Chapter

A State-of-the Art Survey on Chatbots Technology Developments and Applications in Primary Healthcare Domain

David Felipe Mares Silva and Aida Huerta Barrientos

Abstract

Chatbots, defined as artificial intelligence program able to simulate processes of human conversation *via* auditory or textual methods, are deployed by firms to automate customer service. In recent years, chatbots have received tremendous attention from scholars in numerous fields including e-health, e-learning, and e-commerce over many sectors. However, the technology developments and applications specifically in the primary healthcare domain are still insufficiently explored. The principal purpose of the study is to provide a broad review of the current technology developments and applications in primary healthcare domain and future directions in the research. First, we describe features of chatbots considering the healthcare domain. Next, we provide a classification of technology developments and applications in primary healthcare with a focus on recent advances. Then, we present a density map of applications in the primary healthcare domain. Furthermore, we introduce future directions in the core research technology. We expect this study to serve as a comprehensive resource for researchers in healthcare domain.

Keywords: artificial intelligence, chatbot, technology development, primary healthcare

1. Introduction

The changes in the epidemiological gradient that has been observed in the last decades together with the digital transformation have affected different areas of health that, added to the trends toward health prevention, well-being promotion, and personalized medicine, are generating a change in health systems to move away from hospitals and bring services closer to people and their homes [1, 2]. This new perspective that seeks to integrate health systems around people, instead of diseases, has influenced different sectors such as education, infrastructure, communications, finance, economy, and work. Thus, this has been the object of interest for health applications of the technological advances achieved by new business and industrial application models, around different spheres of hardware, software, connectivity, and services and new technologies such as artificial intelligence (AI) and Health 4.0 [3].

Within the technological developments associated with artificial intelligence and mobile communication systems applied to healthcare, chatbots represent a trend that is increasing in popularity as an efficient mechanism that promotes interactions between application users for different sectors, since it provides personalized information and allows interactions in time and a capacity to reach millions of people at the same time [4, 5]. From the patient's perspective, chatbot technologies as representation of natural language processing, along with deep learning and virtual reality, also referred as cognitive services, have been identified as healthcare drivers by their possibility for the creation of great impact applications on medical and preventive health services [2, 6].

An important segment of the technological advances in health in recent years has focused on the use of artificial intelligence, telemedicine, and automated monitoring of physiological signals for the benefit of patient-centered medicine under a vision of personalization and digital well-being, characterized by being preventive, personalized, predictive, and participatory [7]. This personalization of medicine has been promoted through health policies that seek to expand access to primary healthcare (PHC) as a performance indicator for healthcare systems, since it aligns public policy and service provision at the individual level through healthcare services and primary care and at the population level through public health [2, 8].

Chatbots, defined as artificial intelligence programmable to simulate processes of human conversation *via* auditory or textual methods, are referred to in the literature in various ways, such as conversational agents, embodied conversational agents (avatars), social robots, dialog systems, voice user interfaces, and voice assistants, all of which mimic human conversation using text and/or spoken language [3, 5, 9]. In the healthcare domain, chatbot applications have shown good results for performing repetitive tasks of low complexity, delivering personalized content that allows patients to gain greater insight into their health conditions, and have shown the ability to improve patient engagement in certain contexts [10]. So, different applications are observed in healthcare, ranging from mental health, assisted living, customer service, support in states of depression, substance abuse disorders, filling in clinical history, nutrition recommendations, diet, exercise, evaluation of respiratory symptoms, support in the administration, and supply of medications [2, 3, 11]. Many benefits in the field of healthcare are derived from the chatbots' capabilities to be continuously available with up-to-date information, hear and respond in natural language, being able to present information in local languages and dialects, reach millions of people at the same time, supporting environments where health professionals are scarce to off-load repetitive tasks that absorb the time of health professionals, as well as anonymity protection for sensitive health condition [12]. In fact, this technology is still considered in a state of initial development due to the implications derived from the technology such as medical dilemmas in its use such as the lack of empathy perceived by the users, the complexity in the interaction of patients' beliefs about diseases that impact the acceptability and the responsibility of chatbots, content quality, accuracy, sources used, patient safety, and diagnostic capacity, among others. From the quality of chatbots perspective, there are differences not only in the technology, interface, contents, and applications, but also in the methodology for measuring both quality and efficiency [13].

According to Refs. [14, 15], the chatbot applications have proved to be useful for public health functions to deal with the COVID pandemic, by encouraging the adoption of strategies of promotion, prevention, mass dissemination of information, reduction of misinformation as it was used by governments and by the World Health

Organization (WHO) to prepare collective response actions. Despite the fact that there were more than 300,000 health applications available globally in 2017 that were available for download, the measurement tools and evaluation studies of the aspects surrounding the provision of health services through chatbots are still very small [13].

Besides, there are aspects that require further study and supervision for the correct use of chatbots in health-related environments, since chatbots use demographic data of patients that they collect through interactions and that may have legal and ethical complications. This could be the case when chatbots, which do not have the appropriate corpus and are not ethically framed and supervised under good practices by a health professional, may end up presenting risky responses for sensitive conditions such as the use of substances, the combination of medications, or mental health advice [2, 12, 16]. This is added to the fact that the chatbots' programming can behave like a black box with answers that are difficult to follow in its construction, presenting logical but not necessarily correct results [4, 7].

As suggested by Refs. [4, 7, 17], the developers of the substantive processes of the chatbots or the intelligence behind it may have trained said chatbots with incomplete information, with empty data, missing data, opaque imputation rules, or based on target populations that are not necessarily generalizable. Likewise, users of these systems can enter inaccurate information due to the inherent teleology of each person who uses it. For such reason, special consideration should be given to developing evaluation methods of different aspects related to chatbot training for health, not only to measure its usability or acceptability by the user. The ethical and clinical dimensions should be measured as well, which also implies expertise and clinical experience, since these will adapt the best response to the patient's clinical problems, according to their characteristics and needs and, of course, always ensuring their clinical safety [4, 18].

A small group of studies has been identified to measure dimensions associated with health. These present a wide variety of methodologies, sample widths, randomness, and population stratification samples to carry out the measurements with the purpose of evaluating these dimensions [10, 12]. Various use scenarios have been visualized where great benefits can be obtained for health systems in terms of efficiency, among which the capacity to process large volumes of patients stands out, where the risk of late diagnoses must be balanced with the use of resources [9, 19].

This chapter is organized as follows. We begin by reviewing the characteristics and features of chatbots, introducing generalities about primary healthcare in Section 2. The technology developments and application domains in healthcare are presented in Section 3, focusing on the primary healthcare public policy-oriented applications. A revision of benefits, challenges, and trade-offs for healthcare delivery and value-based care models is presented in Section 4. Based on these discussions, some future directions are outlined in Section 5, and we give our general conclusion in Section 6.

