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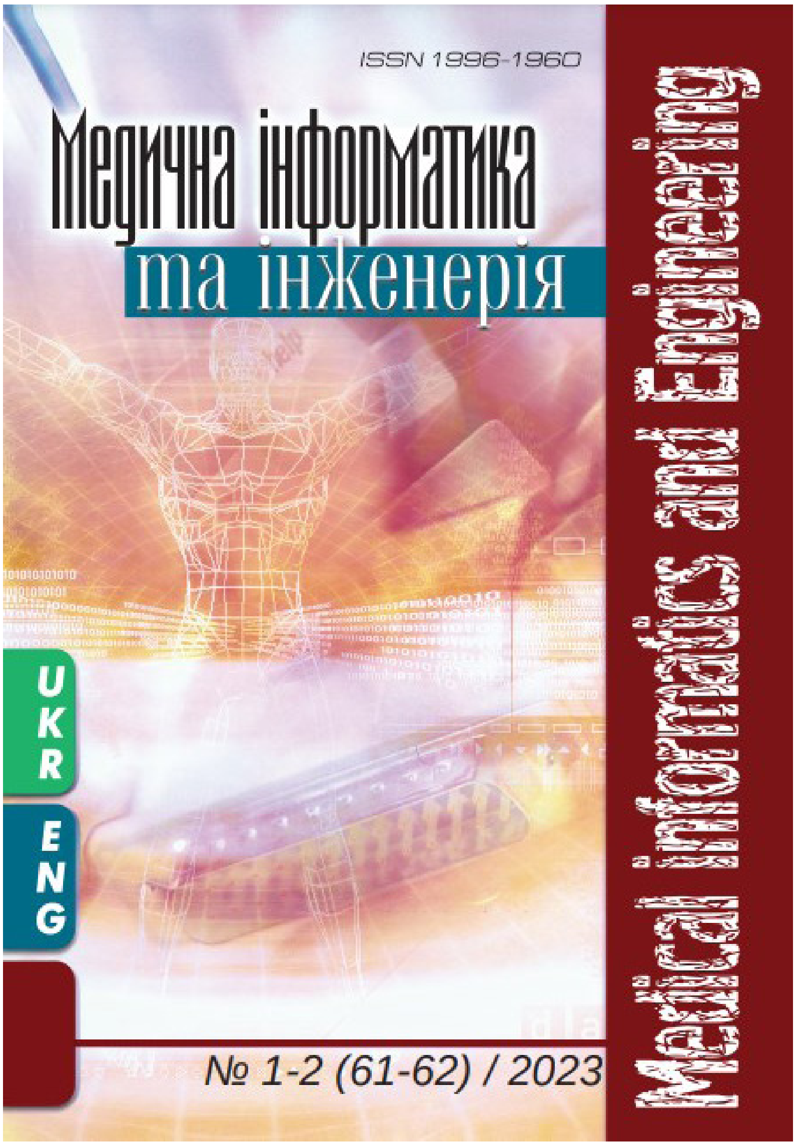

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CONTENT

Foreword

Dear readers,

This special issue of the JAIR is dedicated to the primary field of digital health. The contributions are the result of the discussions at the virtual conference DigiHealthDay which took place on November 11th, 2022. The hosting institution of the DigiHealthDay at the Deggendorf Institute of Technology was the European Campus Rottal-Inn (ECRI). The DIT and the Ukrainian University Shupyk National Healthcare University of Ukraine (Shupyk NHU of Ukraine) decided to realize a joint publication. The guest editors for this issue are Prof. Dipak Kalra (Shupyk NHU), Prof. Dr. Georgi Chaltikyan (DIT), Prof. Dr. biol. hum. Horst Kunhardt (DIT) and Prof. Ozar Mintser (Shupyk NHU). It will be published online via the JAIR and will be additionally published as a reprint via the Ukrainian Journal "Medical Informatics and Engineering". The principal editors of the JAIR are not responsible for the contents and quality process of special issues. For special issues, the guest editors take the sole responsibility of selecting the articles and ensuring the quality process.

The Journal of Applied Interdisciplinary Research, short JAIR, is an academic journal that aims to provide a current and international overview of interdisciplinary research which is also done in an applied manner. The combination of these two types of research is a niche that has so far found little attention in academic journals and we are happy to close a previously existing gap by combining these two types of research in its own new journal. As this type of research is a growing field, it warrants its own journal. Various areas of academia are overlapping more and more, so we want to provide an opportunity for researchers to publish their interdisciplinary research in a journal dedicated to advancing this particular field, and committed to the exchange of ideas across academic disciplines.

The JAIR is generally published annually, and each issue will be dedicated to a primary research field that will be the basis for contributions.

Having published the first issue (#1) in March 2023, which is dedicated to the primary field of artificial intelligence, the next regular issue (#2) will be published in Spring 2024 with the title "Future Skills". The call for contributions can be found at the Journal's website https://jas.bayern.

Your JAIR editors,

Michelle J. Cummings-Koether Kristin Seffer

Guest Editorial

The field of Digital Health can be considered to be a game-changer in the healthcare systems of today. With its vast potential and widespread applications, Digital Health is changing the way in which healthcare is delivered, potentially to all patients and citizens.

This symposium proceedings follows oral and poster scientific presentations, student theses and projects presented and discussed at DigiHealthDay. The DigiHealthDay is an international educational and networking event series organized by the European Campus Rottal-Inn, Technische Hochschule Deggendorf, Germany. Currently in its third edition, the DigiHealthDay-2022 took place on November 11th, 2022. This day-long symposium included keynote talks by leading German and international experts, and audience-centered panel discussions. The hybrid styled event centered around the theme "Global Digital Health – Today, Tomorrow, and Beyond." It attracted more than 1000 participants from 100 countries who joined physically as well as virtually.

This annual symposium aims especially to stimulate new researchers in exploring solutions using modern Digital Health to tackle global health problems. This edition of the DigiHealthDay encouraged researchers to present their projects in themes such as EHR, health information systems, data standards and interoperability, telemedicine and remote health care, mHealth, IoMT, telemonitoring, health data management and analytics and privacy, security, trust, and patient engagement. A special focus was dedicated to Digital Health education, AI research, ethics and regulation.

We are excited to collaborate with the Journal of Applied Interdisciplinary Research jointly with the Ukrainian Journal of Medical Informatics and Engineering to present a collection of articles that were presented during the DigiHealthDay-2022. These articles are organized around the themes of the DigiHealthDay.

The first article introduces a novel approach to embed a social purpose into all innovations, including Digital Health innovations, primarily though training of future NHS leaders in England. Within the theme 'Telemedicine and Remote Healthcare', the next paper gives an overview of the growing use of Telehealth during the COVID-19 pandemic and its value in the care of older persons. In the theme of 'EHR, Health Information Systems' there are two papers that explore the construction of relational databases in information systems, the integration of healthcare information in information systems and the need for the creation of effective informational-analytical platforms. Both papers emphasize the importance of optimizing the data to deliver value, from their perspectives.

An exciting paper in the field of mHealth, IoMT, and Telemonitoring looked at the use of pediatric health applications to create a space for children to learn about health conditions, healthy lifestyles and preventative health measures. The next set of papers in the theme 'Health Data Management and Analytics' contains two articles that deal with the need for a comprehensive real-time medical data management system and mechanisms for evaluating information in the Doctors' Portfolio. The next paper takes a novel system of views on the role of electromagnetic fields in the human body for understanding the essence of the course of metabolism, phenomena of biological life and health.

The special focus on AI Research features a brilliant study to predict the incidence of Dengue in the Philippines using an artificial neural network with humidity, rainfall, and temperature as independent variables. The second paper in this theme explores the issue of bias within AI systems used for health, including the risk of bias in the sources of data used, and their potential implications.

Prof. Dr. Dipak Kalra, International Chair of DigiHealthDay
Prof. Dr. Horst Kunhardt, Scientific Chair of DigiHealthDay
Prof. Dr. Georgi Chaltikyan, Organizing Committee Chair of DigiHealthDay
Prof. Dr. Ozar Mintser, Editor-in-Chief of Ukrainian Journal of Medical Informatics and Engineering
Fara Fernandes, Associate Guest Editor, Technische Hochschule Deggendorf - European Campus Rottal-Inn

A Solid B.A.S.E. to Innovation within the NHS: A New Approach to Social Sustainability

Tamsin Holland Brown[a]

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ABSTRACT

The NHS (National Health Service) Clinical Entrepreneur Programme (CEP) is the world's largest workforce development programme which allows NHS workers to pursue healthcare innovations. The NHS staff learn to successfully develop and spread innovative solutions to the challenges facing the NHS. Social responsibility is the positive and additional contribution of an innovation/ company to society, their ecosystem and community. Many companies know the benefits of a socially responsible approach (customer engagement, team purpose, enhancing reputation, access to contracts requiring adherence to the Social Value Act or the United Nations Sustainable Development Goals) but the challenge has always been a lack of accountability for innovators or businesses in this area.

The UK's National NHS England Clinical Entrepreneur Programme is one of the largest healthcare innovation programmes in the world. Every year, approximately 150 clinicians with an idea or innovation to improve healthcare are accepted onto the programme with an idea or innovation to improve healthcare. There is a new approach within the Clinical Entrepreneur Programme which aims to embed a social purpose into all innovations, using a new principle called B.A.S.E. (thus named because it aims for entrepreneurs to use it as a base for building their innovations). This is a novel approach. Innovation in healthcare needs a socially responsible BASE to an idea or business, which considers the Benefit to society, Advocacy and Accountability, Sustainability and Social Purpose and Ethical leadership by Empowering and Enabling others.

The BASE approach was trailed within the NHS England Clinical Entrepreneur Programme. Firstly, BASE principles were taught face-to-face and on-line. Secondly, the programme itself modelled a socially responsible BASE in its own operational activities. Thirdly, clinical entrepreneurs were able to work through a form and able to submit their social purpose, socially sustainable activities and supply chain aims, which allowed case examples to be highlighted. The BASE programme is a simple, cost-effective approach to engage, improve and lightly monitor socially responsible activities within a health workforce innovation program.

KEYWORDS

Social purpose, value, clinical, entrepreneurship, NHS, National Health Service

1. Introduction

Digital health solutions are the fastest growing area of health innovation.[1] Social responsibility is the positive and additional contribution of an innovation/company to society, their ecosystem and community. Many companies know the benefits of a socially responsible approach, including customer engagement, team purpose, enhancing reputation, access to contracts requiring adherence to the Social Value Act or UN Sustainable Development Goals. However, the challenge for a socially responsible approach has always been a lack of monitoring or accountability for innovators or businesses in this area.[2] Businesses, new innovations and their supply chains can have a major impact on society and surrounding ecosystems. Child labor, toxic waste and below-living wages have been discovered in supply chains to NHS organizations.[3] The biggest problem being that businesses are not accountable to anyone for their actions on society, human rights and ecosystems. There is a need for a culture of integrity, transparency, honesty as well as a dedicated commitment to ethical, fair and socially sustainable development: to incorporate socially responsible values and to be not only accountable for the impact on society but to provide additional benefits.

Social responsibility is beneficial to innovations and businesses, often providing a competitive and reputational advantage; strengthening a product or company's brand and image; engaging the company actively within a community or with potential customers; engaging and retaining workers in the team/company by adding further vision and purpose; providing access to grants and rebates; attracting investors; providing access to government contracts aligned with social value (figure 1) and often providing a higher economic return.[4] The largest healthcare workforce Clinical Entrepreneur Programme (CEP) is run by National Health Service (NHS) England's Accelerated Access Collaborative (AAC) and supports medical health professionals to remain in their NHS jobs whilst enabling them to seed and grow innovative ideas as Clinical Entrepreneurs (CE) to ultimately benefit the NHS (https://nhscep.com/). The CEP became one of the first NHS Innovation programmes to expect entrepreneurs to be accountable for a socially responsible approach and educate and enable CE's to monitor and highlight social value within their innovation journey.

Deliberately avoiding debated and potentially outdated terminology, the terms 'corporate social responsibility' and 'giving back' were replaced by calling the new proposal the social value BASE, which looked at Benefits, Advocacy, Sustainability and Ethical approach.

Innovation in digital healthcare needs a socially responsible BASE, which considers the Benefit to society, Advocacy for and accountability to patient groups or communities, Social purpose including Sustainability across the supply chain and Ethical leadership by Empowering, Educating and Enabling others. The BASE approach was trailed within the NHS England Clinical Entrepreneur Programme. Firstly, BASE principles were taught face-to-face and on-line. Secondly, the programme itself modelled a socially responsible BASE to its own activities. Thirdly, participants were able to share their BASE achievements and good case examples were highlighted.

Monitoring socially responsible activities and holding innovators, entrepreneurs or businesses accountable for their actions has always been challenging.[2] This paper considers simple, celebratory and positive activities referred to as a 'BASE approach', aiming to embed values and a social purpose early, increasing socially responsible activities and highlighting cases to learn from excellence.

Figure 1: The UK Government website provides information about the Social Value Act.

2. Methodology

The BASE approach was trailed within cohort six of the NHS England National Clinical Entrepreneur programme. Prior to the start of the year's programme, the new cohort of Clinical Entrepreneurs starting the year programme were surveyed. They were asked to rate their confidence on a scale of 1–10 where 1 was 'I don't know' and 10 was 'very confident' regarding the following issues:
1) How confident do you feel about knowing how to build social accountability into your plans for your innovation?
2) How confident are you about the next steps you can take to be socially responsible?
3) How confident are you that your innovation can boast concrete examples, awards or certificates related to social accountability?

The socially responsible BASE values were then taught face-to-face at the education events, with additional resources made available on the programme's website. The programme itself also modelled a socially responsible BASE to its own activities by adding BENEFIT by collaborating and offering opportunities and teaching individuals identified through a large UK charity and by forming a partnership with university technical colleges to support students; ADVOCATING for diversity within innovation; being ACCOUNTABLE for the approach by sampling innovations, collecting feedback and reporting back to the board; ADDING well-being activities to each programme meeting for CEs, as well as encouraging a buddy system for participants to support the well-being of each other; SOCIAL PURPOSE was added to strategic objectives and key principles and this was committed to by the CEP board; EMPOWERING AND ENABLING others by allowing some clinical entrepreneurs to step up as clinical leads on the programme in areas such as environmental sustainability, well-being and supporting social enterprise.

Additionally, the programme taught the BASE principles (of additional Benefit, Advocacy & Accountability, Sustainability and Ethical leadership by Empowering and Enabling others) and encouraged participants to work towards measuring and introducing accountability.

Figure 2. Information from the Clinical Entrepreneur Programme (CEP) website. Image by kind permission from www.nhscep.com.

3. Results

Confidence levels regarding social responsibility were low amongst CEs at the start of the programme. Confidence (as rated on a scale of 1–10 where 1 was ‘I don’t know’ and 10 was ‘very confident’) amongst the Clinical Entrepreneurs regarding:

1) How confident do you feel about knowing how to build social accountability into your plans for your innovation?
The average (mean) answer was 4.1 (n=69)
2) How confident are you about the next steps you can take to be socially responsible
Average (mean) answer 4.2
3) How confident are you that your innovation can boast concrete examples, awards or certificates related to social accountability?
Average (mean) answer 3.6

With low confidence in this area of the programme, the CEP then introduced the social value B.A.S.E. approach. The 150 CEs making up the cohort of NHS England Clinical Entrepreneurs were introduced to the B.A.S.E. approach by attending education events throughout the year, accessing the website and/or submitting their BASE achievements.

Confidence levels sampled (n=12) near the end of the year showed the following improvements:
Building social accountability into plans for innovation: 8.8.
Confidence about next steps to be socially responsible: 8.4.
Examples of social innovation: 6.0.

The impact of the programme itself modelling BASE principles

The programme aligned with NHS England priorities **5** and UN sustainability goals **6**. The programme partnered with entrepreneurs identified through Crisis (www.crisis.org.uk), a homeless charity, which awards grants to those applying for capital to set up and start their own business. The CE programme was able to offer these entrepreneurs access to the education and learning events, mentoring and networking opportunities. Four Crisis Entrepreneurs joined the cohort of Clinical Entrepreneurs. Outcomes showed that two of the Crisis Entrepreneurs developed confidence in business skills and both secured business directly through the network. The hybrid CEP events (education and learning events all offered online and face to face) suited the Crisis Entrepreneurs for both access and decreasing anxiety around face-to-face events initially. Due to the success of this programme, the partnership has continued and further partnerships have been explored.

Education about social enterprise

Social enterprise was taught throughout the year by an assigned clinical lead who had founded 'Generation Medics' and been part of the Clinical Entrepreneur Programme since it was founded. Generation Medics provides up-to-date information, unbiased advice, support, information, and networks to empower and inspire people from all communities to fulfil their potential, by making medical and health-care careers accessible to everyone. The founder of Generation Medics provided 1-to-1 support sessions, specific events and educational talks regarding social enterprises to other clinical entrepreneurs. This led to CE's understanding of how social enterprises are set up, created and maintained. Some CEs were inspired to volunteer their time to support other social enterprises.

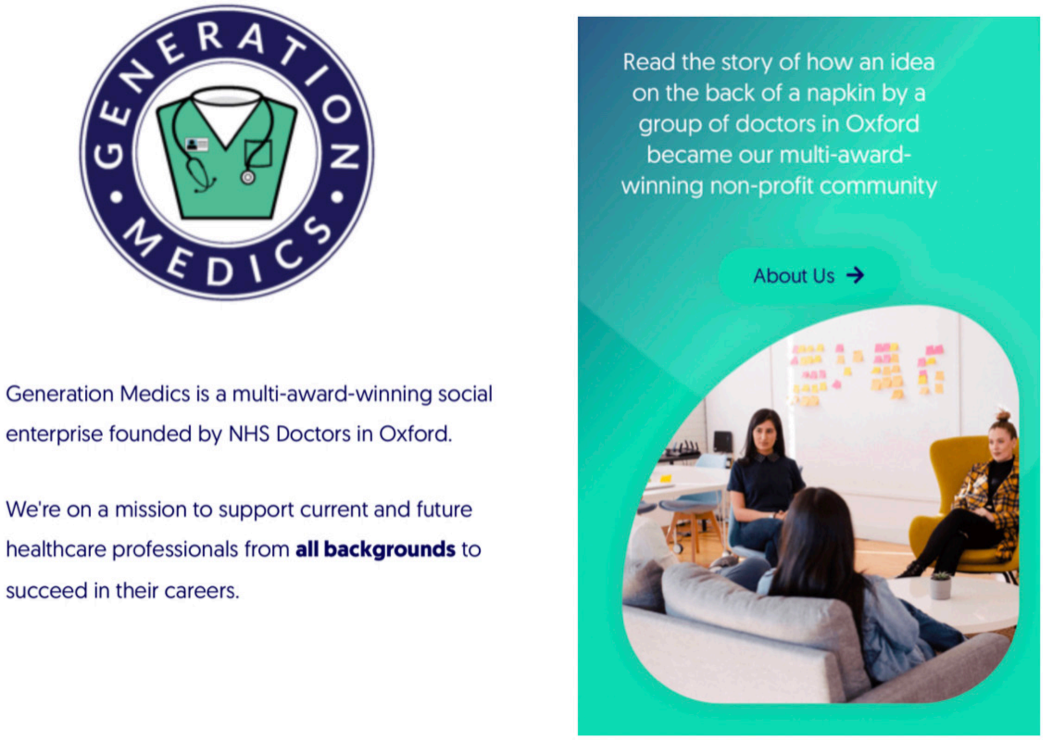

Figure 3: One of the first cohort of Clinical Entrepreneurs, running Generation Medics (a social enterprise) modelled and educated clinical entrepreneurs about social enterprises. Image reproduced by kind permission from www.generationmedics.org.uk.

Social impact of entrepreneurship within underrepresented groups

Of the entrepreneurs highlighted as succeeding at all 4 BASE principles (n=12), the majority (n= 9) identified themselves as part of an underrepresented ethnic group. They were committed not just to their innovation to succeed but to provide opportunities for others in underrepresented groups or groups with larger health inequalities. Addressing healthcare inequalities is currently a NHS priority.

