BMJ Health & Care Informatics

Three-year trends in literature on artificial intelligence in ophthalmology and vision sciences: a protocol for bibliometric analysis

Hayley Monson,[1] Jeff Demaine,[2] Laura Banfield,[2] Tina Felfeli [3,4]

To cite: Monson H, Demaine J, Banfield L, *et al*. Three-year trends in literature on artificial intelligence in ophthalmology and vision sciences: a protocol for bibliometric analysis. *BMJ Health Care Inform* 2022;**29**:e100594. doi:10.1136/bmjhci-2022-100594

► Additional supplemental material is published online only. To view, please visit the journal online (http://dx.doi.org/10.1136/bmjhci-2022-100594).

Received 10 May 2022
Accepted 14 September 2022

Check for updates

[1]Department of Mathematics and Statistics, McMaster University, Hamilton, Ontario, Canada
[2]Library Department, McMaster University, Hamilton, Ontario, Canada
[3]Department of Ophthalmology and Vision Sciences, University of Toronto, Toronto, Ontario, Canada
[4]The Institute of Health Policy, Management and Evaluation, University of Toronto, Toronto, Ontario, Canada

Correspondence to
Dr Tina Felfeli;
tina.felfeli@mail.utoronto.ca

ABSTRACT

Introduction The aim of this study is to provide an insight into the literature at the intersection of artificial intelligence and ophthalmology.

Methods and analysis The project will be performed in four key stages: formulation of search terms, literature collection, literature screening and literature analysis. A comprehensive search of databases including Scopus, Web of Science, Dimensions and Cochrane will be conducted. The Distiller SR software will be used for manual screening all relevant articles. The selected articles will be analysed via R Bibliometrix, a program for mathematical analysis of large sets of literature, and VOSviewer, which creates visual representations of connections between articles.

Ethics and dissemination This study did not require research ethics approval given the use of publicly available data and lack of human subjects. The results will be presented at scientific meetings and published in peer-reviewed journals.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ The bibliometric research in ophthalmology, vision research and artificial intelligence is sparse, with many studies looking only at small cross-sections of research or a small volume of papers.

WHAT THIS STUDY ADDS

⇒ This is the first study to use articles across multiple different databases and perform well-established types of analysis to obtain a clear view of the field of vision research and artificial intelligence and its direction.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ This study will provide a clear view into the present state of ophthalmology and artificial intelligence research and will make predictions about the future of the field. This will allow clinicians to adjust their practices as the field changes and integrate new technologies into their practices as they become available.

INTRODUCTION

Since the term artificial intelligence (AI) was first coined in 1956 by McCarthy and Minsky, its wide-reaching applications to medicine and research have grown in recent years.[1] To date, several studies on the use of AI in ophthalmology have used deep learning technology and machine learning algorithms, which allow for unsupervised programming and training of computer algorithms to make diagnosis of common eye diseases including diabetic retinopathy, macular degeneration, retinopathy of prematurity and glaucoma.[2 3]

Given that the popularity of research in AI and its applications in medicine has grown over recent years, it is important to characterise the field in order to predict future applications of the technology. A bibliometric analysis is a statistical analysis of a large set of research pertaining to a chosen topic. Within ophthalmology, bibliometric analyses have been conducted on the general body of ophthalmological literature and some subspecialties such as glaucoma.[4] Currently, there is no existing bibliometric analysis on the topic of AI in ophthalmology.

The objective of this study is to give a comprehensive view of the impact and importance of AI technology in ophthalmology and vision research through a bibliometric analysis of existing publications in this field from demographic, geographical and topical perspectives. This will allow the medical community to adapt to new technologies and their integration into the future model of patient care.

METHODS

This is a bibliometric analysis of articles relating to AI technology and ophthalmology and vision research. This study will follow the Preferred Reporting Items for Systematic reviews and Meta-Analyses charts reporting guidelines.