2. Features of chatbots considering healthcare domain

The WHO [20] defines PHC as *a whole-of-society approach to health that aims at ensuring the highest possible level of health and well-being and their equitable distribution by focusing on people's needs and as early as possible along the continuum from health promotion and disease prevention to treatment, rehabilitation, and palliative care, and as close as feasible to people's everyday environment*. In this direction, as recommended in Ref. [8], PHC is a combination of public health, medical care, and social assistance, which is essentially anticipatory in nature, and includes actions in different aspects such as health education, food and nutrition, environmental sanitation, maternal-child health, immunizations, prevention and control of endemic diseases, treatment and control of the most frequent diseases, and provision of essential medicines. Under the PHC policy, this analysis of the impact of environmental, physical, demographic, epidemiological, congenital, economic, and social factors is essential for the provision of person-centered health services, taking care to maintain the focus on the prevention and promotion of health before it becomes disease.

In the context of personalization of healthcare, service value-based care models are expected to use persons and patients context, to improve multiple health conditions of patients and populations [7]. Within cognitive computing applications, developments with multiple uses are identified. As Improta et al. [21] explain, a patient can be used both as a decision support system for medical specialists in the phases diagnosis and treatment and as a monitoring system of the clinical environment in health establishments. The use of these cognitive systems also encompasses digital therapies focused on dream therapy [22], the use of a gaming approach for depressive events [23], and treatment of depression and anxiety [24] of both the young and the elderly [25]. AI-based chatbot systems, due to their characteristics of acting as automated conversation agents, play a central role in various health actions, since they can promote health, by providing education and potentially causing behavioral changes. This is observed in the treatment of adolescents with a chronic medical condition using a text messaging platform (chatbot) with written interactions to increase engagement and deliver educational content [26].

On the one hand, the first contact functions, whether they are collective actions or toward the person, usually begin with the exchange of information between people and health personnel, whether they are doctors, nurses, or health promoters, which is essential for developing action plans for healthcare. Such data collection and its corresponding registration in the institutional systems take time, which, if automated and systematized, could increase the effective consultation time for patient management [2]. In this direction, chatbots interact with patients for specific, short, repetitive, and massive tasks. Rule-based chatbots represent great potential for prevention and health promotion tasks [27].

On the other hand, the use of chatbots that interact with patients through natural language processing, can, in addition to obtaining information from patients, perform iterative data collection based on previous responses to build clinical histories and contexts of health conditions [14]. So, health service providers, whether public institutions or private providers, can strengthen their technological instruments with chatbots that perform these basic tasks of collecting information or disseminating healthy practices and training in self-management of people's health. Thus, the information built can be used both for the personalization of responses for patients and for guidance and promotion on services of greater complexity or specialization required by people.

A fine-trained chatbot that includes capabilities for consultation, knowledge gathering, basic reasoning, and giving feedback can accomplish this guidance task, simulating a health professional. Development frameworks that integrate question-and-answer reasoning mechanisms based on a domain-specific knowledge base can achieve this [28]. Chatbot applications in health, in addition to primary care, have covered marketing and research topics. Such is the case of pill reminders, interviewing smoking habits, dietary behavior, and physical activity and even for extraction system to extract mentions of adverse drug reactions from the highly informal text in social media. Also used are voice agents for chronic illness monitoring, medical counseling and education, clinical decision support systems (CDSS) for diagnosing infection diseases, and assisting medical personals in diagnosing internal conditions for patients based on larger collection of hospital case records [28]. These agents can offer a wide range of problem-solving functions that can integrate multiple tasks from natural language understanding and knowledge base query to reasoning and giving feedbacks, through an iterative inquiry process. Currently, there is a wide range of applications for chatbots aimed at mental health, health education, maternal care and sexual and reproductive health, nutrition and physical activation, sleep disorders, support in emergency situations for chronic diseases, management of respiratory diseases and accidents, increase in self-care, and transitions in stages of risk for vulnerable groups [13, 26].

It is important to note that over the past few years, different categorizations of conversational agents have been developed including both text chatbots and voice chatbots. Some also consider the channel on which they are used, whether *via* smartphone, web, or some additional platform where it is used. They can also be classified by the objective they fulfill, whether they are aimed at a function or a specific general-purpose task [5, 29]. However, as suggested in Refs. [5, 30], it is more common to classify the logic approach of the dialogue management system that interacts with user input using a knowledge database to determine the action to be taken in the conversation flow.

Recent literature review studies have observed that the large majority of mental-health oriented chatbots currently in existence do not use machine learning at all, favoring more stable and predictable techniques such as rule-based modeling [2, 31]. However, findings have been presented that indicate that the perception of some users generates a lack of expectation that they will reach a state of development where they will displace the work of health personnel [12]. The most used chatbots in health applications are rule-based; they use a decision tree on a specific condition to define the rules on which the chatbot carries out the flow of the conversation, choosing how it responds to each user input. So, the complexity and resolution of the chatbot depend on the programming logic and the complexity and depth of the rules with which it has been defined. For this reason, these chatbots cannot learn from user conversations or interactions and are limited to the scenarios for which they have been programmed [27]. These chatbots are also part of the dialog systems known as specific task or closed domain that manages to perform tasks specific to a domain such as technical assistance and customer service [29].

Knowledge base-based chatbots use structured data sources that contain knowledge of a specific function (such as frequently asked questions or FAQs) to make that information accessible to users and deliver relevant content. In this way, this type of chatbots uses keywords and functions connected to a knowledge base of multiple databases and data sources [30]. These application-specific domains usually have limited availability of training data. They include linguistic-based approaches, where the user's questions are converted from natural language into a database query, and the identified answer is presented to the user [28].

In dialog systems, the knowledge-based chatbots are known as open domain's retrieval base models since they select a response from a previously constructed repository. This is the complement of generative models, which produces new responses [29]. The open-domain dialogue systems require large amounts of data to train and often allow effective chatbots to be created, even though they cannot perform effectively on specific tasks, and often cannot query databases or add useful information to their chatbots' answers [32]. Nevertheless, information retrieval, knowledge base or NLP, and systematic literature reviews have classified the techniques, algorithms, frameworks, and tools observed as a combination of the one or more of these technologies: Deep Neural Network, Graph Based Lemmatization, LSA, Multi-Document Summarization Naive Bayes, Named Entity Recognition, Parser, POS Tagging, Relation Finding (Similarity Distance), Shallow Syntactical, Stemming, Support Vector Machine, Text Chunking, and Tokenization [30]. For open-domain neural dialog generation, methods are categorized and examined as a variety of main categories such as Reinforcement Learning (RL), Hierarchical Recurrent Encoder-Decoder (HRED), Generative Adversarial Networks (GAN), Variational Auto-Encoder (VAE), Sequence to Sequence (Seq2Seq), and Pre-training Model [29, 30].