Adding Learning from Excellence

Learning from Excellence **7** is a system of capturing excellent practice in healthcare and learning from it. Positive feedback within an organization is captured with thank-you cards or emails to staff via a system that records and analyses the content. Themes can be explored and system changes made to increase excellence in healthcare. This system was introduced into the CEP and resulted in the emergence of a theme surrounding how much the cohort valued and learnt from each other and the health innovation partners on the programme. This system of gratitude also recognized the value of an overlapping programme called HIPP (Health Innovation Placement Pilot) which was valued by many of the CEs for the insights, perspectives and problem solving that they brought to conversations.

Planned follow up to determine the medium to long-term impact of BASE

Monitoring the long-term success of social responsibility initiatives ensures that intended outcomes are achieved and that there is evidence of a positive impact. This involves tracking key performance indicators, such as the number of people reached, the level of engagement and participation, and the amount of resources invested. It also involves assessing the effectiveness of the initiatives in achieving their objectives, as well as the unintended consequences that may arise. Feedback from stakeholders, including patient groups, health-care staff, and the community, can also provide valuable insights into the impact of the CEP social responsibility initiatives. The CEP showcases patient feedback at the end of the year. By monitoring the long-term success of social responsibility initiatives, the CEP expects entrepreneurs to continuously improve, demonstrate their commitment to responsible business practices, and enhance their reputation as socially responsible companies.

4. Conclusion

The Clinical Entrepreneur Programme is a work force development programme for NHS workers. Working within the NHS, already many clinical entrepreneurs have examples of adding social value and additional benefit to local patient groups, communities and networks. Those working with or identifying with under-represented groups engaged in the most examples of social value within their business or innovation. The BASE programme was a simple, cost-effective way to engage CEs and improve their confidence in delivering their innovation in a socially responsible way. This improves their chances of aligning their innovation with the Social Value Act, government contracts, certain grants or investors and strengthening their brand, team and purpose.

Acknowledgments

Thank you to Professor Mahmoud Bhutta for his generosity of time and shared information about supply chain sustainability.

Conflict of interest statement

Dr T Holland Brown works as co-clinical lead for the NHS England Clinical Entrepreneur Programme as well as working as a pediatrician in Cambridge for Cambridgeshire Community Services NHS Trust. She does consultancy work (paid) for ORCHA (Organisation for the Review of Care and Health Apps) and is founder of Hear Glue Ear.

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Telemedicine for Older Adults During COVID-19: A Literature Review

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ABSTRACT

When intended for the older adult population, telehealth has the potential to be beneficial, especially during a crisis like the COVID-19 pandemic, when older people were the most vulnerable group. This paper provides an overview of the growing use of telehealth among people of 65 years and older during the COVID-19 pandemic by reviewing relevant studies published from the beginning of the pandemic (December 2019) until the time of starting the data extraction process. This review found that telemedicine use in general has been beneficial for healthcare providers, caregivers and patients as it is in the management of the epidemic.

Most telemedicine interventions or services were available for the management and control of chronic diseases. Telemedicine has provided the possibility of immediate assessment and counseling of patients infected with COVID-19, multimedia treatment remotely, patient education and training, facilitating real-time data exchange, leading the collection, processing, and storage of medical information for patients, advising on strategic planning and drug use for patients with COVID-19, dealing with the worries of patients. Digital assessment tools helped in implementing social distancing, reduced reliance on public transportation and minimized the virus infection risk that may happen because of in-person contacts. Its use in the management of mental health crises associated and non-associated with COVID-19 is promising.

The paper also reviews the possible limitations that can hinder better use of telemedicine by older adults, such as the limited ability to perform a physical examination, concern about the quality, not getting personally connected to the medical provider, hearing or visual problems and privacy concerns.

KEYWORDS

COVID-19, coronavirus, telemedicine, telehealth, elderly, older adults, geriatric care

1. Introduction

The relationship of the older population with technology, and the intellectual, physical, and psychological difficulties that hinder their adoption of it has always been a topic of research. On the other hand, the ongoing digital transformation of many health, social and financial services that requires the concerned authorities to work more on facilitating the adoption of technology by this age group. Health-related technologies are important tools for the older population since they are the most health-vulnerable age group, and any means to improve their access to health should not be overlooked. It has become clear that older people are among the groups most at immediate risk of acute illness and death caused by COVID-19. According to one study, adults over the age of 65 had a 100-fold higher death risk than younger people,[1] furthermore accounting for 80 percent of deaths in the United States.[2] In addition to that, the indirect effects of COVID-19 and how the world responded to it also pose serious challenges to older people and affect their well-being, dignity, and their rights. The spread of the COVID-19 virus led to a decrease in the accessibility of older adults to the health system when hospitals and clinics have begun to postpone elective appointments and operations.[3] The COVID-19 crisis was a wake-up call, reminding us of the need to pay urgent attention to promote technology literacy among the older population, supporting care and health providers to use technological innovations as a support tool to provide healthcare services.

Hence the need and the importance of using telemedicine technology as a useful complementary option has increased to reconnect the disconnecting points between older adults and the health system, which occurred as a result of the social distancing regulations and pressures on the health system imposed by the virus.

2. Methods

This literature review has been conducted by giving clear research goals and research methods, where relevant research articles were identified and possible ones were accepted, the data were extracted and the results were summarized, discussed, and analyzed.

The research process in this study focused on the changes in health accessibility during the COVID-19 pandemic that necessitated the adoption of telemedicine use by older adults. The selection was made based on the WHO definition of telemedicine as: "Providing health care services, where the distance is a crucial factor, by health care professionals using communications and information technologies where the health information for diagnosis, treatment, and prevention of disease, research, and evaluation, and continuing education for health care providers, all of them are related to the benefit of individual health and communities".[4] Additionally, it discusses the gaps that limited the adoption of this technology. A comprehensive search was performed in the following electronic databases: Google Scholar, academia.edu, PubMed and the homepage of the World Health Organization to identify relevant and published papers whether they are original studies or reviews.

The titles and abstracts were screened during the search. Studies were included if they properly delineated any type of telemedicine services or applications focused toward the older population (age 65 and up) during the COVID-19 period from December 2019 until the date of the data extraction (April 2022). The articles included were those that studied the service in general and not those presented in specific medical specialties.

In this review, all included studies reflected any type of telemedicine services used in all components and at all levels of healthcare (primary, secondary, or tertiary), focused on providing consultation services, diagnosis, triage of patients, or symptom assessment, whether it is related to COVID-19 symptoms or not, provided that use has been tried and studied on the older population during this time period.

No restrictions on publication status were made, any study written in English regardless of the country was included and a wide range of search terms was used alternately during the search process to obtain the largest possible results.

Only open access publications with full-text studies were included. From 113 results, 24 papers were relevant, valuable and included. 80 % of research results were excluded because they were available as closed access studies, letters to the editor, opinion articles, duplicate publications, were not written in English, and studies with incomplete information or not relevant.

3. Results

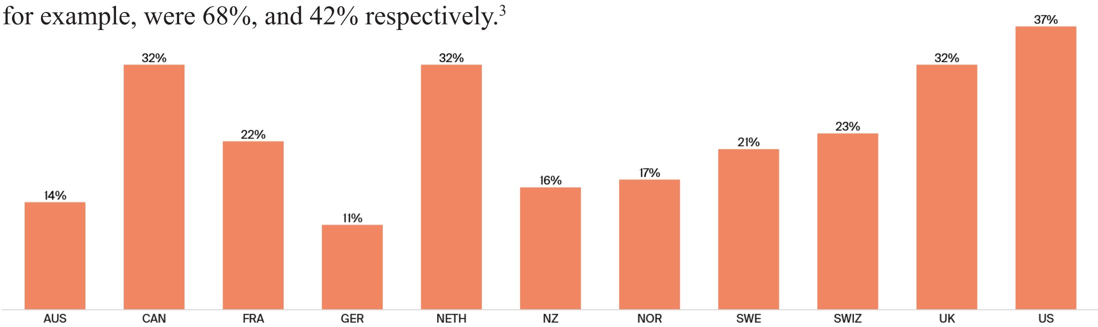
Necessitated Adoption of Telemedicine by Older Adults During COVID-19

Older adults are vulnerable to COVID-19 due to multiple factors, including social, biological, demographic, healthcare access, and behavioral factors. COVID-19 impacts on older people extend beyond high morbidity and mortality rates resulting from direct infection. Regulations designed to limit the virus's spread have also indirectly impacted this population, leading to deteriorating health.[5]

Indirect impacts of COVID-19 on older adults include social distancing instructions that have made accessing healthcare services difficult, resulting in psychological effects such as loneliness, depression, lack of assistance, physical activity, and outdoor activities, ageism, discrimination, and stigma. The digital divide has also increased inequality and isolation for those without access to technology.[5]

Although several studies show that people with limited healthcare access have greater death rates than those with regular follow-up visits. COVID-19 laws and instructions have further affected access to healthcare services. Movement and transportation restrictions, restrictions on health centers and clinics, and social distancing regulations have limited monitoring and follow-up care, reducing social life by limiting meetings with acquaintances and social activities.[5,6]

Adults over the age of 65 account for 15.6 % of the US population but 27 % of yearly medical office visits, with 45 % of these visits to a physician of primary care (PCP).[5] In a study conducted to investigate the health accessibility of older adults during the COVID-19 pandemic in different countries, one of the measurements that has been studied was the percentage of older adults aged 65+ with 2 or more chronic diseases who reported that their appointment with a doctor or other health care provider was canceled or postponed because of issues related to the pandemic and the percentages were 37 in the US, 32 in Canada and the Netherlands.[3] Correspondingly, it was reported in this study that the percentage of older adults who have two or more chronic conditions and the older adults who have three or more, in the US, for example, were 68%, and 42% respectively.[3]



Source: Reginald D. Williams II et al., The Impact of COVID-19 on Older Adults: Findings from the 2021 International Health Policy Survey of Older Adults (Commonwealth Fund, Sept. 2021). https://doi.org/10.26099/mqsp-1695

Figure 1: Percentage of people aged 65+ with two or more chronic conditions who reported they had an appointment with a health care practitioner postponed or cancelled because of the COVID-19 pandemic.

The Aged Group Most at Risk of Infection and Death because of COVID-19

Older adults are the most vulnerable group to COVID-19, accounting for 80% of all COVID-19-related deaths, in other terms individuals over 65 and those with pre-existing medical illnesses, such as hypertension, diabetes, or heart disease are at greater risk of developing severe COVID-19 symptoms. Approximately 66% of adults aged 70 and older have at least one underlying disease, making them more susceptible to severe COVID-19 effects.[6]

3. Impacts of COVID-19 on the Mental Health of the Older Population

Social distance and loneliness

The COVID-19 pandemic has significantly impacted the mental health of older adults, particularly due to the implementation of social distancing and quarantine measures. These measures were initially implemented to protect older adults from physical harm, but little attention was given to their psychological well-being,[6] for instance, quarantine has been found to be associated with several emotional disorders, such as depression, stress, sleep disturbances, low mood, irritability, and long-term post-traumatic stress.[7]

Studies conducted during the COVID-19 pandemic have shown a rise in levels of depression, anxiety, and loneliness among older adults. One of them was a study conducted in China, which showed that 53.8% of respondents rated the epidemic's psychological impact as moderate or severe, with 16.5% experiencing moderate to severe depression symptoms, 28.8% expressing moderate to severe anxiety symptoms, and 8.1% reporting moderate to severe stress.[7] Social distancing, loneliness, and a lack of social activities due to regulations imposed after the outbreak have increased feelings of loneliness among older people.[6] The National Academies of Sciences, Engineering, and Medicine (NASEM) conducted a survey that found that over 30% of people aged 45 and older experience loneliness, with nearly 25% of people aged 65 and older being socially isolated.[8]

Anxiety, panic attacks, and depression

Anxiety, panic attacks, and depression are other psychological effects of the COVID-19 pandemic on older adults. Older adults' fear of getting infected with the virus, experiencing symptoms, or dying has led to anxiety, panic disorders, and depression among them. Moreover, worrying about family members can predict mental distress. The conflicting information that was circulating and the negative information that was often reported in the media contributed to feelings of anxiety and fear.[9] Discrimination and ageism by people who consider older adults as a risk or weakness factor during the pandemic have also contributed to their distress.[6] The financial pressures resulting from the economic situation and the inability to access healthcare were also stressors associated with the pandemic.[10]

In conclusion, the COVID-19 pandemic has significantly impacted the mental health of older adults. Social distancing, loneliness, and a lack of social activities have led to feelings of depression, anxiety, and loneliness. Moreover, anxiety, panic attacks, and depression have also increased among older people during the pandemic. It is crucial to address these psychological effects and take measures to support the mental well-being of the elderly population.

Telemedicine Uptake During COVID-19

As a result of COVID-19, healthcare organizations have been urged to reduce in-person office visits for older adults, as appointments in hospitals and clinics may raise the risk of infection and exposure. Telemedicine has evolved as a critical care-delivery method in an effort to follow these principles while continuing to offer important care to people in need. Patients were able to communicate with healthcare providers in real-time for guidance on their health concerns, especially when they are in quarantine.[11,12]

From January to March 2020, the use of telehealth increased significantly in the United States. Sixty-one percent of hospitals used telemedicine, which increased to 43% of total consultations during a partial lockdown. According to a national sample of 16.7 million people, 30 % of all outpatient consultations during the pandemic were conducted using telemedicine, which was a 32-fold increase compared to the pre-pandemic period. Additionally, 53% of depression visits were provided using telehealth. Similarly, in a survey of 2,350 older adults conducted between 2020 and 2021, 24% reported using telemedicine after the pandemic, compared to 5.4% before the pandemic. However, during the pandemic's first peak, the majority of older people did not use video visits. It showed also that 64.2 % of telehealth visits were conducted to consult about COVID-19 infection, and 35.8% of the calls were related to other concerns. [11,13–15]

Policies regarding the use of telemedicine have also changed in response to the pandemic. For example, the US Department of Health and Human Services encouraged virtual visits during COVID-19, and the Centers for Medicare and Medicaid Services expanded telemedicine coverage.[16]

Studies investigated the unreadiness to use telemedicine among the older population and found that older people who are not married, do not have a spouse or partner, men, Hispanic or Black, who lived in a rural location, had lower income, less education, and worse self-reported health were less willing to use telemedicine. Overall, 72 % of those aged 85 or older matched the criteria for unreadiness.[17,18] It was found that age is the most important factor influencing the access to remote care.[19] Another study about older adults revealed that Medicare-receiving clients who have previous experience accessing the Internet and making video or voice calls, clients with co-morbidities, moderate and high-income more likely to access telemedicine services.[20]

However, having a family member who can help with preparation, such as utilizing home medical equipment, communication difficulties, or setting up technology, as well as attendance during virtual visits to give support with any technological hurdles was beneficial.[21]

The COVID-19 pandemic has increased pressure on healthcare centers, leading to a shift towards telehealth as a means of reducing crowding and physical contact to prevent disease transmission.[22] Telehealth can minimize secondary and tertiary infections by reducing movement to and from medical centers and wait times.[14] In a pilot study, telehealth was found to be highly satisfactory for preoperative geriatric assessment, with participants recommending it to others due to its ease of use, suitability, and time-saving benefits.[23]

Numerous governments and medical institutions have adopted telehealth to confront COVID-19, with some institutions in the US using online triaging to minimize emergency room visits. Telehealth has previously proven effective in epidemic emergencies, utilizing live video consultations, virtual patient monitoring, and mobile applications for symptoms assessment. Telemedicine can be used for emergency medicine triage, reducing in-person contacts and the risk of infection transmission, and minimizing departures without treatment and follow-up.[24]

Telehealth is also useful for early symptom diagnosis and triaging to mitigate possible healthcare access delays, as seen in Wuhan, China, during the initial COVID-19 epidemic.[25] Integrating screening and symptom triaging capabilities into current EHR platforms can identify patients with symptoms early, reducing the physical strain on medical systems. Telephone calls and EHRs can be utilized to screen and treat patients without in-person contact, improving decision-making among health providers.[24]

China and Iran have also adopted telehealth strategies to confront the COVID-19 pandemic, with China's National Health Commission issuing online guidelines and free electronic books, while officials developed a virtual consulting network for safe consultations. The Iranian Society of Radiology developed a social media messenger for teleradiology and teleconsultation options for COVID-19 infection assessment.[26]

In conclusion, telemedicine offers immediate patient assessment and counseling, remote multimedia treatment, patient education and training, real-time data exchange, medical information collection,processing, and storage, strategic planning and drug advice, digital assessment tools, implementation of social distancing, reduced reliance on public transportation, and reduced infection risks due to in-person contact.[27]

4. The Use of Telemedicine in Geriatric Clinics

Benefits from a Healthcare Provider's Perspective

Through reviewing the studies, it was found that most telemedicine interventions or services were available for the management and control of chronic diseases such as psychiatric-mental care, diabetes, cognitive impairment, Parkinson's disease, chronic affective disorder, lymphovenous disease, dementia and arrhythmias.[28–30] Thus, it provides a wide range of advantages for health care providers like the following:

- Timely client care: Providers may have more freedom in arranging appointments using telemedicine. They can use "virtual walk-in visits" to extend care beyond a clinic's typical working hours and four walls. Clinics with more flexibility may be able to better manage client no-shows and withdrawals.[31]

- Ability to evaluate a patient's living environment: Rather than relying on a client's account of their home and living conditions, telemedicine allows physicians to go inside a patient's house with necessary authorization, meet family support systems, evaluate if a visit to the patient's house is required, estimate safety risks related to falls and provide personalized suggestions for home modifications.[22]

- Decrease the burnout among providers: Provider burnout is a widespread problem in the healthcare field, caused by a variety of variables such as fast-paced settings, time pressure, family commitments, and time-consuming documentation. By fostering more reasonable scheduling, greater flexibility, and shorter commute times, telemedicine may reduce provider stress, for example, self-health assessments can be easily done online and after that, the results can be forwarded to clinicians.[21]

- Ability to exchange data for educational and evaluation purposes: Screen sharing allows the therapist to effortlessly present videos, slideshows, and other images to the client during education or the didactic transfer of information to the client concerning therapeutic intervention or diagnosis. This method may also be used for mental health and drug abuse examinations, allowing the doctor to monitor the client's answers in actual time.[32]

- By enhancing flexibility for both physicians and patients, lowering exposure to COVID- 19 and other infectious diseases, and minimizing transportation issues for patients, the adherence rate to treatment can be improved and achieve more timely visits.[21]

- Telehealth can improve the follow-up and show rate:[33] In a study conducted by Gomez, it was found that telemedicine sessions tended to take less time than in-person visits.[34] In contrast, another study conducted by Aliberti on the use of telemedicine from the point of view of doctors, did not get the same result.[21] However, primary care clinicians in both studies noted that telehealth increases the show rates and was efficient, especially for chronic disease follow-up like diabetes, hypertension, and/or depression.[21,22,34]

- Telephone follow-up as well as remote monitoring, in a number of cancer settings (prostate, endometrial, colorectal, and lung cancer), made getting hospital treatment options or data easier.[35]

- In a survey of 163 primary care doctors in the United States who use telemedicine for older adults' medical visits, some PCPs saw that telehealth improved the physician-patient connection, improved the patient experience, and obedience to treatment. Many primary care clinicians believed that telemedicine was useful for some acute situations, managing less complicated chronic conditions, triage, and counseling sessions for mental health disorders, especially when using video.[21]

Geriatric Training for Medical Trainers

During the COVID-19 quarantine, Brazil's Ministry of Education connected medical trainees to long-term care nursing homes through telemedicine to provide medical care, monitor residents, follow up COVID-19 cases, and inform the Municipal Health Secretariat about the most vulnerable ones. This method also allowed trainees to complete their training while maintaining social distancing laws. Students used this opportunity to determine which long-term elderly care facilities needed additional inquiry and monitoring, but faced difficulties communicating with certain facilities, experienced missing or wrong information from personnel, and delays in identifying suspected incidents.[36]

A study conducted in California found that telehealth was effective in delivering the teaching curriculum to students of geriatrics and nursing during the pandemic. The participants did not feel that their access to the curriculum through telehealth reduced the efficiency of their education or their confidence in the ability to manage geriatric syndromes. In fact, it contributed to improving students' knowledge of geriatrics as much as face-to-face delivery.[37]

Benefits from the Patient's Perspective

A systematic review of elderly with dementia using telemedicine during COVID-19 showed that talking with specialists via video calls was appreciated, and having accessibility to telemedicine-based television services resulted in higher use of memory exercise games.[29] In general, the advantages that telemedicine can offer to older adults can be concluded by overcoming or facilitating several barriers that may impede access to health care including:

