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Abstract

Artificial-Intelligence (AI) is becoming more widespread in several areas, from economics and government to consumer-services and even healthcare. In fact, in the latter, there was a big use increase in the past three years, also due to the COVID-19 pandemic. Several solutions have been implemented to tackle the several challenges imposed by this new disease, being one of such solutions chatbots. In this article, we present the results of a Systematic Literature Review (SLR) that identifies the Chatbots applications in COVID-19 disease. In this SLR, we identified 9987 papers from which we selected 30 studies, on which we performed a full-text analysis. From our research, we could conclude that several solutions were implemented, with good acceptance by citizens, despite several limitations, such as limited time to develop the solutions (which narrowed some features, such as AI voice conversation), lack of global implementation and infrastructure limitations.

Keywords: artificial intelligence; chatbot; COVID-19; Bot; conversational agents

1. INTRODUCTION

Today's healthcare industry is becoming more and more reliant on the underlying information technologies. For instance, today practically all registrations take place online, and healthcare digitization is growing (Anderson & Agarwal, 2011). The first shift from paper-based records to electronic health records occurred only a few decades ago (Teixeira et al, 2021), and today we talk about adopting methods like blockchain to communicate health data (Agbo et al., 2019). Academic medical centers were the first to become digital (Evans, 2016; Teixeira et al., 2021), but since then, other areas of the healthcare industry have also used their information systems. These are all examples of Health Information Systems (HISs). A well-functioning health information system ensures the generation, analysis, dissemination, and use of reliable and timely information on health determinants, health system performance, and health status, according to the WHO's statement (World Health Organization, 2007).

The global COVID-19 pandemic, which started in late 2019, has caused approximately 551 million infections and 6 million fatalities as of July 8, 2022. (WHO Coronavirus (COVID-19) Dashboard, n.d.) Survivors experience long-term physical, psychological, and financial effects, which increases the number of years-of-life lost after adjusting for handicap. Despite ongoing vaccination campaigns, 3 COVID-19's long term health impacts continue to be unknown. What is certain is that the emergence

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of new variants (e.g., Omicron B4/5 variants), which are more resistant to antibodies produced by immunization, will likely result in more infections and reinfections in shorter periods (Tuekprakhon et al., 2022). This means that the COVID pandemic is far from over and will continue to be a burden to healthcare systems globally.

Digital-supported solutions that facilitate COVID avoidance, detection, and management remain critical in guaranteeing an adequate response by healthcare professionals and systems, while also recovering all the activity (appointments, surgeries, chronic diseases management) that was lost during the quarantines and first stages of the pandemic.

The emergence of such solutions started as soon as the first cases were detected (Zeng et al., 2020; Drew et al., 2020). From geo-tracking new cases, to help people deal with COVID-19 symptoms or to cope with quarantines and long isolations periods, to more advanced, AI-supported, prediction of the disease's new probable clusters or clinical referral according to intelligent algorithms' severity assessment.

One of such solutions was the development of AI-related chatbots, allowing in most instances a first contact between a citizen (healthy or sick) with the healthcare system, making an initial triage and avoiding the overuse of scarce healthcare resources.

A chatbot is software application that simulates human conversation using voice instructions, text messages, or both. An AI tool called a chatbot, also called a chatterbot (Brush & Scardina, 2021), can be integrated into, and utilized with any important messaging service (Caldarini et al., 2022). These tools, once created, are easily scalable, have low operational cost and provide standardized care, regardless of moral judgements.

AI-related solutions in general, and chatbots in particular are being increasingly used in healthcare (Nadarzynski et al., 2019). This results from a greater acceptance of technology by healthcare users, as they also become more disseminated in the remaining aspects of their lives, but also because, as the knowledge production increases, these systems allow more objective, robust and evidence-based clinical decisions, screening and selecting the best available information (according to the leges artis) from gigantic amount of available data (Parviainen & Rantala, 2021).

The COVID-19 pandemic, as an emergency that quickly overworked healthcare systems worldwide, required the quick development of solutions. While most of the people quarantined, limiting face-to-face interactions, it was only natural that digital solutions, such as chatbots, emerged as important tools in dealing with the pandemic (Dennis et al., 2020).

Our study's goal is to identify some COVID-related chatbots and their variables using a systematic literature review (SLR).

For executing this SLR, we follow the recommendations established by Kitchenham et al. (2009), adapted. As such, this article does not intend to proceed with an extensive review of all the chatbots created during the pandemic, but to highlight some of the most used characteristics of these, namely the ones created during the pandemic. Therefore, the review protocol is briefly explained in section 2. The results and discussion make up sections 3, and finally some conclusions are presented in section 4.