For the chatbots that have been built based on machine learning and AI, the first developments used single-layer representations that were appended through the use of word vectors applied for task-specific architectures. Subsequently, recurrent neural networks, RNNs, were used that increased the number of capable representations including context analysis to achieve better results in architectures for specific tasks, until recent advances based on pre-trained recurrent or transformer language models such as ChatGPT, which no longer uses specific architectures [33].

2.1 Healthcare applications uses, evaluation, and acceptance

Paradigm shifts from the medicalized approach to seeking health systems that focus on the patient and not on the disease are driving the need to readjust the structure of health systems to improve access to health services, not only for a more diverse population but also for systems that are aware of individual differences and people's health contexts. This implies that through these technological advances, the health needs of each person in their context and based on their social determinants are the ones that predominate in the access criteria used by intelligent health systems [34]. This implies that each dialogue system development focused on the different health conditions, especially those that are linked to each other and multifactorial conditions, must work together to offer healthcare services supportive complementary technological and clinical personalization that allows offering a robust experience to people who seek healthcare services. However, before their incorporation into health systems and routine clinical practice, it is essential to review the effectiveness of these technologies, in such a way that there is a clear understanding of under which contexts these tools can be used. This includes understanding the frame of reference; technological, ethical, and clinical evidence; and adaptation to specific populations, among others, which must give support and certainty to the developments, as well as understanding the limitations, biases, good practices, evaluations, and contexts of use [13].

The adoption of chatbots integrates different actors and functions within health systems. Health professionals have systematized the data collection, the appointment schedule, and the dissemination and training of patients for self-care of health and the increase of health literacy. These have proliferated in mental-health and primary-care applications for low complexity actions. Health units are exploring the capacity of chatbots for functions of health education and counseling support, assessment of symptoms, and assistance with tasks such as patient intake process, scheduling, and collecting personal and family histories [2, 28].

Health systems have combined the chatbots with decision support systems to prioritize targets during the pandemic, assess drug side effects from electronic medical records, disseminate information on available health resources, and Management of installed capacity in high demand situations [2, 28]. The evaluation of chatbots and the dialogue generation system (DSG) is still in early stages, and the evaluation methods are incipient, even though the conversational AI global market size is expected to grow at high rates, increasing the value by 2025 [35]. Thus, there are research lines on adaptations of automatic metrics to evaluate the responses generated, such as bilingual evaluation understudy (BLEU), Recall-Oriented Understudy for Gusting Evaluation (ROGUE). In addition, human evaluations and combinations between them have been used. Even given the different architecture and logic configurations in the dialogue management systems that govern chatbots, humans have been used to assess consistency, fluency, coherence, and informativeness [29, 32].

Different works have been carried out to categorize chatbots using their health context and core features, as well as their NLP capabilities. The type of user targeted, personalization, data acquisition for implicit or explicit personalization, domain areas of health, theoretical and therapeutic support, security, and privacy also have been studied [2]. In the evaluation of chatbots, some aspects have been described by authors such as if chatbot is programmed to support people, patients, health professionals in tasks. Some studies include satisfaction surveys with a Likert scale as well as measures of the interactions between chatbot acceptability, perceived symptom severity and stigma [3, 12]. There are also other technical characteristics linked to other aspects of the system such as the content, the user interface, the channel of use, and functionalities that are evaluated such as irrelevant answers, frozen chats, and messages in non-readable linguistic structures that make them nonfunctional [2].

2.2 Acceptance

Chatbots may be useful for sensitive health issues in which disclosure of personal information is challenging, since Chatbots were seen as least acceptable as a consultation source for severe health issues, while the acceptability was significantly higher for stigmatized health issues [2]. There are studies that explore the use of chatbots, smartphones, text messages, and social networks to provide tools and resources to help in psychological transitions, more frequently oriented to specific age groups (adolescents), where the motivations for using health chatbots are explored, in order to predict their acceptance [36]. Some studies report difficulties for chatbot users to understand how they work, suggesting that there may be difficult concepts to understand and that their acceptability may depend on different aspects such as expectations, favorable conditions for their use, social influence, habits, associated costs, and even access to the health system [12].

Some works point out the concerned the ethical implications as the main obstacle to the adoption of these technologies in the treatment of addictions. Some of these are using a nonhuman agent in a supportive role, giving answers contrary to the intention of the users, giving sensitive information to enhance the effect of medications through explicit indications, or even the potential for causing harm to specific populations [3, 18]. Although many countries are developing and using chatbots as app interfaces focused on treating health conditions, during the COVID pandemic, different coordinated efforts were made between industry, governments, and nongovernmental actors to integrate communication strategies to reach millions of users. This was achieved by different approaches and uses to collect and disseminate information on patients, the virus and the situation of health systems, diagnostic support, guidance on conversions of health systems, and vaccination strategies and carry out telehealth actions [14, 37–39].

It should be remarked that technological advances toward precision-driven healthcare, which promotes the application of data science, in particular technologies, such as interactive cognitive systems, artificial intelligence, and machine learning, are aimed to enhance healthcare provision, to solve the patients' personalized demands more accurately and, at the same time, more easily to the service providers. In this direction, many chatbot technologies are still to integrate the health condition-monitoring continuum since they are still task specific, by health condition, environment, or agent [7].

3. Technology developments and application domains in primary healthcare

This study adopted a systematic literature review approach to achieve the set out objectives per the Preferred Reporting Items for Systematic Reviews and meta-Analyses (PRISMA) approach and guidelines provided by Kitchenham [40]. PRISMA is employed because it is *evidence-based*; the steps involved are auditable and have been well established and used in the literature and similar studies [41].

3.1 Search strategy

The search was conducted in Scopus and Science Direct. These databases were selected because they host high-impact publications relating to the chatbots for PHC domain and have been used in reviews covering similar themes. Also, the search was complemented with a citation-tracking approach, which involves checking the reference list of relevant publications to track other relevant publications.

3.2 Selection criteria

General search criteria: The developed search query was used in Scopus without year restriction with a focus on the subject areas of *Chatbots* and *primary healthcare* and only documents available in the English language.

Refining criteria: Studies were included based on these predetermined criteria:

1. Studies that involved the application of conversational AI in the healthcare domain,

2. Studies that involved the development of conversational AI in the healthcare domain,

3. Studies that involved the integration or evaluation of conversational AI in the healthcare domain.

Similarly, articles were excluded based on these predetermined criteria:

1. Studies that did not employ conversational AI for application development,

2. Review studies that mentioned conversational AI but did not explore its applications.

3.3 Data extraction

The result was further reviewed, and the following information was extracted from each publication:

1. Year.
2. Authors.
3. Title.
4. Publication type.
5. Aim.

3.4 Results

Health systems based on primary care in the digital era are turning toward collaboration and the generation of complementary service partnerships that make it possible to obtain many of the benefits of economies of scale through the segmental participation of each actor and health service provider [42]. These value chains that are being built around the current installed capacity and the capacities of the (human) medical teams seek multichannel strategies to offer complementary services. Among these strategies are those that allow systematized service channels such as chatbots from which it has been observed that customer service advantages are obtained.