Database selection

The aim with database selection was to both capture as much relevant data as possible while also maintaining software compatibility and manageability of the sizes of the datasets. As such, four databases were selected including Web of Science (WoS), Scopus, Dimensions and Cochrane. Note that PubMed, Embase and MEDLINE are subsets of Scopus, so searching Scopus should yield the results from both platforms. Furthermore, the Dimensions database also includes PubMed data. The specific databases were chosen as they encompass a wide selection of journals and articles pertaining to the selected topics and are compatible with a wide variety of analytical software including VOSviewer, R Studio and Distiller (https://www.vosviewer.com/).[5–8]

Main outcomes

The main study outcomes will include linkage by coauthorship, co-occurrence, co-citation, citation and bibliographic coupling. In the context of this study, coauthorship networks will offer information about the demographics of the publishing population as well as countries of publication, while co-citation, citation and bibliographic coupling networks will show where collaborations are taking place among authors as well as help to determine which publications had the highest impact; highly cited articles will be counted as more impactful.

Search strategy

A systematic search was conducted on the selected databases from 1 January 2006 until 4 August 2021. To choose a time period, a preliminary curve was graphed using all the results which met the search criteria from the Scopus database (figure 1). A 3-year timeline for the citation analysis was chosen with regard to feasibility of analyses as well as its focused overview of the latest and most relevant technology in AI and ophthalmology.

Keywords have been carefully selected to ensure only relevant documents are analysed. Keywords are separated into two categories, including those relating to AI, and those relating to ophthalmology; these are listed in the table below. The keywords were collected first via combing through of articles deemed highly relevant to the topic, then more were added by referring to ophthalmological and AI vocabulary appendices. Finally, preliminary co-occurrence networks were created with the collected and uncleaned data to determine if any relevant keywords were missing. Table 1 represents the collected keywords, and these will be used to perform the final search. Relevant keywords will also be searched both in their British spellings and American spellings and searched in both capitalised and lowercase forms. Only English articles will be selected for as co-occurrence analysis relies on the measurement of the frequency of keywords. All words in the paper's bodies must be in one language for this analysis to be successful.

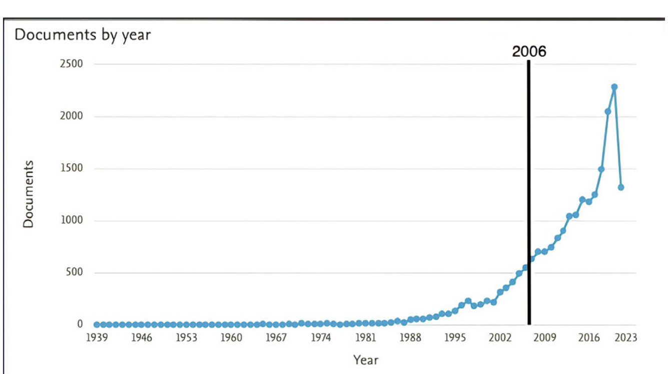

Figure 1 Graph illustration of all the peer-reviewed article hits on utilisation of artificial intelligence and ophthalmology meeting the search inclusion and exclusion criteria from the Scopus database.

Software used

The databases will be searched using the above outlined criteria. The first stage of the search will include those articles which are compatible with the VOSviewer software, these being articles from WoS, Scopus and Dimensions. Duplicates and articles deemed irrelevant will be removed using the Distiller software. These will then be imported into the VOSviewer software and analysis will be performed as outlined in the Methods section: first on each individual dataset and then on the data from all three compatible databases. The second stage will involve downloading articles from all four chosen databases. Duplicates and irrelevant articles will once again be removed using the Distiller software and then R studio software will be used for data analysis.

Data analysis

Networks linking articles will be created based on the following characteristics: countries of publication, author, co-citation and bibliographic linkage. A comparison will be drawn between trends in general ophthalmology research and AI-focused ophthalmology research and investigation conducted into the implications of these statistics as well as determination of the extent of scientific impact from each group. All literature from WoS, Dimensions and Scopus will be amalgamated into one super-network which is less specific, and then networks for each of these databases will be created individually and analysed on a more specific level.

