A Bibliometric Analysis of eHealth Scholarship (2000-2024): Multidisciplinary Contributions and Research Trends

Lana V. Ivanitskaya, Dimitrios Zikos, Elina V. Erzikova

Submitted to: Journal of Medical Internet Research
on: April 30, 2024

Table of Contents

A Bibliometric Analysis of eHealth Scholarship (2000-2024): Multidisciplinary Contributions and Research Trends

Lana V. Ivanitskaya[1]; Dimitrios Zikos[2]; Elina V. Erzikova[2]

[1]Central Michigan University Mount Pleasant US

Corresponding Author:
Lana V. Ivanitskaya

Abstract

Background: Fueled by innovations in technology and health interventions to promote, restore, and maintain health, and safeguard well-being, the field of eHealth yielded significant scholarly output.

Objective: To understand eHealth research trends and multidisciplinary contributions to eHealth, we obtained evidence from three corpora: 10,022 OpenAlex documents with eHealth in title, 5,000 most relevant eHealth articles according to the Web of Science (WoS) algorithm, and all available (n=1,885) WoS eHealth reviews.

Methods: In VOSviewer, we built keyword and concept co-occurrence networks. The scholarship on eHealth was synthesized by analyzing clusters and adding custom overlays that linked technologies to stakeholders and their needs. A co-citation map of sources referenced in WoS reviews demonstrated scientific fields supporting eHealth. Multidisciplinary contributions were also analyzed as co-occurring hierarchical concepts used by OpenAlex to tag eHealth articles.

Results: Common research directions included eHealth studies on 1) self-management and interventions; 2) telemedicine, telehealth and technology acceptance; 3) privacy, security, and design; 4) health information consumers' literacy; 5) health promotion and prevention of disease through active lifestyle choices; 6) mHealth and digital health; 7) HIV prevention. Researchers studied mental health and health literacy of young people; physical activity and lifestyle changes to prevent obesity, hypertension, cardiovascular disease and diabetes in adults and older adults; chronic disease, dementia, and pain management and medication adherence in older adults; cancer survivors and caregivers' needs; as well as providers and health leaders. Echoing chronological developments in eHealth research, keywords internet (2017 mean publication year), telemedicine (2018), telehealth (2018), mHealth (2019), mobile health (2020), and digital health (2021) were strongly linked to literatures indexed with eHealth (2019) and e-Health (2017) keywords. Mean publication year was 2018.77 for eHealth articles and 2019.80 for eHealth reviews, a time lag of about 12 months. Given the volume of articles, review authors were more likely to focus on interventions and less likely to systematize research on eHealth and health literacy. Review authors cited a wide range of medical journals and journals specific to eHealth technologies, as well as journals in psychology, psychiatry, public health, epidemiology, health services, policy, education, health communication, and other fields. The Journal of Medical Internet Research stood out as the most cited source in eHealth reviews. An OpenAlex concept map confirmed these findings while also displaying a prominent role of political science and law, economics, nursing, business, and knowledge management.

Conclusions: Drawing upon contributions from many disciplines, the field of eHealth has evolved from studies of internet-enabled communication, telemedicine, and telehealth to research on mobile health and emerging digital health technologies.

(JMIR Preprints 30/04/2024:60071)
DOI: https://doi.org/10.2196/preprints.60071

Preprint Settings

1) Would you like to publish your submitted manuscript as preprint?

✓ **Please make my preprint PDF available to anyone at any time (recommended).**
Please make my preprint PDF available only to logged-in users; I understand that my title and abstract will remain visible to all users.
Only make the preprint title and abstract visible.
No, I do not wish to publish my submitted manuscript as a preprint.

2) If accepted for publication in a JMIR journal, would you like the PDF to be visible to the public?

✓ **Yes, please make my accepted manuscript PDF available to anyone at any time (Recommended).**
Yes, but please make my accepted manuscript PDF available only to logged-in users; I understand that the title and abstract will remain v
Yes, but only make the title and abstract visible (see Important note, above). I understand that if I later pay to participate in <a href="http

Original Manuscript

Original Paper

Authors

Lana V Ivanitskaya, Ph.D.[1]* Dimitris Zikos, Ph.D.[2] Elina V Erzikova, Ph.D.[3]

Affiliations

*Corresponding Author.

[1]Health Administration Division, School of Health Sciences, The Herbert H. and Grace A. Dow College of Health Professions, Central Michigan University, 208D Rowe Hall, Mount Pleasant, MI 48859 ivani1sv@cmich.edu.
[2]Health Administration Division, School of Health Sciences, The Herbert H. and Grace A. Dow College of Health Professions, Central Michigan University, 208 Rowe Hall, Mount Pleasant, MI 48859 zikos1d@cmich.edu.
[3]School of Communication, Journalism, and Media, College of the Arts and Media, Central Michigan University, erzik1e@cmich.edu.

A Bibliometric Analysis of eHealth Scholarship (2000-2024): Multidisciplinary Contributions and Research Trends

Abstract

BACKGROUND: Fueled by innovations in technology and health interventions to promote, restore, and maintain health, and safeguard well-being, the field of eHealth yielded significant scholarly output.

OBJECTIVE: To understand eHealth research trends and multidisciplinary contributions to eHealth, we obtained evidence from three corpora: 10,022 OpenAlex documents with eHealth in title, 5,000 most relevant eHealth articles according to the Web of Science (WoS) algorithm, and all available (n=1,885) WoS eHealth reviews.

METHODS: In VOSviewer, we built keyword and concept co-occurrence networks. The scholarship on eHealth was synthesized by analyzing clusters and adding custom overlays that linked technologies to stakeholders and their needs. A co-citation map of sources referenced in WoS reviews demonstrated scientific fields supporting eHealth. Multidisciplinary contributions were also analyzed as co-occurring hierarchical concepts used by OpenAlex to tag eHealth articles.

RESULTS: Common research directions included eHealth studies on 1) self-management and interventions; 2) telemedicine, telehealth and technology acceptance; 3) privacy, security, and design; 4) health information consumers' literacy; 5) health promotion and prevention of disease through active lifestyle choices; 6) mHealth and digital health; 7) HIV prevention. Researchers studied mental health and health literacy of young people; physical activity and lifestyle changes to prevent obesity, hypertension, cardiovascular disease and diabetes in adults and older adults; chronic disease, dementia, and pain management and medication adherence in older adults; cancer survivors and caregivers' needs; as well as providers and health leaders. Echoing chronological developments in eHealth research, keywords internet (2017 mean publication year), telemedicine (2018), telehealth (2018), mHealth (2019), mobile health (2020), and digital health (2021) were strongly linked to literatures indexed with eHealth (2019) and e-Health (2017) keywords. Mean publication year was 2018.77 for eHealth articles and 2019.80 for eHealth reviews, a time lag of about 12 months. Given the volume of articles, review authors were more likely to focus on interventions and less likely to systematize research on eHealth and health literacy. Review authors cited a wide range of medical journals and journals specific to eHealth technologies, as well as journals in psychology, psychiatry, public health, epidemiology, health services, policy, education, health communication, and other fields. The Journal of Medical Internet Research stood out as the most cited source in eHealth reviews. An OpenAlex concept map confirmed these findings while also displaying a prominent role of political science and law, economics, nursing, business, and knowledge management.

CONCLUSIONS: Drawing upon contributions from many disciplines, the field of eHealth has evolved from studies of internet-enabled communication, telemedicine, and telehealth to research on mobile health and emerging digital health technologies.

Keywords: VOSviewer; eHealth; digital health; telemedicine; telehealth; mobile health; mheath

Introduction

The field of eHealth is about the use of digital technology in healthcare delivery, management, and education. In its definition, the World Health Organization (WHO) emphasizes the aspect of cost-effectiveness and secure use of information and communications technologies in support of health and health-related fields [1]. Expedited by the recent Covid-19 pandemic [2-3], multiple technologies that are broadly labeled as eHealth facilitate remote patient monitoring, improve access to medical services, and enhance efficiency in healthcare systems. For example, mobile health (mHealth) applications provide significant value for patients [4] and can be used for data sharing with healthcare providers for personalized care, to enable continuum of care and a better understanding of the condition progression and response to therapy during the medical appointments. Artificial Intelligence (AI), a recent advancement in eHealth, poised to reshape medicine improving the experiences of providers and patients [5] through pattern recognition and generate insights that can improve diagnosis, treatment, and patient outcomes. These and other eHealth technologies enable patients to actively participate in their healthcare decisions and promote preventive care through personalized health information [6]. With the potential to streamline workflows and improve healthcare outcomes, eHealth leverages information technology to transform access to and delivery of healthcare services [7].

This study is a comprehensive bibliometric analysis of eHealth studies, with an emphasis on research directions and scientific disciplines involved in eHealth scholarship. Bibliometric methods allow to quantitatively analyze published studies and their metadata to describe research output and to visualize intellectual structures and trends [8] in scientific domains of interest. The field of eHealth was the subject of bibliometric reviews, however, their scope was almost always limited to select technologies, regions, and/or eHealth user experiences or narrowly-defined health and wellness goals.

Most bibliometric reviewers summarized literature subsets defined by eHealth user needs: promoting physical activity, healthy eating, and weight loss [9-12], preventing substance use [13], and providing e-mental health during the Covid-19 pandemic [14]. In addition, researchers reviewed digital technologies for health behavior change [15] and eHealth tools for anticoagulation management after cardiac valve replacement [16]. There was also a distinct subset of bibliometric studies on eHealth and health informatics competencies [17], literacy [18], and information and communication technology use by individuals experiencing homelessness [19].

Region-specific bibliometric reviews demonstrated global interest in eHealth research. Published reviews covered medical informatics and telemedicine in Sub-Saharan Africa and BRICS countries [20], eHealth research in Southeast Asia [21], and European finding of research on ambient assisted living [22].

Technology-focused bibliometric reviews assessed literatures on technology adoption [23], telehealth [24], the internet of things [25], telemedicine in rural areas for cost-effective and sustainable healthcare [26], mobile health as a means of involving citizens and public agencies in cardiovascular diseases prevention [27], and artificial intelligence adoption by healthcare organizations [28].

Two broad-scope bibliometric reviews published in 2022 were dedicated to eHealth [29] and digital technologies [30]. The former study was limited to 2,989 bibiometric records (2000-2021) that mentioned eHealth in titles; the latter included only 403 recent (2017-2021) publications. Other

eHealth reviews, published prior to 2022, did not include many relevant studies on evolving eHealth technologies such as blockchain and AI [6, 31].

To address gaps and limitations of past bibliometric reviews of eHealth, this study was designed to be broad in chronological scope (2000-2024) and inclusive of two document types, articles and reviews, to shed light on how empirical research was systematized by review authors. We posed the following research questions: 1) What research directions define the domain of eHealth, including relevant technologies, stakeholders, and their needs? 2) How did eHealth scholarship – articles and reviews – develop over time? 3) On what scientific fields does eHealth research build, as evidenced by cited sources and OpenAlex concepts that tag eHealth articles?