Public Health application chatbots across many countries and languages other than English were used to reach millions of citizens and all relevant institutions, in order to deliver education of citizens, surveillance and detection of contacts, risk assessment, and dissemination of information, allowing the organization of health systems while promoting cooperation, community, involvement, and accountability of citizens through collective actions [15, 37–39]. Healthcare Evolution, which includes Health 4.0 through telemedicine and artificial intelligence, is emerging toward customization and models based on value, which are connected by integrity into the business models that accompany people throughout life, by customization of healthcare, based on the optimization of determinants by reducing the follow-up effects of different health conditions [7].

The dimensions such as education, economy, income, finance, food security, communications and transport infrastructure, assurance, access to health services allow to investigate the social determinants of health that make up the context of life of people. This health information from the social context improves the personalization toward the person, by combining these data with the medical and family records, to add the self-care and personalized management, the PHC system's strategies to chronic disease monitoring, and provision of medical and assistance services [9]. As part of cognitive services, expert systems for healthcare were explored in the Scopus database. We obtained 1138 results that are observed in the cluster in the **Figure 1**. Green color presents various topics related to decision making, decision support, algorithms, data mining, machine learning, deep learning, and information classification.

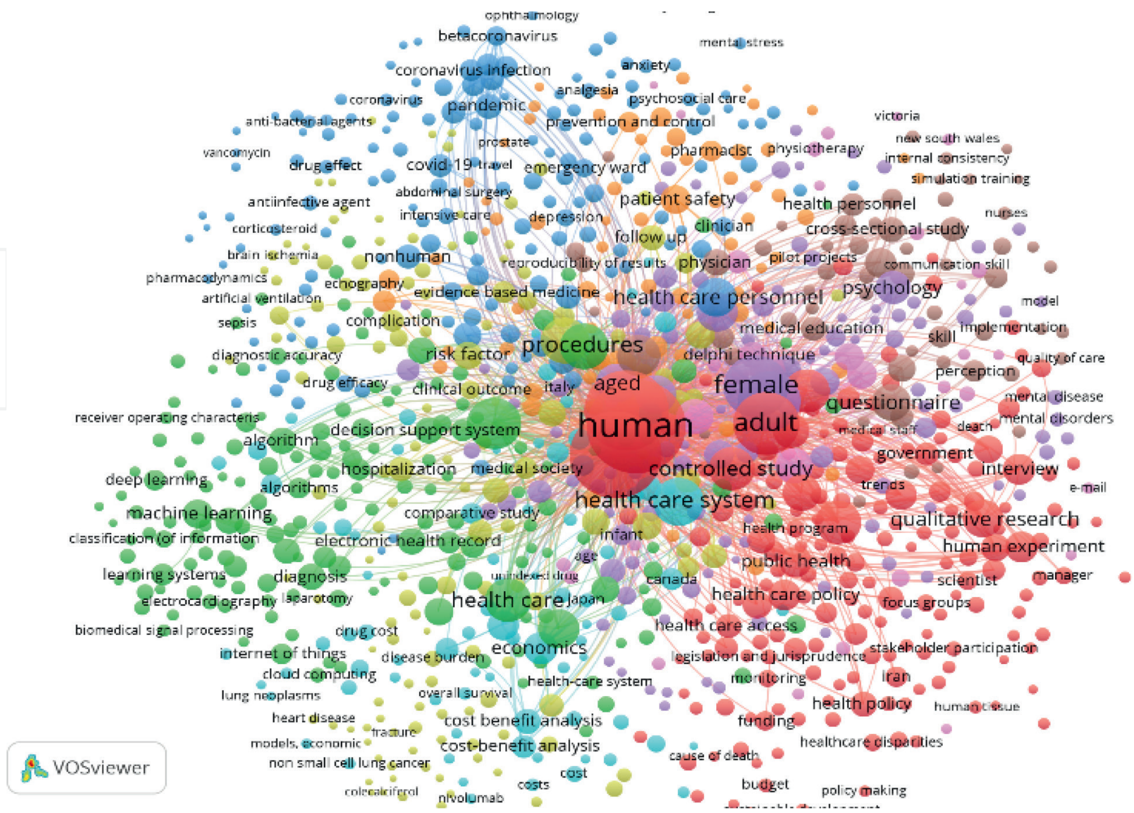

Figure 1.
Visualization by VOSviewer software of word co-occurrence network built using words in titles and abstracts of documents on healthcare expert system field.

Likewise, in the cluster in the color blue, a set of health conditions is presented where the appearance of research related to the SARS-COV 2 virus (COVID-19) is observed and where topics on mental health, anxiety, stress, and depression also appear. In red, public health issues that address different aspects of public healthcare policies are observed, going through issues such as government, financing, budget, participation, inequities in health and access to health, and causes of death. In turquoise, economic topics appear under labels such as economic models, cost-benefit analysis, costs, disease burden, and drug costs. In olive green, the risk themes appear, where risk factors, evidence-based medicine, patient follow-up protocols, patient safety, complications, and hospitalization are displayed. In brown, the nodes with contents linked to existing soft skills in hospital management are presented, such as perception, quality of healthcare, interpersonal and communication skills, and internal consistency. Finally, in pink, there are some small nodes representing studies on issues related to mental health, psychology, and their conditions such as mental illnesses and disorders.

Aforesaid, once again, a close link is observed between the topics where there is no dominant approach that segments the cluster based on a particular research topic. In the same way, for this image, it is interesting to observe that although machine learning and deep learning appear, there are no nodes referring to artificial intelligence. **Table 1** shows the results for PHC chatbot search in Scopus and Science Direct databases. The research topic is still a new research direction, contrasting to the big healthcare apps developed in recent years and available on apps marketplaces.

