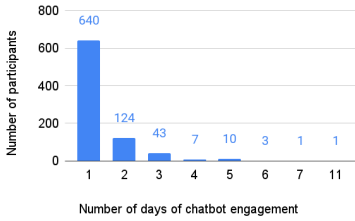


Fig. 6. Number of days participants engaged with the chatbot

Fig. 7. Time spent (in minutes) by participants engaging with the chatbot

4 FINDINGS

In this section, we report findings from the user study we conducted in the wild to understand user experiences with our chatbot.

4.1 Understanding User Engagement with the Chatbot

We analyzed chat logs, surveys, and interviews to understand how pregnant and breastfeeding women adopted the chatbot, what information they looked up in the chatbot, and the challenges they faced in engaging with the chatbot.

4.1.1 Adoption. We found that the participants adopted the chatbot with different motivations, such as clarifying their doubts regarding the COVID-19 vaccines and getting more information about the vaccines. Apart from these motivating factors, other factors also played a crucial role in chatbot adoption.

Participants' trust in the NGO and its staff aided the chatbot adoption. Participants trusted the NGO services since they proved helpful in the past, which translated to their trust in the chatbot introduced by the NGO. A participant shared a similar sentiment,

"Nowadays, links are shared, which result in fraud. I trusted the chatbot because its link was shared in the group ... I felt it has been created by some authority. I didn't feel there would be any information loss." (P10)

Peer network also played an important role in encouraging participants to use the chatbot. WhatsApp group members who used the chatbot shared their positive experiences with the chatbot in the group. They discussed the ease of interacting with the chatbot to clear their doubts and further encouraged other group members to use the chatbot.

Table 3. Chatbot option with corresponding frequency of visits by participants during deployment over 23 days

Chatbot option	Frequency of visits	Position of the option
I would you like to know where else can I get trusted information about the vaccine?	140	7
I am breastfeeding and have received the COVID-19 vaccine. Can I continue or should I stop for some time?	70	4.3
I am breastfeeding my baby, which vaccine should I get and when?	65	1.1
I am pregnant, which COVID-19 vaccine should I get and when?	50	1.1
How can I convince my husband/family?	48	5.2
Are there any effects of vaccine on breastmilk production?	42	3.1
Are there any effects of vaccine on fetal development?	26	3.1
I experienced bad effects from the first COVID vaccine dose. Should I get the second dose?	19	6.2
I am pregnant, should I delay getting the vaccine?	18	5.1
How can I convince my healthcare providers?	16	5.3
How can vaccine improve my protection against COVID?	15	1.2
Which is the nearest health centre where I can get vaccinated ?	15	2.2
What care should I take during pregnancy after getting vaccine?	15	4.1
Can vaccine lead to miscarriage?	14	3.2
How can vaccine improve my immunity against COVID?	14	1.2
Can COVID vaccine cause any allergies, skin or breathing problems?	13	3.5
Do I need to register to get the vaccine?	12	2.1
What precautions should I take to avoid COVID after vaccine?	11	4.2
Do I need to pay to get the vaccine?	9	2.3
Should I get a certificate after vaccination?	8	2.4
Are there any effects of vaccine on fertility?	7	3.3
What care should I take during postpartum after getting vaccine?	6	4.1
Are there any effects of vaccine on other health conditions such as high blood pressure or diabetes?	5	3.4
Should I postpone my second COVID vaccine dose if I am in late pregnancy or recently given birth?	5	6.3
When should I get my second dose of COVID vaccine?	5	6
I am breastfeeding, should I delay getting the vaccine?	3	5.1

"Other group members shared their experiences with the chatbot. Through their experiences, I got to know that it is safe to use the chatbot, and it must be beneficial if so many members are using it." (P02)

These positive experiences gave the perception of the chatbot's usefulness to the group members who hadn't interacted with the chatbot assuming it to be unhelpful and motivated them to use it.

On the other hand, our collaborator NGO also devised their own strategies for encouraging chatbot adoption among pregnant and breastfeeding women in the WhatsApp groups. These strategies were not initially consulted with the research team and were adopted by the NGO on their own accord, but later on, seeing increased participation and usage tracking, the research team decided to continue with the strategies. Prior to deploying the chatbot, the NGO staff started discussions around group members' COVID-19 vaccination status and their challenges in getting vaccinated to draw members' attention to the topic. This was followed up with introductory messages to inform group members about the chatbot's purpose and encourage them to engage with it. Moreover, when a few group members raised questions about interaction with the chatbot, the NGO staff shared a message explaining the step-by-step procedure for initiating a conversation with the chatbot. Further, after three days of deployment, the NGO staff sent reminder messages twice a day to encourage members to interact with the chatbot. The NGO staff also asked the members to share screenshots of their interaction with the chatbot in the group to track the chatbot usage. Through the screenshots, the staff traced and encouraged those who had not used the chatbot. Moreover, as a part of the routine workload, the staff members made 20 calls daily to the members of the groups they were managing to discuss their health. In these calls, they enquired about their chatbot usage and encouraged those who did not use the chatbot with explanations about the benefits of the chatbot. In addition to the above strategies, the NGO staff, on their own accord, suspended the group's regular discussions about health topics to keep the discussion around the chatbots; however, they announced in the group asking members to discuss their other health queries over call. During the deployment, they focused on the members' chatbot usage and asked them to share their experiences with the chatbot in the group, hoping the experiences encouraged others to engage with the chatbot.