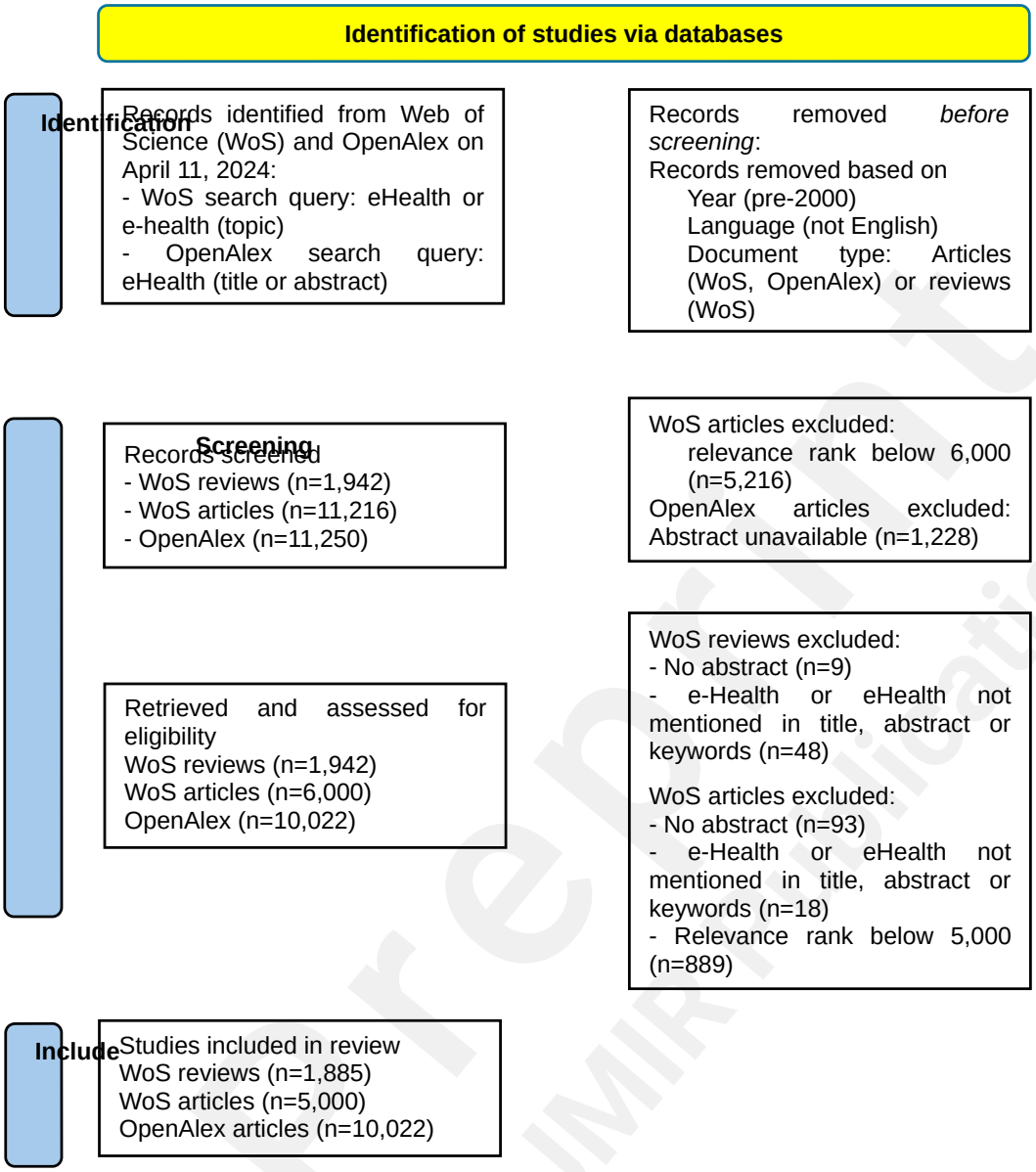
Understanding these questions will provide a structured and evidence-based resource to researchers who want to know what areas have been covered by the literature and in what ways, and how eHealth applications have been analyzed. This bibliographic analysis can also contribute to a better understanding of the more recent trends in eHealth studies and help researchers identify new venues for deeper investigation.

Methods

Overview of Data Sources

We retrieved and screened two sets of Web of Science (WoS) records with eHealth or e-Health in titles, abstracts, or keywords: 1) 5,000 most relevant articles, according to the WoS raking algorithm and 2) 1,885 WoS eHealth reviews written in English since 2000. Figure 1 shows the study identification process as a PRISMA diagram. The hyphenated search term, e-Health, produced both relevant and irrelevant records. Any word ending with “e” before the word “health” was counted as e-Health, prompting manual screening of WoS records. Not knowing exactly how many records would be screened out, we oversampled WoS articles. Only 5,000 WoS articles with the highest relevance ranks were retained post-screening.

Figure 1. A PRISMA diagram for eHealth Publications Included in This Review.



To validate and extend our WoS findings, we also obtained 10,022 OpenAlex articles with eHealth in their titles or abstracts. OpenAlex search query was limited to eHealth to avoid potential issues with the hyphenated search term.

Data Analyses

We built several types of bibliometric networks or maps in VOSviewer [32]. We analyzed keyword (WoS) and concept (OpenAlex) co-occurrence networks to assess eHealth research directions, conceptualized as eHealth technologies, stakeholders, and their needs. Keywords are controlled vocabulary used by the authors and WoS database managers to index studies. They differ from concepts, which OpenAlex assigns to the majority (85%) of published works in its database. OpenAlex uses a hierarchical system of around 65,000 concepts, each linked to a Wikidata ID, to tag scientific publications with one or more concepts that are assigned based on the contents of the title, abstract, and the title of host venue [33]. OpenAlex concepts could add value above and beyond keywords because concepts are organized like a family tree, starting with 19 major categories that branch out into discipline-relevant concepts, relevant to answering question 3, and then to even more specific topics that might add value to understanding eHealth technologies.

To answer research question 1, we analyzed networks by examining clusters – groups of co-occurring keywords or concepts that commonly reflect thematically distinct research directions [34-35]. A comparative analysis of two keyword co-occurrence networks was done. The network built for articles most relevant to eHealth, as determined by the WoS ranking algorithm, was compared to the network for all available eHealth reviews from WoS. We compared clusters and node sizes to analyze similarities and differences in research directions pursued by eHealth article authors versus those who published reviews. We also added custom overlays to keyword maps to highlight who, what, and how of e-Health. We used binary coding to highlight keywords about groups involved with eHealth (who); health conditions, needs or care settings addressed by eHealth interventions (what); and eHealth technologies or technology-related keywords (how). To estimate reliability, a second trained coder independently identified technology-related keywords from a list of 677 keywords selected for mapping, achieving a high level of agreement, κ=.96 (95% CI, .93 to .98), P<.001. Additional keyword coding was done as we developed a conceptual model of eHealth research. Binary codes were assigned to technology keywords based on their relevance to eHealth umbrella terminology or eHealth applications, objectives, infrastructure, data security/privacy, and health analytics.

An abstract review was performed on multiple occasions to decipher ambiguous keywords or to identify examples of studies indexed with specific keywords. Research question 2 was answered by contrasting network overlays to draw conclusions about publication recency for articles and reviews.

Evidence for research question 3 came from the scientific literatures behind eHealth reviews, which were assessed using a co-citation map that depicted relationships among journals based on them being cited together in bibliographies of eHealth reviews. We chose reviews for this analysis because their bibliographies tended to be most comprehensive and focused on well-researched eHealth aspects. A concept co-occurrence network for OpenAlex eHealth studies was used to gather additional evidence about the multidisciplinary nature of eHealth. Similar to the network of WoS article keywords, we enhanced OpenAlex concept network with custom overlays highlighting technologies, health topics (physical health, illness, wellness, and mental health), and other concept characteristics such as risk (e.g., security) and money (e.g., economics). Concept attributes were first coded using LIWC-22, a computational linguistics program, then converted to binary scores (0=not present, 1=present). They were manually verified and refined prior to being added as new overlay scores to the VOSviewer map file, in addition to mean publication year and normalized citations

overlays.

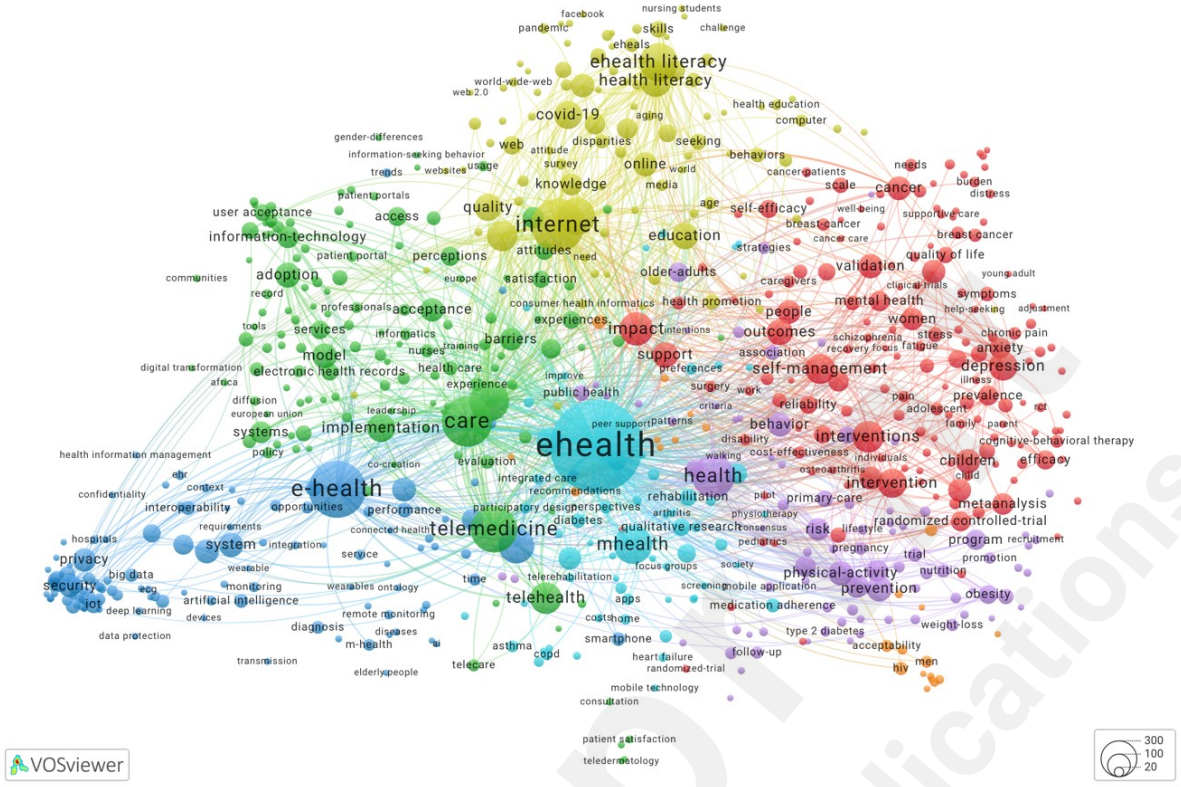
To assist readers in following our map interpretations, we italicized text referring to specific network nodes, whether they are WoS keywords, cited journals, or OpenAlex concepts. Unless noted otherwise, we consistently listed nodes based on the number of articles they represent, from high to low.