Weobot, as a self-care expert, trained and tested approaches as cognitive behavioral therapy (CBT), mindfulness, and dialectical behavior therapy (DBT), have reached a significant awareness for the accompaniment of the substance-use

Year	Author	Proposal
2020	[21]	They present a patented device for automatic processing of clinical data of chronic poly-pathological patients.
2020	[22]	This is a proof-of-concept study, which aims to evaluate the feasibility, acceptability, and preliminary efficacy of a digital cognitive behavioral therapy for insomnia (dCBT-I) for individuals with CM and insomnia (CM-I) in the United States.
2020	[43]	They introduce a chatbot architecture for chronic patient support grounded on three pillars: scalability by means of microservices, standard data sharing models through HL7 FHIR, and standard conversation modeling using AIML.
2019	[44]	They proposed a method as a mobile health service in the form of a chatbot for the provision of fast treatment in response to accidents that may occur in everyday life, and also in response to changes of the conditions of patients with chronic diseases.
2019	[36]	This research aimed to explore participants' willingness to engage with AI-led health chatbots.
2019	[26]	The analysis of the use of smartphones, text messaging, and social media prevalent among teenagers, to engage in their preferred channel to provide tools and resources to help them successfully transition to adult-focused care, is presented.
2019	[45]	kBot, a knowledge-enabled personalized chatbot system designed for health applications and adapted to help pediatric asthmatic patients (age 8 to 15) to better control their asthma. Its core functionalities include continuous monitoring of the patient's medication adherence and tracking of relevant health signals and environment data. kBot takes the form of an Android application with a frontend chat interface capable of conversing in both text and voice, and a backend cloud-based server application that handles data collection, processing, and dialogue management. It achieves contextualization by piecing together domain knowledge from online sources and inputs from our clinical partners.
2019	[46]	The study presents case studies in the healthcare industry that focus on the use of Chatbots to improve patient monitoring and medical services.

Table 1.
Results for PHC chatbot search in Scopus and science direct databases.

disorders; nevertheless, there are a wide range of tests to analyze performance to generate advances in drug/alcohol use [3]. IBM's Watson Cloud Services has developed an app that allows chatbots for different applications, including assistants for learning the treatment process in radiotherapy for cancer patients, genomics, measurement of intellectual disability in children, support for depression episodes in older adults, and medical imaging [47].

Likewise, the use of information and communication technologies that enable quick, simple, clear, and unambiguous access to health information also contributes to the quality of health services. But the focus of public health is very different from the individualized practice of clinical medicine, and as such, public health values and ethics have several justifiable challenges that differ from medical or bioethical ones. Public health is aimed at the population, not individuals, and because of its nature, it is interested in public good [15]. Specific collective health and public health applications for large populations could be observed in many governments, civil society, and international organizations such as WHO. To provide verified information, updated news and reports were provided on pandemic as well as details of symptoms and measures to discount public health systems [15, 39].

3.5 ChatGPT

As discussed earlier, NLP facilitates the interaction of human language with computer systems, so with the release of Generative Pre-trained Transformer 3 (GPT-3), the most recent release version of a language model that uses deep learning to generate text similar to human natural language, it has been trained using large datasets [48]. The NLP systems have evolved from single-layer representations of neural networks using word vectors fed to task-specific architectures; later, multilayered recurrent neural networks (RNNs) were used to add context to achieve better representations, and now pre-trained recurrent or transformer language models have brought great progress in tasks such as reading comprehension, answering questions, and textual detailing, among others. This type of language model has the limitation that even though it can be adapted to different tasks, it requires datasets for specific tasks in order to achieve refinement in those tasks [17]. This means that the almost human responses, the ease of use, and the friendly interaction have a weak side on the training set, which since training with Internet content incorporate deviations from the same information, such as gender, racial, and geopolitical biases [33]. However, the potential for use extends to many of the preventive medicine and PHC applications, especially in the management of electronic clinical records where a correct incorporation of this technology is visualized if said technology is fine-tuned by health professionals that restrain risks in its use.

4. Challenges and trade-offs for healthcare

The capabilities that chatbots will have to favorably influence health work, using the power of computing and big data analysis, which will be exploited by health professionals in ways that are yet to be discovered. However, before the maturation and daily exploitation of this technology arrives, the road will have to go through multiple challenges that are experienced daily in health systems and health establishments, where beyond linguistic accuracy, usefulness, updating of clinical knowledge, the accuracy of medical knowledge, clinical responsibility, the domain of the health condition, the ethics of training and evaluation of the algorithm, and the acceptability of the user, among many others, must be integrated into the problems of organization, budget, culture, generation gap, old infrastructure, telecommunications architecture, financing models, and technologies for healthcare.

Although this technology can structurally change the way of delivering health services, the applications for the delivery of services within hospitals are perceived as much more limited. Hospital procedures, clinical practices, and protocols, due to their complexity and real dynamism, especially in highly specialized fields, place chatbots and NPL technology in the role of support.

However, for the PHC, the range of challenges is wide and almost as large as the universe of application possibilities, which are unique in their forced adaptation and integration to different health systems. In the short and medium term, the challenges for chatbots involve fine-tuning technology, the social dimension of the paradigm shift and evolution of tools, regulations, information management, privacy, data collection mechanisms, and so on. In the case of information management, the information of people and its interoperability with information systems, or medical records are examples of the challenges. The restrictions imposed by the COVID pandemic generated new adaptations of conventional therapies toward digital approaches [14].

Some studies have begun to be carried out for other disorders such as those related to gambling, smoking, sex, Internet, and mobile phone, which manifest compulsive behaviors and will be a subject of deep reflection to review the limits of the use of natural language in healthcare chatbots. However, the evidence indicates that chatbots can take on specific steps within an addiction treatment process and that they should be accompanied by the help of an expert, a peer, or a support group that contextualizes the activities within an addiction program recovery [3]. In this way, it is important to point out that the expected benefits contrast with the less-developed sides of the technology related to design, architecture, the opacity of its programming in the internal layers of the RNNs, privacy, the anonymity of people, honesty in communication, or understanding behavior disorders that lead to irrational actions or even self-deception. These deficiencies have been observed in the responses of the most popular open-domain chatbots and dialogue agents such as Siri, Alexa, Bixby, and ChatGPT, which provide counterintuitive output to user questions, such as mishandling simulated patients with suicidal ideation or providing addresses of marijuana dealers in response to questions about how to treat marijuana addiction [3].

In the same way, even with the increase in the use of chatbots, the evaluation of their effectiveness and feasibility are incipient and it requires more evidence, paying special attention to the methodology used to validate [12]. Similarly, the effectiveness of the soft aspects related to communication competence, and ability to understand users are difficult to evaluate and determinants for their safe adoption [18]. The effectiveness aspects imply the need to pay more attention and effort to include measures that ensure the safety of users, people, and patients, especially in diagnostic work and medical treatment. This complexity is also presented in the privacy and security of the data, the medical control and the authentication of the information obtained by the chatbots. Some regionalized studies showed that these chatbots and apps present from medical disclaimers, HIPAA compliant, child online privacy, and protection act [2]. This scalability characteristic that can bring so many benefits in the prevention promotion that characterizes the PHC, in the collective and population contexts, implies the inclusion of adaptation measures of health messages and prevention campaigns to cultural, educational, social, and economic contexts of each population, including the practices of native peoples [15].