Given that the VOSviewer software does not support the Cochrane database, all documents will be analysed with respect to a number of mathematical informatics models including Bradford's Law which predicts that only a few journals will account for a large proportion of literature in a field[9 10]; Lotka's Law, which predicts an inverse square correlation between the number of authors publishing and the number of articles published, specifically, the number of authors publishing N papers is proportional to the inverse square of that number of papers[11 12]; and Price's Law, which predicts that the growth of productivity in an area of scientific research can be fitted to an exponential curve, levelling off asymptotically after a

Table 1 Summary of keywords and search terms used in systematic search of the selected databases

Ophthalmology	Artificial intelligence
General terms:	▶ Artificial intelligence
▶ Ophthalmology	▶ Deep learning
▶ Ocular	▶ Deep learning system
▶ Eye	▶ Convolutional neural network
▶ Intraocular	▶ Massive training artificial neural network
▶ Iridology	
▶ Visual field	▶ Neural network
Anatomical terms:	▶ Machine learning
▶ Retina	▶ Image processing
▶ Macula	▶ Long short term memory
▶ Fovea	▶ Supervised clustering
▶ Uvea	▶ Unsupervised learning
▶ Sclera	▶ Semi-supervised learning
▶ Cornea	▶ Backpropagation
▶ Conjunctiva	▶ Feed forward
▶ Iris	▶ Feature learning
▶ Vitreous body	▶ Decision tree
▶ Vitreous humor	▶ Transfer learning
▶ Vitreous fluid	▶ Big data
▶ Vitreo	▶ Natural language processing
▶ Aqueous humor	▶ Computer vision
▶ Retinal ganglion cells	▶ Image recognition
▶ Fundus oculi	▶ Semantic analysis
Imaging terms:	▶ Unsupervised learning
▶ Optical coherence tomography	▶ Cognitive computing
▶ OCT	▶ Entity annotation
▶ Color fundus photography	▶ Entity extraction
▶ CFP	▶ Machine intelligence
▶ Slit lamp	▶ Predictive analysis
▶ Confocal microscopy	▶ k-nearest neighbour
▶ Confocal scanning microscopy	▶ Lattice neural network
▶ Confocal laser scanning microscopy	▶ Random forest
▶ Ultrasound biomicroscopy	▶ Feature extraction
▶ Fundus fluorescein angiography	▶ Neural nets
▶ Indocyanine green angiography	▶ Feature fusion
▶ Scanning laser ophthalmoscopy	▶ Deep belief fusion
▶ Ocular ultrasonography	▶ Image segmentation
▶ Microperimetry	▶ Computer-aided detection
▶ Multifocal visual-evoked potentials	▶ Optic cup segmentation
▶ Perimetry	▶ Data mining
▶ Retinal functional imaging	
▶ Retinal vessel segmentation	
▶ Iris recognition	
▶ Visual field tests	
Disease terms:	
▶ Diabetic retinopathy	
▶ Retinopathy	
▶ Retinopathy of prematurity	
▶ Macular degeneration	
▶ Retinal vein occlusion	
▶ Cataracts	
▶ Glaucoma	
▶ Retinoblastoma	
▶ Uveitis	
▶ Iritis	
▶ Choroiditis	
▶ Retinitis	
▶ Chorioretinitis	
▶ Conjunctivitis	
▶ Endophthalmitis	
▶ Optic neuropathy	
▶ Optic atrophy	
▶ Diabetic macular edema	
▶ Mellitus	
▶ Myopia	
▶ Visual disorder	
▶ Vision disorder	
Procedure terms:	
▶ Vitrectomy	
▶ Phacoemulsification	
▶ Paracentesis	
▶ Trabeculectomy	
▶ Canaloplasty	
▶ Laser iridotomy	
▶ Baerveldt valve	
▶ Iridotomy	
▶ Iridectomy	
▶ Goniotomy	
▶ Scleral buckle	
▶ Pneumatic retinopexy	
▶ Phacoemulsification	
▶ Extracapsular	
▶ Photocoagulation	
▶ Selective laser trabeculoplasty	
▶ Canthotomy	
▶ Brachytherapy	
▶ Catholysis	
▶ Closure of cyclodialysis cleft	
▶ Corneal transplantation	
▶ Decompression of dacryocele	
▶ Decompression of orbit	
▶ Pars plana lensectomy	
▶ Retrobulbar injection	
▶ Strabismus surgery	
▶ Synechiolysis	
▶ Tarsorrhaphy	
▶ Transscleral cyclophotocoagulation	

period of time.[13,14] For this data analysis, the R Bibliometrix package will be used. Comparison of ratios between these numbers with the expected informetric models will further elucidate anomalies in the data and contribute to the objective of developing an understanding of the impact and trajectory of research in AI technology and ophthalmology.