Results

eHealth Research Directions: Articles

In Figure 2, we presented a keyword co-occurrence cluster map for WoS articles. Clusters are thematically linked groups of nodes, in this case, keywords. We provided a URL to an interactive map where the number of articles indexing each keyword can be explored, as well as keyword interconnections. The more keywords co-occur across many articles, the more likely they are to be located near each other, within the same cluster, and linked. The map shows 677 keywords and 1,000 strongest links. Nodes *eHealth* and *e-Health*, which were used interchangeably, had the strongest co-occurrence link. In addition, *eHealth* was strongly linked to nine other keywords: *telemedicine*, *mHealth*, *internet*, *digital health*, *self-management*, *mobile health*, *intervention*, *telehealth*, and *depression*.

Figure 2. A Keyword Co-occurrence Network for 5,000 eHealth Articles: A Cluster Map. Keywords that occur 10 times or more were mapped. An interactive map is available from Leiden University's VOSviewer Online application: https://tinyurl.com/2yr4vj6g.



Next, we summarized clusters by categorizing their most frequently occurring keywords in Table 1 to identify stakeholders, care needs or settings, and eHealth technologies. Cluster 1 (red) encompassed thematically diverse nodes related to eHealth with a centrally positioned *self-management* keyword indexing 217 articles, the third highest occurring keyword after *impact* and *interventions*. Abstracts that mentioned "self-management" suggested the authors defined it as an oversight of one's own health conditions, e.g., to cope with a chronic disease by reducing anxiety, fatigue, or depression or to prevent negative health outcomes. Mental health (*depression*, *anxiety, psychological distress*, *schizophrenia*, *cognitive-behavioral therapy*), cancer, and pain related keywords were particularly prominent in this cluster. The cluster had keywords that described study populations: young people, cancer survivors, and caregivers. Article authors reported eHealth intervention technologies – web-based and mobile applications – used for assessment, reporting of symptoms and adverse events, cognitive interviewing, and supporting self-management goals, for example, by generating and communicating self-management actions. Together, keywords *intervention* and *interventions* indexed 863 studies.

Cluster 2 (green) keywords were dedicated to *telemedicine* and *telehealth*, as well as health organizations' electronic record systems (e.g., *electronic health records*) used for storing information that is accessed, used, and documented during a telehealth session. This cluster's keywords mentioned eHealth stakeholders who were patients, different provider groups, health leaders, and also communities. Specifically, telemedicine was researched as a means of building community capacity and communities of practice. In rural communities, telemedicine connected remote populations to providers, strengthening local health systems. It was also used for knowledge sharing in communities of practice where geographically dispersed providers could improve their medical practice. Also prominent in this cluster were nodes related to *acceptance* and *adoption* of eHealth technologies. Abstracts that mentioned TAM, *Technology Acceptance Model*, or *UTAUT*, Unified

Theory of Acceptance and Use of Technology, referred to stakeholder reactions to telehealth technologies and their impact on patient-provider relationship with an emphasis on improved *access* to care and *patient empowerment*, *patient engagement*, and *patient participation*.

Keywords in cluster 3 (dark blue) were especially focused on technological aspects of eHealth, which we categorized into three groups. The first group consisted of keywords relevant to the eHealth technology infrastructure, e.g., *internet, online, internet of things, cloud computing, blockchain, information-systems, interoperability, smartphone, cloud,* etc. The second group included *security, blockchain, authentication, encryption, access control, cryptography, privacy protection, access-control*, and other data security and privacy considerations. The third group was about health analytics: *artificial intelligence, machine learning, big data, algorithm, algorithms, deep learning, data mining, etc*. In cluster 3 most frequent stakeholder keywords were *management* and *hospitals*, in contrast with patients in cluster 1 and providers in cluster 2.

Cluster 4 (yellow) was about eHealth literacy, health information seeking, and concerns about misinformation and decision making during the Covid-19 pandemic. This subset of studies focused on younger and older age groups, with a strong focus on students. Using eHealth tools and skill assessments for health education, researchers studied demographic and behavioral aspects of health information seekers who engage with online health information. Keywords such as *internet, eHealth literacy, social media, computer, digital health literacy, consumer health informatics, world-wide-web,* and *website*. This cluster also included keywords *disparities* and *digital divide* represented eHealth technologies in this cluster.

The remaining three clusters contained the smallest number of keywords. Nodes in cluster 5 (purple) reflected the needs of adults and older adults in physical activity and lifestyle changes to prevent obesity, hypertension, cardiovascular disease and diabetes. Researchers studied how these needs were addressed through eHealth interventions and mobile applications. Cluster 6 (light blue) keywords suggested a focus on eHealth, mHealth, and digital health applications, as well as telemonitoring, telerehabilitation, and communication technologies, for managing chronic diseases and medication adherence in older adults. The care types spanned primary care, rehabilitation care, home care, and integrated care. Finally, cluster 7 (orange) was dedicated to eHealth interventions for HIV prevention among men who have sex with men.

In addition to Table 1 lists, we coded who, what and how of eHealth into the map overlays to demonstrate the value of interpreting keywords in relation to other network nodes. As we coded these elements, we found keywords that could be described as general or umbrella terms (*ehealth, e-health, technology, digital health, internet use,* etc.) and more specific eHealth applications (*telemedicine, mhealth, telehealth, mobile health, electronic health record, telecare*, etc.). Finally, we encountered many instances of keywords that shed light eHealth objectives (*ehealth literacy, health literacy, communication, education, prevention, quality-of-life*, etc.) which we also coded and made available as an overlay (see Appendix). Scattered across all clusters, eHealth objectives often overlapped with our stakeholders' health conditions, needs, or care settings.

Table 1. Keywords Indexing eHealth Research Articles, by Cluster: Who, What, and How of eHealth.

Cluster number (color) and name	Who: Keywords that Designate Groups Involved with eHealth	What: Health Conditions, Needs, or Care Settings	How: eHealth Technologies and Technology-Related Keywords
1 (red): Self-management	*children, people, adolescents, women,*	*self-management, depression, cancer,*	*ehealth intervention, web-based intervention, e-*

and interventions for mental health, dementia, cancer, and pain	*parents, adolescent, caregivers, survivors, youth, cancer survivors, cancer-patients, child, family, pediatrics, childhood, individuals, young-people, carers, families, family caregivers, parent, young-adults, caregiver, informal caregivers, mothers, young adult, young-children*	*quality-of-life, anxiety, mental health, social support, mental-health, quality of life, stress, dementia, breast cancer, cognitive-behavioral therapy, oncology, chronic pain, breast-cancer, pain, chronic illness, disability, cognitive-behavior therapy, psychotherapy, fatigue, palliative care, mindfulness, distress, psychological distress, supportive care, schizophrenia, disorder, patient activation, alzheimers-disease, cognitive behavioral therapy, illness, osteoarthritis, hospital anxiety, sleep, substance use, functional assessment, glycemic control, health-related quality of life, help-seeking, anxiety disorders, cancer survivorship, depressive symptoms, low-back-pain, psychological treatments, symptom management, cancer care, insomnia, urinary incontinence, well-being, behavioral health, comorbidity, loneliness, person-centred care, postpartum depression, self-management program*	*learning, mobile apps, version, mobile app, e-mental health, web-based, online intervention*
2 (green): Telemedicine, telehealth, telecare, and technology acceptance	*patient, physicians, nurses, professionals, developing countries, older people, saudi arabia, patients, facilitators, communities, europe, physician, africa, australia, developing-countries, doctors, leadership, european union, healthcare*	*access, primary health care, empowerment, patient empowerment, patient-centered care, patient participation, disease management, patient engagement, consultation, human factors, telepsychiatry, behavioral intention, information-seeking behavior, patient safety, peer support*	*telemedicine, technology, telehealth, information-technology, usability, electronic health records, user acceptance, information-systems, electronic health record, records, health informatics, technology acceptance model, telecare, ict, information technology, technology acceptance, medical informatics, informatics,*

	professionals, middle-income countries, stakeholders		*health information technology, patient portal, personal health records, record, electronic health, personal health record, patient portals, e-mail, health information systems, health information-technology, mobile phones, information management, health information exchange, medical-records, e-health services, electronic medical-records, digitalization, data mining, electronic medical records, information systems, digital transformation, gamification, health records, teledermatology, remote consultation, technology adoption, medical records, nursing informatics, tam*
3 (dark blue): e-Health technology, including privacy, security, design	*management, hospitals, elderly people*	*diagnosis, medicine, monitoring, multiple sclerosis, medical services, chronic diseases, ecg, diseases, decision-support, tuberculosis, patient monitoring, personalized medicine, home monitoring*	*e-health, iot, internet of things, cloud computing, blockchain, interoperability, artificial intelligence, smartphone, machine learning, big data, authentication, cloud, networks, protocol, m-health, architecture, encryption, internet of things (iot), sensors, mobile, sensor, access control, ehr, remote monitoring, fog computing, algorithm, 5g, algorithms, edge computing, electronic healthcare, deep learning, cryptography, network, privacy protection, smartphones, access-control, platform, ehealth services, body area networks, wireless, health information management, attribute-based encryption, data protection, ontology, sensor networks, servers, wearable technology, activity recognition, ai,*

			devices, e-health systems, transmission, wearables, patient monitoring, mobile-health, accelerometer, artificial intelligence (ai), data privacy, e-health system, electronic health record (ehr), mobile computing, ontologies, protection, wearable, wireless sensor networks, connected health
4 (yellow): eHealth literacy	*older adults, students, china, users, consumers, nursing students, african americans, college students, young adults, adolescence, consumer, chinese, university students*	*health literacy, communication, covid-19, education, knowledge, health promotion, information-seeking, disparities, patient education, health education, health information-seeking, health disparities, readability, information seeking, awareness, online health information seeking, decision making, misinformation, covid-19 pandemic, personalization, cyberchondria, health information seeking, coronavirus*	*internet, ehealth literacy, online, internet use, social media, web, digital divide, e-health literacy, eheals, computer, digital health literacy, digital literacy, consumer health informatics, health technology, world-wide-web, website, electronic health literacy, social networks, instrument, assessment, online health information, computer literacy, websites, facebook, web 2.0*
5 (purple): Health promotion and prevention of disease through active lifestyle choices	*adults, older-adults, population*	*prevention, physical-activity, physical activity, exercise, obesity, disease, engagement, primary-care, overweight, pregnancy, weight-loss, hypertension, diet, health behavior, behavior-change, behavior change, smoking, type 2 diabetes, smoking-cessation, cardiac rehabilitation, cardiovascular-disease, smoking cessation, cardiovascular disease, diabetes mellitus, self-regulation, weight loss, childhood obesity, blended care, health-promotion, sedentary*	*ehealth interventions, mobile application, user experience*