- Geographic barriers: Telemedicine makes it easier for those who live in distant areas to get the treatment they need and to reach the provider they want, regardless of the distance.[22]

- More experienced doctors and high-quality treatment are available: patients can reach experienced clinicians who are geographically far from their residences via telemedicine. Patients may contact doctors with expertise in their specific diseases and care planning through telemedicine modalities, and they can receive care that is individualized to their sexual orientation, culture, lived experience, race, and gender.[30]

- Team-based and coordinated care: Geographic distances between providers and patients, on the other hand, might impede communication. Telemedicine improves team-based treatment by remotely linking numerous physicians with a client, boosting provider cooperation and the sharing of health information across geographic boundaries. Similarly, telemedicine makes group-based therapy more accessible, which has similar therapeutic outcomes as in-person groups.[12,38] For example, at the University of Rochester, specialized in the care and research of geriatric oncology, a multidisciplinary team provides comprehensive care for older adults with cancer using telemedicine. The team includes a geriatric oncologist, resident trainees, advanced practice providers, fellows, a nurse navigator (NN), physical therapist, dietician, pharmacist, social worker, nurse, occupational therapist, and clinic coordinator. An initial assessment phone call is made before the visit, and then the visit is conducted using telemedicine in the presence of a multidisciplinary team and the patient with the possibility of a family member present. [12]

- Psychological barriers: Clients who are afraid of leaving their homes to get therapy, for example, those with (panic disorder or agoraphobia or some dementia patients) can get care in their safe place. Transferring individuals with dementia out of residential care might be disruptive. Telemedicine provides comprehensive, personalized health care (for conditions such as dementia) to older people in remote locations and others within their own comfort environment.[1]

- Physical barriers: Telemedicine enables people with physical disabilities that prevent them from moving or, when movement is considered dangerous to their lives, to receive medical care without the need to go to the clinic. It reduces the dangers that older people may face when moving and leaving the house, such as falls and/or stressful movements.[22] For instance in winter, when there is snow and ice, many older adults canceled their medical appointment for fear of falling.[19]

- Access and continuity of care have improved: Telemedicine enables clients to have access to high-quality treatment while reducing travel expenditures, increasing the possibility that they will see their physician on a regular basis and keep planned visits.[33,38]

Benefits from Caregiver's Perspective

Telemedicine relieves the pressure imposed on caregivers in terms of the possibility of remote monitoring, reducing the burden of leaving daily work or work to accompany the patient for medical visits besides reducing stress and enhancing the quality of life.[1] In a study conducted to investigate the satisfaction of patients using telemedicine, one participant was a husband of a 93-year-old patient, who assisted with his wife's video visit, stated that "We even enjoyed it more than sitting right there, it was more convenient to stay at home".[19]

Telemedicine Services in Mental Healthcare

Telehealth can provide high-quality psychiatric treatment for older persons, as demonstrated by a pre-pandemic evaluation of geriatric telepsychiatry.[39] Videoconferencing-based neuropsychology has been proven to be a legitimate and effective replacement for in-person examinations. The cognitive screening instruments adapted for use in telemedicine settings are widely available, such as the Mini-Mental State Examination (MMSE), common mental health questionnaires including the Geriatric Depression Scale (GDS), and the Montreal Cognitive Assessment (MoCA), showing high diagnostic efficacy.[28] While evaluations can be carried out with expertise and equality in the vast majority of cases, the Department of Health and Social Care and the Court of Protection acknowledge the need to ensure confidentiality, even in emergency situations.[40]

Telemedicine has been used for the evaluation of cognitive function, mental state, physical examination components, and capacity assessments for involuntary detention in old age psychiatry.[40] Cognitive behavioral therapy, health literacy education, and mindfulness-based therapy were the most frequently used treatment methods, particularly for those with chronic medical illnesses and caregivers of dementia patients.[41,42] Despite its limitations, a systematic evaluation found that group treatment using video conferences has effective outcomes equivalent to traditional treatment, with high participant satisfaction.[38]

In response to the urgent need for personalized health treatments for older adults during the COVID-19 pandemic, the Telemedicine Care Support Group for Socially Isolated Seniors was developed as an evidence-based group intervention that can be delivered over the phone or via video call.[10] The guide, available on the official website GeroCentral.org, includes a collection of key psychiatric services for seniors planned for group management by telephone or televideo to alleviate arising healthcare di parities. It also includes a regularly updated list of additional mental health resources for older adults related to COVID-19. The handbook draws on three widely used proof treatments for older adults: Problem-Solving Therapy (PST) methods to help with social connectedness, Acceptance and Commitment Therapy (ACT) methods to help with anxiety management, and Cognitive Behavioral Therapy (CBT).[10]

Telemedicine has also helped reduce stigma associated with serious mental illness and substance use disorders, as clients can disclose their conditions from the comfort of their own homes, maintaining privacy and anonymity while receiving care.[7]

5. Limitations and Challenges of Using Telemedicine among the Older Population

A study in Singapore found that telemedicine consultations declined rapidly after having peaked at 43% during the partial lockdown.[14]

Limitations Related to the Service

Limited physical examination: There are several limitations to consider when conducting remote visits. Vital signs monitoring, such as through basic monitoring devices, can be useful in some cases, but may not be sufficient for proper diagnosis, monitoring, or treatment in others.[14] Providers assessing patient understanding: Cognitive testing is another important aspect of geriatric visits, but it can be challenging during remote visits due to the absence of eye contact and nonverbal cues. Remote visits also pose challenges for movement and objective physical function evaluations, which typically require visual examination.[12] In a study conducted to investigate the opinions of clinicians in geriatric clinics who used telemedicine, one of the doctors reported that it was simpler for his patients to deceive, he was drawing while looking at the clock, but his doctor could not see what he was looking at; thankfully, his child was conscious that he was copying a clock.[43]

In the context of the COVID-19 pandemic, many unspecified platforms have been used for remote medical visits, which can lead to inconsistency in service and a limitation of data on optimal telehealth use. Privacy is also a critical issue, as uninvolved people may overhear conversations during telephone or video examinations of older adults living at home, outside the context of a healthcare facility where privacy can be monitored.[40]

Limitations Related to the Healthcare Provider or Health System

Some medical providers have concerns about clinical quality, technical quality, safety, privacy, and responsibility when using telemedicine.40 In addition to the fact that not all medical providers are familiar with outdated telemedicine sessions and platforms.[44] When using telemedicine, the clinician relies on the medical history and record, therefore, digitalizing the medical record and history of patients is necessary. However, this information may not always be available.[40]

Patients' requests for confidentiality, or requests that sensitive information collected by the health-care professional who uses telemedicine not be shared with the patient's primary healthcare practitioner can be particularly difficult in cases where there is no mediator between the remote practitioner and the patient 's primary healthcare practitioner.[40] Policies governing telemedicine services vary between countries and provinces. There are still many aspects of telemedicine that have not been included in the policies of many countries, such as payment and reimbursement mechanisms, accreditation, and insurance, making implementation difficult.[45]

Limitations Related to the Older Population

A survey by the University of Michigan in July 2020 revealed concerns among the older population about the limited ability to perform physical exams (75%), quality (67%), personal connection to the medical provider (45%), hearing/visual problems (25%), and privacy (24%).[46] Recent research found that 38% of Medicare recipients were unprepared for home telemedicine, with concerns reported by older people and their families.[30] Some individuals believe that telemedicine consultations are insufficient without a physical examination and are less satisfying.[21]

Physical disabilities, such as hearing, vision, or cognitive problems, can make telemedicine challenging, and support from a capable caretaker may be required.[40,47] A study found that 52% of older participants reported difficulty discussing sensitive issues using telehealth.[43] Lack of technology experience and concerns about efficacy and satisfaction were found among older individuals in China, with 93% having access to the Internet and digital devices but none having utilized telehealth.[48] Even if they understand

understand how to use the technology, dealing with telemedicine platform video connection difficulties can be challenging for older individuals.[40]

The use of telemedicine for advanced services requires additional expenditures and efforts for equipment maintenance and sterilization.[33] In 2018, approximately 13 million (38%) of older adults in the United States were not prepared for video visits, mainly due to a lack of experience with technology. If social supports could assist in setting up video visits, the number of unprepared older adults would decrease to 10.8 million (32%). However, even telephone visits may not be accessible for everyone, with an estimated 20% of older patients facing issues such as hearing difficulties, communication challenges, or dementia.[17]

Limitation of Reviewed Research

Most telemedicine research is conducted in high-income countries, with the US accounting for the large majority, followed by China. There is a lack of research in low and middle-income countries. Few studies examine telemedicine use in geriatric clinics, Doraiswamy conducted a scoping assessment on the usage of telemedicine during the COVID-19 pandemic and he revealed that only 4.2% of the articles focused on the use of telemedicine in the geriatric clinic.[14] Only a tiny percentage of the publications found in our review were empirical research, thus highlighting the need for more research on safety, usefulness, demand, cost-effectiveness, and scalability. Furthermore, standardizing terms and studying all parties involved is crucial.

Difficulties communicating with the older population or caregivers due to the risk of infection or transmission of COVID-19 should be considered as a limitation of studies evaluating the use of telemedicine during the COVID-19 pandemic. Studies are carried out more frequently in urban areas rather than rural areas, although the service is more important for rural people.

Future research should focus on practitioners' and older adults' opinions and experiences, as well as the evolution of telehealth since the pandemic. Overall, while telehealth can be a valuable option for providing medical care to older adults, it is important to consider its limitations and take steps to address them to ensure the best possible care.

6. Discussion and Recommendations

Governmental and institutional interventions are crucial to promote telemedicine use. Governments can provide financial facilities and subsidies for healthcare providers to use telemedicine, cancel co-payments for virtual visits, cover communication devices as a medical need, and provide subsidies to older people in order to help them obtain digital tools needed for telehealth consultations. Standardizing telehealth legislation and guidelines on norms of practice is also necessary to ensure the quality of telehealth services, gain consent, protect patient confidentiality and data security, validate both the patient's and the healthcare professional's identities, and avoid fragmented patient care.

Technological interventions must take into account the digital divide experienced by older adults, therefore developers must involve older people in the development and pre-testing of telemedicine tools. They must develop easy-to-navigate interfaces, clear basic instructions, large fonts or graphics, and tools that can satisfy the demands of older people with cognitive or physical problems. Practical and rapid backup operations to solve problems arising from equipment failure or connection should be available. Steps to reduce the danger of hacking by ensuring that secure software is used must be taken.

Medical practitioners play a crucial role in encouraging the use of telemedicine among the older population, and they must meet certain licensing requirements. They must also have triaging protocols to determine when telehealth is acceptable for triage only or when it is counterproductive and a face-to-face consultation is necessary. They should suggest and encourage the use of the service by the patients as a result of the trust built between them.

Educational and practical interventions are essential to promote the use of telemedicine among older people. Public education should be conducted to dispel patients' misunderstandings and expectations about technology. It is critical to emphasize that the use of telehealth does not imply that patients should fall behind in their follow-up. The education process should not be limited to provide theoretical instructions and information about the service but should be accompanied by practical interventions, where older people can experience this technology to overcome their fears.

Defining one party responsible for driving the telemedicine intervention development and connecting all parties together to achieve goals that comply with other parties' goals is also crucial.

7. Conclusion

In conclusion, promoting the use of telemedicine among older people requires a multi-faceted approach involving governmental and institutional interventions, technological interventions, medical practitioner interventions, and educational and practical interventions. By implementing these recommendations, the older population can benefit from telemedicine and improve their healthcare access.

Conflicts of interest statement

The author declares that there is no conflict of interest regarding the publication of this paper.

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Assessment of the Possibility of Implementing the Strategy of Information Integration of Health Care Systems

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ABSTRACT

This study considers the problems of globalization of medical education and practical health-care in consideration of the wide implementation of information technologies. The creation of unified educational medical systems is hindered by many factors, among which the most important are the lack of standardized technological platforms and educational programs, assessment processes, and most importantly, data processing methodology. The purpose of the study was to assess the possibility of integrating health-care information at the current stage of information systems development, in order to support future medical education. Conclusions: 1. The creation of a single integrated health-care system on a global scale seems unlikely today. We can only talk about the extent of harmonization of the relevant systems through the interoperability of their data. 2. The constant avalanche-like growth of data dictates the continuous growth of data management problems. At the same time, the right combination of localization, adaptation to cultural diversity and technologies, in the context of sufficient resources and adequate infrastructure in specific countries, is extremely necessary.

KEYWORDS

Medical platforms, continuous professional development (CPD), globalization of education, regional platforms, information technology, integration of healthcare systems, big data, integration, interoperability and discrimination of medical data, flipped learning, online learning

1. Introduction

Information integration of health-care systems is carried out both in the direction of providing medical care and in the globalization of medical education. The obvious goal of the integration of information systems is the creation of a virtual supersystem that provides the interconnection of systems in the strategy of providing medical or educational ambassadors to clients, a consistent work process and an integrated flow of information across the supersystem, and also contributes to the adoption of well-informed decisions in the field of health-care.[1] It is believed that an integrated information system (a network of interoperable and interconnected systems) is characterized by higher performance in terms of quality and security. It also facilitates the implementation of new clinical and administrative processes, the deployment of agreed clinical guidelines, and the coordination and management of patient care across healthcare settings.

Collaborative care is critically dependent on the ability to easily share information between service providers. At the same time, the inability to seamlessly share information between systems and between healthcare organizations is one of the main obstacles to advancing collaborative care, cost containment and globally consistent medical education underpinned by standardized educational platforms and medical evidence derived from integrated health information.

Study aim: To assess the possibility of integration of health-care information at the current stage of information systems development.

2. Data received and discussion

Online education in its various forms is growing steadily worldwide due to the confluence of new technologies, the global adoption of the Internet, and the growing demand for skilled labor. By 2025, online education should become a mass phenomenon.[2] Eventually, the globalization of e-education will inevitably occur, just as we have witnessed the globalization of e-mail, e-commerce, and e-government.

Modern technologies allow teachers to objectively assess competencies using online assessments and receive the necessary personalized feedback. The transition to e-learning was a catalyst for adult learning theory, which redefined the role of medical educators as facilitators and assessors of competence.

The expansion of online education beyond national borders is primarily determined by global factors. These include having standard technology platforms (such as the Internet), bridging the digital divide, accommodating different languages and cultures, standard curriculum and assessment processes. Already this short list of factors should direct the organizers of such services.

But there are also regional and institutional factors. Regional factors include relevant country laws, information and communication technology (ICT) capabilities, Internet/mobile technology penetration, income gaps, and the digital divide. Institutional factors make up a group of conditions such as: support from administration, marketing, technology and top management; institutional culture, characteristics of the educational institution (public and private, commercial and non-commercial).

Finally, the institutional factor combines the characteristics of the educational program, the level of education, the peculiarities of the forms of information transmission - the online mode (mixed, inverted, fully online, as well as the degree of synchrony/asynchrony). At the micro level, the student factor is important, including motivation, culture, learning style and level of IT skills; learning outcomes using metric technologies (for example, Bloom's taxonomy); features of knowledge transfer technologies (learning platforms, LMS type), usefulness, ease of teaching and the level of IT skills; learning mode (cognitive, affective, managerial).

The huge number of factors that ensure quality education makes it practically impossible to compare different online education systems to choose the optimal integration model.

This study is indicative in this regard. In their work, O'Doherty et al.[3] tried to evaluate the experience of online education from the point of view of analyzing: a) barriers to the development and implementation of online education and b) ways to overcome them. Each article was analyzed and deductively coded under the appropriate headings.

A comprehensive literature review was conducted over three months by an interdisciplinary research team. The search, conducted by two reviewers, included dozens of well-known databases: Science Direct, Scopus, BioMedical, etc. Search queries included online learning, health educators, development, barriers, solutions, and digital literacy. Titles and abstracts were independently screened and considered for inclusion/exclusion criteria. Consensus was reached on which articles should be included. Data evaluation was carried out with the help of the checklist of qualitative studies. Of the 3,101 (!!) abstracts found in the search, only ten (!!!) full-text articles met the inclusion criteria. Data extraction was completed for seven articles of high methodological quality and for three articles of lower quality.

It is possible to debate for a long time about the main goal of research, but if only 0.25% of quality articles can be found as a result of search operations, then great doubts arise regarding the main problem - the integration of learning systems.

The literature findings suggest that the main barriers affecting the development and implementation of online learning in medical education include lack of time, weak technical skills, inadequate infrastructure, lack of institutional strategies and support, and negative attitudes towards all participants. Solutions for these include faculty development, incentives and rewards for time spent developing and delivering online content, improved institutional strategies, and support and positive attitudes from all involved in developing and delivering online content.

Even more problems are observed in the creation of an integrated platform in practical medicine, although it is absolutely clear that the integration of health-care platforms allows to significantly increase the efficiency of the institutions, simultaneously connecting various health-care services, pharmaceutical support, etc.

There are too many *different programs*, restrictions, and health data standards that need to be supported.[4,5] For example, in the US, the Readmission Reduction Program, an initiative of the Affordable Care Act, requires the Centers for Medicare and Medicaid Services (CMS) to reduce payments to facilities that have excessive readmissions; the Affordable Care Act of 2010 (the Affordable Care Act - ACA), Medicare and Medicaid programs.

There are many different interoperability standards in use: consolidated clinical data architecture (Consolidated Clinical Document Architecture C-CDA); specification of the document on continuity of patient care (Continuity of Care Document - CCD); of the Continuity of Care Record (CCR) standard. The Fast Healthcare Interoperability Resources (FHIR) medical information exchange standard is used. The standard describes the formats of medical data and the exchange of this data. FHIR is a trademark of the non-profit organization HL7 and is recommended in the US for access to public health information.[8] The goal of the standard is interaction between outdated healthcare systems, as well as access to medical data from various devices (computers, tablets, mobile phones). The known life cycle of software development is SDLC (Software Development Lifecycle).

The development of a healthcare integration platform is a strategic project in a healthcare organization, and such projects have very high visibility. In addition, a healthcare integration platform must have a set of well-defined functions, so requirements will need to be defined in advance. But its formalization also has no regional characteristics.

A similar situation is observed throughout the international space. It is enough to mention eight standards for improving the quality of medical care for mothers and pregnant women in medical institutions proposed by the World Health Organization (WHO). For example, Standard No. 1.: "Every woman and newborn receives routine, evidence-based care and management of complications during labour, childbirth and the early postnatal period".

Each of the listed standards is a complex document that requires considerable effort to encode medical data. Thus, in CDA, it is determined that the content of the document consists of a mandatory text part (which ensures the interpretation of the document content by a person) and optional structured parts (for software processing). The structured part is based on the HL7 reference information model and provides a basis for referencing the concepts of coding systems such as SNOMED or LOINC. A patient summary contains a basic data set of the most important administrative, demographic, and clinical information facts about a patient's health, covering one or more medical encounters. It provides a practitioner or system with the means to combine relevant patient data and forward it to another practitioner (system) to support continuity of care. To be certified for this federal program, an electronic medical record must be able to generate a CCD (or equivalent CCR) that includes allergy, medication, problem, and lab results sections in addition to patient information. Some of these sections also contain mandatory dictionaries, such as LOINC for laboratory results, according to the federal program. This provides a snapshot in time containing relevant clinical, demographic and administrative data for a particular patient. It is clear that the CCD specification contains specific US requirements; therefore, its use is limited by this state. Because CCD is a new format that harmonizes the continuity of medical records and the HL7 clinical document architecture specification, most electronic medical record vendors have adopted CCD to ensure the continuity of medical records. Accordingly, the use of this standard has become widespread in other countries, but with other insufficiently developed specifications. Not surprisingly, different providers of electronic medical records have implemented the CCD standard in different and often incompatible ways.[1]

The second part of the problems is related to the so-called data discrimination. Data discrimination, also called "algorithmic discrimination," is a bias that occurs when predefined types of data or data sources are treated differently than others in advance or unanticipatedly .