2. METHODOLOGY

For this article, we adhered to the recommendations made by Kitchenham et al. (2009), which adapt guidelines from, among other sources, the Cochrane Collaboration (Clarke & Oxman, 2000). Our review is displayed in Fig. 1. In the first stage, an iterative systematic search technique was defined, so to obtain from the most popular specific databases a satisfactory string of references. The second step was identifying a set of study inclusion and exclusion criteria, which was implemented firstly automatically, then through human-approach methods. In this last stage, an objective set of criteria was implemented to guaranteeing that the final set of articles contained part or all elements that were to be analyzed in further stages. To extract the components (healthcare and informatic domains) required to respond to the research questions, we created a data extraction model in the fourth phase. On the fifth phase, we summarized the extracted elements using a synthesis method.

2.1. *Searching Technique*

We used standard filtering options to look for articles in computer science, medical information systems, and medical informatics in four online databases: **b-ON** and **Clarivate** (general libraries) and **Scopus** and **PubMed** (which focus on health and biomedical sciences). Firstly, the title, abstract and keywords were screened with multiple terms combinations: "*covid*" AND either ("*artificial intelligence*" OR "*bot*" OR "*chatbot*"); "*covid*" AND "*artificial intelligence*" AND "*bot*"; "*covid*" AND "*artificial intelligence*" AND "*chatbot*", and a final search including all terms (AND). Filters that avoided non-scientific published articles were implemented. The results were 9987 articles. From these, duplicates, other-than English, and non-scientific or non-published (e.g., early access) articles were removed. The titles and keywords were screened to eliminate articles not related to bots and chatbots. Afterwards, we came with a final set of 90 articles. The abstracts of these were screened independently by two researchers to only include articles related to AI-chatbots medical solutions implemented during the COVID-19 pandemic. When these researchers didn't agree of an article met the inclusion criteria, a third independent researcher served as a tiebreaker. This resulted in 30 articles, from which data was extracted. All articles had had to be published between 01st January 2020 and 31st December 2021.