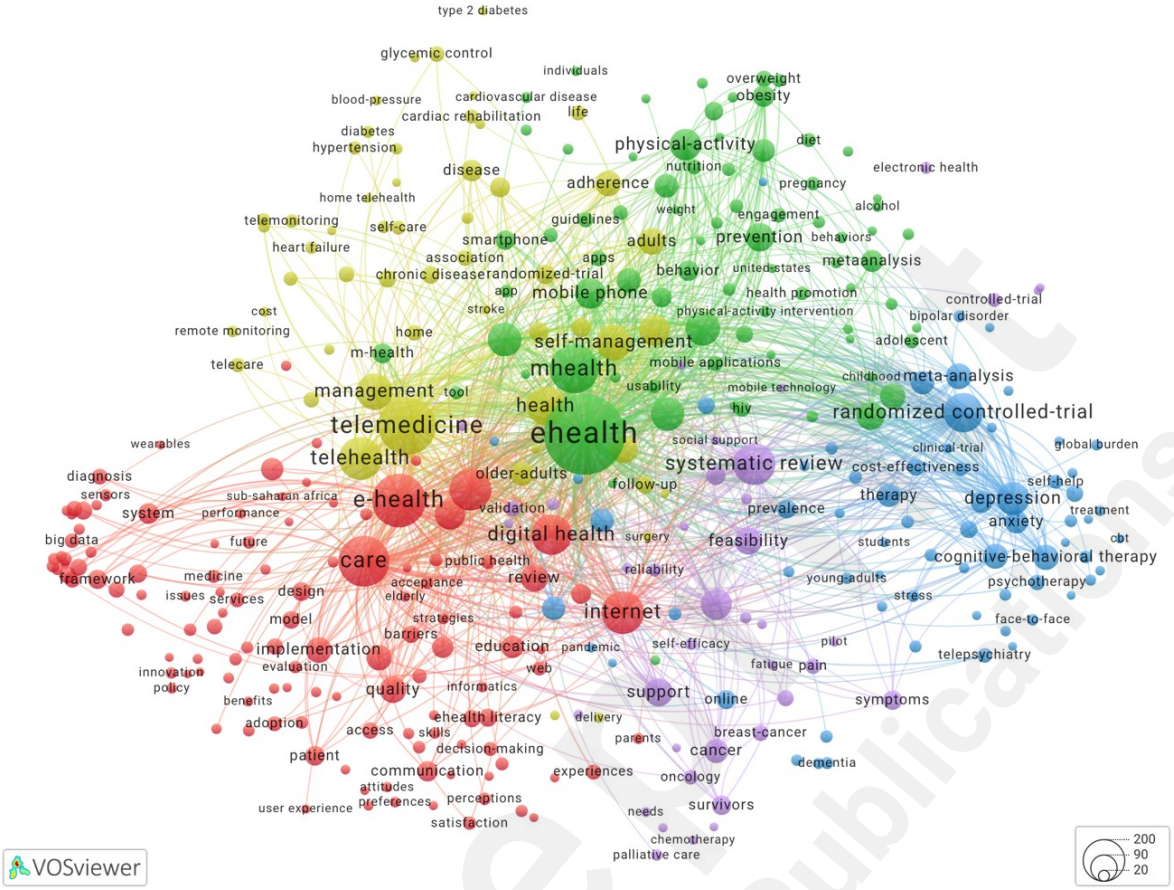
		behavior, blood-pressure, healthy lifestyle, self-monitoring, preventive medicine, behaviour change, impairment, walking, cardiovascular diseases, health behaviors, lifestyle intervention, mellitus, secondary prevention	
6 (light blue): mHealth and digital health	*elderly, aged, society*	*primary care, chronic disease, rehabilitation, diabetes, medication adherence, self-care, asthma, copd, home, integrated care, stroke, heart failure, multimorbidity, inflammatory bowel disease, shared decision-making, arthritis, health equity, heart-failure, chronic obstructive pulmonary disease, equity, medication, screening, inequalities, obstructive pulmonary-disease, physiotherapy, rheumatology, ulcerative-colitis*	*ehealth, mhealth, digital health, mobile health, mobile phone, user-centered design, apps, app, participatory design, telemonitoring, mobile applications, telerehabilitation, information and communication technology, mobile technology, health apps, virtual-reality, application*
7 (orange): HIV prevention	*united-states, men, gay, young men, african-american*	*decision-making, hiv, hiv prevention, sex, antiretroviral therapy, sexual health, behavioral intervention, hiv/aids*	*Acceptability, intervention development, digital, digital technology*

Note. Keywords are listed in the order of their occurrence counts, from high to low, excluding the keywords used to index less than 10 articles. To explore keywords interactively, link to Figure 2 map overlays: https://tinyurl.com/2d7h2z87 for keywords that designate groups involved with eHealth (who); https://tinyurl.com/2bko7z7h for health conditions, needs, or care settings (what); and https://tinyurl.com/2xhg93ha for eHealth technologies and ideas (how). All overlays to Figure 2 map are listed in Appendix.

eHealth Research Directions: Reviews, Compared to Articles

Figure 3 shows a cluster map for WoS reviews. Cluster colors in Figures 2 and 3 were set automatically by VOSviewer based on the number of nodes in a cluster. Despite differences in cluster colors, many keywords, for instance those related to mental health or obesity prevention, were grouped in similar ways in both maps. Out of 358 keywords that appeared in Figure 3, 89% of keywords were present in Figure 2. Similarly to Figure 2, the node *eHealth* in Figure 3 was strongly linked to nodes *mHealth, telemedicine, digital health, telehealth,* and *internet*.

Figure 3. A Keyword Co-occurrence Network for 1,885 eHealth Reviews: A Cluster Map. Keywords that occur 10 times or more were mapped. An interactive map is available from Leiden University's VOSviewer application: https://tinyurl.com/28o3h7hs



An in-depth analysis of clusters in Figure 3 was beyond this study's scope. Our goal was to shed light on highly reviewed and under reviewed eHealth areas, to deeper explore research question 1, and examine time lags in review production to answer research question 2.

A close examination of a subset of 318 keywords that appeared in Figures 2 and 3 revealed differences in eHealth topics covered by articles versus reviews (see Table 2). A delta of z-scored keyword occurrence counts for keywords used to index reviews vs. articles was used as an indicator of research focus for the two document types. We asked, which eHealth topics were more or less likely to be covered by eHealth reviews, as compared to eHealth articles? Several patterns emerged when we analyzed differences (Δ > .5 SD).

Table 2. Top keywords Indexing eHealth Articles, by Cluster, Compared to Keywords Indexing eHealth Reviews.

eHealth articles (Figure 2)		eHealth Reviews (Figure 3)
Cluster number (color) and name	10 most frequent keywords	Keywords more (+) and less (-) likely used to index reviews, as compared to articles, in SD units
1 (red): Self-management and interventions	*impact, interventions, self-management, intervention, depression, outcomes, support, children, validation, cancer*	More likely: *randomized controlled-trial* (+1.9), *feasibility* (+.7); less likely: *impact* (-1.0), *cognitive-behavioral therapy* (-.7), *social support* (-.7), *self-efficacy* (-.6)
2 (green): Telemedicine, telehealth, telecare, and technology acceptance	*care, telemedicine, technology, telehealth, implementation, adoption, model, acceptance, barriers, information-technology*	More likely: *telemedicine* (+1.2), *telehealth* (+1.1); less likely: *adoption* (-1.2), *acceptance* (-1.2), *barriers* (-.8), *implementation* (-.7), *trust* (-.7), *usability* (-.7), *user acceptance* (-.7)
3 (dark blue): e-Health technology, incl. privacy, security, design	*e-health, management, system, health-care, framework, privacy, security, design, challenges, healthcare*	less likely: *e-Health* (-2.2), *privacy* (-.9), *security* (-.8), *design* (-.6), *internet of things* (-.5), *cloud computing* (-.5)
4 (yellow): eHealth literacy	*internet, ehealth literacy, information, health literacy, communication, covid-19, quality, education, online, health information*	Less likely: *internet* (-7.5), *ehealth literacy* (-3.0), *information* (-2.2), *health literacy* (-1.9), *communication* (-1.5), *health information* (-1.2), *literacy* (-1.0), *covid-19* (-.9), *education* (-.8), *internet use* (-.8), *older adults* (-.6), *quality* (-.5), *skills* (-.6)
5 (purple): Health promotion and disease prevention	*health, prevention, physical-activity, behavior, adults, risk, physical activity, exercise, program, older-adults*	No differences were observed greater than +/-.5 SD
6 (light blue): mHealth and digital health	*ehealth, mhealth, digital health, mobile health, mobile phone, primary care, chronic disease, qualitative research, rehabilitation, diabetes*	More likely: *digital health* (+1.4), *mhealth* (+1.0), *mobile health* (+.8), *mobile phone* (+.7); less likely: *ehealth* (-7.5), *primary care* (-.8)
7 (orange): HIV prevention	*decision-making, hiv, united-states, acceptability, men, implementation science, recommendations, gay, hiv prevention, intervention development*	No differences were observed greater than +/-.5 SD

As expected, review authors attempted to summarize experimental research. A *randomized*