Discrimination of data can lead, first of all, to a significant decrease in the quality of medical care, insufficient diagnosis of diseases and prediction of the results of their treatment. Quality care requires collaborative communication, information sharing, and coordinated decision-making between physicians and patients. Complete and accurate patient and patient data are especially important when using big data to build clinical decision support tools and inform precision medicine initiatives. However, systematically missing data can distort these tools and threaten their effectiveness.[1,6] Discrimination leads to a decrease in the patient's trust and her/his willingness to share information with her/his doctor. This, in turn, has important implications for the quality of data available for medical decision-making and healthcare delivery. Patients who experience data discrimination may be disadvantaged by the systematic absence of data in their medical records. We covered this problem in more detail using the example of pathomorphology.[7]

Thus, the global integration of practical health-care systems cannot be implemented directly at present.

The paper by Palvia et al.[2] concludes that the idea of finding one educational model that is suitable for everyone clearly did not work. The right combination of localization, adaptation to cultural diversity and technology including learning management systems is needed in the context of resource and infrastructure shortages in certain parts of the world.

3. Conclusions

1. The creation of a single integrated health-care system on a global scale appears to be unpromising today. We can only talk about the issue of harmonization of the relevant systems.

2. The constant avalanche-like growth of data determines the continuous growth of data management problems. At the same time, the right combination of localization, adaptation to cultural diversity and technologies, in the context of sufficient resources and adequate infrastructure in specific countries, is extremely necessary.

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Ontology-Based Approach for the Creation of Medically-Oriented Transdisciplinary Information-Analytical Platforms

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ABSTRACT

The process of development of information and communication technologies and the total informatization of the health-care sector led to significant changes to quantitative and qualitative characteristics of medical information, available to broad auditory. This led to the need to create effective informational-analytical platforms, that are required to cover vast arrays of polythematical informational resources that are characterized by a high degree of intensity, dynamism and diversity both in terms of content, structure, purpose, and formats, standards and creation technologies. Such platform should be used for finding, organizing and using the information needed by the users, and thus allowing them to process these arrays effectively.

One of the most useful tools for organizing all kinds of knowledge is ontology as a formal representation of some subject area. A system, capable of effective utilization of such formalization with the means of interactive documents is proposed. An example, designed for the effective finding of information based on ontologies is shown.

KEYWORDS

Transdisciplinarity, ontology, taxonomy, medical information resources, medical knowledge systems, narrative, discourse

1. Introduction

The rapid development of information technologies transforms the formats of interaction that developed at the previous stages of human evolution. A network-centric phase of evolution is being formed, the operationality of which is implemented on the basis of transdisciplinarity, which is a certain hyperproperty of all information resources and processes that make up the modern network environment.[1–4]

These processes are especially manifested in the medical sphere. A high level of integration of medical and engineering technologies requires ensuring their consolidation during application. There is also problem of doctors' consolidation while providing medical support to their clients. Today, almost every the problem of doctors' consolidation while providing medical support to their clients. Almost every patient contacts a certain clinic for help if he suffers from diseases that are treated by various specialists.

The transdisciplinary approach is to provide a consolidated interpretation of these approaches, methods and tools that are used in the modern treatment process. This is realized by taking into account the whole set of interdisciplinary contextual relations between medical information resources, as knowledge systems that have a manifestation in the processes of interaction between doctors and patients of different profiles. The transdisciplinarity of medical ontologies is able to ensure the implementation of cognitive-communicative scenarios of interaction between doctors and patients based on the constructive use of distributed systems of medical knowledge and their diagnostic data.

Processing medical information resources and medical knowledge systems, which are dynamically accumulating, is a rather difficult task. Firstly, this information has quite large volumes, especially in the share of the newest methods of treatment. Secondly, the set of information has a rather complex formation structure and is organized in different and more outdated formats and even more, in the process of active use of medical information resources in the network, network-centric transdisciplinary environments are formed in which extremely large volumes of medical information circulate, which defines the problem of big data.[1,5,6]

Digital formats of information resources, which form the basis of interaction in network medical environments, also determine the problem of their integrated and more consolidated use.[7–10] First of all, it should include the semantic consolidation of information resources, the cognitive procedures of which implement the presentation of combined information in the form of a complete model.[8] However, the very procedure of semantic unification with subsequent analytical processing during interaction is quite complex and has a reflexive-recursive nature.[1–11]

2. Analysis of recent publications and formulation of the problem

The problems of information consolidation and its further analytical processing have been actively studied over the past 30 years.[7–10,12] The directions of these studies can be conditionally divided into two groups.

Representatives of the first group[7,12,13] define the category of consolidation as the unification of the same type of information based on characteristic attributes. According to this approach, the difference between consolidation and integration is leveled. The selection of characteristic groups of attributes of relevant information and data is appropriate for the integration of databases that characterize the single-type information resources. In fact, this interpretation of consolidation reduces it to the simple use of certain data in the process of solving practical unified problems.

Contrary to this approach, other researchers[1,8–10] consider consolidation as a certain unification of semantic processes that are implemented in the network space. The use of ontological engineering mechanisms is proposed as a consolidation construct.[1,15,16] The use of the methodology of ontological systems provides a representation of the semantic properties of information resources and in a certain way implements interaction with them and between them.

For example, the concept of "consolidated information"[1,8] is considered in the format of system-integrated various information resources, which in aggregate are endowed with signs of completeness, integrity, non-contradiction and make up an ontological model of the problem area for the purpose of its analysis, processing and effective use in support processes of decision-making.

However, the use of ontology as a primary construct for the consolidation of information resources in the processes of analytical processing during network interaction has certain problems. The ontological system[1,9,10,15,16] can be represented in the form of an ordered six of the type (1):

$$O_t = <X,R,F,A,D,R_s> \quad (1)$$

where X – set of concepts of a given subject area (SA); R – finite set of semantically significant relationships between concepts; F – is a finite set of interpretation functions defined on relations; A – a finite set of axioms used to write always true statements in terms of concepts; D – set of additional definitions of concepts; R_S – a set of restrictions defining the scope of conceptual structures formed from concepts based on axioms.

As we can see from definition (1), the rules for handling information in the process of interaction based on the use of ontologies depend on axiomatic definitions. They impose certain strict restrictions on the interaction process. Based on formula (1), only conceptual structures forming true statements can be included in it.[16]

Therefore, for the further use of the ontological approach to the formation of consolidated information for its analytical processing in the process of network interaction, it is necessary to single out a basic construct to which axiomatic restrictions do not apply.

Taxonomy as a semantic platform of consolidation

As a construct for the formation of consolidated information, taking into account the semantics of all its thematic fragments, it is most effective to use the category of taxonomy.[1,18,19] The advantages of its use include the following:

- taxonomies determine the conceptual structure of the ontology;[1,16,18]

- nodes of taxonomies contain contextual descriptions of their meanings, which allows to consider them as concepts;

- taxonomies are formed by classes of concepts characterized by their certain properties according to the ontology definition (1);

- taxonomies can form multiple relations among themselves, each of which is a binary relation between certain contexts of concepts of the ontological system.

We single out the taxonomy from formula (1). An arbitrary taxonomy is an oriented graph without cycles and, according to Dovgyi & Stryzhak, Aksu-Koç, and Guajardo & Watson[1,18,20] it is formed by concepts that are hierarchically interconnected. That is, it is defined by an ordered pair of the following form:

$$T = <X,R_t> \quad (2)$$

where:T – taxonomy, X – set of concepts, R_t – set of binary relations between taxonomy T concepts.

As we can see, formula (1) can be derived from formula (2) by the orderly inclusion of categories that define the subject area with the information resources of which network interaction is realized.

However, at the taxonomic level, we can form their variety, i.e. a certain hyperset of taxonomies, each of which, while forming an ontology, is characterized by the inclusion of certain sets of axioms that differ from each other. These axioms are determined on the basis of the interpretation of the contexts meanings, which in turn determine the concepts of the taxonomy and in the subsequent ontology.

If we define the contexts of the nodes of taxonomies as elements of certain knowledge, then their totality reflects a certain fragment of the picture of the world. However, when considering the whole variety of taxonomies, we will get the hyperproperty of reflection, which implements the reflection of all taxonomies on themselves. Such a reflexive reflection of the taxonomy on itself has a verbal character. This can be deduced from the fact that the nodes of an arbitrary taxonomy form specific statements that have the value of truth.[1,17,20]

We present the variety of taxonomies in the form of the following expression:

$$\grave{T}_{Rt} = \{T_{Rt} | R_t = \langle\langle X_n(K_t^n), Y_m(K_t^m)\rangle\rangle\} \quad (3)$$

Expression (3) defines the following: the variety of taxonomies, as a hyperset, is formed by all taxonomies that can be interpreted as complex concepts that have binary relations between them and form nested tuples. Each such concept is characterized by a set of contexts of the type – K_t^n.

What is the result in a constructive manner? Now we can claim that the consolidation of information resources, which is reflexively reflected by the variety of taxonomies, is formed on the basis of intercontextual relations formed between the concepts of these taxonomies. That is, the consolidation of information resources is a verbal-active function that implements the interpretation of a set of binary relations between all contexts that reflect the meanings of concepts that form the content of subject areas whose information resources are involved in network interaction.

This can be represented in the form of a characteristic predicate:

$$\Pr(x_1,\dots,x_n) = 0 \Rightarrow \exists T \subseteq \grave{T} : \forall x \in X \exists Y \subseteq X : T = YG_{rx} \quad (4)$$

where, x_n– simple concepts of taxonomies T and corresponding diversity $\grave{T}$,G – hyperproperty of the class of concepts forming a specific taxonomy, in this case – Y.

According to Dovgyi & Stryzhak,[1] verbal-active reflection is a prerequisite for the existence of verbal-active recursion. We denote verbal-active reflection through F_f.

$$(F_f : X \to X \to Y) \quad (5)$$

Reflection (5) can be represented in a recursive form:

$$F_f(X) = \begin{cases} F_f(X, \grave{T}) \to \grave{T} \\ T \\ XG_X \end{cases} \quad (6)$$

Thus, we consolidated all concepts of a certain set of information resources, which can be represented in the form of a variety of $\grave{T}$ taxonomies of T concepts from different subject areas. Moreover, in fact, consolidation represents a certain knowledge base that combines facts from different subject areas, and thereby combines different network information resources.

Now we can define the category of information consolidation as a taxonomic diversity[1] of information resources formed by the concepts of all taxonomies, which in turn form this diversity.

Consolidation is characterized by the existence of verbal-active reflection and recursion, which are set over the corresponding taxonomic images of information resources involved in network interaction. According to Dovgyi & Stryzhak,[1] the information resources on which the verbal-active functions of reflection and recursion are set are transdisciplinary. That is, transdisciplinarity is a hyperproperty of consolidated information, which is activated in the process of network interaction, which has a manifestation in the format of a cognitive-communicative act between relevant information resources and users.

Narrative discourse as a format of active manifestation of consolidated information

Intercontextual connectivity of online medical information resources can also be defined through the concept of discourse.[21,22] The discourse itself can be represented by verbal-active reflection, on the basis of which taxonomic diversity is realized. This allows us to present the discourse through a cognitive-communicative act, which simultaneously is being realized, on the basis of inter-contextual connections, the consolidated use of selected information resources and their interpretation, as a display and representation.[1,21–23]

The use of consolidated medical information in a certain way realizes its systemology, which is quite important for its further analytical processing. That is, taxonomic diversity $\grave{T}$, formed on the basis of a certain classification of concepts, provides the implementation of the hyperfunction of semantic analysis, systematization, etc. According to Dovgyi & Stryzhak,[1] we can transform an arbitrary taxonomy of a species (2) or taxonomic diversity (3) to the format of an ontology of a species (1). This allows us to determine the format of narrative discourse for consolidated network information.[1,21–23]

Taxonomies according to Dovgyi & Stryzhak and Nadutenko[1,24] have one useful property. They are marked trees, in which the names of concepts act as marks. We will assume that all concepts form a certain set of names $\sum$, which are the marks of all taxonomy nodes T and taxonomic diversity $\grave{T}$. Under such conditions, the arbitrary taxonomy of the type T or taxonomic diversity $\grave{T}$ are univalent sets of Böhm trees.[11] That is, the topology of the interaction of sets of concepts of taxonomies can be represented as a set $\sum$ – marked trees formed by its nodes.

$$\sum = \{X_1,X_2,\ldots, X_n,a_1,a_2,\ldots, a_m\} \tag{7}$$

where X_i – concept class, a_i – terminal node.

Having defined property classes $R_1, R_2,\ldots,R_m$, that implement the division of all concepts into hierarchical classes and determine the relations between concepts, we will get the corresponding taxonomy.

Also, the Böhm tree can be represented through the characteristic predicate (4) in the form of a semantic convolution:

$$\sum = XG_{X_i} \tag{8}$$

Moreover, repeated application of the characteristic predicate represents a hierarchically growing composition of Böhm trees in the following form:

$$\sum = \grave{T}GXG_{X_i} \tag{9}$$

It is clear that a hyper-relation G includes a relation of partial order.

We expand the interpretation of the notion 'concept'. According to Barendregt and Nadutenko,[11,24] each concept of an arbitrary taxonomy can be defined as a term. This makes it possible to determine the process of taxonomies formation based on the use of certain sets λ-terms.[11] On their basis, the calculation of the semantic nature of the contextual values of the terms-concepts is implemented, which determines the conditions for the existence of interactive interaction with information resources in a consolidated format.

$$\{X_1,X_2,\ldots, X_n,a_1,a_2,\ldots, a_m\} \rightarrow \lambda \rightarrow \grave{T} \rightarrow \sum =\{X_1,X_2,\ldots, X_n,a_1,a_2,\ldots, a_m\} \tag{10}$$

where, ($\grave{T}$) – taxonomic diversity

$$\{X_1 [..] ,X_2 [..] ,\ldots, X_n [..]\} \rightarrow \{X_1[B],X_2[D],\ldots, X_n[V,P]\} \rightarrow \grave{T} \tag{11}$$

$$\sum = \{\perp\} \cup \{\lambda x_1,\lambda x_2,\ldots, \lambda x_n, \lambda a_1,\lambda a_2,\ldots, \lambda a_m\} \tag{12}$$

$\perp$ – the smallest element of all taxonomy context meanings; B, D, V, P – semantic values of contexts.

Expressions (10)–(12) reflect the generalized metaprocedure of forming consolidated information in the process of interactive interaction with network information resources.

Inputting the smallest context value and defining the contexts themselves passively defines the order relation over the set λ-terms, and thereby creates the conditions for the formation of taxonomic diversity, as a technological basis of consolidation for subsequent analytical processing.

The main components of transdisciplinary information and analytical environment

The operational component of the transdisciplinary consolidated medical information environment is implemented in the format of a narrative discourse. It is the discourse that determines the conditions for further analytical processing of medical information and data. This operationality is determined by a set of hyperproperties – reflection, recursion, reduction, which define a closed set $\mathscr{R}3$ of the type:

$$\mathscr{R}3 = \{\mathscr{R}_f, \mathscr{R}_k, \mathscr{R}_d\} \tag{13}$$

where is the reflection – $\mathscr{R}_f$, recursion – $\mathscr{R}_k$ and reduction – $\mathscr{R}_d{}^2$, the specified hyperproperties are transdisciplinary and cognitive in nature.[1–4,19]

The functional interpretation of these hyperproperties is implemented through certain cognitive functions that implement structuring metaprocedures; analysis/identification of the problem; synthesis; of choice, etc.

The set indicated by $\mathscr{R}3$ ensures the implementation of the following rules, based on which analytical processing of medical information is performed.

Formation of classes of medical information. For this, such a class is named and further filled with document concepts that have a binary relation with the class name based on the formation of a stable binary relation between its property and one of the hyperrelations of the closed set $\mathscr{R}3$. Such a relation has the form:

$$< r^t_{kl}, R_g , > | r^t_{kl} \in \mathscr{R}^T_{kl} | \mathscr{R}_g \in \mathscr{R}3, g \in \{f, c, d\} , \mathscr{R} \tag{14}$$

where T – concept type, t – type property, kl – a special index that determines whether the concept belongs to a specific class.

The multiplicity of the given binary relation is determined by the fact that it associates some set of concepts with the name of the class that forms this set of concepts.

$$\{x^t_{kl} < r^t_{kl}, \mathscr{R}_g > X^T_{kl}\} \tag{15}$$

where X^T_{kl} – the name of the class that was formed by the set of concepts x^t_{kl}

Concept classes are also elements of the document taxonomy and can form new classes.

$$\{Y^{t_i}_{kl} < \mathscr{R}^{T^{t_j}}_{kl}, \mathscr{R}_g > X^{t_n}_{kl}\} \cong \mathbb{X}^{T_l}_{kl} \tag{16}$$

Representation of the class name of the species $X^{t_n}_{kl}$ says that this class is formed from concepts that have t_n property.

Above each class, as an element of a taxonomy of a certain complexity, a binary relation of its partial ordering is determined. The entire set of classes forms a complete taxonomic system of the document, over which a complete partial ordering can be determined. Then the root vertex of the taxonomy of the entire document is a fixed point of the set that includes all concepts of the document. The taxonomic system, which is formed on the basis of the specified set of concepts with a fixed point[11,17] is also complete. For a complete taxonomic system, one of the fixed points is the name of this document.

Moreover, the complete taxonomic system is a structured object and can be considered from the standpoint of the homotopy type theory. Taxonomy, as a structured object, is formed on the basis of stable binary connections between document concepts. Thus, it can also be considered as a binary tree,[11,17,18] which is also a homotopy type and is characterized by the hyperproperty of univalence. This allows us to claim that the taxonomy of an arbitrary document is univalent to the entire space of binary trees that can be formed from its concepts.

$$T \cong B_D \tag{17}$$

where B_D – an arbitrary Böhm tree.

Transformations of the type (14)–(17) are determined on the basis of definitions and rules (1)–(13) and ensure the implementation of the following technological conditions of the doctor's information-analytical activity:

- creation of a complex IT solution for the formation of a united network-centric information environment, which will unite the information resources of all specialists involved in the interaction;
- ensuring the solution of cognitive meta-tasks when processing text documents, databases and knowledge-base: structuring, analysis, synthesis and selection;
- support for information search processes and the formation of network digital collections of text documents relevant to the topics of research and expertise;
- implementation of an interactive form of interaction with each document and ensuring its attributive integration with processed information resources;
- provision of continuous monitoring of information processes, analysis of their states and decision-making based on the received information;
- formation of interoperable protocols supporting network-centric interaction and interconnection between documents, information systems, databases and knowledge bases, which have a significant amount of interdisciplinary relations, and are created on the basis of the use of various information technologies and standards;
- provision of automated analysis and creation of rating systems of research objects and processes related to them, taking into account the whole set of factors affecting the relevant objects and processes;
- ensuring the processes of multi-criteria comparative analysis of information sources according to their properties and selection according to the specified criteria of relevant records and documents found in information systems and environments;
- selection of statistical data from documents being processed or already having been processed and their processing according to defined features and criteria;
- ensuring the processes of solving the problem of rational choice and developing, on its basis, alternative options for solving typical tasks and their substantiation according to determined indicators;
- formation of a multi-level scheme for the implementation of innovative solutions at all stages of the life cycle "problem–research–selection–justification–development–implementation–production–support" in the form of an ontology of processes;
- support for experts interaction with specialized information resources and with each other in the format of narrative discourse.

Based on the principles mentioned above, a constructive option that ensures the fulfilment of the specified requirements for the creation of an appropriate medical transdisciplinary information and analytical environment is the development and implementation of intelligent network-centric cognitive services that are able to provide analysis, evaluation and selection of certain descriptions that characterize the patient's health condition, including decision-making concerning the choice of treatment methods.

The implementation of the specified IT technological solution is possible only under the conditions of the formation of a united medical information space in the format of a narrative discourse. The specified format of interaction ensures full-scale integrated use of distributed information resources and corporate systems of medical knowledge.

3. Conclusions

Transdisciplinary ontologies of medical information resources ensure the implementation of the interaction of doctors with information resources in the format of narrative discourse. They are the network intellectual tool that is able to form an appropriate unified information space based on the transdisciplinary procedure of lexical-semantic analysis of information resources. They also provide encapsulation of an arbitrary information resource, which was created according to a certain information technology and to a different-from-others standard, into this united information space. Thus, transdisciplinary ontology forms this space in the format of a narrative discourse for the use of all kinds of descriptions and documentary display of information, all contexts of which are processed by cognitive services of a network dynamic system with a complex component-oriented structure of services. Then the basis of decision-making will be a transdisciplinary interactive medical document, which will be created on the basis of transdisciplinary ontologies.