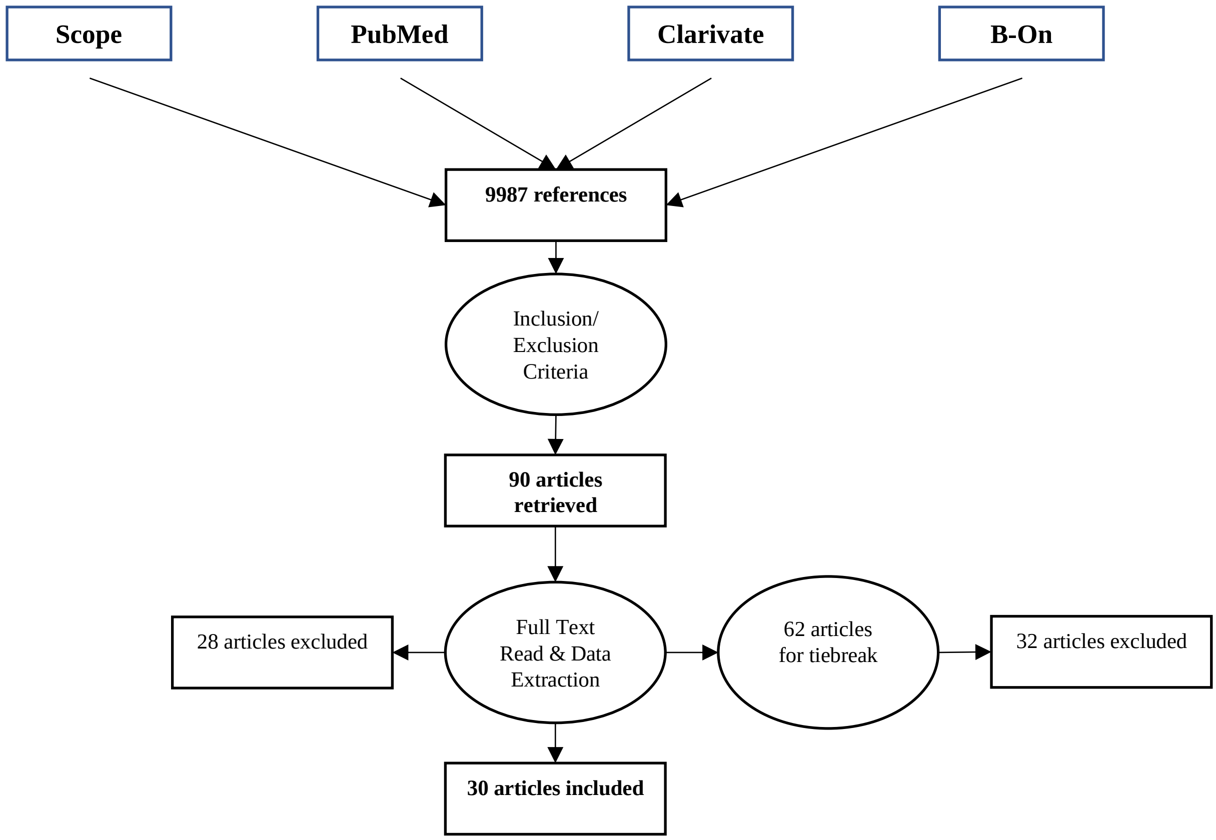

Fig.1 Articles retrieving flowchart

2.2. *Selection Standards for Studies*

We divided the criteria for this study's selection into inclusion and exclusion criteria (Tables 1 and 2). The exclusion criteria were developed as part of the methodology and the inclusion criteria as an iterative process involving all researchers, using a set of 10 articles chosen randomly. We only included research that met all the inclusion criteria and omitted studies that met any of the nine exclusion criteria.

Nº	Criteria
EC1	Non-scientific published paper
EC2	Early access papers or later amended papers
EC3	Study presenting AI-solutions but not using chatbots as fundamental tool
EC4	Study that presents frameworks instead of actual implement solutions
EC5	Papers without full text available
EC6	Papers not written in English
EC7	Duplicate publication from multiple sources
EC8	Study not published between 1st Jan 2020 and 31st Dec 2021
EC9	Study that presents frameworks instead of actual implement solutions

Table 1 – Exclusion Criteria

Nº	Criteria
IC1	COVID-19 general health information
IC2	COVID-19 symptom management
IC3	COVID-19 screening
IC4	COVID-19 health professional referral
IC5	COVID-19 contact tracing / public health surveillance
IC6	Mental health promotion either due to COVID-19 related quarantine(s) or isolation

Table 2 – Inclusion Criteria

2.3. ***Data processing***

The data was extracted using a standard form, divided in two main sections – medical-related data and IT-related data. Moreover, general variables were also extracted. These three categories are summarized in table 3.

General	Medical	IT
Geographic implementation	Health goal (screening, health advice, health promotion, etc…)	Chatbot implementation vs. framework
Languages	Outcomes	User interface (voice, text, …)
	Development input	
	Long-term COVID	

Table 3 – Extracted Variables

Afterwards, the data was compiled and summed up so to avoid overrepresentation of specific types of solutions in the literature.

We used Excel and Google Sheets as the main software platforms to data processing.

3. RESULTS

Based on the research and selection flow, 30 articles were included in this work (Table 3):

N’	Article title	DOI
1	An artificial intelligence-based first-line defence against COVID-19 digitally screening citizens for risks via a chatbot	10.1038/s41598-020-75912-x
2	Artificial intelligence can improve patient management at the time of a pandemic The role of voice technology	10.2196/22959
3	Chloe for COVID-19 Evolution of an intelligent conversational agent to address infodemic management needs during the COVID-19 pandemic	10.2196/27283
4	Did chatbots miss their Apollo Moment Potential, gaps, and lessons from using collaboration assistants during COVID-19	10.1016/j.patter.2021.100308

