

# Bibliometric Analysis of Chatbots in Health-Trend Shifts and Advancements in Artificial Intelligence for Personalized Conversational Agents

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## Abstract

*Bibliometric analysis provides a summary for research reported in scientific literature. This can highlight patterns and trends in academic research areas, and assist in research directions. Recent growing requirements for efficient communications and increased user learning needs in the health domain, has instigated mass exploitation of chatbots. 2148 documents were analysed to show a shift in research focus around the year 2016. The rate of documents produced in the last few years is more than the collective 20 year period, and future outputs may soar. The emergence of machine and deep learning technology with chatbot usage suggested research opportunity to be exploited in techniques which embed advanced AI abilities. Key authors still spearhead the research direction but a new wave of outputs will further disperse topics into advanced techniques such as personalised disease detections and sophisticated interface that significantly mask any artificiality to their composition.*

## Keywords:

Embodied Conversational Agents; Artificial Intelligence; Bibliometrics; Trends

## Introduction

Bibliometric analysis provides a summary for research reported in scientific literature. Quantitative information can be generated to allow this to occur. It is a firmly established scientific method that can be used for research evaluation. Initial overviews of scientific productions or selections of publications can be subdivided into lists of author productions, subject bibliography, geographical or institutional elements, and other indicators of performance and scientific interest. This can highlight patterns and trends in academic research areas, and assist in research directions.

One area that has recently undergone rapid development and changes in direction is use of chatbots in healthcare. The health domain has less implementation of chatbots than others, such as business and marketing. However, recent growing requirements for efficient communications and problem solving in the health domain, has instigated mass exploitation of chatbots. They can help remove burden of tasks in some areas to free up resources and staff in other areas. An increase in research has occurred in recent years and bibliometric analysis has tools to explore past, present, and future perspectives for chatbot usage.

Chatbots can be embedded into an array of software platforms, with mobile devices being most common. In general, global mobile usage is increasing annually. There was a 65% increase in mobile app download from 2016 -2020 (140.7 billion to 218 billion downloads) [1]. This is just one of many

delivery methods that are increasing, and portable devices in health are widely used and uncomplicated for chatbot implementation.

AI has been integral to chatbot development, and the most described use of AI are front-end user-facing (as opposed to data-facing). User-facing intelligent agents interact with people and use Natural Language Processing (NLP) to decipher data, suppose meaning, and respond to the user. For example, AI-based conversational agents and medical chatbots can provide medical consultation to patients based on their interpretation of the patient's data. A 2018 bibliometric analysis exploring the emergence of deep learning technology with chatbot usage suggested research opportunity to be exploited in this area [2]. A 2019 Journal of Medical Internet Research (JMIR) article suggested a suitable potential role for AI presented via chatbots or conversational agents should supplement rather than replace medical professionals [3]. The implementation of such instruments was more important than attempting to emulate human social and communication skills. Further exploration into motivations for using health chatbots suggested 3 broad themes: understanding of chatbots, AI hesitancy, and motivations for health chatbots. If these concerns are not being addressed this may impact development.

A pivotal 2020 research paper asserted there was a lack of chatbot integration into formal medical education settings, and created a novel conversational virtual patient that could support machine learning [4]. This allowed students to practice their decision-making regarding obstructions of blood vessels by blood clots. The study addressed the 3 themes in chatbot usage motivations—they provided co-creation workshops for students to understand how chatbots work, helped to add social characteristics to the chatbots to reduce hesitancy, and the topic was desired by students for motivation as use in their studies. This represents an acceleration in application and directions for chatbots in health settings. Indeed, distinct themes of chatbot and conversational agent implementation are evolving as AI synthesis improves. Treatment and monitoring, health service support, pedagogy, psychology and behavioural changes, and diagnostics are key topics [5].

Therefore, the objective was to understand key features in the cumulative work and identify similar trending documents to explore what has been addressed each year, by whom, and how this can help to predict future topics of interest. As there are few analyses that explore all subtypes of agents, there was usefulness in a bibliometric analysis that explores overall applications of chatbots, and does not focus on technical aspects or features.