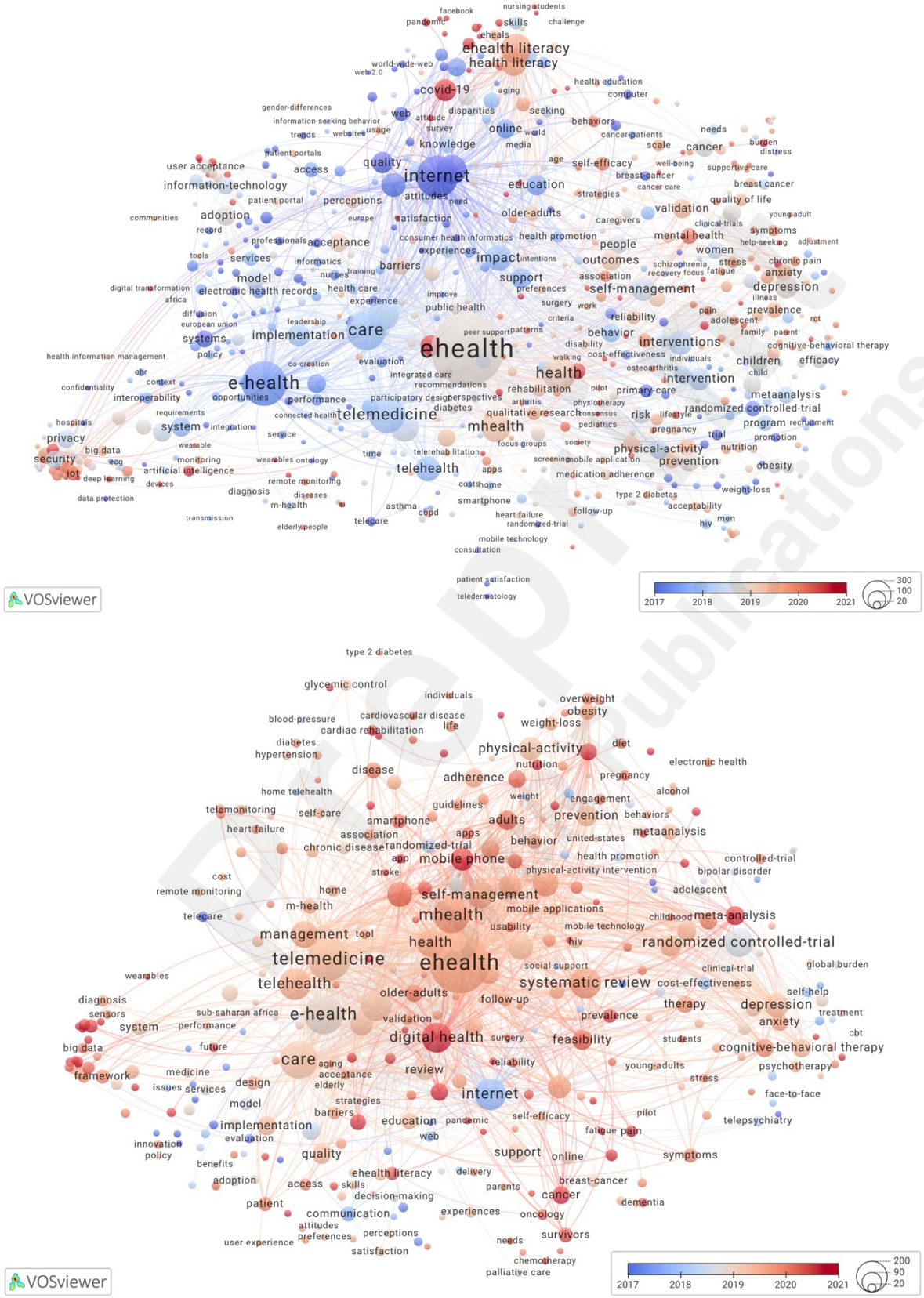
controlled trial keyword indexed a disproportionately greater share of reviews than articles. Second, review authors favored studies on telemedicine, telehealth, digital health, and mobile health (mHealth). Feasibility studies were also a likely subject of literature reviews.

Other keywords salient in the eHealth article map did not receive much attention from review authors. Two findings that stood out the most were 1) few reviews of *eHealth* (or *e-Health*) literature, a research domain this study was designed to address, and a disproportionately small number of reviews of eHealth literacy relative to the number of articles in this area. Also, reviews somewhat underrepresented studies on e-Health technologies indexed with keywords *privacy* or *security*, and issues of eHealth technology adoption, such as *barriers*, *usability*, and *user acceptance*. Keywords related to mental health research, for instance eHealth applications of *cognitive-behavioral therapy* or those related to *social support* and *self-efficacy* were more frequently used to index articles than reviews. These under-reviewed topical areas may be considered by systematic review authors interested in eHealth.

Publication Recency

A comparison of mean publication years overlays for articles and reviews offers a unique opportunity to understand research production trends on the topic of eHealth. Calculated across 318 keywords that appeared in Figure 2 and 3, the mean publication year was 2018.77 for eHealth articles and 2019.80 for eHealth reviews, a difference of about 12 months. The time gap between the mean publication date for all articles and all reviews indexed with a specific keyword was 8 months for *mHealth,* M(356)= 2019.47 for articles and M(303)=2020.10 for reviews. The time gaps were 11 months for studies indexed with *eHealth,* M(2,089)=2019.08 and M(837)=2019.96, for articles and reviews, respectively; 15 months for *telemedicine,* M(522)=2018.32 and M(422)=2019.62; and 16 months for *telehealth,* M(242)=2018.07 and M(236)=2019.93. Figure 4 shows publication recency overlays for eHealth articles and reviews. Both map legends range from 2017 (blue) to 2021 (red) and are centered around 2019 (grey color). In the top overlay of Figure 4, *eHealth* was most strongly linked to *telemedicine* (M=2018) and *mHealth* (2019), followed by *internet* (2017), *telehealth* (2018), *mobile health* (2020), and *digital health* (2021).

Figure 4. Publication Recency Overlays to Maps in Figures 1-2: Keywords Indexing Articles (top) and Reviews (bottom). Interactive overlays: https://tinyurl.com/2dgeo5u2 (articles) and https://tinyurl.com/24tkgc5z (reviews).



Mean publication years were most recent (2021-2022) for eHealth articles indexed with *Covid-19* or *pandemic*, *mindfulness*, *wearables*, *digital health*, *deep learning* and *blockchain*, *burden*, and

artificial intelligence. Some of the same keywords (*deep learning, Covid-19*, and *artificial intelligence*) also represented the most recent (2021-2022) collections of reviews, in addition to the following keywords: *men, sedentary behavior, internet of things (iot), fatigue,* and *patient-reported outcomes*.

Excluding methods-related keywords, keywords with the oldest mean publication years (2012-2016) represented eHealth articles on *telepsychiatry, computer, web, information technology, ethics, weight loss, medical informatics, breast-cancer,* and *primary-care*. In addition to *health information technology and medical informatics*, the oldest reviews (2016-2017) were indexed with keywords *computer, health communication, smoking-cessation, telecare, records, user acceptance, electronic medical records,* and *internet use*. Importantly, e-Health consistently indexed older publications in both maps, as compared to eHealth, which is a welcome terminology standardization trend given the difficulties we encountered while retrieving e-Health publications.

Multidisciplinary Contributions to eHealth Scholarship: Journal Names in Reference Sections of eHealth Reviews

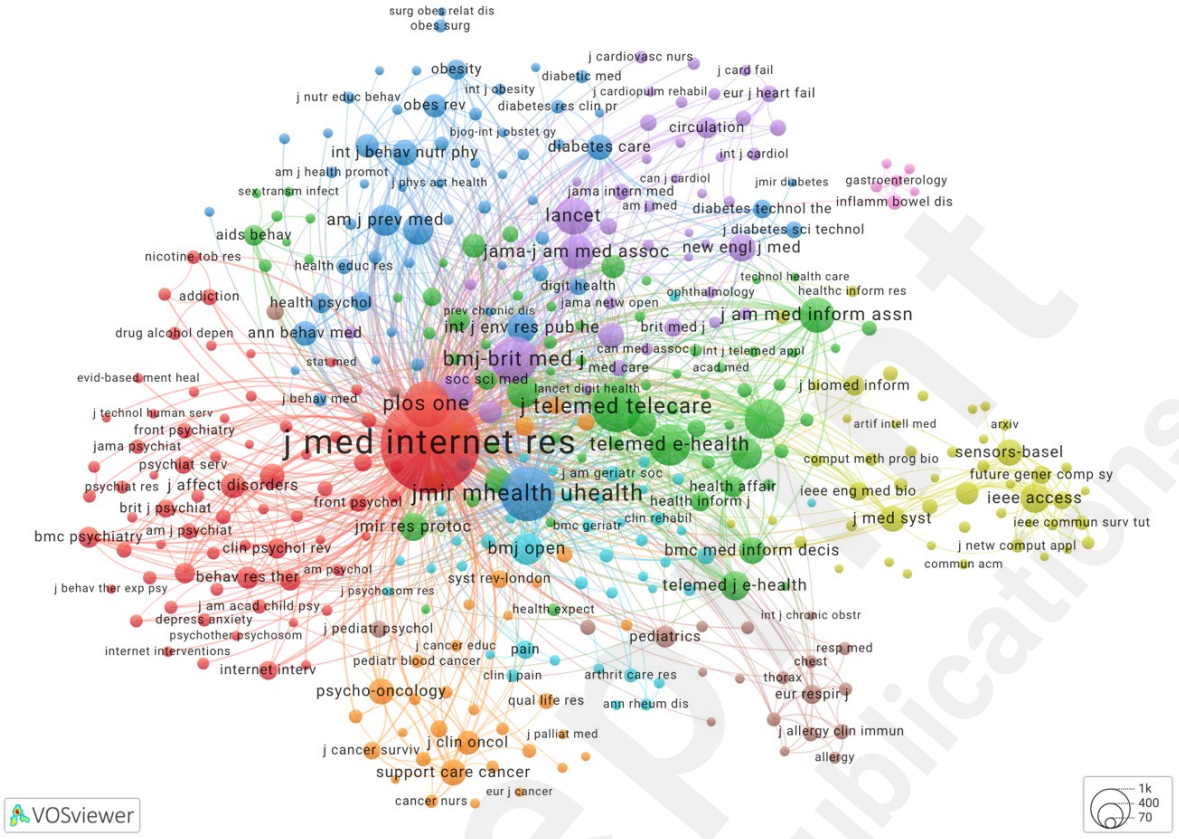
We analyzed multidisciplinary contributions using journal names that appear in reference sections of eHealth reviews (see Figure 5).

A nine-cluster model of journals contributing to eHealth reviews highlighted the leading role of the *Journal of Medical Internet Research* (*JMIR*). It was cited the most, specifically, 6,329 times in 1,884 reviews for which citation lists were available. It belonged to the largest cluster (cluster 1, red) with a large group of journals mostly dedicated to psychology and psychiatry.

Cluster 2 (green) largest nodes were telemedicine, eHealth and telecare journals, followed by journals in other disciplines – health informatics, public health, health services, medical education and health communication, clinical practice, HIV/AIDS research, and healthcare policy. Interestingly, we did not observe journals specializing in social media in this or any other cluster, given social media keywords observed in Figures 2 and 3.

Cluster 3 (dark blue) encompassed mHealth and ubiquitous health content (*JMIR mHealth and uHealth*), followed by cited sources in the fields of preventive medicine and public health; nutrition, obesity, and exercise; behavioral medicine and health psychology; and diabetes and endocrinology, among other disciplines.

Figure 5. A Co-Citation Network of Sources for 1,885 eHealth Reviews: A Cluster Map. Sources that occur 50 times or more in eHealth reviews' reference lists were mapped. Link to an interactive map: https://tinyurl.com/274ugxye.



Cluster 4 (yellow) was somewhat unique in that its sources were less likely to be co-cited with sources from other clusters. Related to sensors, artificial intelligence, and health informatics, journals in cluster 4 had an information technology, computing, healthcare, and biomedical focus. An interdisciplinary journal *Nature* was also in this cluster.

Cluster 5 (purple) included journals in general and internal medicine, cardiology and cardiovascular medicine, epidemiology, and other specialized medical fields. Several leading medical journals (*BMJ: British Medical Journal, The Lancet, JAMA: Journal of the American Medical Association, and The New England Journal of Medicine*) were among the largest nodes in this cluster.