4.1.2 Engagement. We studied message exchange between participants and the chatbot to identify the engagement pattern of participants. The message exchange informed not only the participants' COVID-19 vaccine-related concerns but also their other health-related concerns.

Statistics on usage: Participants exchanged 7430 messages with the chatbot, with the average number of messages per participant as 9. The average number of user sessions, uninterrupted conversation after which the session was reset, was 2 (min. 1 and max. 17). We observed the participants interacting with the chatbot mostly from 6 A.M to 12-noon. Fig. 5 shows the exchange of messages across the day. Most of the participants, 640 in number, engaged with the chatbot for one day, while one participant interacted with the chatbot for 11 days. Fig. 6 shows the number of days participants engaged with the chatbot. Moreover, fig. 7 shows the time duration spent by the participants interacting with the chatbot.

Topics visited: We found that the participants explored the breastfeeding-specific options 212 times and pregnancy-specific options 116 times. Breastfeeding-specific three most visited topics included the continuation of breastfeeding after vaccination, vaccine suitable for breastfeeding women, and the effect of breastfeeding on breastmilk after vaccination. At the same time, pregnancy-specific three most visited topics included vaccines suitable for pregnant women, the timing of vaccination for the second dose based on the pregnancy phase, and delaying vaccination. Most visited topics common across pregnancy and breastfeeding included reliable sources for information lookup related to vaccination, timings of vaccine doses in general, and on facing infections after the first

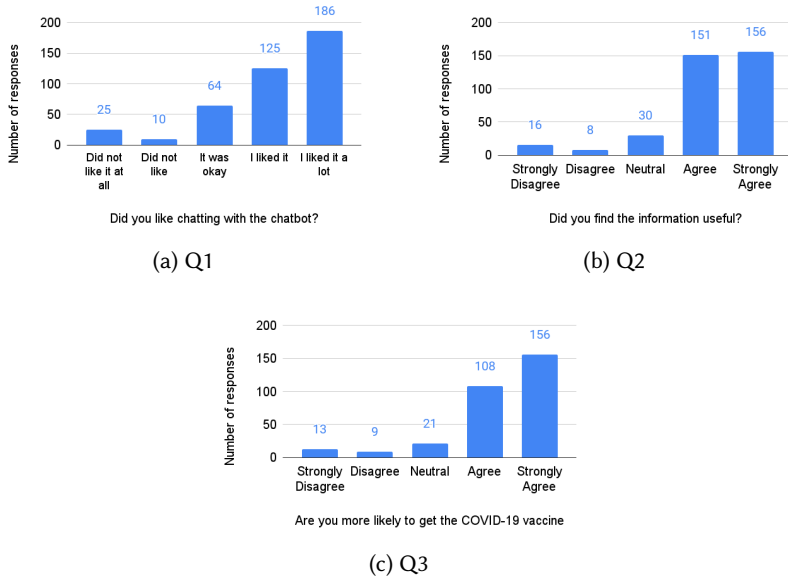


Fig. 8. Feedback on the chatbot engagement given by the users through the weekly surveys

dose. Table 3 presents an overview of all the chatbot options visited by the participants. First column shows the option, the second column shows the number of times an option was visited, and the third column shows the position of the option in the chatbot. The notation followed for the position is X.Y, where X denotes the option's position in the first-level menu, and Y denotes the option's position in the second-level menu. For example, 6.2 means the option is at the sixth position in the first-level menu and the second position in the second-level menu. We found the frequency of visits to the chatbot options to represent the user's interest in the options. Upon analysis, we found that the option most visited by the users was placed at the bottom of the menu with many options. Similarly, several options which were not at shallow depth were found to be frequently explored by users. This depicts that users visited those options which were relevant to them irrespective of the placement of these options.