## Methods

### Search Properties

Two bibliographic databases were harvested that are considered the largest-Web of Science database and Scopus. The field tags for title, abstract, and keywords were used when paired with search query associated with chatbots (e.g. conversational agent, virtual assistant) AND healthcare (e.g. health, medical, surgical, nursing). Inclusion criteria were the articles to be in English language and be one of the following types: articles, proceedings papers, books, book chapters, and conference papers. The search area was set from 1st January 2000 to 1st May 2021. Files were merged in Excel and Kutools was used to exclude duplicates. There were approximately 280 duplicates that were deleted. Bibliometrix and Biblioshiny [6] in RStudio and VOSviewer [7] were used to perform analyses and output the figures included.

## Results

### Dataset Characteristics

The dataset included 2148 documents consisting of 1186 sources. Most of the published literature in chatbots in health domains were articles (1146; 54%), and conference/proceedings papers (960; 44%). There were 58546 references, 4245 author keywords, 6597 authors of multi-authored documents, 3.14 authors per document, and 11.47 mean citations per document.

The top 10 affiliations were in USA/Canada. The top 5 were Northeastern University (63 documents), University of Pittsburgh (59) Boston University (56), University of Washington (41), and Stanford (36). Seoul National University (29) was the top university outside of the northwest hemisphere.

Table 1 displays the top 10 most cited papers, and articles in their respective sources. Notably, with just over 3 years since publication, an article by Huimin Lu and colleagues from Kyushu Institute of Technology, Kitakyushu, Japan, has 74 citations per year [8]. This is a high average in a short period compared to other prevalent articles, such as Bickmore, 2005.

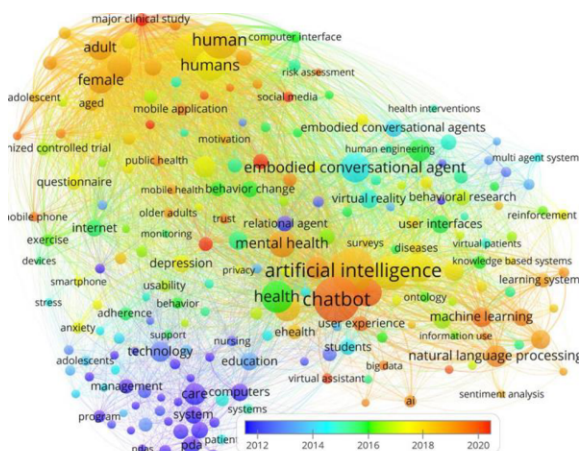


Figure 1: Author keywords network and frequencies per year. Technology-based research shifted to AI, and application-based in 2016

A Historical Direct Citation Network suggested Timothy Bickmore was the most frequently cited author, with Bickmore's most cited article in row 2 of Table 1. This is due to the high document production paired with longer time passing since publication than other similarly prevalent documents. The most cited proceedings article was in the Proceedings of the Special Interest Group on Computer-Human Interaction Conference on Human Factors in Computing Systems, by Bickmore, Pfeifer, and Jack, in 2009 with 164 Total Times Cited. This article involved an animated, empathic virtual nurse interface and details of embodied conversational agents. Indeed, Bickmore was the most cited author in the dataset and had 45 documents with a fractionalised score of 13.14. Not specific to chatbots and health, Bickmore has an h-index of 61[9]. The most recent 2021 paper is titled 'Automating Cancer Genetic Counseling with an Adaptive Pedagogical Agent'.

To investigate these changes viewed in Figure 1, the annual scientific growth rates were calculated and word dynamics graphs were created. They suggested the overall annual growth rate was averaged at 12.4% for the 1991-2021 dataset. However, from 2017 the annual growth rate was 45.81%, and in 2020 404 (19%) of documents were produced. This is equivalent to around 20% of the total documents in 30 years, just in 2020.

Therefore, 600+ documents are estimated to be produced in 2021. This indicates the potential for thousands of documents each year from 2022.