In addition to general medical research sources, cluster 6 (light blue) had journals on pain, digital medicine, geriatrics and aging, rehabilitation and disability, rheumatology, and neurology. Cluster 7 (orange) was dedicated to cancer and oncology journals, and journals in related healthcare fields, including psycho-oncology, palliative care and symptom management, nursing in oncology, quality of life and patient outcomes, cancer education, nursing, and palliative care.

Most journals in cluster 8 (brown) belonged to either respiratory medicine and allergology or pediatrics and adolescent medicine, confirming our earlier findings about eHealth interventions for this age group. Finally, cluster 9 (pink) consisted of gastroenterology journals, particularly those focusing on inflammatory bowel diseases and related conditions. It is also important to note that some fields, such as nursing, were represented by journals in many clusters.

Multidisciplinary Contributions: A Concept Map of eHealth Studies from OpenAlex

In addition to a cited journals analysis, we gathered evidence of multidisciplinary contributions directly from a large corpus of eHealth articles in OpenAlex, which were tagged with one or more of concepts. Concepts reflect disciplines, theories, methods, and other abstract ideas. After removing most methods and statistics related concepts (e.g., sample or odds ratio), geography, general ideas (e.g., work), and merging synonymous concepts, we mapped the remaining 392 concepts representing disciplines and ideas relevant to eHealth (see Figure 6). Each mapped concept occurred at least 20 times.

Figure 6. A Concept Co-occurrence Network for 10,022 eHealth Articles from OpenAlex: A Cluster Map. Concepts that occur 20 times or more were mapped. An interactive map is available from Leiden University's VOSviewer application: https://tinyurl.com/248zvmlx

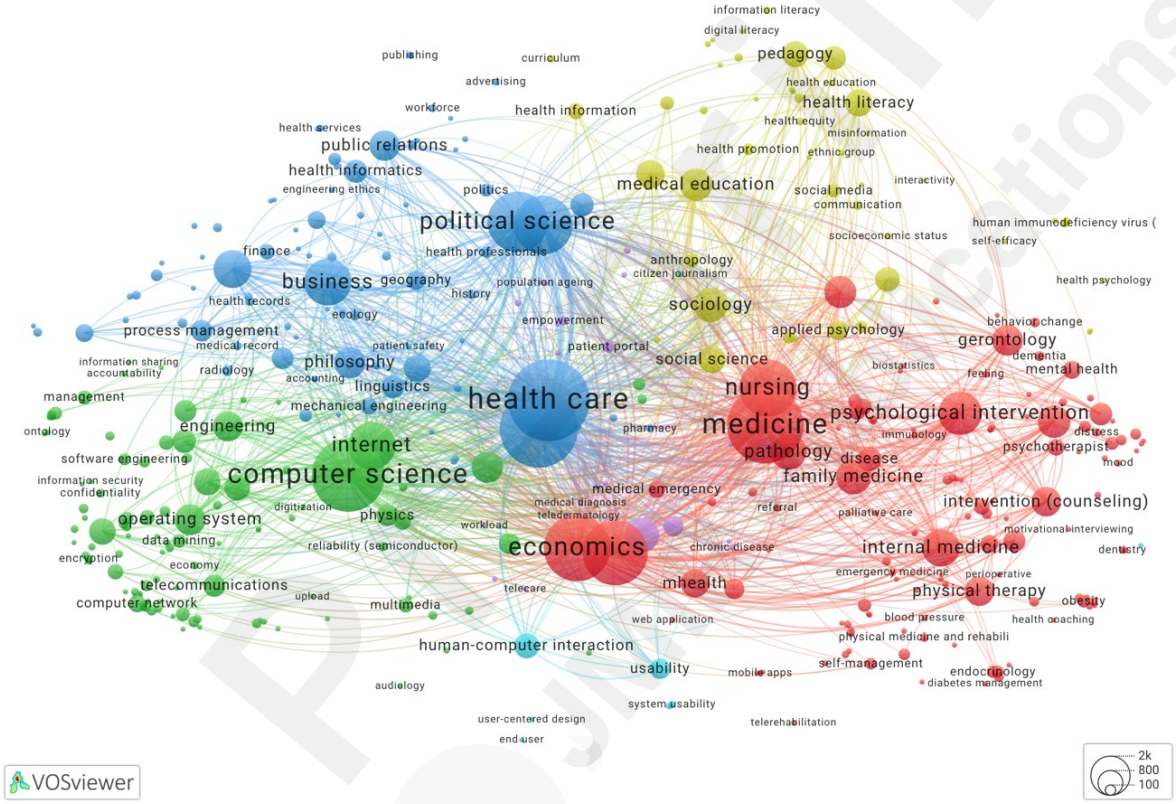


Figure 6 validated our earlier journal-level findings from Figure 5, confirming eHealth research connections to healthcare services, medicine, psychology, public health, education, and computer science. It also added to our understanding of the multidisciplinary nature of eHealth research by highlighting the prominent role, according to node size, of political science and law, economics, business, and knowledge management. The strongest connections with eHealth were observed for *medicine* and *nursing*, *computer science*, followed by *economics* and *economic growth*, *political science*, and *law*. Whereas these concepts were most central to eHealth, numerous other fields, ranging from human-computer interaction and engineering to philosophy and linguistics, contributed to eHealth scholarship. In Figure 6 network, eHealth had the strongest links to *internet* and *intervention*, followed by the four concepts strongly connected to eHealth in Figures 2 and 3 – *telemedicine, mHealth, digital health,* and *telehealth.*

In Table 3, we contextualized our cluster-based findings with map overlays, examining how study attributes and concept characteristics were distributed across the map depicted in Figure 6.

The mean publication year of OpenAlex studies, by map node, added evidence needed to answer research question 2 about eHealth research development over time. According to mean publication year overlay, the nodes with the most recent mean publication year were *misinformation* (2022) and new technologies such as *edge computing* (2021), *deep learning* (2022); pandemic concepts (2021); and concepts about mental health and psychological well-being including *depressive symptoms*, *mental health literacy, insomnia*, *loneliness*, all of which had a mean publication year of 2021. Older eHealth articles were represented by studies classified by OpenAlex as *computer science*, *engineering, business, health informatics,* and *public relations*. Setting aside concepts not specific to eHealth technologies, *telematics* (2008), *semantic web* (2013), *web service* (2013), *information technology* (2013), *ubiquitous computing* (2013), *health information technology* (2014), *information sharing* (2014), *cross-domain interoperability* (2014), and *informatics* (2014) were the oldest technology-related concepts with the pre-2015 mean publication year.

Other overlays were dedicated to concept characteristics, such as relatedness of OpenAlex concepts to eHealth technology or its objectives and different aspects of health. We pointed out patterns in how these characteristics were distributed across Figure 6 concepts in Table 3. Below we highlighted several points most pertinent to multidisciplinary contributions.

Table 3. Overlays to Figure 6 Map: Overlay Name, Interactive Map Link, Definition, and Summary

Overlay Name/ Interactive Map Link / Definition	Summary of findings
Publication year: https://tinyurl.com/27wsed82 Mean year for all articles represented by a concept	Overall, older publications on map's left (business, engineering, law, political science, and many computer science concepts) than on the right (medical and health disciplines, human-computer interaction). Notable exceptions in cluster 2: *edge computing*, *deep learning*, *enhanced data rates for GSM evolution*, *audiology*, and *blockchain* with 2020-21 mean pub. years.
eHealth technology or related concept: https://tinyurl.com/23gsmjc4	Most technology concepts fell under computer science and engineering. Health literacy ideas (e.g., *digital divide*) and *social media* tended not to co-occur with other technology concepts.
eHealth objective: https://tinyurl.com/2a834blf Concepts related to desired outcomes or goals	Objectives were widely spread across clusters. They fell into the categories of healthcare services (access, safety, and quality); supporting providers; fostering sustainable and efficient health systems; encouraging collaboration and communication; promoting public health; enhancing user experience, empowerment, and engagement; safeguarding data and information security.
Health issues or field: https://tinyurl.com/2cqsn3yb Broadly defined concepts related to health and health disciplines including illness, wellness, and mental health	A plethora of disciplines concerned with disease, health, and wellness (from high to low node size): *Medicine*, *psychology*, *internal medicine*, *pathology*, *family medicine*, *psychiatry*, *environmental health*, *gerontology*, *physical therapy*, *public health*, *clinical psychology*, *surgery*, *alternative medicine*, etc.
Illness: https://tinyurl.com/2ybh33ne Concepts specific to diseases and health conditions	Pathology, surgery, infectious diseases, and cancer concepts had the highest count of studies.
Wellness: https://tinyurl.com/2avqly69 Concepts specific to health promotion and maintenance	Health literacy, alternative medicine, and quality of life, self-management, physical activity interventions had the highest count of studies.
Mental health: https://tinyurl.com/23hcfw2n Concepts related to cognitive, behavioral, and emotional well-being	Psychology and psychiatry concepts, especially those related to interventions, had the highest count of studies. Conditions included anxiety, dementia, distress, suicide ideation, insomnia, depression, and addiction.
Risk: https://tinyurl.com/27e7agsm Concepts related to risk in technology or health domains	Risk reduction concepts were related to computer security (access control, information security, cloud computing security) and engineering risk analysis. Other risk concepts included pandemic risks, poison control, patient safety, suicide prevention, adverse effects, vaccination, and injury prevention.
Economics and business:	Economics, economic development, business, and

https://tinyurl.com/2ajltxvq Relevant concepts and fields	marketing concepts had the highest count of studies.

The technology overlay demonstrated that 137 out of 392 concepts (35%) mapping eHealth were directly linked to technology, a clear indication that eHealth multidisciplinarity is only partially grounded in data sciences, engineering, and computer sciences. Interestingly, the *social media* concept (also represented as a keyword in Figures 1 and 2) stood out as an eHealth literacy technology with relatively weak co-occurrence relationships to most other eHealth technologies. We found some evidence of research on social media information campaigns and pandemic interventions, for example, a moderated Facebook group that brought together 200 providers and more than 58,000 laypeople from Denmark to support an informed approach to following pandemic guidelines [36]. Nevertheless, our maps consistently depicted social media as a small domain, suggesting this research played a modest role in the eHealth corpora we examined.

When OpenAlex map and WoS maps were created, VOSviewer calculated node scores indicative of mean citations and normalized citations. These analyses were outside of the study scope but we shared them in our Appendix.

Discussion

Key Findings

Our bibliometric inquiry into eHealth resulted in empirically documented research directions, verified using more than one collection of eHealth studies extracted from two different databases. We identified seven research directions by analyzing keyword clusters: 1) self-management and interventions; 2) telemedicine, telehealth and technology acceptance; 3) privacy, security, and design; 4) health information consumers' literacy; 5) health promotion and prevention of disease through active lifestyle choices; 6) mHealth and digital health; 7) HIV prevention. Multiple age groups and stakeholder types were represented in published research. Researchers studied mental health and health literacy of young people; physical activity and lifestyle changes to prevent obesity, hypertension, cardiovascular disease and diabetes in adults and older adults; chronic disease, dementia, and pain management and medication adherence in older adults; cancer survivors and caregivers' needs; as well as providers and health leaders.