Topics missing: Participants looked up certain information on vaccines that the chatbot could not provide. The topics included issues with menstrual periods after vaccination and the possibility of getting vaccinated if on periods, information on boosters, initiation of breastfeeding after vaccination, and vaccination after experiencing a miscarriage. An example of text messages sent by participants seeking the above information include - "If someone had a miscarriage, should she get the COVID-19 vaccine or not?".

Additional information lookup: Apart from the information on vaccines, participants sent text messages asking questions related to pregnancy, breastfeeding, family planning, and childcare. Examples of text messages sent by participants for information beyond vaccine include - "Till when should a baby be breastfed?" and "What must be the time difference between the first and second baby?". Since our chatbot focused on COVID-19 vaccination, it did not provide responses to such queries.

4.1.3 Challenges. Participants faced a few challenges that affected their interaction with the chatbot.

Confusion with the chatbot link and behavior: A couple of participants assumed the chatbot to be a mobile application to be downloaded from the play store. Hence, they got confused when the link did not lead to the mobile play store and instead opened a WhatsApp chat. They cleared their confusion from the NGO staff. A few participants were doubtful about where the link would lead to. A participant shared,

"Initially, I was scared to use the link. I thought if I click the link, then my details would be tracked, and I would receive repeated calls regarding vaccination. With such calls, my family would have got irritated." (P4)

Moreover, participants could not comprehend the reason behind the unresponsiveness of the chatbot, which happened due to a technical glitch in the WhatsApp API that lasted for a day. They assumed the chatbot to be non-functional when they did not receive any reply and, thus, discontinued using the chatbot. A participant felt that the chatbot was unresponsive because she explored similar menu options repeatedly, and thus she stopped using the chatbot. Moreover, a few participants expressed getting confused with the chatbot's inability to provide answers to the questions typed by them. The chatbot did not recognize messages beyond the presented options during the conversation, and the participants failed to understand this behavior. This lack of understanding of the chatbot's behavior confused the participants and affected its usage.

Static nature of the chatbot: A few participants expressed interacting with the chatbot repeatedly, hoping to receive new and updated information. However, when they realized that the chatbot provided static information, they discontinued using the chatbot. The information once fed to the chatbot remained the same during the deployment, hence, the participants could not get any new information after exhausting the options offered by the chatbot. Thus, without continued knowledge gain, the chatbot's engagement received a setback.

4.2 Understanding Affordances and Impact of the Chatbot

In this subsection, we present the affordances offered by the chatbot and the impact it had on participants. We describe below the affordances of the chatbot perceived by participants.

Timeliness of the chatbot replies: All the interview participants appreciated the quick replies received from the chatbot. A participant shared,

"The chatting style is good. It gives an immediate reply. It gives an option, and we click on an option. For any doubt, it gives the answer in a good way. Then it again gives options." (P2)

We observed a similar trend in the survey, where 310 out of 375 (82.6%) survey respondents, who attempted the question on timely access to information using the chatbot, expressed getting information quickly from the chatbot. Moreover, participants found the chatbot to fit well into their routines as it provided answers 24/7 and did not extend help in a time-bound manner. Participants shared being occupied during the day with their household chores and babies and getting time for themselves late at night. They leveraged the chatbot's 24/7 availability to fit their own availability.

Convenience of chatting style: Participants were impressed that the chatbot offered options for queries without needing them to type their concerns. Participants found it convenient to seek information on their concerns with minimal typing effort by selecting an option and receiving a quick reply. Moreover, participants expressed that sometimes framing their healthcare concerns as a question becomes challenging. The chatbot covered up this challenge by offering the ease of selecting an option aligning with their concern to get the information. A participant shared the complexities of typing healthcare concerns,

"If we have to google, we have to type or speak, and the language to convey is sometimes difficult. In chatbot, there are options and answers which are very good" (P13)

The chatbot supported the language complexities and typing effort involved with asking the health query by offering ease of selecting options.

Authentic information: Participants' desire for a single well-constructed authentic answer to their healthcare query was met by the chatbot. Participants shared facing challenges in seeking an authentic solution on platforms like Google and YouTube. A participant voiced this emotion as,

"Searching on the Internet gives multiple videos. Every video presents a different idea, which causes confusion." (P4)

Participants, who could access and search for information on Google and YouTube, expressed getting multiple answers from these online sources, which resulted in confusion due to their inability to confirm the authenticity of the information. On the other hand, the chatbot provided an unambiguous authentic answer. Moreover, we observed a similar trend in the survey where almost all the survey respondents (334/368, 90%), who expressed their opinion on the understandability of the information provided by the chatbot, found it easy to understand the information. Hence, the information disseminated by the chatbot was well-received by the participants.