Indeed, there were 960 conference proceedings overall and 479 were between 2018 -2021 which suggested 50% of proceedings from the last 21 years were within the last 38 months. To explore this recent increase, Annual Scientific Production and Thematic Evaluation were performed; 2016 was the start of a substantial increase in article production, therefore a thematic split was added at 2016. Between 2001-2016 emerging clusters of usability of systems, digital assistance, and e-learning (see Figure 1). From 2016-2021 more branches had developed with themes surrounding, mental health promotion, education, human behavior, and artificial intelligence. Overall, with this timesplit at 2016 due to substantial increase in documents, a shift from technological development and integration in devices, to

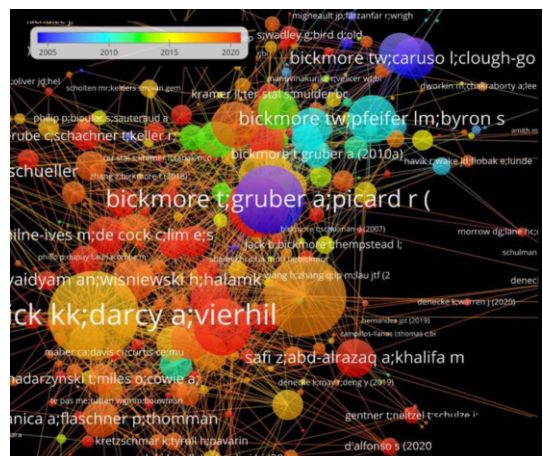


Figure 2: Amount of citations by publication year, showing the impact of Bickmore 2005-2010 (purple), with more recent documents having accelerated to similar levels of citations.

Table 1: Top 10 most cited papers in addition to their source, and number of documents from each source. Source documents showed less submission to many journals but contained frequently cited papers.

Paper	Total Citations	TC per Year	Normalized TC	Sources	Documents
LU H, 2018	297	74	34.18	Mobile Networks and Applications	3
BICKMORE T, 2005	265	15.5882	9.37	Patient Education and Counselling	18
BLAYA JA, 2010	240	20	8.48	Health Affairs	1
FANNING J, 2012	225	22.5	12.22	Journal of Medical Internet Research	82
FITZPATRICK KK, 2017	219	43.8	13.44	JMIR Mental Health	19
MILNER R, 2009	219	16.8462	9.43	The Space and Motion of Communicating Agents (book chapter)	1
LIN YH, 2004	202	11.2222	9.63	IEEE Transactions on Information Technology in Biomedicine	3
YI MY, 2006	183	11.4375	8.30	Decision Sciences	1
DEPP CA, 2010	176	14.6667	6.22	The Journal of Nervous & Mental Disease	2
COOK DJ, 2009	164	12.6154	7.06	Methods of Information in Medicine	8

domains of applications and methods of data processing were mapped.

As indicated in Figure 3, emerging themes were in the domain of Artificial Intelligence; such as machine learning, deep learning, and natural language processing. This was a similar finding to a 2018 bibliometric study with 'Deep Learning' as a very early emerging theme in 2015 [2]. Three primary words were increasing in occurrences the most. 'Conversational agents' are a further development of typical 'chatbot' architecture whereby a deliberate module using Natural Language Processing (NLP) This utilizes artificial intelligence and allows goal-based verbal interactions with humans[4].

Between 2020-2021, 32.6% of documents had author keywords of 'machine/deep learning, or AI. The topics and authors were investigated to show several of these titles included individuals with medical and surgical re-search backgrounds who had utilized deep learning in health.

For example, one source within the dataset in this study was a 2018 article exploring the method to develop deep learning algorithms to improve performance in a specific endoscopic procedure [1]. Although the lead author had publication dates from early 2000, it was first research

output with deep learning in healthcare, several other papers follow this trend. In 2021, a AI driven intelligent tutoring system was used via a virtual conversation agent, to improve treatment seeking behaviour [10]. This mass uptake of AI was present in not only the majority of influential emerging researchers, but present in authors in this domain for decades. In a wide variety of health topics, these authors suggest substantial improvements to each issue under investigation.

The two most relevant sources were Lecture notes in computer science (88 articles), and the Journal of Medical Internet Research (82 articles). Journal of Medical Internet Research had the highest number of documents from 2019 and we predict will continue to absorb most of future articles. This is due to its specialty in health informatics and emerging technologies and global leading position with a 2019 impact factor of 5.03 [11].

However, that Table 1 highlights that for many years highly cited documents were found in an array of sources which have had less submissions within the timeframe of this dataset.

## Discussion

The goal of this bibliometric analysis was to understand key features of the collective outputs and how changes in technology may have shifted focus-this can help to predict upcoming topics of interest. In summary, the results indicated a distinguished increase in document out-put that denotes intense growth in the next few years. It can be surmised that due to advancements in deep learning and AI techniques, a second wave of research is occurring. Natural language processing-based conversational software agents depend upon the incorporation of human intelligence into their own knowledge structures. The displayed AI of the agent can be further developed when deep learning algorithms are inserted, which are close to human cognition in the deciphering and pattern recognition of data. From this, the focus of development in machine/deep learning in health will increase dramatically, and future research may investigate its utility in symptom recognition and diagnosis.