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Health Apps for Children: Deploying Digital Health in a Safe, High Quality and High Efficacy Way in the Pediatric Field

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ABSTRACT

Research shows children and young people (CYP) engage with digital software applications (apps) from as young as one year old. CYP often see the value of wearables and enjoy the educational experience of being proactively involved in their health education and management. Parents, carers and teachers are heavy influencers of digital health use, but adults themselves lack policies around digital health education, often focusing on risks, and are less familiar with child-led digital health education. Health applications (apps) can create a space for children to learn about health conditions, healthy lifestyles and preventative health measures: Providing personalized knowledge as their bodies and needs develop. CYP are growing up in a world where many health services are likely to have a so-called 'digital front door', with some health management strategies or results likely to be delivered on-line or virtually. Due to stretched resources, CYP may need to be able to self-manage mild health conditions and could be better prepared to transition to adult services where they are likely to need to manage their digital health records and safe sharing of their personal health information.

CYP have the ability to be the 'Trojan horse', introducing apps, wearables and digital health solutions to parents, carers or wider family members without digital literacy or experience. Pediatric apps and related health tech or wearables need to keep a child safe, connected, educated, empowered and healthy. Children should ideally access health apps that are safe, appropriate for their age and support management of their health preventatively and proactively. Some health apps for adults have been seen to simply extend their included age range to include children without the appropriate research or considering safety or health differences between children and adults. Children have specific health, cognitive, developmental and physiological needs which need to be reflected in the health apps and digital health solutions recommended by health care professionals.

This paper examines the considerations needed for designing, recommending, and using pediatric health apps.

KEYWORDS

Pediatric, digital health, apps, children

1. Introduction

Ideally all parents should be engaging in face-to-face, individualized, healthy and positive learning at all times with their children, but in reality many parents use screens (including TV, computers, tablets and smartphones) to entertain their children, with one study showing 65% of parents giving the child a device to 'stay calm' and 29% giving a child a device at bedtime[1] (despite health recommendations to reduce screen time at bedtime to improve sleep quality). If children are using devices, there is an opportunity to provide apps which educate, prevent or support health and well-being. Without health care professionals recommending or prescribing pediatric health apps, and in the absence of robust guidance for parents, children are at risk of accessing incorrect, unsafe or inappropriate apps.

Research shows most preschoolers spend a significant amount of their day on screens. One study of children under 5 years demonstrated 96.6% of the research group using digital tools, with most of them starting to use devices under the age of one.[1] Children as young as 15 months can learn from apps but do best when they have parental guidance and assistance.[2]

Research of older children shows that they can view health app use as an adult-only arena, but find they are easily able to access health apps, with one third reporting that they have used adult apps despite having to navigate what content might be irrelevant for their age.[3] Health apps create a space for learning about health, provide teaching about health education, healthy lifestyles and preventative health. Research has shown teenagers engaging with health education material online and via social media with older teenagers often requesting apps with content around love, relationships and sexual health.[4] Children are aware that apps need to accommodate for their growth and change both physically and mentally. Secondary school or high school children engaged in app research appear to use apps in a thoughtful, sensible and engaging way, often skipping content they believe is relevant only for adults.[3] Teachers, parents and carers can help by supporting access to health apps: using safe 'app libraries' within schools would be a way of recommending trusted health apps, and supporting proactive education around digital health use.[4]

Pediatric apps and related health technologies (such as wearables or implanted devices) need to keep a child safe, connected, educated, empowered and healthy[5,6] and acknowledge that children have specific needs that are different to adults.[7] Table 1 shows potential considerations for developing, recommending, assessing and using apps meant for children, that may be different to that expected for adult apps. Children should access health apps that are appropriate for their age that support the holistic management of their health preventatively and proactively as well as supporting their skills to navigate health systems effectively.[4–6]

2. Methodolody

Using accessible UK, Australian, Canadian and US-based health guidance, policies, research or best practice regarding health apps, this paper considers the specific considerations for developing or using safe, effective pediatric apps.

Age range
Research shows that for children under 5 years of age, their parents are often the best targets for improvements in child health, education and support.[8] Between 4–14 years, children have specific developmental needs and require forms of protection around what digital content they access. Adult apps are unlikely to be suitable and therefore should not be allowed to drop their targeted range unless pediatric focused research can demonstrate effectiveness, value and safety. Over 14 years of age, children start to have access to social media and may also start to transition to adult health services.

Table 1. Specific considerations for developing safe and effective pediatric apps

Construction	*Benefit*	*Concerns*	*Mitigation*	*Resources*
Apps spanning greater than 5-year age range[5,9] (RCPCH p2040 document; children's design guide document)	App can grow with the child. Wide reach if apps can address greater than 5-year age range. (App may need to consider differences in design for different ages, how health presents or is managed in different age groups).	Apps spanning greater than 5 years need to be able to justify why their app suits a wider audience, is able to address different developmental needs, and considered how health presentations differ in presentation and management over different age groups	Explanation about how age groups are addressed. Consideration of age appropriate sections within the app.	Children's design guide: https://childrensdesignguide.org/dsd-cards-developmental-stages-of-5-6-7-9-10-12-y-o/ NICE guidance NG204 https://www.nice.org.uk/guidance/ng204/chapter/Recommendations#communication-and-information/Recommendations#communication-and-information.
Who is the app aimed at? The child, the parent or carer, the health care professional (HCP) or a mix.[10]	Research shows children benefit from health app use mostly when over the age of 5 and when a parent or carer helps them navigate app use. Apps designed for both the parent/carer and the child or young person (CYP) can encourage family support around the child's health. Children's apps could provide health education to wider family members. Potential benefits of HCP having access to data.	Risk of poor clarity regarding which part of the app is targeting which individual. Can child access the parent/carer or HCP section? If so, is that appropriate?	Clear sections for parent or child. Clear explanation about who app is aimed at.	J Edwards, J Waite-Jones, T Schwartz, V Swallow. Digital Technologies for Children and Parents Sharing Self-Management in Childhood Chronic or Long-Term Conditions: A Scoping Review Dec 2021. Children 2021, 8(12), 1203; https://doi.org/10.3390/children8121203

Construction	*Benefit*	*Concerns*	*Mitigation*	*Resources*
Duration and timing of screen time: consideration of impact on mental health[11] sleep[12,13] physical activity[14] and development[15]	Access to app versus screen time. Healthy screen time	1. Access to devices at bedtime need additional consideration due to concerns around sleep disruption 2. Notifications causing anxiety 3. Tech addiction 4. Impact on social skill development	1. Screen time or light emission may need altering at the end of the day 2. Notifications appropriate to age group. Easily changed. 3. Time limit or recommendations interacting with app need to be safe. Opportunities to engage with others via the app.	New WHO guidelines on physical activity, sedentary behavior and sleep for children under 5 years of age. April 2019 News release Geneva. Canadian Pediatric Society Digital Health Task Force[15]
Security and ability to share information, e.g. on social media[16] **Who has access to the child's data and can the child or family share health data?**	Child connecting with others offers wider support network and access to further resources.	Sharing health data on social media is unsafe. Social media sites have poorly controlled age restrictions.	Clear age-appropriate information. Consent Assent Parental/carer controls.	B Cawthorne. Age restrictions on social media services. UK Safer Internet Centre. April 2018.
Connection to others (parents/safe adults/local community/ charities/ school/ health care professionals/ medical records)[17, 18]	Connection allows children to access a wider support network.	Vulnerability Developing a sick role.	Clear age-appropriate information. Consent Assent Parental/carer controls.	

Construction	*Benefit*	*Concerns*	*Mitigation*	*Resources*
Education (age appropriate info/) [5,8,19] **(Committee on the Science of Children Birth to Age 8: 2015)**	Health apps can provide access to health education.	Poor understanding. Age appropriate content needs to cover all developmental ages and stages.	Age appropriate content that addresses different learning styles. Clear messaging about what to do if child needs additional help To access education.	Age-appropriate pedagogies for the early years of schooling. Foundation paper summary. Dept. of Education and Training, Queensland Government.
Equalities (digital environment/ digital access/ digital literacy)[20] **(Gann, NHS Digital, 2019)**	Digital health has the potential to reduce inequalities if done well. Children without access at home need to be able to access via school (e.g. digitally healthy schools) or libraries or clubs.	Children without ready access to digital environments.	Health care professionals prescribing bear responsibility for establishing patients' digital access and digital environment prior to prescribing.	National Institute for Health and Care Excellence. NICE and health inequalities.
App changes and updates (Who will be alerted? When and why?)[11]	Alerts to switch to another app. Parents or children can then switch to another app if needed, or are alerted to improved updates, additional functionality.	App functionalities may be lost if updates not well communicated. Users may stop using the app if functionality changes. If an app ceases to exist, users who were previously relying on the app or managing their health through the app may stop managing their condition and may not download an alternative app if the knowledge of an alternative is not easily available.	Choice regarding whom is alerted and when may help.	Bespoke Digital Health Libraries. orchahealth.com

Construction	*Benefit*	*Concerns*	*Mitigation*	*Resources*
Empowering children (self-management/ transitioning to adult services)[21]	Young children need to feel empowered to manage their health. They are a group where small changes can make a lifetime of changes. Access and transition to adult services can be supported.	Over-monitoring. Creation of health anxieties. Sick role Dependency	Young people need to navigate the physical, cognitive and emotional change in the move to independent adulthood. (Reference Helen & Douglas House 2014: Transition and beyond toolkit. Oxford: Helen & Douglas House). Collaboration between children and adult services helps support young people. (Reference Helen & Douglas House 2014: Transition and beyond toolkit. Oxford: Helen & Douglas House).	Young Minds (2020) Transferring from CAMHS to adult mental health services. Southampton Children's Hospital Ready Steady Go resources for health professionals. Queen's Nursing Institute (2017) Transition from children to adult community services: learning resource. London: QNI. Campbell F, Biggs K, Aldiss SK, O'Neill PM, Clowes M, McDonagh J, While A and Gibson F (2016) Transition of care for adolescents from pediatric services to adult health services, Cochrane Database. Chambers L and Kelly K (2015) Stepping Up: Developing a good transition.
Researched information (app researched for specific age group or cohort)[5–7]	Research of the app provides usability, accessibility data as well as best timing of app use, optimum user experience.	Research cannot capture all benefits and concerns. Expert opinion is sometimes used to fill gaps.	Research for targeted age group accessing the app.	National Institute for Health and Care Excellence Research Recommendations Process and Methods Guide July 2015.
Provide correct, up-to-date information, targeted to needs and age of the child[5, 22] **(NHS England National Information Board, Nov 2016)**	Apps can provide fast updates and respond to changes (for example new healthcare options provided in pandemic).	App not updated does not provide most accurate information.	Updates provided within certain time frame.	UK government Department for Education ‘Development Matters’ document. Updated July 2021.

Construction	*Benefit*	*Concerns*	*Mitigation*	*Resources*
Child's voice represented and captured?[23] (Note: this may overlap with coproduction)	Improved child engagement.	Not adequately representing the patient and public voice.	Coproduction. Patient and public involvement (PPI).	Royal College of Pediatrics and Child Health 'Children and young people voice'. RCPCH &Us programme including 'Resources for working with children, young people and families.'
Alerts and reminders (reminders versus increased anxiety and health/tech addiction).[11] Research suggests push notifications link to smartphone addiction	Improved health management. Enhanced communication of health or treatment needs. Adherence to management plan.	Tech addiction "Push notifications for incoming messages were strongly linked to smartphone addiction." Reference 1 Alerts to others needs to be balanced against child empowerment and self-management. Alerts can cause the user to dwell more about their health conditions than is useful Alerts can cause anxiety Alerts can negatively affect task performance if the receiver is doing a task at the time they receive the text.[7]	Guidance on the app to advise best timings. Learning and education around pros and cons of push notifications/ alerts. Choice regarding notifications.	Seul-Kee Kim, So-Yeong Kim, and Hang-Bong Kang. An Analysis of the Effects of Smartphone Push Notifications on Task Performance with regard to Smartphone Overuse Using ERP. Comput Intell Neurosci. 2016; 2016: 5718580 Published online 2016 Jun 5. doi: 10.1155/2016/5718580
Accessibility (e.g. hearing, eyesight, language)[5,24,25]	Accessibility for developmental ages, reading ages, different languages, adaptability for eyesight and hearing differences. Accessibility on different devices (e.g. Apple, Android, web).	Exacerbation of inequalities.	Different languages, can size of text be altered, are videos accompanied by text to read. Coproduction, codesign and research into accessibility of different ages or developmental stage.	National Deaf Children's Society. https://www.ndcs.org.uk/ Royal Society for Blind Children. https://www.rsbc.org.uk/ Mencap (UK) https://www.mencap.org.uk/ Cardmedic (UK) https://www.cardmedic.com/

Construction	*Benefit*	*Concerns*	*Mitigation*	*Resources*
Further support needed. E.g. emotional or mental or physical health (Is it clear who the child should speak to/reach out to for additional support?)[26]	Safety nets and enhanced support networks can be created around the child.	Child doesn't know how to move from the app to engaging an adult/ supporter/parent or carer.	The app could encourage the child to speak to a parent, trusted family member or teacher if they need further support.	Royal College of Pediatrics and Child Health child protection resources https://childprotection.rcpch.ac.uk/resources/
Safeguarding[27]	Safeguarding concerns can be addressed.	Safeguarding concerns not addressed.	Clear information about how safeguarding issues can be addressed.	Safeguarding (RCPCH) https://childprotection.rcpch.ac.uk/resources/intercollegiate-roles-and-responsibilities/
App mindful of space saving to allow for other app download[28]	The less 'space'/ fewer bytes an app uses up on a device or phone the more likely the app and other apps are to be used.	Apps using large amounts data are less accessible. Optional downloading of sections.	To allow sections of the app to be downloadable or linked	T Allingham, N van Hout. How to free up space on iPhone and Android. Save the Student: Mobile Phones 2022. savethestudent.org
Coproduction and codesign[5, 29]	Improved accessibility, usability, adherence, management, and timing of app use.	Product not suitable for target users.	Ensure coproduction, co-development and co-design at all phases of app development.	https://www.coproductioncollective.co.uk/

Construction	*Benefit*	*Concerns*	*Mitigation*	*Resources*
Well-being and mental health considerations alongside physical health[26]	Enhanced and holistic health and well-being approach.	Reduced social and emotional interactions when interacting with app.	Time recommendations listed on an app. Potentially specifying the minimal time required to maximally benefit from the app, within respected national guidance or pediatric health institutions screen time recommendations.	mentalhealth.org.uk www.mind.org.uk
Reduce poly-app prescription[30]	Number of health apps the child recommended should be kept to the most effective minimum to prevent over-use of device.	In the same way that polypharmacy[25] is avoided to reduce side effects and improve adherence, health app use should be kept manageable and sensible.	Prescribed health apps should take into account previous apps the child to family are already using.	P Rochon, M Petrovic, A Cherubini et al. Polypharmacy, inappropriate prescribing, and deprescribing in older people: through a sex and gender lens. The Lancet, Healthy Longevity Vol. 2, Issue 5 E290-E300 May 2021
Does the design of the app support play and/or creativity?	Play and creativity are important developmental areas that can be supported through design of digital health tech and apps.	Aiming for play and creativity not to reduce health message or impact	Integrating play and games or gaming where appropriate.	S A Mummah, T N Robinson, S Sutton. IDEAS (Integrate, Design, Assess and Share): A Framework and Toolkit of Strategies for the Development of More Effective Digital Interventions to Change Health Behaviour. J Med Internet Res. 2016 Dec; 18(12): e317. Published online 2016 Dec 16. doi: 10.2196/jmir.5927 PMCID: PMC5203679 S Livingstone & K Pothong (2022) Imaginative play in digital environments. Information, Communication & Society, 25:4, 485-501, DOI:10.1080/1369118X.2022.2046128

Safety
There are potential risks associated with the use of health apps. Children may be exposed to inappropriate content, receive incorrect information, or unknowingly share personal information with third parties. Over-dependency on technology, obsessive tech use or tech addiction can negatively impact children's lives. Pediatric health apps need to be designed specifically for children and their use is best supervised by adults. Parents, teachers and perhaps libraries need to play a role in educating children about safe online behavior and safe app usage to ensure their safety and privacy. Health professionals can play a role in guiding parents and children on the appropriate use of health apps and the potential risks involved.

Adaptations to pediatric app assessments
The Organization Reviewing Care and Health Apps (ORCHA) in the UK and the USA updated their assessments of pediatric apps in 2022, which meant ORCHA reviewers now look at the following additional features within pediatric apps:

- Age range
- Physical ability/disability
- Cognitive/learning abilities
- Language
- Flagging exclusion of certain population groups
- Clinical scenarios where caution required
- Pros, cons, risks and risk mitigation
- Use of app alerts and AI that could cause harm.
- Appropriate evidence and research.

Current digital health landscape for pediatric and child health
Pediatrics and child health is a rich area for patient engagement, since children are often happy and motivated to interact with devices. However, both the number and the quality of pediatric health apps have lagged behind apps available for adults (>18 years). In 2022, ORCHA had identified 181 pediatric apps (compared to 1,198 for adults) that reach the threshold for recommending to patients, which is around half of the apps assessed by ORCHA. Additionally, many children's hospitals have not adopted apps or digital solutions into practice, with a US study in June 2022 showing 25% don't use any and 25% of those that do are deploying only simple appointment scheduling apps.

Suggested areas of future research

1. The relationship between push notifications or alerts on health apps and childhood anxiety or childhood tech addiction
2. How CYP (children and young people) use of apps and wearables changes over time?
3. What is the best adaptation of apps and wearables for the younger population?
4. What features of health apps are appealing or unappealing to CYP?

5. Successful and unsuccessful health education (and/or behavior changes) in CYP delivered via health apps.

6. What factors/functions/tech interactions shape CYP engagement with health apps?

7. How many apps are enough?: Patients experience of being prescribed more than one app by healthcare professionals?

8. What is the impact of reduced parent child interactions when a child uses apps regularly?

9. How best to encourage parent/teacher/adult supervision of CYP app use?

10. Acquisition of developmental skills (such as language/vocabulary acquisition rates) and amount of time spent on specific apps.

The young person's perspective
"I followed it [wearable and app] off my brothers because they go to the gym and all that, so I thought I might as well do something that contributes to my well-being".[3]
"I want personalized care", "I want to be in control of decisions to share my information[31]
"We should learn everything and then choose which path to follow" Malala Yousafzai.
"Change is coming whether you like it or not" Greta Thunberg.
Children consulted on this paper: "An app is fun and an app is an opportunity to learn. When a child is on a long car journey and they borrow their mom's phone to play a game, if the children's game is fun it is an extra-long learning experience [and] for the child [it is] super fun." (Female, aged 12)

3. Conclusion

Children and their parents are downloading health apps even though ~85% of apps on app stores do not reach the quality thresholds that health or care professionals need, and many children are using apps that are designed with adults in mind. This paper considers protective features needing consideration when developing, designing, recommending and using apps in pediatrics, such as age-appropriate information, screen time, cost, accessibility, safety, emotional health, play, creativity, safeguarding needs, and growth with the child as they continue to change and transition to adult services.

App libraries within schools or community libraries could provide an opportunity to empower children to access trusted apps, self-manage mild conditions, understand preventative health, and improve their digital health literacy. Targeting children's health improves adult health, and relieves the pressure on healthcare services. Very small differences in health behaviors in childhood can make a large difference in adult health outcomes. Safe and effective children's health apps, together with adult support, have an opportunity to be simple health interventions that could make a lifetime of difference.

Glossary

Tech addiction: "Addiction refers to a behavioral disorder in which a person uses content such as SNS, Internet browsing, and mobile games for an excessive amount of time without self-control, such that it interferes with daily life" (ref 1).
Screen time: Time spent using a device.
Coproduction: Citizens/the public/direct stakeholders are involved in creating policies or services.
Polypharmacy: Use of multiple medicines. (Poly-app use can be considered in a similar way)

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Conflict of interest statement
T Holland Brown works as a pediatrician in the National Health Service (NHS). She founded the free Hear Glue Ear app (though has not benefitted financially from the app) and does paid pediatric consultancy work for ORCHA (Organization for the Review of Care and Health Apps).

K Prince has no conflicts to declare.