DISCUSSION

We anticipate that the field of AI in ophthalmology has grown at an exponential rate over the past 3 years per Price's Law. Furthermore, we predict that most of the identified articles will be related to diagnostics rather than to direct patient care technology, such as surgical robots. Diagnostic algorithms are more realistically and immediately applicable to patient care; they are low cost and easy to create and implement. Surgical robots are costly, require more professional skill to develop and have narrower applications in ophthalmology.

It is anticipated that the bulk of the literature will be produced by more populated countries such as the USA and China, though extensive collaboration between these countries is not predicted because of their geographical locations. Collaboration between neighbouring countries, such as Canada and the USA, is more likely. Furthermore, we predict that publication volume will drop in 2020 with some doctors diverting their research to the SARS-CoV-2 virus.

Due to the specificity of the field, the bulk of the research will be found in a few non-specific journals, with fewer and fewer articles being found in increasingly specific journals. This would align with the Bradford zones outlined in the analysis. Inverse correlation between the topicality of the journal and the number of articles is predicted given that the field is narrow and still emerging.

Limitations

The authors would like to acknowledge the limitations of this bibliometric study. First, only English articles will be selected for in order to produce the most effective analysis, and this may limit the scope of the search. Second, only three of four of the selected databases are supported by the VOSviewer software and as such network analyses can only be performed on documents from these. The availability of information is also largely dependent on database indexing; PubMed documents will not export accompanying citation information and so only co-occurrence and coauthorship networks can be made with these data. In order to address and overcome these limitations, meta-networks will be created with all the data from Scopus, WoS and Dimensions. Then, each dataset will be analysed individually using all available techniques in order to glean more detailed information. All data will be analysed with the above outlined informetric models using the R Bibliometrix package.

Twitter Tina Felfeli @TinaFelfeli

Contributors Conception and design—TF. Acquisition of data—HM, LB and TF. Data analysis—HM and JD. Interpretation of data—HM, JD and TF. First draft of

the article—HM, JD and TF. Critical revision—HM, JD and TF. Final approval of the version to be published—HM, JD, LB and TF. Guarantor of the work—TF.

Funding Funding for the publication of this study was provided by Fighting Blindness Canada, Clinician Scientist Emerging Leader Award given to Dr. Felfeli.

Competing interests None declared.

Patient consent for publication Not required.

Ethics approval The Institutional Review Board of the University of Ontario deemed that ethical approval was not necessary, as this was a pure bibliometric study.

Provenance and peer review Not commissioned; externally peer reviewed.

ORCID iD

Tina Felfeli http://orcid.org/0000-0002-0927-3086

REFERENCES

1. Anyoha R. *The History of Artificial Intelligence - Science in the News*. Harvard Graduate School of Arts and Sciences, 2017: 1. https://sitn.hms.harvard.edu/flash/2017/history-artificial-intelligence/
2. Lee A, Taylor P, Kalpathy-Cramer J, *et al*. Machine learning has arrived! *Ophthalmology* 2017;124:1726–8.
3. Grzybowski A, Brona P, Lim G, *et al*. Artificial intelligence for diabetic retinopathy screening: a review. *Eye* 2020;34:451–60.
4. López-Muñoz F, Weinreb RN, Moghimi S, *et al*. A bibliometric and mapping analysis of glaucoma research between 1900 and 2019. *Ophthalmol Glaucoma* 2022;5:16–25.
5. Web of Science: Summary of Coverage - Web of Science platform - LibGuides at Clarivate Analytics [Internet]. Available: https://clarivate.libguides.com/webofscienceplatform/coverage [Accessed 28 Jul 2021].
6. Elsevier. *Content coverage guide*. Elsevier, 2010: 1–24. https://www.elsevier.com/__data/assets/pdf_file/0017/114533/Scopus_GlobalResearch_Factsheet2019_FINAL_WEB.pdf
7. Cochrane Library. About the Cochrane Database of Systematic Reviews [Internet]. Available: https://www.cochranelibrary.com/cdsr/about-cdsr [Accessed 28 Jul 2021].
8. Dimensions. A Guide to the Dimensions Data Approach [Internet]. Available: https://www.dimensions.ai/resources/a-guide-to-the-dimensions-data-approach/ [Accessed 10 Aug 2021].
9. BS C. Sources of information on specific subjects 1934. *Engineering* 1985;10:85–6 https://cir.nii.ac.jp/crid/1570854175272181632
10. Garfield E. Bradford's Law and Related Statistical Patterns. *Curr Contents* 1980;19:5–12.
11. Lotka AJ. The frequency distribution of scientific productivity. *J Washingt Acad Sci* 1926;16:317–23.
12. Kawamura M, Thomas CD, Tsurumoto A, *et al*. Lotka's law and productivity index of authors in a scientific Journal. *J Oral Sci* 2000;42:75–8.
13. Price DJ. Quantitative measures of the development of science. *Arch Int dHistoire des Sci* 1951;4:85–93.
14. Fernández-Cano A, Torralbo M, Vallejo M. Reconsidering Price's model of scientific growth: An overview. *Scientometrics* 2004;61:301–21.