Minimal learning curve: Unplatformed use of WhatsApp for deploying the chatbot was perceived as helpful by the participants. The participants were familiar with WhatsApp and could understand chatting with the chatbot by themselves and required minimal support from the NGO staff to interact with the chatbot. In support of the unplatformed design, a participant shared the challenges encountered in adopting new systems,

"Not everybody is educated, however, any person, young or old, can use it (chatbot). It is easy. We cannot use every app, you need to open it, input details, and type things. Not everybody can do that. In chatbot, it gives answer easily, and it's easy to understand." (P8)

Adaptability to the poor network infrastructure: chatbot also adjusted well to the poor network infrastructure of the participants. Most of our participants resided in low-resource areas and faced poor network connectivity. A participant shared,

"Internet does not work well in the village. The Internet is not strong enough to use YouTube. WhatsApp works well despite the weak Internet" (P2)

Poor connectivity made it challenging to use platforms like YouTube to access health information. Our chatbot could work well under these poor network constraints as it did not require high bandwidth to offer healthcare support.

Further, we wanted to assess the impact of the chatbot in real-world settings. We tried identifying how the chatbot impacted the participants' knowledge and behavior toward COVID-19 vaccination.

Knowledge gain and validation: Almost all the participants shared that not only they were able to clear their doubts from the chatbot, but also they were able to learn more about the COVID-19 vaccine. Participants had mixed vaccination status - no, single, and two doses. Despite their vaccination status, the participants felt that the chatbot contributed to knowledge gain regarding the COVID-19 vaccines. A participant shared,

"I had questions about vaccines. People in my neighborhood used to say that one should not get the vaccine and that if I take the vaccine, I will not be able to get pregnant. Through the chatbot, I got to know it will not affect my pregnancy" (P5)

A similar observation was made in the survey, where 332 out of 373 responses (89%) regarding knowledge gain showed knowledge gain in respondents after chatbot interaction. The chatbot presented the participants with options from which they could identify their concerns and also learn about other possible aspects of their concerns. Participants expressed looking for an option related to their concern and at the same time, also exploring other related options that haven't yet

occurred to them. Moreover, participants looked up information relevant not just to their current phase but also beyond that. In the interviews, pregnant women expressed exploring chatbot menu options pertaining to breastfeeding to ensure the safety of the vaccines during their next phase. Additionally, few participants interacted with the chatbot to validate their retrospective choice. A few breastfeeding participants, who had gotten the first dose during the early months of pregnancy, interacted with the chatbot to confirm if doing so was safe. Similarly, those who had both doses shared that they could clear their unresolved doubts after getting vaccinated. Participants with both doses shared that they got vaccinated but were not completely aware of the vaccine's effects on their health. They either did not seek clarifications from others or were unsatisfied with the provided clarifications. They found the chatbot a convenient option because it was readily available to seek or validate information. Moreover, participants gathered information that would help not only them but also other women similar to them. A participant shared,

"I had got both the doses, but I explored all the available options to know about vaccination so that I can help those who do not know." P14

Thus, few participants explored the options related to both pregnancy and breastfeeding to gain knowledge and share the same in their social circle.

Fostering vaccination intention and administration: Beyond knowledge gain, the chatbot was able to aid participants' decision-making regarding COVID-19 vaccination. After interaction with the chatbot, those participants who hadn't been vaccinated were able to form an opinion on whether to get vaccinated or not using the information gained from the chatbot. Participants expressed that the chatbot was a convenient option for them to get vaccine-related clarifications based on which they were able to build their decision. Amid different notions about vaccines among their family members, and community health workers, participants perceived the chatbot to provide accurate information believing the information to be vetted by the NGO staff. A participant shared how she wanted to delay her second dose initially but eventually changed her decision after her interaction with the chatbot,

"I would not have got the second dose, and nobody would have known that. From chatbot, I got to know that it is beneficial for the baby and could also be got in pregnancy and after delivery." (P8)

Those who developed the intention but could not get vaccinated were facing disapproval from their family members or healthcare staff, such as ASHA workers⁹. Family members believed the vaccine could harm the woman and the child and thus objected to the vaccination. Given the power dynamics, those women decided not to get vaccinated. However, they could clear their concerns from the chatbot and still develop a decision on whether they themselves want to be vaccinated or not. A participant shared,

"I wanted to get the vaccine but my husband is against it so I cannot get it. I showed the chatbot to my husband to tell him that vaccines are safe but he didn't approve of vaccination. My parents-in-law also didn't approve due to fear of mishappening as it is my first pregnancy" (P3)

They tried convincing their family members regarding vaccination using the chatbot, however, where the opinion of COVID-19 vaccines being harmful was quite prevalent, the participants could not convince their families for vaccination. On the other hand, a few participants mapped the knowledge from the chatbot to encourage their family members to get vaccinated. They felt that