J Warner is Adjunct Professor, University of Redlands in Business and Entrepreneurship, and national science foundation I-Corps mentor. He has previously been the US president of ORCHA.

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The Future of Medicine and the Logic of Data Management – Data Discrimination Problems

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ABSTRACT

Considered problems of medical data management. It is emphasized that this process has the greatest potential to ensure accurate and cost-effective patient care, as well as knowledge transfer during medical education. Analyzing the main areas of professional application of data: integration of big data, working with data of various types (from batch to stream) and their transformation for further use, we note that all the listed areas do not have a clear interpretation and recommendations for their use.

The purpose of the study was to substantiate the strategy of a safe and effective medical data management system and the logic of creating completely open data systems. This strategy will allow streamlining the data flows of instrumental and laboratory studies and ensure the delivery of their big data directly to medical institutions or medical research centers.

Conclusions: 1. There is a need for a comprehensive real-time medical data management system that will allow physicians, patients, and external users to enter their medical and lifestyle data into the system. 2. The inclusion of big data analytics will help to better predict or diagnose diseases, and accordingly help in the development of an effective plan for the prevention of complications and treatment of the disease. 3. Scaling communication with each patient in real time is possible only with the help of artificial intelligence. Manual intervention simply cannot serve thousands of users at the same time, each in their own way, addressing each individual directly. This conclusion should be especially emphasized when creating a perfect model of family medicine organization. 4. Transferring information is at the heart of developmental biology, and thus it is imperative that we can form a logical and structured approach to the healthcare language. If, as it appears, information theory has much offer to biology, further advances will depend on its integration. Given that these fields share many terms with developmental biology, effective collaboration may necessitate redefining the meaning attached to signaling, communication and information, in the context of the biology and medicine. Biosemiotics is inherently concerned with the language and rules of signals and codes in biological systems. It combines many ideas from diverse areas including systems theory, information theory and linguistics and may offer us a new perspective on the classification and meaning of biological and medical signaling.

KEYWORDS

Big data, medical data discrimination, data analytics, eHealth, electronic medical records, health care, medical information management, metadata, metatechnologies, infonomics, internet of things

2. Introduction

Health data management is tasked not only with organizing medical data, but also with integrating and analyzing it to make patient care more efficient and to obtain information that can improve medical outcomes while protecting data privacy and security.

As medical practices continue to use more sophisticated electronic health record systems, the need for effective health data management is increasing. Health data management is the process used to record, store, protect and analyze the data you receive from various sources. Effective healthcare data management allows healthcare professionals to develop a comprehensive view of a patient's condition.

Effective data management practices are vital to keeping up with the vast amount of data that healthcare facilities generate each month. They also help to deliver more personalized care, more effective communication and regulatory compliance.

Good data management benefits the patient, providers and insurers, and has far-reaching implications for the health of the entire population. In particular, health data management helps to: Create a complete picture of a patient's health by integrating data collected from various sources; increase patient engagement with predictive analytics and faster diagnosis based on available data; improve health problem tracking and predict complications; provide data for making effective business decisions that will increase the efficiency of the medical institution; and, finally, adhere to standardized care plans to improve disease management.

The purpose of the study was to substantiate the strategy of a safe and effective medical data management system and the logic of creating completely open data systems. This strategy will allow streamlining the data flows of instrumental and laboratory studies and ensure the delivery of their big data directly to medical institutions or medical research centers.

3. Results

Our main focus in this publication is the problem of data discrimination, also called "algorithmic discrimination".[1,2] The last is defined as "the bias that occurs when predefined types of data or data sources are intentionally or unintentionally treated differently than others." The use of big data can make discrimination more common.[3] Big data analytics is defined as a set of advanced digital technologies (such as data mining, neural networks, deep learning, profiling, automated decision making, and scoring systems) designed to analyze large data sets in order to identify patterns, trends, and associations related to the behavior of patients, play an increasingly important role in our everyday life - automatic registration for doctor's appointments, electronic registration of those wishing to learn to ensure continuous professional development. All of these problems are influenced by computers and algorithms, not humans. Thus, data analysis technologies increasingly tap into people's sensitive personal characteristics, their daily activities, and their future capabilities. Therefore, it is not surprising that today big data technologies and their applications are carefully studied in order to analyze and understand the new ethical and social problems of big data, especially related to the privacy and anonymity of data, informed consent, epistemological problems (first of all, the question of the validity of the obtained knowledge that is not subject to any doubts; from this point of view, the concept of the norm and conformity to this norm with the mandatory distinction between the actually existing and the proper) and more conceptual problems, such as changing the concept of personal identity through profiling or analysis, can be considered key "datafication", "information" society, etc.[4]

Another reason for data discrimination is the processing of information. Because the data scientist needs to translate the problem into formal computer code, the choice of target variable and class labels is a subjective process. Another algorithmic cause of discrimination is related to data bias in the model. For the development of automation of the intelligent data analysis model, appropriate sets for training are required, since the training to make classifications is carried out taking into account the given examples.

Accordingly, if the training data is contaminated with discriminatory or biased cases, the system will consider them valid examples from which to learn and reproduce the discrimination in its own results. This contamination can occur due to historically biased datasets or due to manual assignment of class labels by data collectors. An additional problem with training data can be data collection bias or sampling bias. Data collection bias can be the under-representation of certain groups and/or protected classes in a data set, which may result in unfair or unequal treatment, or the over-representation in a data set. In this way, "disproportionate attention is paid to a protected class group, and increased attention, in turn, may lead to a greater likelihood of observing a targeted violation." In this context, the phenomenon of "overfitting" was mentioned, where "models can become too specialized or specific to the data used for training", and instead of finding the best possible decision rule, they simply learn the most appropriate rule. The training data thus causes it to shift. Another possible algorithmic cause of discriminatory results is proxies for protected characteristics (e.g., race, gender, age). These include the creation of a negative vicious circle where certain inputs in the data set cause statistical deviations that are learned and fixed by the algorithm in a self-fulfilling cycle of cause and effect.

"Error of omission" is another form of cost function misspecification that occurs when terms that cause discrimination are ignored or not accounted for in the model. Simply put, this means that the model does not take into account the differences in how the algorithm classifies protected and unprotected classes.

Data processing and reasoning techniques are often biased toward "middle" or dominant groups. This is especially observed when conducting surveys. The whole concept of testing reinforces this, as average results (such as the frequency with which a certain effect is observed) are applied to the rest of the audience. Even when testing against carefully segmented mailing lists, the ultimate definition of "success" is determined by data decisions based on averages. Working with averages prioritizes a generalized "ideal" client that, at best, can only reflect some of the user's preferences.

In today's strategy, data decision-making algorithms must be constantly self-learning: thanks to the use of artificial intelligence (AI), it is possible to react and interact with each individual visitor in real time. We emphasize that the ability to scale communication with each person in real time is possible only with the help of AI. Manual intervention simply cannot serve thousands of users at the same time, each in their own way, addressing each individual directly. This conclusion should be taken into account when creating a perfect model of family medicine organization.

An important aspect of this chapter is the analysis of security opportunities for fair data mining. Many papers describe algorithmic decision-making as a “black box” system in which the algorithm's inputs and outputs are visible, but the internal process remains unknown, leading to a lack of transparency about the methods and logic behind evaluation and assessment. Predictive systems are becoming especially important. The reasons for the opacity of automated decision-making are numerous: first, algorithms can use huge and highly complex data sets that cannot be interpreted by researchers, who often lack the necessary computer science knowledge to understand algorithmic processes; second, automated decision-making may inherently surpass human understanding because algorithms do not use the theories or contexts that exist in normal human decision-making; and finally, algorithmic processes of firms or companies may be subject to intellectual property rights or subject to trade secret provisions.[2,5] If there is no transparent information about how the algorithms and processes work, it is almost impossible to evaluate the fairness of the algorithms or to detect discriminatory patterns in the system.[5]

Human bias is identified as another major obstacle to fair data collection, and human subjectivity underlies the design of data mining algorithms, as decisions about which attributes to consider and which to ignore are subject to human interpretation and will inevitably reflect implicit or explicit meanings of their attributes.

Thus, there is quite a large number of reasons for data discrimination. Their correct analysis does not yet have a corresponding algorithm. On the other hand, communication is at the heart of developmental biology, and it is therefore essential that we can develop a logical and structured biomedical approach to the language of health care. We have proposed the use of the ideas of systemic biomedicine, in particular the logic of signaling principles for timely warning about incorrect use of data.

Conventionally, the study of informational signaling has focused on the linear, and is concerned with *components* of pathways, ostensibly neglecting the context and networks within which these components function. With the advent of systems biomedicine, the conceptualization of cell signaling has evolved from the relatively simple linear cascades of previous decades, towards an appreciation of signaling as interplay between highly complex and context-dependent modules of activity.[6] These larger and more complex systems have necessitated bioinformatics, the mathematical modelling of cell signaling networks as systems.

Modeling of signal networks enables verification of theoretical molecular mechanisms, highlights ‘molecular hubs’ and allows an appreciation of pathways, in the context of other operational networks.[7] Crucially, the latter confers an appreciation of the emergent properties of positive or negative-feedback signaling networks, namely biostability and ultra-sensitivity, or adaptation and desensitization, respectively. Remarkably, modeling of the non-linear dynamics of cell signaling networks also reveals striking similarities between signaling networks of the cell and telecommunications.

Cognitive neuroscience was an early adopter of mathematical modelling, following from the recognition that human consciousness represents an emergent property of networks rather than a tangible property of signal transduction itself.[8] Indeed, recent work modeling signal transmission in neural networks revealed that the ‘transmitting’ neuron transmits a signal as a modulation of delay time, while the ‘receiving’ cell ‘decodes’ the signal by tracking the delay time, in a striking resemblance to the principles of spread spectrum technique, employed in wireless communications.[9] Modeling networks of cell signaling in development has furthered the appreciation of such parallels.

Biological and medical semiotics is inherently concerned with the language and rules of signals and codes in biological and medical systems. It combines many ideas from different fields, including systems theory, information theory, and linguistics. Accordingly, biomedical semiotics can offer for us a new perspective on both the classification and meaning of biological and medical signaling, and on errors associated with data discrimination.[10,11]

3. Conclusions

1. There is a need for a comprehensive real-time medical data management system that will allow physicians, patients, and external users to enter their medical and lifestyle data into the system.

2. The inclusion of big data analytics will help to better predict or diagnose diseases and predict diseases, and accordingly help in the development of an effective plan for the prevention of complications and treatment of the disease.

3. Scaling communication with each patient in real time is possible only with the help of artificial intelligence. Manual intervention simply cannot serve thousands of users at the same time, each in their own way, addressing each individual directly. This conclusion should be especially emphasized when creating a perfect model of family medicine organization.

4. Transferring information is at the heart of developmental biology, and thus it is imperative that we can form a logical and structured approach to the healthcare language. If, as it appears, information theory has much offer to biology, further advances will depend on its integration. Given that these fields share many terms with developmental biology, effective collaboration may necessitate re-defining the meaning attached to signaling, communication and information, in the context of the biology and medicine. Biosemiotics is inherently concerned with the language and rules of signals and codes in biological systems. It combines many ideas from diverse areas including systems theory, information theory and linguistics and may offer us a new perspective on the classification and meaning of biological and medical signaling.

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Secondary Nomination and Co-Referencing of Medical Terms in the Strategy of Harmonizing Indicators of Knowledge Assimilation in the Doctor's Portfolio

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ABSTRACT

Some issues of the formation of the portfolio of doctors during continuous professional development are considered. Particular attention is paid to the peculiarities of the evaluation of the analyzed information, in particular, the problems of secondary nomination and co-referentiality of medical terms. The purpose of the study was to substantiate the prerequisites for creating a new type of portfolio by using methods of intellectual analysis of multidimensional information, as well as the formation of models and cognitive structures, which should become a central event in person-oriented active learning. It is shown that in order to ensure an adequate mechanism for evaluating multidimensional information in the doctors' portfolio, it is advisable to use ensembles of algorithms for intelligent analysis of big data. Conclusions: 1. The portfolio of doctors and pharmacists is of exceptional importance for the functioning of the system of continuous professional development of the relevant specialists. It helps organize lifelong learning and allows you to keep all evidence of learning and professional activity. 2. Taking into account the importance of the portfolio, it should be capable of standardized and formally calculated evaluation. 3. The entry of information into the portfolio is preceded by the determination of the semantic equivalence of the available information regarding the acquisition and assimilation of knowledge. 4. It is proposed to use ensembles of approaches to the analysis and arrangement of information in the portfolio - a combination of several algorithms that function simultaneously and provide an opportunity to correct possible errors. 5. The proposed decision-making algorithm during the preliminary analysis of information for the portfolio.

KEYWORDS

Doctor's portfolio, continuous professional development of doctors, intelligent algorithms of information analysis, co-referencing of medical information, secondary nomination of medical terms, cognitive structures

1. Introduction

Today, the portfolio mechanism is used in the world not only as a method of qualitative transfer of knowledge, but most importantly, as a mechanism for qualitative evaluation of the acquired knowledge! Therefore, the problems of improving the accounting mechanism, assessing the quality of acquired knowledge in the system of continuous medical education are discussed very widely. Among the large number of such evaluation mechanisms, the application of electronic Portfolio technology is more relevant today both for the formalization of knowledge and competences, their monitoring, and for the holistic assessment of the quality of education in the system of continuous medical education.[1–4]

Currently, portfolio is a web technology that allows a doctor to record his educational activities and professional successes throughout the entire period of professional development. However, the logic of the approach to assessing the need to acquire knowledge for different medical professions based on average indicators, the same approach to measuring very different competencies in different medical specialties, level the peculiarities of professional activity.

In addition, the decentralization of the system of acquiring knowledge, the emergence of new centers for the training of doctors caused the problem of comparing and evaluating educational programs, and the problem of understanding texts of high complexity became obvious even for qualified representatives of the medical profession. The secondary nomination of medical terms[5] is one of the obvious difficulties in the integration of educational activities. Accordingly, the priority task is to ensure the co-reference of clinical information related to the comparison of data obtained from different sources for their inclusion in the portfolio.[6,7]

The purpose of this work is to justify the prerequisites for creating a new type of portfolio by using the methods of intellectual analysis of multidimensional information, as well as the formation of models and cognitive structures, which should become a central event in person-oriented active learning.

Today, problems of improving the mechanism of accounting and assessing the quality of acquired knowledge in the system of continuous medical education are constantly being discussed. Among the large number of such assessment mechanisms, the application of the "electronic portfolio" technology is more relevant both for the formalization of knowledge and competences, their monitoring, and for the integral assessment of the quality of education in the system of continuous medical education.

We consider the portfolio as a personal professional-oriented technology for the authentic assessment of the educational results and industrial successes of a doctor, an effective means of quantifying educational and professional growth in his continuous professional development.

The portfolio can be used to demonstrate the competences acquired by the doctor in various areas of medical education, including interdisciplinary and transdisciplinary ones, assimilation by the doctor of certain non-clinical skills, and apply them in his work. In many countries around the world, the use of the portfolio is mandatory in order to obtain and confirm the qualification of a doctor.[3,4]

The amount of characteristics that probably characterize the training and work of a doctor is counted in the hundreds. In addition, the quantitative assessment of educational procedures is often complicated by the unstructured nature of the information. Therefore, it is quite difficult to give a valid integral description of the activity of a specialist. But in today's world, working with big data is the norm. For this, there are many powerful methods of information processing, among which the methods of Intelligent Data Analysis (IDA) occupy an important place.

It is generally accepted that IDA is a process in which, with the help of mathematical and computational algorithms, raw data is structured and various regularities in these data are formulated or recognized.[8] For the portfolio, the integral assessment of professional growth is quite difficult, first of all, as a result of the lack of formalization of ways to improve qualifications.

An excessively large number of options for obtaining knowledge, a non-unified system of assessment of knowledge and competences are also important. It is logical to justify typical models of professional development (which is constantly replenished). Then the task of integral characteristics of the professional development of the individual is reduced to a simpler problem of pattern recognition. But even in this version, we have quite a large number of difficulties associated with qualitative (not quantitative!) indicators, erroneous information, etc. Given that currently none of the algorithms can provide a valid assessment of the professional growth of a specialist, we suggest using *ensembles of algorithms*, that is, a combination of several algorithms that learn simultaneously and correct each other's mistakes. This approach is often used in order to strengthen the "positive qualities" of individual algorithms, which can work poorly on their own, but in a group - give a good result.[9]

We use two classic approaches of ensembles – bagging (in which the basic algorithms are representatives of the same family, they are trained in parallel and almost independently of each other, and the final results are only aggregated) and boosting (the models are no longer trained separately from each other, but each of the next one manages the errors of the previous one, meaning that if one weak algorithm failed to detect any pattern in the data because it was too hard for it, then the next model should do it.

Additional coefficients were used to improve recognition results. One of them was called the *prioritization coefficient*, and the second is the *coefficient for determining the content equivalence* of various thematic professional development courses. The importance of determining priorities is due to the need to select from the total amount of information about the doctor that needs priority attention for use in the assessment. In this way, it will be possible to assess the specialist's competence as soon as possible, as well as the need to correct the trajectory of his professional development. Of course, higher priority information should be processed first.

Considering that the portfolio is a classic information technology as well as the fact that the educational process requires continuous evaluation and management of the quality of service provision, we used the SLA (Service Level Agreement) strategy. Today, this technology is used and has a high level of trust by millions of people around the world.[10] The SLA system of post-graduate training of doctors and pharmacists consists of four parts: a glossary, a brief description of the systems, the roles of process participants and the results of the technological learning process. The characteristics of the SLA action are important - territorial, temporal and functional. The basis in this direction is the ratio of the characteristics of the subject area and the volume of the educational material, the depth of study of the educational materials, the level of evidence of the information and the reliability of the connections between the educational elements.

Taking into account that a change in priority can affect the target performance metrics, the calculated priorities must be well understood by all participants in the process. Changes in priorities should occur in parallel with the dynamics of solving the problem and with the appearance of new information that can radically change the initial formulation of the task.

The *coefficient of determining the content equivalence* of various thematic courses for the improvement of specialists is extremely important in the conditions of difficulties in solving problems of uncertainty in the choice of training courses, certification of training course providers, training quality control systems, etc. There is a need for informal comprehensive measurement and the simultaneous use of various assessment tools, methods of multidimensional analysis and special methods of integration of scores on various quantitative and qualitative scales. It is necessary to determine which content obtained as a qualification improvement is equivalent, and which is essential for obtaining a qualitative change in the doctor's qualification.

The content equivalence of various thematic courses is also specified using the VEN (Vital Essential Non-essential) strategy, which is a prescriptive segmentation of the "necessity" of educational elements. This strategy is quite often used in medicine and production; especially together with ABC analysis.[11]

The result of ABC analysis is the grouping of educational objects according to the level of influence of the overall result on the level of knowledge transfer. In our problem, this strategy will allow us to determine priority sections of educational content in accordance with international standards and answer the question: "Which educational courses should be considered for inclusion (exclusion) in the list of educational services?". The use of ABC analysis will allow ranking the range of training courses according to various parameters. It is possible to organize educational content providers, the quality of knowledge transfer, and knowledge management systems and other educational resources in this way.

The last module in decision-making regarding the professional growth of an individual is the analysis of texts of high complexity. The essence of the problem lies in the huge multiple nomination of pathology terms (the emergence of terminological "traps", or co-referentiality), which are further complicated by the terminological discrepancy of pathological conditions in diploma and postgraduate education.

In the absence of special rules, coreference names will be used differently in different sections of text systems. Accordingly, there is a problem of unification and standardization of input, search, extraction, storage and exchange of data both in relation to the completion of educational procedures and the assessment of professional competences in various clinical situations.

The integration of medical information systems into a single space involves the provision of common referentiality of clinical information related to the comparison of data obtained from different sources. But the great complexity of determining the semantic compatibility of various text structures during computer processing of electronic records does not allow today to effectively solve the problem of the correct record in the portfolio of a specialist.

To solve the coreference problem, it is recommended to use special software systems.[12] The most common approach is to build a model of the mentioned pairs.[13] The classifier first identifies all the mentioned pairs that are co-referential. These pairs are then grouped into chains using clustering methods such as the nearest neighbor method. The second option is the mention rating model.[14] With this method, the task is reformulated as a ranking function rather than a classification function. All candidate mention antecedents are ranked to determine which candidate is the most likely.