As deep learning utilization can facilitate personalization, there may be a niche topic of conversational agents that assist in personalised diagnosis for patients. Artificial intelligence chatbots can be trained to understand medical literature and be applied to disease detection by a two way relay of information to and from patients. This informs the patient of the meaning behind a symptom, but also analyses this information to diagnose a disease/condition. Such indicators as symptom intensity, duration, and location can be securely linked with

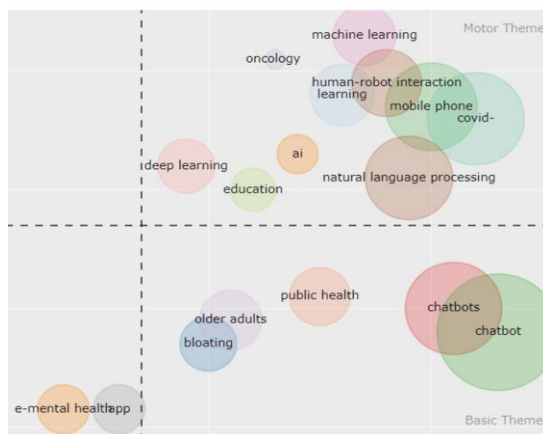


Figure 3: 2020-2021 authors keywords shows dominant developments in Artificial Intelligence related areas, with COVID-19 also being a novel term

medical data via blockchain technology to create individually precise decision making by the agent.

Yet, for such advanced optimisation in data processing and personalised interactions, further development of front-end interface is required. As early as 2005, there was utilization of user profiles to support personalized and self-adaptive features [12], but more research is required as the interface is still a barrier between successful uptake of any product or intervention created. If the increase of publications occurs as predicted, then there will be an abundance of new chatbot applications and interventions which may be determined by their UI. The present themes of human-robot interaction and mobile phones (see figure 3) suggest they are of recent interest but possibly overlooked. The Conference on Human Factors in Computing Systems may play a part in the future of this topic, as for 2020 and 2021 Bickmore and more than 7 co-authors have published 4 articles in the proceedings which explore interface with artificial systems. This indicates once again how Bickmore and colleagues from Northeastern University are continuing to spearhead into new areas. Rapid citations and impact by several rising authors in the US with shorter research history may form niche spheres of exploration, or be parallel in this domain-is it unclear. Future research should work more closely with end users to exploit the new features produced by AI and machine learning, to create optimally compatible conversational agents for not only the specific group of users, but for each person. One successful method is to include the stakeholders in the process co-creation methods.

Co-creation methods have impactful results on the end users' understandings and further development towards a patient-facing intervention that will be most impactful to them [13]. This is because co-creation methods have foundations in learning theory principles and encourages participation from end users, experts, and other stakeholders to communally create resources, such as conversational agents [14]. Social characteristics can be iteratively designed that will engage the intended end users and may adapt to a users' attitudes or challenges through advanced natural language processing paired with appropriate social features.

Limitations in the interpretation of the dataset were on the large period of 21 years analyzed. More insight into contemporary documents in the last 5 years may have further comprehended current trends. However, fundamental authors have been consistently popular, and there was interest in this change over time to determine how these fundamental individuals will play a part in future direction. There was less focus on specific topics in health, such as appearing themes of 'older adults', or 'mHealth'. This was partly due to the subtraction of such applied themes in favor of AI based outputs. As mentioned, between 2020-2021, 32.6% of documents had author keywords of 'machine/deep learning and will increase. However being in the top 10 (8<sup>th</sup>) word frequency mHealth was shadowed in this bibliometric analysis and future work should discuss recent outputs.

## Conclusions

Technology has developed to a point where research in hardware is comparatively marginal from before year 2000. Instead, health informatics, AI, and areas for implementation are blossoming. AI related topics are seeping into all health related domains and there is only sign of increase. Key authors still spearhead the direction but a new wave of outputs will further disperse topics into advanced techniques such as personalised disease detection and sophisticated interfaces that significantly mask any artificiality to their composition.

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