⁹ASHA (Accredited Social Health Activists) workers are frontline health workers employed by the Ministry of Health and Family Welfare, India. They are responsible for connecting the rural population with the state health system. Their responsibilities include counseling women on birth preparedness, safe delivery, nutrition, breastfeeding, immunization, contraception, prevention of common infections, and childcare.

since the vaccine is safe for pregnant and breastfeeding women, it would also be safe for others and hence tried building intention in their family members for COVID-19 vaccination. A participant shared,

"I told my mother-in-law that I am breastfeeding and my condition is more sensitive than hers, and if I can get the vaccine, so can she."(P13)

Based on the participants' feedback to the three questions asked by the chatbot once a week, we realized the chatbot's effectiveness in building intention for COVID-19 vaccination among the participants. Figures 8 present participants' feedback on the three questions asked by the chatbot. We observed a similar trend in the survey, where 367 out of 379 responses (96%) showed that the chatbot helped the survey respondents decide in favor of vaccination. Hence, the chatbot could build participants' intention for vaccination, which also translated into actual vaccination for some.

Hence, the chatbot could aid participants' decision-making regarding vaccination positively and contribute to their knowledge about vaccines. However, we cannot attribute interaction with the chatbot as the sole factor behind the participants' vaccination. We believe the chatbot helped the participants decide in favor of vaccination, but there would have been other factors also influencing their vaccination which we did not investigate in the current study.

4.3 Understanding Aspirations around Chatbots for Healthcare

Participants visualized the application of chatbots for healthcare support beyond COVID-19 vaccination and also identified certain extensions of the current chatbot.

Non-judgemental space: Participants felt that chatbots have the potential to offer private and non-judgemental space to them. They can seek information from chatbots on health topics they otherwise feel hesitant to discuss with healthcare professionals and their family members. A participant shared how a chatbot could help clear her doubts regarding sex after delivery,

"I will be more comfortable talking about sex to chatbot ... We are not having sex because I have doubts. If the child is being breastfed, will there be any harm to the baby? How much time before or after the sex can I breastfeed the child? I feel embarrassed to ask this from anyone. I don't feel good about discussing this with others." (P2)

Participants feared judgment from others when discussing certain health topics such as sex, contraception, and health issues in private parts and felt that the chatbot could support them in discussing these health topics. Moreover, a participant shared her hesitancy to ask health-related doubts from community healthcare workers in group settings and felt that the chatbot could offer her a personal space,

"ANM (Community health worker) said we should get the vaccine, but I had doubts. I could not ask ANM because at that time, there were women from our village there, and there was a huge crowd. I was concerned that I would have to ask in front of the crowd." (P1)

Participants also desired chatbots to offer healthcare information on a myriad of topics spanning the first 1000 days of pregnancy and motherhood. Topics included hygiene, nutrition, baby movements, labor pain, breastfeeding, post-delivery care, child and mother vaccination, and child-related issues such as teething. Other topics included staying stress-free while looking after the house and children, child education, strategies to manage time with the child, and reinforcing the feeling of mothers doing something meaningful for themselves apart from looking after the child and their house. Thus, the participants perceived chatbots to support their healthcare needs and provide a sense of their identity during motherhood.

Human-bot collaboration: Participants perceived chatbots to serve as a channel of health information along with the human healthcare support available to them. For instance, one of the participants shared,

"NGO staff also have a workload, they are busy with calls. If we have a chatbot, we can ask our doubts from the chatbot first, and if they are not clear, then we can ask from NGO staff." (P10)

Participants had access to NGO staff, healthcare professionals, and their family members to seek health information. However, a few participants expressed receiving delayed support for their urgent queries from the NGO staff due to their workload. Visiting healthcare professionals in hospital settings was also challenging for participants due to mobility constraints. Further, they had doubts about health-related knowledge and beliefs shared by their family members and neighbors. Participants perceived the chatbot to offer information to their health queries in a timely and remote fashion. They desired health experts' support when the chatbot failed to resolve their queries satisfactorily. A similar finding was observed by Yadav et al. [46], who also highlighted the desire of breastfeeding women to use chatbots as the first point of contact. Moreover, some participants believed that the chatbot provided well-structured information on their concerns but did not provide detailed guidance like NGO staff. They preferred contacting health experts to gain an in-depth understanding of their health concerns, such as the reason behind their health problems based on their lifestyle. Participants further expressed missing out on the experiential knowledge of the group members, which they get in the WhatsApp groups when they ask their queries or participate in the daily group discussion. The participants could identify the limitations of the chatbot; hence, they desired health experts' support to cover up for knowledge and experiences not addressed by the chatbot.