5. Future directions

In recent years, technological advances in the health area have been oriented toward the incorporation of artificial intelligence, telemedicine, and automated monitoring of physiological signals as enablers of patient-centered medicine, the creation of value in health services, and the change toward a culture of prevention through digital well-being. Studies by leading consultants anticipate that chatbots will be used as a first-access channel to help navigate all the options available in the health system, leading people toward virtual solutions or traditional services [42].

The possibilities of chatbots for health will be the person-to-person interfaces of new health technologies, from applications focused on health and well-being and wearable IOT devices to monitoring physiological signals, assisted living, digital mental health therapies, social robotics for nursing care [49], personalized drugs and genomic medicine, and the supply chain around the health and well-being needs of people. As the chatbots in the health domain are increasingly used to enable interaction with humans on an emotional level, for example, to comfort and entertain older people, lonely people, or those with dementia based on cognitive services and intelligence, new ethical challenges also arise to review, such as the need to explore new governance models to guarantee principles such as the *welfare principle*, which postulates artificial intelligence systems (AIS) must, above all, allow the growth of the well-being of all [1, 50]. In this direction, artificial intelligence (AI) is beginning to occupy a central place in the design of new therapies and treatments throughout the different dimensions of healthcare. These capabilities and the impact of cognitive computing will be reflected in the outcome of medical care, well-being, and medicine in the healthcare domain [51]. The personalized healthcare services are transforming the healthcare sector toward the integration of recent technological developments under new value-based care models to improve the efficiency of traditional healthcare systems. Technological advances in health have been oriented in recent years toward the incorporation of artificial intelligence, telemedicine, and automated monitoring of physiological signals, and recent studies have focused on integration around the patient with personalization and digital well-being.

Chatbots will be a strong component in the ecosystem of technologies surrounding the patient in this so-called personalized medicine since they are expected to be used as user interface for all these developments, which involves the use of new AI, Internet of Things (IOT), and genomic technologies to promote participatory, personalized, and participative preventive health where care is designed around people and not a place. This behavioral shift from healthcare to healthy aging will require more efficient and productive public health through the use of new generations of communication technology. In addition, health systems and public health needs will drive a shift in hospitals in the future to become a continuum care facilitator and to mentor people's

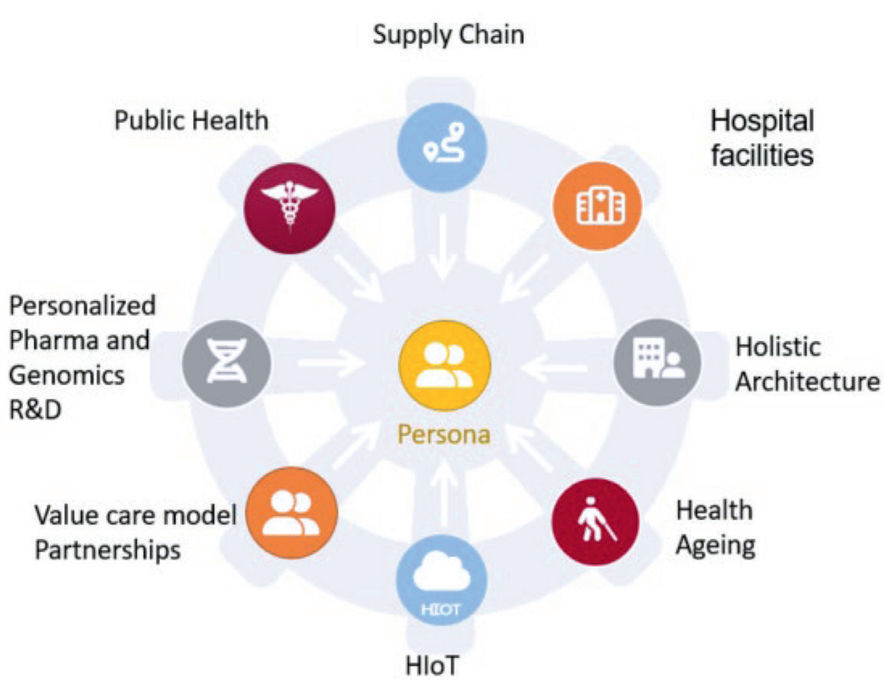

Figure 2.
Health system recent tendencies.

healthy habits. Infrastructure adaptations for holistic health will be pushed by the Internet of Things for health as an enabler of value-based care models **Figure 2**.

The new pharmaceutical developments toward personalized medicine based on AI are expected to bring personalized medicine closer to patients by articulating integrated healthcare supply chains created around patient experience [42]. Each of these evolutions produced in each health system component will transform healthcare delivery, by forming next-generation integrated healthcare service delivery networks as ecosystems of complementary collaborations around people's well-being. These technologies will allow people to be accompanied through the decisions inherent in each stage of life and throughout the phases of each health condition. Many actions to improve health need to be conducted by other economic sectors and be technology based. Most of the so called *social determinants of health* are beyond the scope of action of health systems; however, health systems need to be prepared to evolve in order to become resilient to social changes, epidemiological shifts, or emergency situations, by proactively detecting early signs of epidemics and be prepared to act early in response to surges in demand for services, which represents a paramount challenge to be faced by disarticulated health service providers. As suggested in Ref. [52], Massive Internet Of Things (MIoT) has been conceived as a viable future scenario to face infectious deseases, especially if combined to other technologies like Blockchain for data privacy and access issues and federated learning. This is conceived as a11 distributed interactive artificial intelligence paradigm, proposed as a solution to single database or big data sets, since it relies on the sharing of machine learning models, instead of the raw data itself, as one of the puzzle pieces of the intelligent healthcare.

Another dimension of this complexity is observed in the training of deep learning models that require large amounts of data, distributed among different institutions and owners, and that, because they contain sensitive medical data, cannot be integrated into a single database in the cloud. For these, new approaches are being explored, such as Federated Learning, a collaborative artificial intelligence technology where information obtained by millions of devices is not shared, but only the trained models [52].

6. General conclusion

Healthbots are potentially transformative in centering care around the user; however, they are in a nascent state of development and require further research on development, automation, and adoption for a population-level health impact [2]. Simple and task-oriented agents will represent a manageable channel for adoption in PHC, for the diagnosis of low-complexity diseases, high stigma, or in contexts where there are few health resources, increasing digital literacy and access. Current trends indicate that chatbots are a mechanism capable of engaging people in healthcare, which allow many interventions to be focused on patients and people; however, there is a lack of a clear regulatory framework for such health interventions, as well as a general opportunity for service providers' active engagement. Similarly, applications that are based on AI should incorporate ways to monitor the measures taken by programmers to ensure the ethical, technical and clinical, and population quality of chatbots along with patient safety in each functionality. Models based on GPT and deep learning will have to mature and refine their responses and the quality of medical information and update their practices for more complex tasks to those searched in the PHC.