Below we synthesize our eHealth technologies and their objectives. We discuss levels of eHealth research and multidisciplinary contributions, reflecting on the development of the eHealth field over time.

Research on eHealth technologies, infrastructure, and health analytics

We found that the keyword eHealth served as a catch-all term, labeling research on a variety of technologies. Applications of eHealth can be categorized as telehealth services, mobile health (mHealth), wearables, health record management, and educational and informatics tools. Research into common applications of eHealth is shown in Table 4, using WoS articles as an illustration.

Table 4. Characteristics of eHealth WoS Articles by eHealth Application

eHealth application	Keywords from Figure 2	M pub. year
Educational and Informatics Tools	e-learning, consumer health informatics	2016.24

Telehealth Services	telemedicine, telehealth, telecare, telemonitoring, telerehabilitation, teledermatology	2018.02
Health Record Management	electronic health record, ehr, patient portal, personal health records, personal health record, patient portals	2018.45
Mobile Health (mHealth)	mhealth, mobile health, m-health, apps, app, mobile application, mobile applications, mobile app, mobile apps, health apps	2019.74
Wearables	wearables, wearable, wearable technology	2021.01

Maps offered insights into the eHealth infrastructure of interest to researchers: networks, data exchange, computing technologies, hardware, information systems, and platforms. For example, eHealth scholars studied internet, cloud computing, 5G, sensors and other networks, as well as blockchain technology for secure data exchange. Also, they researched wireless sensor networks and body area networks that expand the reach of eHealth applications, facilitating remote monitoring and health interventions over vast geographic areas. Study keywords included hardware, from smart phones to specialized sensors in wearables that enable data collection and health monitoring. Multiple studies were indexed with keywords that described platforms – websites, social media, and mobile apps.

Our analysis also indicated eHealth research emphasis on the security and privacy of data, e.g., through advanced access control mechanisms and encryption techniques. Finally, most recently, eHealth research focused on artificial intelligence in support of health analytics.

Objectives of eHealth

Many keywords and concepts reflected intended uses for eHealth technologies. Research into clinical applications of eHealth technology was in support of patient monitoring, diagnosis, treatment, and rehabilitation, as well as patient-provider communication. Public health objectives were directed at improving health literacy, education, prevention, quality of life, and well-being.

We found strong evidence of eHealth research into fostering engagement, self-care, participation, and person-centeredness, such as these keywords from Figure 2 that indexed the highest number of studies: *self-management, self-efficacy, social support, engagement, satisfaction, participation, self-care, empowerment, motivation, patient empowerment,* and *involvement*. These findings are consistent with prior research that emphasized that consumer-oriented eHealth solutions, patient-centeredness, and ownership of one's health were defining features of eHealth [7].

Research directions by level: individual, community, health system, and society

We found evidence of eHealth research at the individual, community, health organization or system, and society-wide level. At the individual level, researchers studied health consumers' and providers' participation in telemedicine, mobile health, and web-based interventions. There was a strong focus on interventions to meet health needs in the areas of mental health, wellness, chronic and infectious diseases, with an emphasis on such outcomes as self-management and self-care, prevention, behavior change, adherence, self-efficacy and motivation, health risk reduction and mortality. Individual-level eHealth studies were not limited to interventions; they also included a large body of health literacy research, as well as descriptive studies of internet and social media use by individual health information seekers.

Several small nodes in our maps referred to communities, notably, *community* in Figure 3, and *community, communities, and community-based participatory research* in Figure 2, and *community health* in Figure 6. In their abstracts, scholars discussed interventions for communities, aiming to produce community-level outcomes, for example, to promote knowledge exchange among geographically dispersed providers or between laypeople and providers [e.g., 37]. In addition, eHealth scholars studied disease-specific online communities and conducted community-based participatory research to build a variety of eHealth tools for caregivers in support of their emotional, belongingness, and help-seeking needs.

At the organizational or health system level, there was evidence of theory-guided technology acceptance and adoption research (see cluster 2 in Figure 2). At this level, researchers studied electronic health/medical records, patient portals, and health information and clinical decision support systems. We found many publications on acceptance and adoption of eHealth technologies by patients, providers, and organizational leaders; as well as studies concerned with user satisfaction, building trust, removing access barriers, and innovation promotion.

The societal or global level was represented by two sets of studies. The first set encompassed pre-pandemic and pandemic publications of health information available through global social media and the internet, with a focus on the quality and usage of health information from electronic sources. The second set included past research on new and emerging technologies with potential impact on all levels of eHealth, including the societal level: internet of things, cloud computing, blockchain, artificial intelligence, etc. At the highest level, these technologies can be applied, for example, for disease surveillance, secure data sharing, or population health predictions. Society-level eHealth researchers were concerned about standardization, policy, ethics, and governance. Given regional and global efforts to strategically allocate resources for health technologies, such as WHO's Global Initiative on Digital Health [38], we expect an increase of eHealth publications at the societal or global level.

Interestingly, we did not find much research on social media eHealth interventions. Social media keywords appeared in our maps but their node sizes were unexpectedly small, considering worldwide use of social media platforms [39] and health researchers' interest in harnessing their power for health communication campaigns [40-41]. The role of social media within eHealth has been conceptualized as an "interacting for health" intervention technology and as a means of obtaining health information, an eHealth domain titled "health in our hands" [7]. Thinking broader, social media can be an eHealth technology in support of health policy analysis, for instance, for gathering digital publics' input on health services and systems [42] or gouging public reactions to health policy issues. Most likely, we did not capture many relevant social media studies that did not mention eHealth in their titles, keywords, or abstracts.

How eHealth research developed over time

The earliest eHealth scholarship was rooted in computer and web technologies used for patient-provider communication and treatment of specific health conditions, as well as in telecare and medical informatics. In contrast, the most recent eHealth scholarship was represented by articles and reviews dedicated to the Covid-19 pandemic and a variety of newer technologies, such as artificial intelligence, wearables, digital health, blockchain, and internet of things. In our keyword maps, Covid-19 had strong links to telemedicine, expedited by the recent Covid-19 pandemic [46], and digital health.

The keyword e-Health, as compared to eHealth, consistently indexed older articles and reviews, suggesting a shift toward terminology standardization. We recommend that library database managers and future authors consistently index their studies with keyword eHealth to avoid problems in retrieving e-Health publications.

Another likely terminology shift is towards *digital health*, adopted in many WHO documents and defined as "Digital health is the systematic application of information and communications technologies, computer science, and data to support informed decision-making by individuals, the health workforce, and health systems, to strengthen resilience to disease and improve health and wellness" [43]. Digital health has gained popularity as an umbrella term alternative to eHealth, according to our analyses. This finding confirmed nearly decade-long concerns documented by Shaw and colleagues in their interviews with eHealth researchers, educators, practitioners, and policy makers [7]. One of their informants stated:

> You know eHealth is really old fashioned? Nobody talks about eHealth anymore. Electronic health—everything's electronic! The devices, everything! We' re talking about digital health, digitizing health, not eHealth [7, p. 3].

As more studies are indexed with digital health, the use of an eHealth keyword may decline. We recommend that future bibliometricians query both search terms to achieve historic depth of their corpora for tracking this research field's evolution.

eHealth articles versus reviews: Areas for future research

Review authors favored eHealth experiments, as well as studies on telemedicine, telehealth, digital health, mHealth and feasibility studies. Our topic-specific, standardized comparison of the volume of studies versus reviews helped to identify well researched eHealth areas that received limited attention from review authors. One of such areas was eHealth; this review addressed this literature gap.

We also drew attention to a small number of eHealth literacy reviews relative to the number of articles in this area. Other likely under-reviewed areas include eHealth technologies indexed with keywords privacy or security and eHealth technology adoption topics, such as barriers, usability, and user acceptance. Another potential area for systematic reviews was eHealth provision of cognitive-behavioral therapy and mental health related topics of social support and self-efficacy.

The multidisciplinary nature of eHealth

Scholarship on eHealth was supported by contributions from a variety of health-related disciplines. Some of the journals were technology-oriented (JMIR, telemedicine journals, journals about sensors), however, most cited journals were not specific to health technology, suggesting a broad support for eHealth applications from a variety of medical fields. Psychology, psychiatry, public health, preventive medicine journals were prominent in our source co-occurrence map. Other journals were specific to age groups, ranging from pediatric to gerontological sources, which suggests that eHealth draws upon literatures concerned with health across the human lifespan.

Moreover, our analysis of OpenAlex corpus produced evidence that the eHealth scholarship originated as computer science and engineering research in support of medicine, nursing, and public health. with ongoing contributions by eHealth literacy scholars. The core interest of eHealth – technological innovations and interventions – were supported by disciplines concerned with policy, law, and economy. In sum, eHealth is a field at the intersection of technology, medicine, health

services, business, public health, health promotion and literacy, and many other fields.

Limitations

One of the study limitations is exclusion of e-Health articles from OpenAlex search query to avoid potential issues with the hyphenated search term. The literature of interest is undoubtedly broader than the 10,022 articles we mapped. Moreover, our study addressed high-level patterns in meta-data, limiting visualizations to keywords and concepts that met a pre-set occurrence thresholds, specifically, keywords used in no less than 10 studies and concepts tagging 20 or more OpenAlex articles.

Conclusion

The multidisciplinary field of study at the crossroads of health and technology is widely recognized as eHealth. Over the past 25 years, researchers studied a broad range of established and emerging technologies – educational and informatics tools, telehealth services, health record management, mobile health, and wearables – in support of consumer-oriented solutions for patient monitoring, diagnosis, treatment, rehabilitation, and patient-provider communication. Beyond healthcare services, the field of eHealth offers a large body of literature on health literacy, disease prevention, and wellness. Conducted at the individual, community, health system, and society level, eHealth research continues to develop by incorporating new technologies, responding to health emergencies, and addressing the needs of diverse stakeholders.

Acknowledgments

The authors wish to thank the anonymous reviewers for their suggestions.

Funding

None declared.

Conflict of Interest

Authors declare that they have no conflict of interest.

Data and materials availability

All data are available in the main text or the supplementary materials. Map files can be downloaded from map URLs provided in figures. Original YouTube comments (initial posts and first-level replies) can be accessed through YouTube using the video descriptions provided in Supplementary Materials.

Multimedia Appendix 1

Additional overlays and publication impact.