Question-answering support: A participant found the chatbot's style of providing information, using multi-level menu options, inconvenient as compared to direct answers available in the WhatsApp group. The participant felt more time is spent navigating options compared to directly putting up a question. Some participants also suggested providing typing support as an additional feature to the chatting style of the chatbot. They suggested that the chatbot should provide options, but for concerns outside the options, they should be able to type to ask questions. Participants expressed having more doubts when scanning the chatbot menu options, which at times, they failed to find in the menu options. A participant shared,

"Bot gives an answer for a doubt, but if we have other related doubts then it might not have an answer ... it might also not have all the options" (P10)

They desired to resolve those doubts from the chatbot itself by typing questions. However, the participants perceived asking questions from the chatbot as similar to that in WhatsApp groups and were unaware of the underlying complexities of interpreting mixed language questions by the chatbot. These participants were similar in demographics and literacy levels to those who found the chatting style of menus convenient.

Chatbot integration to enhance NGO's workflow: The NGO staff suggested making the chatbots diverse enough to provide information on varying health topics related to the first 1000 days of pregnancy and motherhood. The NGO staff desired to delegate the tasks of answering basic factual health queries to the chatbot to focus on managing discussions in the WhatsApp groups in which the members get an opportunity for experiential learning and also on group members having certain health complications. They perceived the chatbot as a useful tool to offer healthcare information to group members, which could aid their self-learning and, at the same time, reduce their workload.

Thus, participants' aspirations reflected the pathways for future use of the chatbot as a tool for getting healthcare support in a non-judgmental and timely fashion. Participants could identify the extent of using a chatbot for their health needs in the future. Moreover, NGO staff also visualized chatbots as a support in their workflow.

5 DISCUSSION

In our work, we wanted to understand how chatbots can help in addressing vaccine hesitancy among pregnant and breastfeeding women. Our findings suggested different ways in which users interacted with the chatbot and learned from it in the context of vaccine uptake. The findings also suggest the challenges and limitations that users faced and what they desired from the chatbot. Learning from our experience, we discuss how chatbots can be used for addressing vaccine hesitancy, what methods can be used to engage users with chatbots and retain them, and also how chatbots are perceived by first-time users in low-resource settings. Through our discussion, we would like to bring forth future design guidelines for the development and deployment of chatbots for effective implementation, especially in the context of vaccine uptake.

5.1 Vaccine Hesitancy & Chatbots

Vaccine hesitancy is observed across the globe. A primary reason arising from the lack of knowledge remains to be the uncertainty associated with outcome and side-effects. In India, typically, there is a positive notion for vaccination, and it is highly encouraged for maternal and child health. However, Covid-19 was a new and deadly infection with little understanding, and its vaccines were also newly developed, which caused hesitation among pregnant women. As indicated by our research, at times, they were discouraged by community health workers because of the lack of knowledge about the vaccines and doubts about their effectiveness. Previous research[43] on understanding the factors responsible for influencing vaccine hesitancy in pregnant women has also revealed the factors to be lack of proper knowledge of vaccines and mistrust of the effectiveness of the vaccines. Moreover, in our study, we also found that the pregnant women's decision-making around vaccination was also affected by the perception and attitude of their husbands and family members and recommendations from healthcare workers.

Hence, we believe that interventions like chatbots have the potential to tackle hesitancy and improve decision-making not just for COVID-19 vaccination but also for other vaccinations by addressing the core issue of lack of awareness. Research by Jarrett et al. also found that the factors helpful for the effectiveness of interventions targeted at vaccine hesitancy include increasing vaccine knowledge and awareness and tailoring interventions for specific population groups having hesitancy [20]. Our chatbot attempted to incorporate these factors, which favored its adoption and usage.

In previous research, Becker et al. [10] proposed a mobile app to provide information and encourage the decision-making of parents for children's HPV vaccination. The app was designed to help build participants' intention for the vaccination, awareness, and knowledge around HPV. However, some participants failed to retain information due to low engagement with the app. Participants reported forgetting to use the app and suggested push notifications to remind them to use the app. We leveraged this finding to develop the intervention on a frequently used and popular platform - WhatsApp - and used reminder prompts to keep the participants reminded of the chatbot. Moreover, people use WhatsApp anyway for their other daily activities, so reminders are sufficient for using the chatbot within the app. Moreover, unlike any app, people are already familiar with WhatsApp and thus do not require any training. WhatsApp is also optimized to work on low-end phones as well as in poor bandwidth environments and is robust to crashes and other problems that a mobile app may encounter. We found our chatbot to positively influence support