5	Extensible Chatbot Architecture Using Metamodels of Natural Language Understanding	10.3390/electronics10182300
6	Health chatbots for fighting COVID-19 A scoping review	10.5455/AIM.2020.28.241-247
7	A semantic web framework for automated smart assistants A case study for public health	10.3390/bdcc5040057
8	An assessment of self-reported COVID-19 related symptoms of 227,898 users of a social networking service in Japan	10.1016/j.lanwpc.2020.100011
9	Chatbots in the fight against the COVID-19 pandemic	10.1038/s41746-020-0280-0
10	Diagnostic Accuracy of Web-Based COVID-19 Symptom Checkers Comparison Study	10.2196/21299
11	Early SNS-Based Monitoring System for the COVID-19 Outbreak in Japan A Population-Level Observational Study	10.2188/jea.JE20200150
12	Elena plus Care for COVID-19, a Pandemic Lifestyle Care Intervention Design and Study Protocol.	10.3389/fpubh.2021.625640
13	Information Delivered by a Chatbot Has a Positive Impact on COVID-19 Vaccines Attitudes and Intentions	10.1037/xap0000400
14	Large-scale epidemiological monitoring of the COVID-19 epidemic in Tokyo	10.1016/j.lanwpc.2020.100016
15	Perceived utilities of COVID-19 related chatbots in Saudi Arabia A cross-sectional study	10.5455/AIM.2020.28.219-224
16	User reactions to COVID-19 screening chatbots from reputable providers.	10.1093/jamia/ocaa167
17	Utility and usability of an automated COVID-19 symptom monitoring system (CoSMoS) in primary care during COVID-19 pandemic A qualitative feasibility study	10.1016/j.ijmedinf.2021.104567
18	An Automated Patient Self-Monitoring System to Reduce Health Care System Burden During the COVID-19 Pandemic in Malaysia Development and Implementation Study	10.2196/23427
19	AI Chatbot Design during an Epidemic like the Novel Coronavirus	10.3390/healthcare8020154
20	Digital triage Novel strategies for population health management in response to the COVID-19 pandemic	10.1016/j.hjdsi.2020.100493
21	Leveraging conversational technology to answer common COVID-19 questions.	10.1093/jamia/ocaa316
22	Towards developing a pocket therapist An intelligent adaptive psychological support chatbot against mental health disorders in a pandemic situation	10.11591/ijeecs.v23.i2.pp1200-1211
23	Use characteristics and triage acuity of a digital symptom checker in a large integrated health system Population-based descriptive study	10.2196/20549
24	A Guide to Chatbots for COVID-19 Screening at Pediatric Health Care Facilities	10.2196/18808
25	Chatbot as a Telehealth Intervention Strategy in the COVID-19 Pandemic	10.19153/cleiej.24.3.6
26	Detection of recovery of covid-19 cases using machine learning	10.31782/IJCRR.2021.SP183
27	Engagement and Effectiveness of a Healthy-Coping Intervention via Chatbot for University Students During the COVID-19 Pandemic Mixed Methods Proof-of-Concept Study.	10.2196/27965
28	Implementation of a digital chatbot to screen health system employees during the COVID-19 pandemic.	10.1093/jamia/ocaa130
29	Population subgroup differences in the use of a COVID-19 chatbot.	10.1038/s41746-021-00405-8
30	Self care nursing Teleassessment nursing with chatbot application the coronavirus disease-19 pandemic period in north sumatra	10.3889/oamjms.2021.7172

Table 4 – List of included articles

According to the preselected variables, the overall results can be seen on table 5.

		# (/30)	%	Articles
General Features				
Geographical implementation				
	USA	7	23,3	7, 16, 20, 21, 23, 28, 29
	Canada	2	6,7	3, 15
	South America	1	3,3	25
	Japan	3	10,0	8, 11, 14
	Southeast Asia	3	10,0	17, 18, 30
	EU	3	10,0	5, 12, 13
	Africa	1	3,3	22
	Multiple regions	2	6,7	1, 9
	Not specified / n.a.	8	26,7	2, 4, 6, 10, 19, 24, 26, 27
Number of languages				
	1	20	66,7	4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 23, 28, 29
	2	1	3,3	3
	+3	9	30,0	1, 2, 21, 22, 24, 25, 26, 27, 30
Medical Features				
Health goals ⁋				
	Screening	15		1, 3, 8, 9,10, 11, 14, 16, 19, 20, 23, 24, 25, 28, 29
	Occupational safety	1		28
	Relay information	10		3, 5, 7, 12, 13, 15, 20, 21, 25
	Mental health promotion	3		12, 22, 27
	Control of symptoms in infected people	3		17, 18, 30
Outcomes				
	Differential diagnosis	1	3,3	1
	General health information	4	13,4	3, 12, 15, 30
	Referencing to health professional	7	23,3	8, 11, 14, 17, 18, 20, 23
	Health validated advice	2	6,7	22, 27
	Others	1	3,3	28
	Not specified / n.a.	15	50,0	2, 4, 5, 6, 7, 9, 10, 13, 16, 19, 21, 24, 25, 26, 29
Development input				
	Experts input	2	6,7	3, 25
	Validated medical questionnaires	1	3,3	27
	National/regional statistics	1	3,3	1
	Others	3	10,0	8, 28, 30
	Not specified / n.a.	23	76,7	2, 4, 5, 6, 7, 8, 10, 11, 12, 13, 14, 15, 16, 17, 18, 29, 20, 21, 22, 23, 24, 26, 29
Long-term COVID		0	0	

IT variables				
Article type:				
	Chatbot implementation	23	76,7	1, 3, 5, 7, 8, 9, 11, 12, 13, 14, 17, 18, 19, 20, 21, 22, 23, 25, 26, 27, 28, 29, 30
	Purposed framework/technical specifications	7	23,3	2, 4, 6, 10, 15, 16, 24
User interface				
	Voice	8	26,7	2, 16, 20, 21, 22, 13, 24, 25
	Text	8	26,7	3, 10, 11, 12, 13, 15, 27, 28
	Voice and text	14	46,6	1, 4, 5, 6, 7, 8, 9, 17, 18, 19, 23, 26, 29, 30

⁋ Several apps presented more than one feature.