Another well-known method is the use of the previous tree model.[15] In this case, a graph is constructed from the document, where nodes are mentions, and arcs are connections between pairs of mentions that are coreference candidates. Then coreference chains are modeled as latent trees on the graph.

To solve the coreference problem, we used ontological models (graph models) and correspondence rules. Cognitive load is reduced if taxonomic techniques are used, which organize the terms in the controlled dictionary into a hierarchy. The main purpose of taxonomy is to create an ontological structure for human understanding of information and its integration from different sources.

Thus, decision-making during the preliminary analysis of information for inclusion in the portfolio can be presented in the form of an algorithm (Fig. 1).

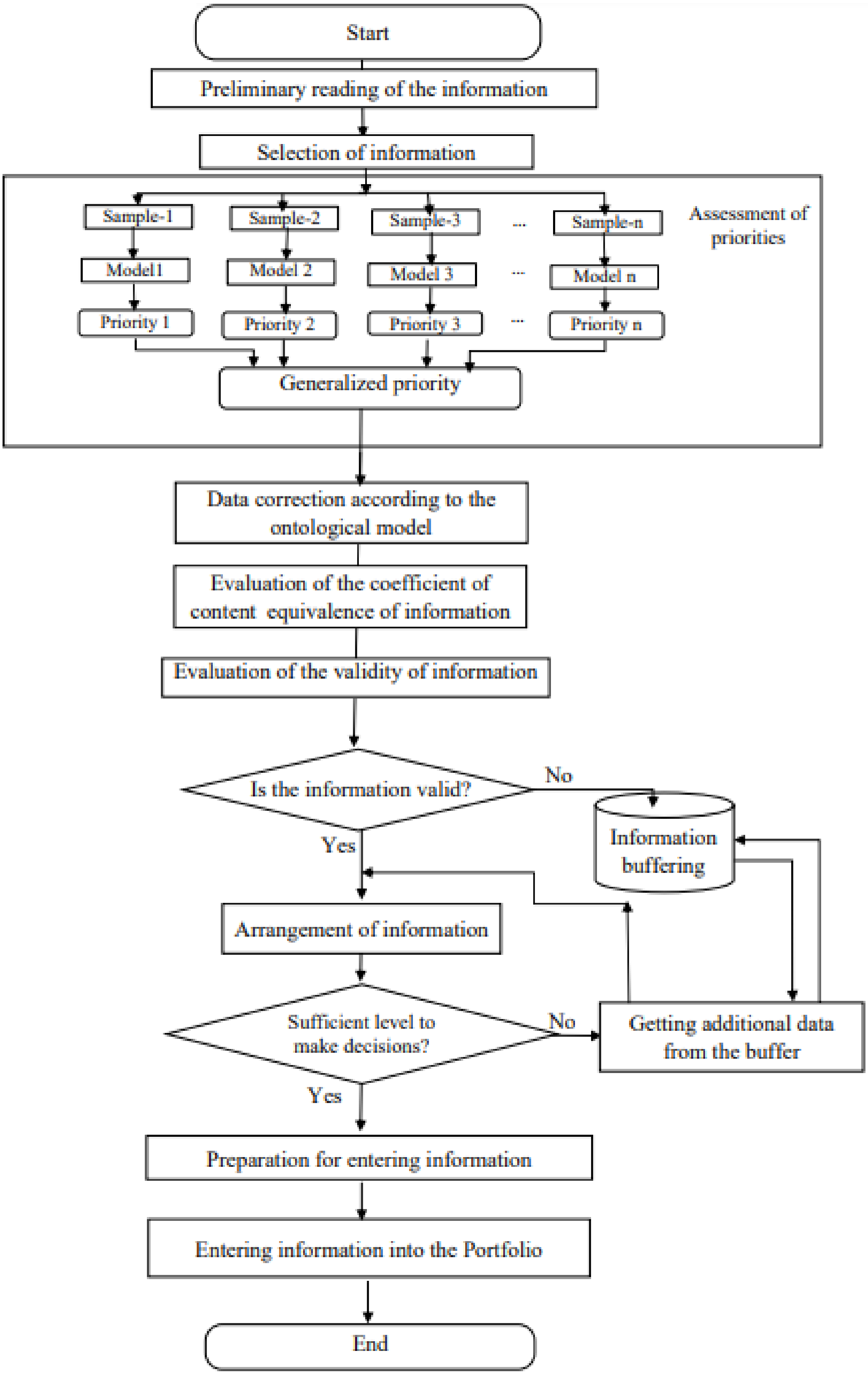

Figure 1: Algorithm for decision-making during the preliminary analysis of information for inclusion in the portfolio.

As can be seen from the algorithm, the main processes in the processing of information before entering it into the doctor's portfolio are the evaluation of its validity and the organization of data. The biggest difficulties, the solution of which forms the basis of the validity of information, are the issues of secondary nomination and coreference of data. Note that we are talking only about the preliminary analysis of information before entering it into the portfolio. Even greater problems await the researcher at the second stage of information processing. They are related to the content analysis of the accumulated data and will be discussed in future publications. At the same time, what has been said emphasizes the complexity of creating a portfolio, and taking into account the importance of introducing the portfolio mechanism into health care practice – the need for a comprehensive discussion of the technology of its creation.

2. Conclusions

1. The portfolio of doctors and pharmacists is extremely important for the functioning of the system of continuous professional development of the relevant specialists. It helps organize lifelong learning and allows you to keep all evidence of learning and professional activity.

2. Taking into account the importance of the portfolio, it should be capable of standardized and formally calculated evaluation.

3. The entry of information into the portfolio is preceded by the determination of the semantic equivalence of the available information regarding the acquisition and assimilation of knowledge.

4. It is proposed to use ensembles of approaches to the analysis and arrangement of information in the portfolio - a combination of several algorithms that function simultaneously and provide an opportunity to correct possible errors.

5. The proposed decision-making algorithm for the analysis of preliminary information for the portfolio.

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Informational Analytical Representations of the Magneto-Electrochemical Theory of Life and Health

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ABSTRACT

The results of a theoretical study related to the role of the electromagnetic field in the process of realizing the phenomenon of life are presented. The aim of the theoretical study was to conceptualize a system of views on the role of internal electromagnetic fields in the human body for understanding the essence of the course of metabolism, the phenomena of biological life and health. General scientific and theoretical methods were used in this theoretical study. The main conclusions of the theoretical study were made as follows: 1. The life of a biological system is a process of magnetoelectric activation of its biomolecules, which starts and ensures their biochemical activity (coherent energy channeling - biochemical soliton flow) and determines structural integrity in their collective interaction of a single organism (transportation of solitons by water-energized structures - controlling soliton flow). 2. Modern deepening of fundamental knowledge to the level of the course of magnetoelectric processes at the molecular level in living biological systems is expedient to be fully integrated into medical science with a change of the electrochemical paradigm of metabolism to a magneto-electrochemical one. 3. Knowledge and understanding of quantum-mechanical features of biopolymers' functions in living systems, the understanding of their energy functioning, the organization of form and role of electromagnetic components is clearly the next step to deepen the fundamental knowledge of pathogenesis of diseases related to internal organs with a further approach to optimize their treatment and prevention.

KEYWORDS

Magneto-electrochemical theory of metabolism, cell membrane, electromagnetic field, the phenomenon of life, complex medicine

1. Introduction

Understanding the essence of biological life is one of the main unsolved questions of fundamental science. What exactly are the mechanisms and processes that make the molecules of our body alive? How exactly and at the expense of what is this happening? The answers to these questions can allow modern medical science to significantly advance, as they could discover the latest mechanisms of influence on the tissues of the human body in order to prolong their viability and the life of a person as a whole. Science of the 21st century has improved significantly. The latest knowledge about the organization and principles of functioning of living matter at the subatomic, atomic, molecular and cellular levels is now available. It is now clear that everything that happens in tissue cells is related to their metabolic processes. It has been proven that all metabolic processes are the result of magnetoelectric interaction between atoms and molecules. That is, molecular chemistry is a secondary consequence of electromagnetism. Accumulation of the results of scientific research in this field led to a greater understanding of the role and place of electromagnetic phenomena in the organization and functioning of living biological systems, including the human body. Today, the fact of the presence of an electromagnetic component in the human body is an indisputable truth, and determination of electromagnetic parameters of the human body is already widely used for diagnostic purposes in medicine. Mankind has practically investigated the nano-level structure of matter at the current stage of scientific development, and it has come to an understanding of the organizational field of the structure of matter. The scientific opportunity for the further development of medicine has been formed now thanks to the possibility of transdisciplinary implementation of the latest fundamental scientific knowledge. However, there are no generalizing theoretical works in this direction in medicine.[1–6]

Therefore, the aim of this theoretical study was to conceptualize a system of views on the role of internal electromagnetic fields in the human body for understanding the essence of the course of metabolism, the phenomena of biological life and health.

2. Methodolody

The analysis of the presented data is a fragment of research work of the Department of Internal Medicine and Emergency Medicine of Poltava State Medical University (23, Shevchenko St., 36011, Poltava, Ukraine) on "Development of algorithms and technologies for implementing a Healthy Lifestyle in patients with Non-communicable Diseases (NCDs) based on the study of functional status" (state registration number 0121U108237: UDC 613 616-056-06: 616.1 / 9-03).

Scientific work is carried out in conjunction with the following scientific institutions: 1) Poltava State Medical University (23, Shevchenko St., 36011, Poltava, Ukraine), the cooperation coordinator is the Head of the Department of Internal Medicine and Emergency Medicine, prof., DM M.M. Potiazhenko; 2) Shupyk National Healthcare University of Ukraine (9, Dorogozhytska St., 04112, Kyiv, Ukraine), the cooperation coordinator is the Head of the Department of Informatics, Information Technologies and Transdisciplinary Education, prof., DM O. P. Mintser 3) Lithuanian University of Health Sciences (9, A. Mickevičius St., LT-44307, Kaunas, Lithuania), the cooperation coordinator is the Head of the Nephrology Department, Prof., DM I.A. Bumblyte.

General scientific methods (dismemberment and integration of elements of the studied system, imaginary experiment, logical, historical research, analysis, induction, deduction, and synthesis of knowledge) and theoretical methods (method of constructing theory, logical methods, and rules of normative nature) were used in this theoretical study.

3. Results and discussion

Performing a systemic medical analysis provided the basis for the main concepts that were formulated in postulates.[2,7,8] The fundamentality of principles of the structure of the matter of macrocosm became the basis for the formulation of the following conceptual conclusions of electromagnetic phenomenology of metabolism of living biological systems, including the human body:

- All living biological systems, including the human body, at the atomic level have an electromagnetic nature of their structure and consist of field structures – fermions, which are united by the field forces of electromagnetic, strong, and weak nuclear interactions, the carriers of which are bosons;

- All living biological systems, including the human body, have inherent properties of wave-particle duality, which determines the presence of wave characteristics in their structure;

- All chemical reactions that take place in living biological systems, including the human body, have an electromagnetic nature and are the result of the manifestation of electromagnetic interactions of substances in them and are the result of the manifestation of electromagnetism;

- All living biological systems, including the human body, can be considered at the micro level of their structure as a form of fundamentally organized energy, which has total energy characteristics of the particles of the microcosm that form them, because the particles (quarks, antiquarks, etc.) that make up an atom are inherently energy.

The systematic analysis of modern fundamental knowledge about the molecular level of the structure of matter became the basis of the following postulates:

1. A molecule is a material manifestation of matter and a fundamental structural and functional component of micro-level organization of a living biological system of any level of complexity, including the human body; a molecule consists of atoms that are complexes of field structures.

2. Atoms are connected in a molecule by electromagnetic wave fields, the source of which are the atoms themselves, which took part in chemical interaction and self-organization of this molecule.

3. The chemical bond between atoms in a molecule is a result of the interaction of electromagnetic wave fields of atoms and it can be covalent (with the generalization of electrons) or polar (with the transition of electrons).

4. Any molecule can be represented as a model of electromagnetic wave packets, in the nodes of which there are atoms that are the source of wave generation; at the same time, electromagnetic wave packets are the result from radiation interference of all atoms of molecules of a biological system.

5. The geometry of molecules is determined by quantum mechanical characteristics of the atoms that make them up and corresponds to the minimum total energy in the ground state and, accordingly, the maximum total energy of all chemical bonds of this molecule.

6. A real molecule consists of resonating electromagnetic wave field structures (according to the principle of superposition of Dirac states), that is, it does not have a specific structure, but is formed exclusively as a result of continuous resonance – the electromagnetic superimposition of many different atomic structures.

7. A molecule has energy characteristics, which are determined by electromagnetic characteristics of the atoms forming it and contain the energy of electron rotation, the energy of oscillation and

rotation of the nuclei of each atom forming it with a different contribution of each type of energy to the total energy of the molecule; at the same time, each energy component is quantized.

8. A molecule can be in the ground state or in an excited electronic state, which is classified depending on the total spin of the molecule and is subject to the rules of electronic transitions that have different probabilities.

9. Molecules of biological systems have individual quantum mechanical features due to the special composition of atoms (carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P), sulfur (S)), the biopolymer structure of most molecules, with a significant molecular mass and length of molecules, and have different variants of possible states of structural organization in space.

10. The state of an electron in a molecule is described using a wave model based on the Schrödinger equation, which is called a molecular orbital and includes localized σ-orbitals, localized and delocalized π-orbitals, and n-orbitals; at the same time, there are significant difficulties in their adequate calculation, since when accounting for interelectron repulsion there are no opportunities to separate variables in any coordinate system, this necessitates the use of approximate methods in determining the shape of molecular orbitals (scientific representations of the shape of molecules are relatively conventional).

11. The principal quantum-mechanical difference between the functioning of polymer biomolecules of living systems and the molecules of inanimate matter is their ability to transform unorganized (thermal, chemical, etc.) energy into a coherent form and its intermolecular transfer due to the system of delocalized π-electrons (quantum - Millikan mechanical model).

12. Delocalization of π-electrons in the molecular systems of living organisms is an important and fundamental quantum-mechanical feature of energy circulation in the universe (including the model of the "electronic circuit of life") and the phenomenon of biological life; all of the most important biomolecules are partially or fully connected systems precisely because of this.

13. Each of two or more autonomous π-electron systems of a living biological molecule can exhibit spectral independence and simultaneously interact with other molecules; at the same time, the interaction of π-electron systems inside the molecule is caused by energy migration along it, that is, energy transfer between different functional groups of this molecule, which is considered as a quantum mechanical feature of intramolecular and intermolecular transfer of energy and charge.

14. The ability to intramolecular and intermolecular transfer of energy and charge is determined by the inherent quantum mechanical features of the structure of biopolymers of living biological systems and turns out to be their fundamental distinctive property.

15. Energy conversion processes in the molecules of living biological systems are accompanied by the phenomenon of photon/electron emission, which is determined by various mechanisms of occurrence (with stimulation, this is secondary luminescence/photon emission; without stimulation, this is intrinsic luminescence/photon emission, etc.); it is a special case of energy transfer, has distinctive features in various cell ultrastructures (respectively in various tissues, organs, body parts); it is the most characteristic of molecular structures that contain complex proteins with chromophore coenzyme groups.

16. The fundamental difference of living biological systems is the presence of deterministic self-organization of their molecules through the implementation of information-energy processes of intramolecular and intermolecular energy transfer due to the excitonophonic/soliton mechanism of conversion of ATP chemical energy by biopolymers into coherent energy with further transmission in the form of a soliton/biosoliton/electrosoliton along the chain biopolymer.

17. The soliton mechanism of energy transfer along the chain of biopolymers is the electromagnetic basis of the phenomenon of the life of living biological systems; all biopolymers of a living organism with enharmonic atomic groups convert chemical (perhaps of another kind) energy that excites their oscillations into coherent energy/solitons, which are further transported along the chains of the biopolymer, ensuring its chemical interactions and mechanical movement.

18. The organismic universality of the energy-carrying molecule ATP and the consistency of the interactions between completely different biopolymers in living biological systems are the result of the constant impact of coherent energy on the structured water environment of a biological organism.

19. Water in living biological systems plays a key role in the process of transmitting and receiving coherent soliton energy by self-organizing into fractal energy-stressed paramagnetic crystal structures that form multi-level branched, long-lasting fractal complexes connected to biopolymers, the existence of which is supported by coherent energy flows/solitons.

20. Helix 30/11 is the main most typical fragmentary element of self-organization of water into fractal structures, which in living biological systems forms energy-stressed fractal crystalline thread-like water structures, supported by energy constantly supplied by biopolymers, and forms large ever-growing hierarchical structures that combine all of the water of a living organism in a dynamic balance of opposite processes of destruction and growth of its energy-stressed crystalline structures.

21. The framework structure of the water helix 30/11 is an empty tube with an inner diameter of 3.2 nm, created by oxygen atoms; protons cover its inner and outer surfaces, and this leads to the presence of pronounced paramagnetic properties of water and can explain the mechanism of the occurrence of internal tension in the crystal lattice of energy-stressed water crystals of living biological systems and the effect on their orientation, on the transport of solitons of the Earth's external magnetic field.

22. The phenomenon of biological life at the micro level is characterized by the presence of a state of connectedness/organization of water into energy-stressed crystal structures due to the constant supply of coherent energy from biopolymers and stops when this energy flow disappears, which corresponds to the onset of the phenomenon of biological death and is manifested by the degradation of energy-stressed fractal crystal self-organization of water to the unbound state of an aqueous solution devoid of so-called biological anomalies (the theory of collective processes of Hall).

23. Bioenergetics processes at the molecular level of living biological systems are completely determined by the flow of magnetoelectric processes and include the following stages:

- transformation of the chemical energy of ATP into a coherent form – a soliton;
- channelization of the generated coherent energy (solitons) along the biopolymer chain to ensure its biochemical and mechanical activity;
- transport of coherent energy (solitons) to the surrounding polarized environment of water with its subsequent structuring, formation of crystalline hierarchical water systems that perform the function of remote non-chemical energy transfer (remote energy-information communication) to remote biopolymers to ensure the possibility of implementing collective processes between biopolymers of all living organisms system (human organism) (the theory of collective processes of Hall);
- the selectivity of the contact between biopolymers in the process of implementing energy-informational soliton communication is determined exclusively by magnetoelectric phenomenology based on the principle of resonance-frequency interaction between molecules;
- a fundamental difference in the behavior of biopolymers in vivo of a normally functioning/healthy

biological system is their ability to collectively interact with the formation of a conditional unit – a molecular cell, which possesses the qualities of a life phenomenon, unlike biopolymers in an in-vitro solution.

24. A molecular cell is a new substantial formation that contains two or more biopolymer-aqueous structures, the collective processes of excitation which are associated with the perception, transformation and transportation of energy, create a long-range information-controlling interaction of biopolymers in resonance processes, which turns out to be specific property and sign of living matter; is a new conditional "transitional" unit of life evolution of a biological substance on Earth, which has applied significance for the formalization of bioenergetics processes in living systems.

25. The phenomenon of biological life is completely determined by magnetoelectric processes at the molecular level: absent energy processes – absent life.

26. The phenomenon of biological death at the molecular level has a quantum-mechanical description, caused by a change in the energy characteristics of the atoms of molecules due to the cessation of energy movement, and has a number of objective manifestations; the main and primary manifestation is the disintegration of energy-stressed water crystal structures with the subsequent phenomena of the disappearance of the energy-information connection between biopolymers, after which biological disintegration begins.

All this demonstrates that the structure and functioning of the molecular level of the organization of living biological systems of various levels of complexity, including the human body, is determined and implemented due to the course of magnetoelectric processes. The initial quantum mechanical features of substances determine the subsequent magnetic and electrostatic qualities of tissue molecules, and the chemistry of biological molecules is a secondary property that is derived from their magnetoelectric and energy parameters, since:

- All living biological systems, including the human body, have an electromagnetic nature of structure, consist of resonating electromagnetic wave field structures-oscillators and are united by electromagnetic field interactions;

- All living biological systems, including the human body, exhibit the properties of wave-particle duality and can be modeled at the molecular level in the form of resulting interfering electromagnetic wave packets, in the nodes of which there are atoms that are a source of wave generation, which causes the presence of wave characteristics of structures at the macro level of organizations;

- All chemical reactions that occur in living biological systems, including the human body, have an electromagnetic nature and are the result of the manifestation of field and electromagnetic interactions of substances in them;

- Since the atoms that form molecules are essentially energy, all living biological systems, including the human body, can be considered at the micro level of their structure as a form of fundamentally organized energy, which is characterized by the total energy characteristics of the components of the microcosm that form it;

- The phenomenon of life at the molecular level is due to the constant course of electromagnetic processes that ensure the structural and functional integrity of a living biological system, and which cease with the onset of its death;

- Water is a mandatory component of ensuring the life of a biological system, as it creates conditions for non-chemical information-energy cooperation of biological molecules of the body.