the participants regarding knowledge gain and intention around the COVID-19 vaccination. Our findings hint at the potential of the chatbot to tackle hesitancy around vaccinations in general. In India, the Ministry of Health and Family Welfare considers pregnant women to be at a high risk of influenza, and Influenza infection can lead to high hospitalization rates and fetal and maternal deaths [11]. However, the uptake of influenza vaccine is low among pregnant women [18]. Thus, it would be interesting to explore how chatbots can contribute to tackling hesitancy for other such vaccines. We observed that family members and health workers influence the decision-making of pregnant and breastfeeding women around vaccination. Hence, chatbots can also be used to educate family members and health workers to change their knowledge and attitude around vaccination. Yadav et al. [46] have also suggested using chatbots as an educational intervention for community health workers to educate them on breastfeeding. Similarly, chatbots can be used to educate family members about vaccination.

Moreover, chatbots could disseminate information using audio and videos along with text to serve those with low literacy levels who find reading challenging. The menu-based approach also presents an opportunity to inform users of concerns beyond their immediate doubts, therefore, expanding their knowledge base. The chatbots also have the potential to provide healthcare information in a more personalized manner. The chatbot could first ask a series of questions to understand the user's health conditions, existing knowledge, and concerns and can then provide follow-up options to offer a more personalized experience. Combined with the fast pace by which such chatbots can be built and spread for specific applications, we believe that more research exploration is needed to measure the utility and effectiveness of such chatbot-based interventions for vaccination and other healthcare problems.

5.2 User Engagement & Retention for Chatbots

We developed a menu-based chatbot with focused information available for the users. While the development and deployment of such chatbots is extremely fast and easy, they do suffer from user engagement issues arising from the exhaustion of information available to the end-user. We continuously monitored the usage of the chatbot and observed a peak of 288 users in a single day engaging with the chatbot to as low as one or two within the span of deployment.

Initially, when participants started interacting with the chatbot, they could find new knowledge to gain. However, after having exhausted the chatbot menus, they could not gain more information from the chatbot. Few of those participants who interacted multiple times with the chatbot expressed that they did so with the motivation to seek updated information from the chatbot. This finding provides an important design direction for the future. A possible way of developing this chatbot could be to observe the use of the chatbot and then push new information dynamically to users as they complete existing information on the chatbot. This could be done periodically [15] or adaptive to user engagement, i.e., the updated rate could be higher for active users and so on. However, new information has to be added to the chatbot in a way that does not result in the user being overwhelmed by the elaborative and multi-level menu options presenting an abundance of information. Different mechanisms can be adopted to avoid this information overloading, such as removing the oldest menu options before pushing the new ones or clubbing different menu options or their information together concisely.

Post-deployment data indicated the desire of participants to have chatbots on other relevant health topics, like the first 1000 days of pregnancy and maternal care, such as understanding baby movements and post-delivery care. Participants' suggestions also focused on taboo topics related to women's health, such as sex, family planning, menstruation, and body image. These suggestions are similar to findings presented by [46], where breastfeeding women sought answers to sex-related queries from the chatbot. In India, in addition to limited healthcare access, there is

hesitancy to discuss sensitive topics related to sexual health. Thus, participants desired to leverage the one-on-one interaction offered by the chatbot to seek help on topics they hesitate to discuss with their families and healthcare professionals.

Adding all the different health topics in one chatbot all at once could overwhelm users and may also deviate from the specific task, e.g., vaccine hesitancy in our case. So, it is better, as discussed earlier, to add topics with time and as the user progresses. This may also provide a level of personalization, and users may find the chatbot to be a personal resource for information. In the context of low and middle-income countries where people often share smartphones, privacy concerns of users will also be taken into account, for example, erasing conversation history from the phone after use. The chatbot can assist a user in choosing the correct option of maintaining or erasing history based on the ownership of the phone at different times.

In light of the latest developments in the area of chatbots, especially with the advent of ChatGPT¹⁰, one may argue for going with Chatbots based on Generative AI technologies like ChatGPT instead of menu-based chatbots as Generative AI Chatbots offer access to an unlimited amount of topics. However, we believe that before such developments, we need to be aware of a few issues. Despite using the best technological advances, the Generative AI Chatbots still suffer from Hallucinations, i.e., providing plausible but factually incorrect answers. For critical healthcare domains and with potentially vulnerable users (those who have had limited or no exposure to Chatbots), incorrect answers may cause adverse health outcomes, loss of trust in technology solutions, and so on. Moreover, development with such technologies often requires a subscription to pay for the services, which is significantly costlier, to begin with and then increases significantly as usage increases than the cost of developing and maintaining WhatsApp-based chatbot. Also, while Generative AI Chatbots offer a vast opportunity to access information about different topics, targeted deployments, as in our case for Covid-19 vaccine hesitancy, may often be more suitable to achieve desired outcomes.