Table 5 - Results

Moreover, when reviewing the articles some qualitative data was also extracted. From the 24 articles describing implemented solutions, we can highlight some of the applications, such as Chloe, Symptoma, ADA, Instant Expert, COOPERA, Elena+, CoSMoS, MGB Chatbot, TeleCOVID and Atena.

4. DISCUSSION

Firstly, we can see a wide geographic distribution of solutions, despite most of them being in the Northern Hemisphere. These probably results from the wider technological advancement of these countries and a greater smartphones usage by the population, as most of these solutions were implemented on these devices (or at least made available). As most solutions were limited in their implementation to the countries where they were created, it is only normal that the number of languages be also restricted to one or two official languages, such as in Canada (English and French).

When it comes to the analyzed health variables, most of solutions (15) were created as screening tools. This is easily explaining as the necessity to ease the burden on the healthcare systems, which also justifies the second most found goal – relay information. Unexpectedly there is a lack of representation of mental health solutions, despite the unsettling circumstances created by the pandemic, such as lockdowns, unemployment or loss of job, or future unpredictably. The reason can be because there are already several applications on the market related to mental health, not being specifically design for COVID, and thus leading to an underrepresentation in the literature. Outcomes are as expected, according to the health goals provided early. Directing people to proper healthcare professionals or relaying personalized information are natural results of screening tools and health information search tools. The number of unknown outcomes is high (50%), but this can be either due to the quick development of this tools that ended up in embryonic stages, and thus lacking a clear single outcome, or these are considered so obvious that are not properly reported in the articles, so a conclusion cannot be formally drawn.

The number of articles without the scientific tools used in the solutions' development is also high (23), resulting probably from the fact that a high number of applications were create either by the private sector alone or in conjunction with the public sector. This leads to the development stages (or at least parts of it) being proprietary knowledge.

When it comes to the IT variables, the high number of articles reporting actual solutions, instead of just frameworks, shows some high degree of maturity of these types of solutions, either technological, but also when it comes to market penetration.

Finally, from the analysis of these articles, we can also understand the very small number of solutions using voice interactions. This may be explained by a lack of maturity of this approach as well as technical difficulties that made it difficult to design and implement in very short periods. Nevertheless, the number of dual solutions (text and voice) shows that the tools developers are becoming increasingly aware about the importance of flexibility and adaptably.

5. CONCLUSION

The use of chatbots in healthcare is becoming more prevalent than ever, assisted by the evolving field of artificial intelligence (AI). The current pandemic saw the development of several AI-assisted solutions, either to screen, to inform, or to present mechanisms to cope with the uncertainty of the first stages of the pandemic. In a second moment, we started to also see new solutions related to vaccination or symptoms management, trying to ease the burden on overworked healthcare systems. Other tools were also designed, namely related to public health systems, such as to control and monitor sick people, as well as trying with these to predict new disease's clusters.

As the pandemic is relatively new, and the search query also limited the articles to its first stages, the data presented by these articles are limited, in number of users as well as features.

Nevertheless, according to a subjective analysis of these articles, where these solutions were used, there was an apparent reduction in healthcare resources. Despite stricter scientific protocols being needed to conclude this definitively, this aspect is very positive and may reinforce the need of these tools, not only in this pandemic, but also as important helpers of healthcare professionals, in a world with increasing health challenges, such as the increase burden of chronic diseases, increase demand to healthcare by third-world countries and climatic changes.

Limitations

Several limitations can be presented to this article. The most pressing one may refer to the English exclusion criteria, which can partially explain why none of the articles referred to China, despite being not only the first location where this disease appeared, but also a country known for using digital solutions to monitor its citizens. Moreover, some articles referred to the same applications, analyzing its' different aspects (e.g., design vs. implementation or features vs. usage data), which means some conclusions may be overestimated. Finally, as just four online repositories were chosen to do our search, some articles not indexed in these may have been missed, again with the risk of overestimation of the solutions presented in English or in the most relevant journals.

Future Work

In the future, the authors feel it would be interesting to perform the same analysis to solutions related to long-term COVID, or even develop themselves a framework or a tool, using the findings of this article. In addition, just one of the presented chatbots was in (Brazilian) Portuguese, so it could also be interesting to develop a tool in Portuguese, easing the burden on our National Health System's professionals as the pandemic continues further into the future.

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