Health chatbots have a maturation period ahead, where the development methodologies applied to each use case are standardized. Meanwhile, for primary healthcare, those chatbots that manage to integrate with users, patients, health professionals, and service providers will be the ones that will have an impact on the systematization of repetitive PHC tasks, in which a lot of health systems' time and resources are invested nowadays.

The benefits will reach beyond the limits of health establishments and will go to other applications that, focused on improving the experience of people and patients, promote well-being over disease. In this way, they will impact the continuum of care, prevention, promotion, foresight, and personalization of medicine, together with intelligent collective public health work in real time. What will be seen soon in the healthcare domain for chatbots will be applications that include interaction on social networks, triage of patient symptoms, support and counseling before and after the clinical encounter, and as sources of information and support in organizing tasks, process management, appointments, files, medicines, and supply chain, among many other tasks. However, these benefits could be achieved mainly as a complement to a digital approach for healthcare providers, to aid health professionals and improve doctor-patient communication for low-severity conditions. This approach can be led by primary-care services adopters, whose interdisciplinary teams can jump the adoption barriers linked to culture change and technology transfer.

Finally, the challenge will be to assess the best fit for this technology within healthcare systems' settings, and PHC public policies, and how to manage the best approach to incorporate the daily profiles of health personnel who do not use technology, especially in countries with a lower level of development, which run the risk of not being able to integrate the value base that makes this technology possible, limiting themselves to becoming end users or even staying completely outside the new paradigm.

Conflict of interest

The authors declare no conflict of interest.

Author details

David Felipe Mares Silva and Aida Huerta Barrientos*
Faculty of Engineering, Department of Operations Research, National Autonomous Mexico University, Mexico City, Mexico

*Address all correspondence to: aida.huerta@comunidad.unam.mx

References

[1] Kickbusch I. Health promotion 4.0. Health Promotion International. 2019;**34**(2):179-181

[2] Parmar P, Ryu J, Pandya S, Sedoc J, Agarwal S. Health-focused conversational agents in person-centered care: A review of apps. npj Digit Med. 2022;**5**(1):21

[3] Ogilvie L, Prescott J, Carson J. The use of Chatbots as supportive agents for people seeking help with substance use disorder: A systematic review. European Addiction Research. 2022;**28**(6):405-418

[4] Wang J, Hwang G-H, Chang C-Y. Directions of the 100 most cited chatbot-related human behavior research: A review of academic publications. Computers and Education: Artificial Intelligence. 2021;**2**:100023

[5] Saka AB, Oyedele LO, Akanbi LA, Ganiyu SA, Chan DW, Bello SA. Conversational artificial intelligence in the AEC industry: A review of present status, challenges and opportunities. Advanced Engineering Informatics. 2023;**55**:101869

[6] Muschenich M, Wamprecht L. Health 4.0 - how are we doing tomorrow? Bundesgesundheitsblatt, Gesundheitsforschung, Gesundheitsschutz. 2018;**61**(3):334-339

[7] Taimoor N, Rehman S. Reliable and resilient AI and IoT-based personalised healthcare services: A survey. IEEE Access. 2021;**10**:535-563

[8] Dassah E, Aldersey H, McColl MA, Davison C. Factors affecting access to primary health care services for persons with disabilities in rural areas: A "best-fit" framework synthesis. Global health research and policy. 2018;**3**(1):1-13

[9] Hong G, Smith M, Lin S. The AI will see you now: Feasibility and acceptability of a conversational AI medical interviewing system. JMIR Form Res. 2022;**6**(6):e37028

[10] Seitz L, Bekmeier-Feuerhahn S, Gohil K. Can we trust a chatbot like a physician? A qualitative study on understanding the emergence of trust toward diagnostic chatbots. International Journal of Human-Computer Studies. 2022;**165**:102848

[11] Jang S, Kim J-J, Kim S-J, Hong J, Kim S, Kim E. Mobile app-based chatbot to deliver cognitive behavioral therapy and psychoeducation for adults with attention deficit: A development and feasibility/usability study. International Journal of Medical Informatics. 2021;**150**:104440

[12] Miles O, West R, Nadarzynski T. Health chatbots acceptability moderated by perceived stigma and severity: A cross-sectional survey. Digital Health. 2021;**7**:1-7

[13] Aitken M, Clancy B, Nass D. The Growing Value of Digital Health: Evidence and Impact on Human Health and the Healthcare System. Parsippany, NJ, USA: IQVIA Institute for Human Data Science; 2017. p. 1

[14] Bharti U, Bajaj D, Batra H, Lalit S, Lalit S, Gangwani A. Medbot: Conversational artificial intelligence powered chatbot for delivering tele-health after covid-19. In: 5th International Conference on Communication and Electronics Systems, ICCES 2020. Coimbatore, India: Institute of Electrical and Electronics Engineers Inc; 2020

[15] Petričević S, Mustić D. Communicating a global pandemic with

whatsapp and healthbot in Croatia. In: 11th International Symposium on Graphic Engineering and Design, GRID 2022. Novi Sad, Serbia: University of Novi Sad - Faculty of Technical Sciences, Department of Graphic Engineering and Design; 2022

[16] Belen Saglam R, Nurse JRC, Hodges D. Privacy concerns in Chatbot interactions: When to trust and when to worry. In: Stephanidis C, Antona M, Ntoa S, editors. 23rd International Conference on Human-Computer Interaction, HCII 2021. Springer Science and Business Media Deutschland GmbH; 2021. pp. 391-399

[17] Nath S, Marie A, Ellershaw S, Korot E, Keane PA. New meaning for NLP: The trials and tribulations of natural language processing with GPT-3 in ophthalmology. British Journal of Ophthalmology. 2022;**106**(7):889-892

[18] He L, Basar E, Wiers RW, Antheunis ML, Krahmer E. Can chatbots help to motivate smoking cessation? A study on the effectiveness of motivational interviewing on engagement and therapeutic alliance. BMC Public Health. 2022;**22**(1):726

[19] Ben-Shabat N, Sharvit G, Meimis B, Ben Joya D, Sloma A, Kiderman D, et al. Assessing data gathering of chatbot based symptom checkers - a clinical vignettes study. International Journal of Medical Informatics. 2022;**168**:104897

[20] Organization WH. A Vision for Primary Health Care in the 21st Century: Towards Universal Health Coverage and the Sustainable Development Goals. Switzerland: World Health Organization; 2018

[21] Improta G, De Luca V, Illario M, Triassi M. Digital innovation in healthcare: A device with a method for monitoring, managing and preventing the risk of chronic Polypathological patients. Translational medicine UniSa. 2020;**21**:61-64

[22] Crawford MR, Luik AI, Espie CA, Taylor HL, Burgess HJ, Jones AL, et al. Digital cognitive behavioral therapy for insomnia in women with chronic migraines. Headache. 2020;**60**(5):902-915