We believe that our work provides some good insights and design directions that researchers may use to increase user engagement and retention with simple menu-based chatbots. We also believe that despite the challenges of user retention, menu-based chatbots provide a good tool for information awareness in low-resource settings.

5.3 Perception about chatbots in low-resource settings

A chatbot's adoption and feasibility in a population can be affected by the population's perception of the chatbot. Prior works have studied how people view chatbots given their cultural context. Yadav et al. conducted a wizard-of-oz experiment to study how women in rural areas engage with the chatbot to seek information on breastfeeding-related queries [46]. Interviews with the participants revealed how they found the chatbot to support their information needs on issues they were hesitant to discuss with doctors or others, especially male doctors. The chatbot provided a means for the participants to seek help despite the associated hesitations. Further, participants perceived the chatbot to be the first point of contact for healthcare queries, given its tendency to overcome their mobility and other such challenges associated with visiting doctors. Moreover, the participants visualized the chatbot as a human being given the female avatar of the chatbot and talked with it as if talking with a human being, such as using a low tone. Some perceived the chatbot to be a lady doctor, while some as a community health worker. The study findings depict the positive attitude of women in rural settings.

In our study, participants appreciated the chatbot's capability to provide information to their queries instantly and whenever they desired. Our participants shared traveling long distances to

¹⁰www.openai.com

visit a doctor and their inability to discuss all concerns, given the long line of patients alongside an expensive healthcare infrastructure. On the other hand, while interacting with the chatbot, they could ask any number of queries whenever they wanted. Thus, our chatbot's adoption was favored by its capability to overcome contextual challenges faced by the participants. Going forward, designers and developers should identify and exploit such contextual barriers, which could be overcome with technology. Moreover, our participants could identify shortcomings in the current chatbot and could offer suggestions for improving the chatbot. The participants were highly interested in using the chatbot for a wide range of topics covering maternal and child health, especially taboo topics such as family planning. They perceived chatbots to offer a safe space to them for topics they feel hesitant to discuss with others. Overall, the perception of chatbots among women in rural settings, specifically around healthcare, has been found to be positive, with women showing acceptance towards such tools. However, a proper understanding of chatbots capabilities, limitations, back-end data collection, and workflows might still be needed by women for better awareness and adoption.

6 LIMITATIONS

Our study demonstrated the chatbot's potential to inform participants' decision-making around COVID-19 vaccination, however, it had a few limitations. Firstly, our chatbot provided static and limited information. The knowledge base included only those queries which were identified during the formative phase and did not incorporate any new information over time. The static nature might have negatively impacted repeated interaction with the chatbot, with no new knowledge to gain on the participants' part. Moreover, given the nature of the chatbot, it did not answer participants' queries beyond the menu options. Participants reported having confusion in interpreting the chatbot's reply to their text queries which might have hampered participants' engagement with the chatbot.

Further, we deployed our chatbot in an NGO-run WhatsApp groups where members were already enthusiastic about their health issues and hence, had an intrinsic interest in enquiring about COVID-19 vaccination. Moreover, we benefited from NGO's long-standing presence and trust in the community. Our participants had trust in the NGO, which helped develop an initial inclination towards using our chatbot. For the general population, there may be additional challenges in spreading the chatbot that we may not have encountered in our study. In different populations, different challenges would occur, such as reaching out to pregnant and breastfeeding women, motivating them about their health, and gaining their trust to encourage them to use an intervention, among other such challenges. Despite these challenges, it would be interesting to explore how a chatbot would work if introduced in a population without a link with any trusted entity.

7 CONCLUSION

In this paper, we examined the COVID-19 vaccine hesitancy in pregnant and breastfeeding women in resource-constrained settings to deliver an intervention targeted at tackling their vaccine hesitancy. The factors behind COVID-19 vaccine hesitancy included a lack of proper knowledge, fear of side effects, and limited agency around vaccination. With the understanding of these factors, we developed a chatbot, over WhatsApp, in Hindi that offers informational support for tackling vaccine hesitancy. We evaluated the impact of our chatbot on our participants through online surveys, telephonic interviews, and chat logs. Our participants appreciated the convenience of seeking authentic information through the chatbot. Moreover, our chatbot worked well under the constrained network of our participants to build their knowledge and intention around vaccination. We believe our work contributes to the HCI community by providing insights into the causes of vaccine hesitancy among pregnant and breastfeeding women in resource-constrained settings. We

also offer an understanding of the effect of a chatbot targeted at tackling vaccine hesitancy through healthcare information dissemination in real-world settings.

ACKNOWLEDGMENTS

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Received January 2023; revised July 2023; accepted November 2023