Supplementary File. Summary of selected databases and search strategies.

Database	**Description**
Web of Science	Over 81 million records encompassing topics in life sciences, biomedical sciences, arts, and humanities. Focused on natural and health sciences and technology,[8].
Scopus	Over 77 million records from journals in the health sciences, life sciences, social sciences, and physical sciences. This includes most of the MEDLINE database and some articles from PubMed,[9].
Cochrane	A database of systematic reviews in healthcare,[10].
Dimensions	The largest and newest of the databases which includes scientific journals and studies from many well reputed sources including PubMed, PubMed Central, and Crossref. Contains 153 million records to date,[11].

Sample Search Strategy

(ophthalmolog* OR opthalmolog* OR ophthamolog* OR opthamolog* OR ocular OR intra-ocular OR intraocular OR retin* OR macula* OR fovea OR uvea OR sclera OR cornea* OR conjunctiv* OR (eye* AND iris*) OR (pupil AND dilat*) OR “vitreous body” OR “vitreous humo?r” OR “aqueous humo?r” OR vitreal OR “aqueous humor” OR “optical coherence tomography” OR OCT OR “colo?r fundus photograph*” OR “slit lamp*” OR “confocal microscop*” OR “confocal scanning microscop*” OR “ultrasound biomicroscop*” OR “ultrasound bio-microscop*” OR “fundus fluorescein angiograph*” OR “indocyanine green angiograph*” OR “scanning laser ophthalmoscop*” OR “ocular ultrasonograph*” OR “microperimetry” OR “multifocal visual-evoked potential*” OR “macular degeneration” OR (eye AND cataract*) OR glaucoma OR uveitis OR iritis OR choroiditis OR chorioretinitis OR endophthalmitis OR “optic neuropathy” OR “optic atrophy” OR “diabetic macular edema” OR vitrectomy OR phacoemulsification OR paracentesis OR trabeculectomy OR canaloplasty OR iridectomy OR goniotomy OR phacoemulsification OR extracapsular OR (photocoagulation

AND eye*) OR “selective laser trabeculoplasty” OR “pneumatic retinopexy” OR “scleral buckle” OR canthotomy OR catholysis OR “closure of cyclodialysis cleft” OR “decompression of dacryocele” OR “decompression of orbit” OR “pars plana lensectomy” OR “retrobulbar injection*” OR “strabismus surgery” OR synechiolysis OR tarsorrhaphy OR “iridology” OR “visual field*” OR “fundus oculi” OR myopi* OR “visual disorder*” OR “vision disorder*” OR “confocal laser scanning microscop*”)

AND

(“artificial* intelligen*” OR AI OR “deep learning” OR “convolutional neural network*” OR MTANN OR “artificial neural network*” OR “machine learning” OR “long short term memory” OR “supervised clustering” OR “supervised learning” OR “unsupervised learning” OR “semi-supervised learning” OR “semi supervised learning” OR backpropagation OR “back-propagation” OR “feed forward” OR “feed-forward” OR “feature learning” OR “decision tree*” OR “transfer learning” OR “big data” OR “natural language processing” OR “computer vision” OR “image recognition” OR “semantic analys*” OR “cognitive computing” OR “entity annotation*” OR “entity extraction*” OR “machine intelligence” OR “predictive analys*” OR “k-nearest neighbour” OR “k nearest neighbour” OR “lattice neural network*” OR “random forest*” OR “random-forest*” OR “feature extraction” OR “optic cup segmentation” OR “data mining” OR “computer-aided detection” OR “computer aided detection” OR “deep belief fusion” OR “deep-belief fusion” OR “feature fusion”)