References

1. World Health Organisation. WHO EMRO | eHealth | Health topics. World Health Organization - Regional Office for the Eastern Mediterranean. Published 2023. https://www.emro.who.int/health-topics/ehealth/
2. Mann DM, Chen J, Chunara R, Testa PA, Nov O. COVID-19 transforms health care through telemedicine: Evidence from the field. Journal of the American Medical Informatics Association. 2020;27(7):1132-1135. doi:https://doi.org/10.1093/jamia/ocaa072
3. Alonso SG, Marques G, Barrachina I, et al. Telemedicine and e-Health research solutions in literature for combatting COVID-19: a systematic review. Health and Technology. 2021;11(2):257-266. doi:https://doi.org/10.1007/s12553-021-00529-7
4. Rowland SP, Fitzgerald JE, Holme T, Powell J, McGregor A. What is the clinical value of mHealth for patients? NPI Digital Medicine. 2020;3(1). doi:https://doi.org/10.1038/s41746-019-0206-x
5. Rajpurkar P, Chen E, Banerjee O, Topol EJ. AI in health and medicine. Nature Medicine. 2022;28(1):31-38. doi:https://doi.org/10.1038/s41591-021-01614-0
6. Barello S, Triberti S, Graffigna G, et al. eHealth for Patient Engagement: A Systematic Review. Frontiers in Psychology. 2016;6(6). doi:https://doi.org/10.3389/fpsyg.2015.02013
7. Shaw T, McGregor D, Brunner M, Keep M, Janssen A, Barnet S. What is eHealth? Development of a Conceptual Model for eHealth: Qualitative Study with Key Informants. Journal of Medical Internet Research. 2017;19(10):e324. doi:https://doi.org/10.2196/jmir.8106
8. Donthu N, Kumar S, Mukherjee D, Pandey N, Lim WM. How to conduct a bibliometric analysis: An overview and guidelines. Journal of Business Research. 2021;133(133):285-296. doi:https://doi.org/10.1016/j.jbusres.2021.04.070
9. Müller AM, Maher CA, Vandelanotte C, et al. Physical Activity, Sedentary Behavior, and Diet-Related eHealth and mHealth Research: Bibliometric Analysis. Journal of Medical Internet Research. 2018;20(4):e122. doi:https://doi.org/10.2196/jmir.8954
10. Fang T, Cao H, Wang Y, Gong Y, Wang Z. Global Scientific Trends on Healthy Eating from 2002 to 2021: A Bibliometric and Visualized Analysis. Nutrients. 2023;15(6):1461. doi:https://doi.org/10.3390/nu15061461
11. Železnik U, Kokol P, Starc J, Železnik D, Završnik J, Vošner HB. Research Trends in Motivation and Weight Loss: A Bibliometric-Based Review. Healthcare. 2023;11(23):3086. doi:https://doi.org/10.3390/healthcare11233086
12. Palozzi G, Antonucci G. Mobile-Health based physical activities co-production policies towards cardiovascular diseases prevention: findings from a mixed-method systematic review. BMC Health Services Research. 2022;22(1). doi:https://doi.org/10.1186/s12913-022-07637-8
13. Johansson M, Romero D, Jakobson M, Nelleke Heinemans, Lindner P. Digital interventions targeting excessive substance use and substance use disorders: a comprehensive and systematic scoping review and bibliometric analysis. Frontiers in psychiatry. 2024;15. doi:https://doi.org/10.3389/fpsyt.2024.1233888
14. Ellis LA, Meulenbroeks I, Churruca K, et al. The application of e-mental health in response to COVID-19: A scoping review and bibliometric analysis (Preprint). JMIR Mental Health. Published online August 16, 2021. doi:https://doi.org/10.2196/32948
15. Taj F, Klein MCA, van Halteren A. Digital Health Behavior Change Technology: Bibliometric and Scoping Review of Two Decades of Research. JMIR mHealth and

uHealth. 2019;7(12):e13311. doi:https://doi.org/10.2196/13311
16. Wu Y, Wang X, Zhou M, Huang Z, Liu L, Cong L. Application of eHealth Tools in Anticoagulation Management After Cardiac Valve Replacement: Scoping Review Coupled With Bibliometric Analysis. JMIR mhealth and uhealth. 2024;12:e48716-e48716. doi:https://doi.org/10.2196/48716
17. Kokol P, Saranto K, Blažun Vošner H. eHealth and health informatics competences. Kybernetes. 2018;47(5):1018-1030. doi:https://doi.org/10.1108/k-09-2017-0338
18. Wang C, Wu X, Qi H. A Comprehensive Analysis of E-Health Literacy Research Focuses and Trends. Healthcare. 2022;10(1):66. doi:https://doi.org/10.3390/healthcare10010066
19. Calvo F, Carbonell X, Johnsen S. Information and communication technologies, e-Health and homelessness: A bibliometric review. Walla P, ed. Cogent Psychology. 2019;6(1):1631583. doi:https://doi.org/10.1080/23311908.2019.1631583
20. Tapera R, Singh Y. A bibliometric analysis of medical informatics and telemedicine in sub-Saharan Africa and BRICS nations. Journal of Public Health Research. Published online June 16, 2021. doi:https://doi.org/10.4081/jphr.2021.1903
21. Lwin HNN, Punnakitikashem P, Thananusak T. E-Health Research in Southeast Asia: A Bibliometric Review. Sustainability. 2023;15(3):2559. doi:https://doi.org/10.3390/su15032559
22. Puliga G, Nasullaev A, Bono F, Gutiérrez E, Strozzi F. Ambient assisted living and European funds: a bibliometric approach. Information Technology & People. 2020;ahead-of-print(ahead-of-print). doi:https://doi.org/10.1108/itp-10-2019-0565
23. Cobelli N, Blasioli E. To be or not to be digital? A bibliometric analysis of adoption of eHealth services. The Tqm Journal. 2023;35(9):299-331. doi:https://doi.org/10.1108/tqm-02-2023-0065
24. Sahoo S, Sahoo J, Kumar S, Lim WM, Ameen N. Distance is no longer a barrier to healthcare services: current state and future trends of telehealth research. Internet Research. 2023;33(3). doi:https://doi.org/10.1108/intr-10-2021-0774
25. Rejeb A, Rejeb K, Treiblmaier H, et al. The Internet of Things (IoT) in healthcare: Taking stock and moving forward. Internet of Things. 2023;22:100721. doi:https://doi.org/10.1016/j.iot.2023.100721
26. Palozzi G, Schettini I, Chirico A. Enhancing the Sustainable Goal of Access to Healthcare: Findings from a Literature Review on Telemedicine Employment in Rural Areas. Sustainability. 2020;12(8):3318. doi:https://doi.org/10.3390/su12083318
27. Palozzi G, Antonucci G. Mobile-Health based physical activities co-production policies towards cardiovascular diseases prevention: findings from a mixed-method systematic review. BMC Health Services Research. 2022;22(1). doi:https://doi.org/10.1186/s12913-022-07637-8
28. Shaikh AK, Alhashmi SM, Khalique N, Khedr AM, Raahemifar K, Bukhari S. Bibliometric analysis on the adoption of artificial intelligence applications in the e-health sector. DIGITAL HEALTH. 2023;9:205520762211492. doi:https://doi.org/10.1177/20552076221149296
29. Tian H, Chen J. A bibliometric analysis on global eHealth. DIGITAL HEALTH. 2022;8:205520762210913. doi:https://doi.org/10.1177/20552076221091352
30. Huma Sikandar, Alhamzah F. Abbas, Nohman Khan, Muhammad Imran Qureshi. Digital Technologies in Healthcare: A Systematic Review and Bibliometric Analysis. International Journal of Online and Biomedical Engineering (iJOE). 2022;18(08):34-48. doi:https://doi.org/10.3991/ijoe.v18i08.31961
31. Uribe-Toril J, Ruiz-Real JL, Nievas-Soriano BJ. A Study of eHealth from the Perspective of Social Sciences. Healthcare. 2021;9(2):108. doi:https://doi.org/10.3390/healthcare9020108

32. van Eck NJ, Waltman L. VOSviewer Manual 1.6.20. CWTS, University of Leiden. 2023. https://www.vosviewer.com/documentation/Manual_VOSviewer_1.6.20.pdf
33. Concepts | OpenAlex technical documentation. Openalex.org. Published March 7, 2024. Accessed April 26, 2024. https://docs.openalex.org/api-entities/concepts
34. van Eck NJ, Waltman L. Citation-based clustering of publications using CitNetExplorer and VOSviewer. Scientometrics. 2017;111(2):1053-1070. doi:https://doi.org/10.1007/s11192-017-2300-7
35. Waltman L, van Eck NJ, Noyons EC. A unified approach to mapping and clustering of bibliometric networks. Journal of Informetrics. 2010;4(4):629-35. https://doi.org/10.1016/j.joi.2010.07.002
36. Furstrand D, Pihl A, Orbe EB, Kingod N, Søndergaard J. “Ask a Doctor About Coronavirus”: How Physicians on Social Media Can Provide Valid Health Information During a Pandemic. Journal of Medical Internet Research. 2021;23(4):e24586. doi:https://doi.org/10.2196/24586
37. Sims JM. Communities of practice: Telemedicine and online medical communities. Technological Forecasting and Social Change. 2018;126:53-63. doi:https://doi.org/10.1016/j.techfore.2016.08.030
38. Global Initiative on Digital Health. www.who.int. https://www.who.int/initiatives/gidh
39. Pew Research Center, Americans’ Social Media Use (January, 2024). Available at:https://www.pewresearch.org/internet/2024/01/31/americans-social-media-use.
40. Rayward AT, Vandelanotte C, Corry K, Van Itallie A, Duncan MJ. Impact of a Social Media Campaign on Reach, Uptake, and Engagement with a Free Web- and App-Based Physical Activity Intervention: The 10,000 Steps Australia Program. International Journal of Environmental Research and Public Health. 2019;16(24):5076. doi:https://doi.org/10.3390/ijerph16245076
41. Namkoong K, Nah S, Van Stee SK, Record RA. Social Media Campaign Effects: Moderating Role of Social Capital in an Anti-Smoking Campaign. Health Communication. 2017;33(3):274-283. doi:https://doi.org/10.1080/10410236.2016.1258616Mann DM, Chen J, Chunara R, Testa PA, Nov O. COVID-19 transforms health care through telemedicine: Evidence from the field. Journal of the American Medical Informatics Association. 2020;27(7):1132-1135. doi:https://doi.org/10.1093/jamia/ocaa072
42. Ivanitskaya LV, Erzikova EV. Visualizing YouTube Commenters’ Conceptions of the United States Healthcare System: A Semantic Network Method for Evidence-Based Policymaking (Preprint). Published online March 10, 2024. doi:https://doi.org/10.2196/preprints.58227
43. World Health Organization (WHO) Classification of digital interventions, services and applications in health: a shared language to describe the uses of digital technology for health, 2nd ed. Geneva: WHO; 2023. ISBN 978-92-4-008194-9 (electronic version) ISBN 978-92-4-008195-6 (print version).

Supplementary Files

Multimedia Appendixes

Additional overlays and publication impact.
URL: http://asset.jmir.pub/assets/5352a0b2ed6a10804c80451c6e2cda79.docx