[23] Li J, Theng YL, Foo S. Game-based digital interventions for depression therapy: A systematic review and meta-analysis. Cyberpsychology, Behavior and Social Networking. 2014;**17**(8):519-527

[24] Luik AI, Bostock S, Chisnall L, Kyle SD, Lidbetter N, Baldwin N, et al. Treating depression and anxiety with digital cognitive Behavioural therapy for insomnia: A real world NHS evaluation using standardized outcome measures. Behavioural and Cognitive Psychotherapy. 2017;**45**(1):91-96

[25] St-Hilaire A, Hudon C, Preville M, Potvin O. Utilization of healthcare services among elderly with cognitive impairment no dementia and influence of depression and anxiety: A longitudinal study. Aging & mental health. 2017;**21**(8):810-822

[26] Beaudry J, Consigli A, Clark C, Robinson KJ. Getting ready for adult healthcare: Designing a Chatbot to coach adolescents with special health needs through the transitions of care. Journal of Pediatric Nursing. 2019;**49**:85-91

[27] Janssen A, Rodríguez Cardona D, Passlick J, Breitner MH. How to make chatbots productive – A user-oriented implementation framework. International Journal

of Human-Computer Studies. 2022;**168**:102921

[28] Ni L, Liu J. A framework for domain-specific natural language information brokerage. Journal of Systems Science and Systems Engineering. 2018;**27**:559-585

[29] Youness F, Madkour M, Elsefy A. Recent applied techniques for open dialog generation systems. In: 2022 5th International Conference on Computing and Informatics (ICCI). New Cairo, Cairo, Egypt: IEEE; 2022

[30] Soares MAC, Parreiras FS. A literature review on question answering techniques, paradigms and systems. Journal of King Saud University-Computer and Information Sciences. 2020;**32**(6):635-646

[31] Alazraki L, Ghachem A, Polydorou N, Khosmood F, Edalat A. An empathetic AI coach for self-attachment therapy. In: 2021 IEEE Third International Conference on Cognitive Machine Intelligence (CogMI). IEEE; 2021

[32] Wen T-H, Vandyke D, Mrksic N, Gasic M, Rojas-Barahona LM, Su P-H, et al. A network-based end-to-end trainable task-oriented dialogue system. In: Proceedings of the 15th conference of the European Chapter of the Association for Computational Linguistics, Valencia, Spain. 2016;**1**:438-449

[33] Brown T, Mann B, Ryder N, Subbiah M, Kaplan JD, Dhariwal P, et al. Language models are few-shot learners. Advances in neural information processing systems. 2020;**33**:1877-1901

[34] Adamopoulou E, Moussiades L. Chatbots: History, technology, and applications. Machine Learning with Applications. 2020;**2**:100006

[35] Markets Ra. Conversational AI market by component (solutions and services), type (Chatbots and IVA), technology (NLP and ASR), business function (sales and marketing, and operations), Mode of Integration, Vertical, and Region - Global Forecast to 2026. 2021:305.

[36] Nadarzynski T, Miles O, Cowie A, Ridge D. Acceptability of artificial intelligence (AI)-led chatbot services in healthcare: A mixed-methods study. Digital Health. 2019;**1**:5

[37] Erazo WS, Guerrero GP, Betancourt CC, Salazar IS. Chatbot implementation to collect data on possible COVID-19 cases and release the pressure on the primary health care system. In: 11th Annual IEEE Information Technology, Electronics and Mobile Communication Conference, IEMCON 2020. Institute of Electrical and Electronics Engineers Inc; 2020

[38] Kobayashi T, Nishina Y, Tomoi H, Harada K, Tanaka K, Matsumoto E, et al. Corowa-kun: A messenger app chatbot delivers COVID-19 vaccine information, Japan 2021. Vaccine. 2022;**40**(32):4654-4662

[39] Rizzato Lede DA, Inda D, Rosa JM, Zin Y, Tentoni N, Medici MM, et al. Tana, a healthcare Chatbot to help patients during the COVID-19 pandemic at a university hospital in Argentina. Studies in health technology and informatics. 2022;**290**:301-303

[40] Kitchenham BA. Systematic review in software engineering: Where we are and where we should be going. In: Proceedings of the 2nd International Workshop on Evidential Assessment of Software Technologies. New York, United States: Association for Computing Machinery; 2012

[41] Moher D, Liberati A, Tetzlaff J, Altman DG. PRISMA group* t. preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. Annals of Internal Medicine. 2009;**151**(4):264-269

[42] Deloitte. The Future Unmasked, Predicting the Future of Healthcare and Life Sciences in 2025. Deloitte; 2020

[43] Roca S, Sancho J, García J, Alesanco Á. Microservice chatbot architecture for chronic patient support. Journal of Biomedical Informatics. 2020;**102**:103305

[44] Chung K, Park RC. Chatbot-based heathcare service with a knowledge base for cloud computing. Cluster Computing. 2019;**22**(1):1925-1937

[45] Kadariya D, Venkataramanan R, Yip HY, Kalra M, Thirunarayanan K, Sheth A. KBot: Knowledge-enabled personalized chatbot for asthma self-management. In: 2019 IEEE International Conference on Smart Computing (SMARTCOMP). IEEE; 2019;**1**:138-143.

[46] Sheth A, Yip HY, Shekarpour S. Extending patient-chatbot experience with internet-of-things and background knowledge: Case studies with healthcare applications. IEEE Intelligent Systems. 2019;**34**(4):24-30

[47] Rebelo N, Sanders L, Li K, Chow JCL. Learning the treatment process in radiotherapy using an artificial intelligence–assisted Chatbot: Development study. JMIR Formative Research. 2022;**6**(12):e39443

[48] Aydın Ö, Karaarslan E. OpenAI ChatGPT Generated Literature Review: Digital Twin in Healthcare. In: Aydın Ö, editor. Emerging Computer Technologies. İzmir Akademi Dernegi; 2022;**2**:22-31

[49] Jagadish B, Mishra PK, Kiran M, Rajalakshmi P. A real-time health 4.0 framework with novel feature extraction and classification for brain-controlled IoT-enabled environments. Neural computation. 2019;**31**(10):1915-1944

[50] Miura C, Chen S, Saiki S, Nakamura M, Yasuda K. Assisting personalized healthcare of elderly people: Developing a rule-based virtual caregiver system using Mobile Chatbot. Sensors. 2022;**22**(10):3829

[51] Behera RK, Bala PK, Dhir A. The emerging role of cognitive computing in healthcare: A systematic literature review. International Journal of Medical Informatics. 2019;**129**:154-166

[52] Wassan S, Suhail B, Mubeen R, Raj B, Agarwal U, Khatri E, et al. Gradient boosting for health IoT federated learning. Sustainability. 2022;**14**(24):16842