Thus, the primacy of magnetoelectric interaction at the molecular level is the root cause of the existence and adequate functioning of living biological systems of various levels of complexity, including the human body, since the vital activity and functioning of living biological systems in the corridor of the physiological norm (called health) is completely determined by the magnetoelectric support of the molecules of its organism according to the participation of energetically changed water environment. It is important to note that, based on these positions, life and health acquire new characteristics of their conceptual apparatus, since they should be described as the state of having adequate (which exactly – to be specified in the future) levels of magnetoelectric energy processes between biomolecules, which objectively manifested at the macro level by the normal level of metabolism, functioning of tissues and organs of the human body according to the magneto-electrochemical theory. Accordingly, it is logical to consider the disease as a disorder of the magnetoelectric state of biomolecular structures, and death is their complete absence, and the human body is one of the forms of the magneto-electrochemical organization of biological matter on Earth.

This radically deepens the understanding of the structure, organization, and functioning of the human body, fundamentally changes the nature of the interpretation of biological processes that occur in the human body in normal and pathological conditions, expands the possibilities of in-depth study and description of the pathogenesis of diseases of the human body, and demonstrates the need for a paradigmatic transition from the electrochemical concept of exchange substances to magneto-electrochemical.

The magneto-electrochemical theory of metabolism is of great importance for the theoretical branches of medicine. Life can be understood as an electro-magneto-biochemical process in which information is exchanged. And this process is disrupted when a disease occurs, or even a disease is the result of a violation of these processes. Therefore, it is important to continue theoretical studies of the pathogenesis of diseases at the quantum level. It is important to integrate the results obtained into the relevant theoretical branches of medicine.

4. Conclusions

The life of a biological system is a process of magnetoelectric activation of its biomolecules, which starts and ensures their biochemical activity (coherent energy channeling – biochemical soliton flow) and determines structural integrity in their collective interaction of a single organism (transportation of soliton by water-energized structures – controlling soliton flow).

Modern deepening of fundamental knowledge to the level of the course of magnetoelectric processes at the molecular level in living biological systems is expedient to be fully integrated into medical science with a change of the electrochemical paradigm of metabolism to a magneto-electrochemical one. This is necessary because a true understanding of the etiology of diseases of internal organs/NCDs requires a clear and correct understanding of what actually happens to the biopolymers of the human body at the molecular level, what transformations occur with them under different conditions and under the influence of various factors of the internal environment, which are determined by the style human life (nature of nutrition, level of physical activity, etc.).

Knowledge and understanding of the quantum-mechanical features of the functioning of biopolymers in living systems, the understanding of the essence of their energy functioning, the organization of the form and role of electromagnetic components is clearly the next step to deepening the fundamental knowledge of the pathogenesis of diseases of internal organs with a further approach to optimize their treatment and prevention.

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Conflict of interest

The author has no conflict of interest to declare.
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Predicting Dengue in the Philippines using an Artificial Neural Network

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ABSTRACT

Dengue fever is an infectious disease caused by *Flavivirus* transmitted by the Aedes mosquito. This disease predominantly occurs in the tropical and subtropical regions. With no specific treatment, the most effective way to prevent dengue is vector control. The dependence of the Aedes mosquito population on meteorological variables make the prediction of dengue infection possible using conventional statistical and epidemiologic models. However, with the increasing average global temperature, the predictability of these models may be lessened employing the need for an artificial neural network. This study uses an artificial neural network to predict the dengue incidence in the entire Philippines with humidity, rainfall, and temperature as independent variables. All generated predictive models have mean squared logarithmic error of less than 0.04.

KEYWORDS

Dengue, Philippines, artificial neural network, climate change

1. Introduction

wDengue fever is an infectious disease caused by *Flavivirus* transmitted by the vector mosquito Aedes. The dengue virus has 4 serotypes (DENV-1, DENV-2, DENV-3, DENV-4) which mostly occur in the urban and suburban areas in tropical and subtropical regions. It is estimated that 50 million people contract a dengue infection globally per annum. In the Philippines, an estimated 170,000 cases occur annually on average but in 2022, there are 220,705 dengue cases tallied. Currently, there are no specific treatments for dengue and the most effective way to prevent it is through vector control.[1–7]

The two most important vectors for dengue transmission are: Aedes aegypti and Aedes albopictus. The life cycle of these vectors is divided into egg, larva, pupa, and adult stages; which is heavily influenced by different meteorological, geological, and anthropological variables. The typical adult mosquito lays eggs just above the waterline of a stagnant water. It takes 48 hours in a warm, humid environment for the embryo to develop. Once developed, the eggs are tolerant to desiccation up to more than a year.[1] The adult mosquito then typically emerges after 10 days. The adult female mates and feeds on blood necessary for egg maturation. The blood meal biting activity takes place in the morning and afternoon.[8,9] However, blood meals also do occur at night in lighted rooms.

Temperature, rainfall, and relative humidity affect the transmission of dengue.[10] Annual rainfall of more than 200 cm provides the conducive environment for the growth of the Aedes mosquito population.[11] The Aedes mosquito population growth is more abundant up to 500 meters above sea level, although they can thrive up to 1,200 meters.[12] Climate variability strongly influences the dengue epidemic. A maximal temperature of more than 32°C and a maximal relative humidity of more than 95% influence the incubation period, feeding frequency, and longevity of the Aedes mosquito.[13] There is low mosquito mortality at temperatures between 15°C to 30°C. Pupae development occurs in less than 1 day at 32°C to 34°C, but takes 4 days at 22°C.[14–18]

With the dependence of the Aedes mosquito population dynamics on weather, variables such as climate change, undoubtedly, will have an impact on the spread of dengue infection. It is estimated that the average global temperature will increase by 2°C to 4.5°C by the year 2100.[19] There are many studies that predict dengue infection using weather variables. Different statistical models were employed such as: Poisson regression, autoregressive integrated moving average (ARIMA), seasonal autoregressive integrated moving average (SARIMA),[20,23] negative binomial, quasi-likelihood regression,[20,21] and distributed lag non-linear model (DLNM).[22] There are also attempts to employ machine learning techniques such as random forest and gradient boosting to make dengue infection predictions.[24–26] These predictive models have varying degrees of predictions on dengue incidence.

With the ease of accessibility and less expensive computing power available nowadays, there is increased application of artificial neural networks in making predictions in different areas of science. Coupled with the use of programming and software packages such as Python and TensorFlow, this research will attempt to predict dengue incidence in the Philippines using an artificial neural network

2. Materials and Methods

Study Setting

The study was conducted in all 17 administrative regions in the Philippines: Region 1 to 12 (including 4-A and 4-B), Autonomous Region of Muslim Mindanao (ARMM), Cordillera Autonomous Region (CAR), and CARAGA. The Philippines has two seasons: wet (June to October) and dry (November to May). However, there are four climate types in the Philippines based on modified Coronas classification: Type I (dry from November to April, we from May to October), Type II (seasonal rainfall from November to December), Type III (same as Type I but with maximum rainfall from May to October), and Type IV (evenly distributed rainfall annually).[27]

Data Collection

Data on dengue incidence is freely available on the Department of Health (DOH) website as PDF reports. These dengue reports are the sum of all case definitions of dengue cases with or without the confirmation of polymerase chain reaction. This is attributed to the limited resources available especially in remote and rural areas where dengue case definition is based on signs and symptoms only. The meteorological data such as: humidity (as %), rainfall (as mm), temperature (as °C) were requested from the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) and were received as Excel files. Missing dengue values were addressed by getting the average value from the same region from different years but of the same week time frame. Missing meteorological values were filled using the average value from the same weather station and from a different year period but of the same month time frame. These files from DOH and PAGASA were encoded to comma separated value (CSV) files for data analysis. Dengue data were reported on a weekly basis from each administrative region while the meteorological data were reported on a monthly basis from each weather station where most administrative regions have two to three weather stations. To reconcile these differences, the weekly tally of dengue was summed up to reflect a monthly value while the meteorological values were averaged out from the weather stations to reflect the regional value. The data on dengue and weather variables are from the year 2013 to 2018.

Artificial Neural Network

Data were analyzed in Python 3 using Jupyter Notebook as the interface while also employing several libraries such as Numpy, Pandas, Keras, and TensorFlow. A training and test set were created for each region. The training set consists of data from 2013 to 2017 and the test set contains data from 2018. An artificial neural network was created with 1 input layer, 6 hidden layers, and 1 output layer, as shown in Figure 1. The input layer is composed of humidity, rainfall, and temperature. The output layer is composed of dengue incidence.

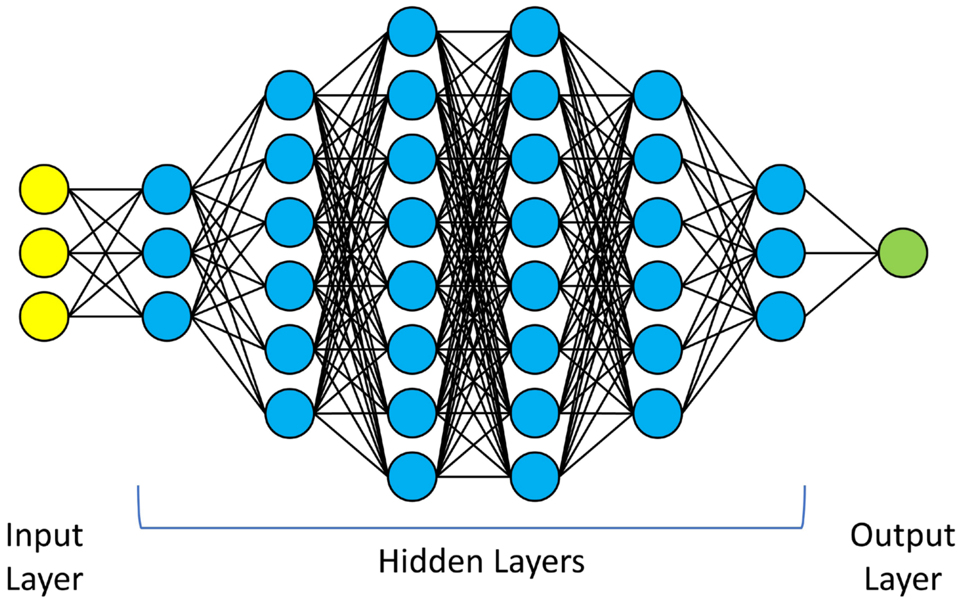


Figure 1: Artificial neural network architecture

The artificial neural network uses rectified linear unit (ReLU) as the activation function and adaptive moment estimation (Adam) as an optimizer. It was trained with batch size of 24 in 500 epochs for each administrative region. The created model from the training set was used to predict the dengue values in the test set. The prediction was evaluated using mean squared logarithmic error (MSLE).

3. Results

Table 1 shows the descriptive statistics of monthly humidity, rainfall, temperature, and dengue incidence for each administrative region. ARMM has the lowest average dengue incidence of 157.26 while Region 4-A has the highest at 2,616.97. NCR has the lowest average humidity of 75.24% while CAR has the highest at 87.25%. Region 12 has the lowest average rainfall of 81.99 mm, while Region 7 has the highest at 1,130.61 mm. CAR has the lowest average temperature of 19.47°C, while Region 11 has the highest at 28.7°C.

Table 1: Descriptive statistics of monthly humidity, rainfall, temperature, and dengue incidence in each administrative region of the Philippines (2013 to 2018).

Region	*Humidity (%)*				*Rainfall (mm)*				*Temperature (°C)*				*Dengue Incidence*			
	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
ARMM	76	2.69	68	80	160.07	90.76	2.8	393.4	28.22	0.66	26.8	29.9	157.26	80.76	16	495
CAR	87.25	4.12	78	96	307.52	400.32	0	1822.6	19.47	1.01	15.8	21.4	681.99	670.35	58	2965
CARAGA	82.74	3.11	76	89.33	298.01	200.62	47.4	1126.47	28.10	1.02	24.97	30.5	812.79	506.97	144	2574
NCR	75.24	7.16	61.33	89	195.18	201.78	0.1	890.6	28.45	1.26	25.03	30.97	1569.15	1329.74	78	7977
1	79.41	4.63	71.33	88.67	198.22	274.02	0	1069.93	27.61	1.22	23.87	29.9	1024.88	1013.94	99	4917.99
2	84.36	2.27	79.8	88.82	171.85	125.91	8.56	526.84	26.31	2.29	21.62	29.7	697.51	786.54	57	3821
3	79.70	3.93	71.67	87.83	249.67	189.07	23.72	803.02	27.75	1.21	24.58	30.27	2515.51	2202.24	139.98	13134
4-A	83.92	2.62	77	88.33	237.88	154.1	13.08	540.5	26.91	1.26	23.82	29.32	2616.97	2280.62	197.9	14568.15
4-B	81.37	3.17	73.67	86.83	183.92	139.7	12.08	599.25	27.93	0.75	26.30	29.82	769.62	580.72	102.5	3298.83
5	84.67	2.02	81	88.5	248.7	163.84	23.35	733.18	27.71	1.06	25.15	29.58	234.18	130.55	36	500
6	81.03	2.15	76	86.48	176.2	120.26	3	476.5	28.42	0.8	26.2	30.2	1424.78	1391.65	147	6924
7	81.52	2.75	75	86.09	1130.61	73.88	1.53	271.23	28.09	0.8	25.9	29.73	1687.05	1291.86	102	5307.99
8	85.02	2.56	78.17	90.53	297.37	199.86	33.17	1045.8	27.74	0.89	25.41	29.27	442.98	298.53	31.02	1840.02
9	81.66	2.32	75	86	163.37	103.66	2.65	522.2	28.3	0.47	26.6	29.3	518.76	216.22	184	1155
10	84.73	2.66	77.5	89.5	180.46	103.38	2.9	443.95	26.11	0.68	24.3	27.65	1078.71	699.18	344	3414
11	78.7	3.36	70	85	161.47	94.14	14.2	430.5	28.7	0.69	26.5	30.6	599.91	388.52	116	2581
12	77.53	4.72	65	84	81.99	51.8	0.1	256.8	27.99	0.93	26.5	31.1	1019.04	573.58	278	3443

ARMM – Autonomous Region in Muslim Mindanao
CAR – Cordillera Autonomous Region
NCR – National Capital Region

The Python code implementation of the artificial neural network in Figure 1 is shown below:

```
ann = tf.keras.models.Sequential()
ann.add(tf.keras.layers.Dense(units=3, activation='relu'))
ann.add(tf.keras.layers.Dense(units=6, activation='relu'))
ann.add(tf.keras.layers.Dense(units=8, activation='relu'))
ann.add(tf.keras.layers.Dense(units=8, activation='relu'))
ann.add(tf.keras.layers.Dense(units=6, activation='relu'))
ann.add(tf.keras.layers.Dense(units=3, activation='relu'))
ann.add(tf.keras.layers.Dense(units=1))
ann.compile(optimizer = 'adam', loss = 'mean_squared_logarithmic_error')
ann.fit(train_climate, train_dengue, batch_size = 24, epochs = 500)
```

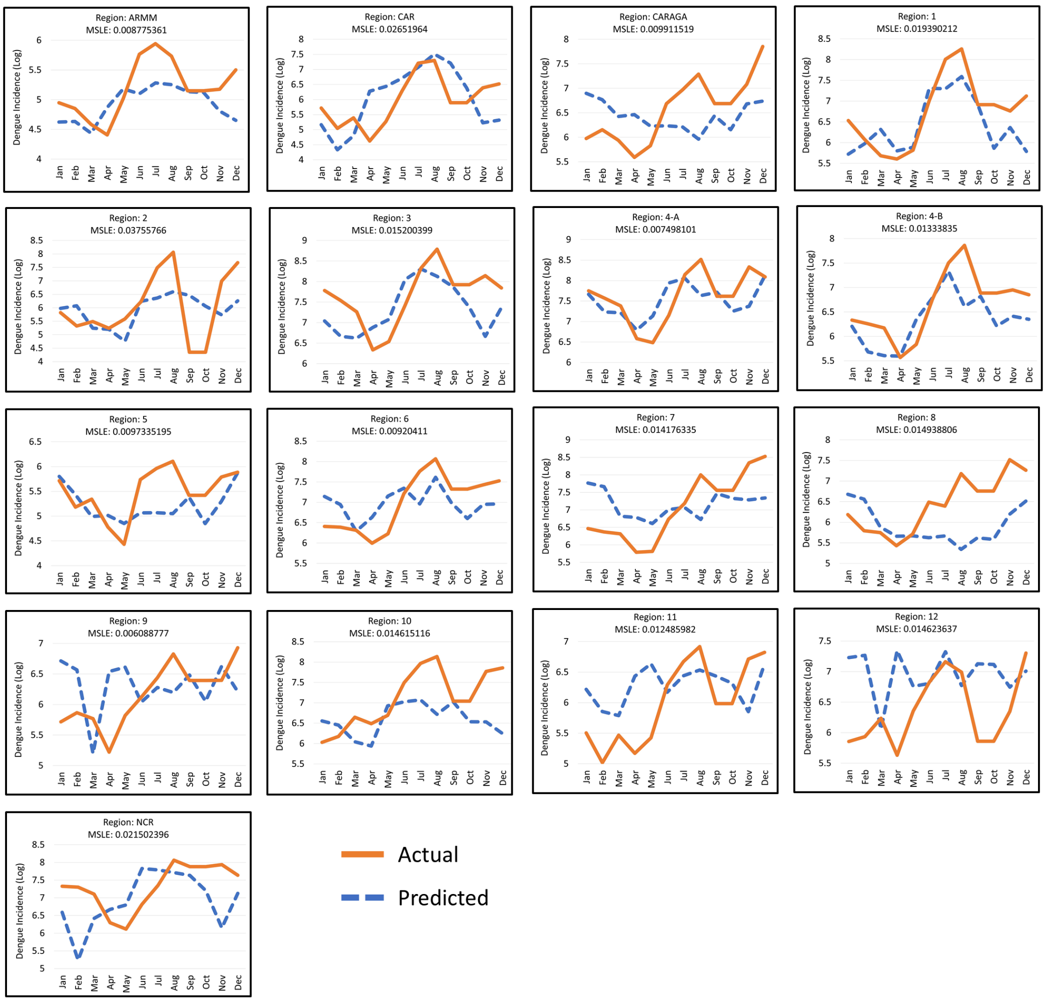
The resulting predictive models from the artificial neural network have a mean squared logarithmic error (MSLE) of less than 0.04 in all administrative regions. Table 2 provides the values of MSLE in each region. Region 9 has the lowest MSLE of 0.006, while Region 2 has the highest at 0.0376. Figure 2 provides a comparison of the actual and predicted dengue incidence in each administrative region using the generated predictive models.

Table 2: Mean squared logarithmic error of each administrative region in the Philippines.

Region	*MSLE*
ARMM	0.008775361
CAR	0.020651964
CARAGA	0.009911519
NCR	0.021502396
Region 1	0.019390212
Region 2	0.03755766
Region 3	0.015200399
Region 4-A	0.007498101
Region 4-B	0.01333835
Region 5	0.0097335195
Region 6	0.009920411

Region	*MSLE*
Region 6	0.009920411
Region 7	0.014176335
Region 8	0.014938806
Region 9	0.006088777
Region 10	0.014615116
Region 11	0.012485982
Region 12	0.014623637

Figure 2: Comparison of the actual and predicted dengue incidence in all administrative regions in the Philippines (2018).



4. Disscussion

Although there is a low MSLE in each administrative region, visual inspection of the actual and predicted dengue incidence revealed that there are predictive models that are better than the other. For example, the predictive model of Regions 4-A and 4-B provide really close predicted values to the actual values, especially at the peak incidence, while the predictive model of Region 2, 5 and 12 provide predicted values far from the actual values. The importance of using MSLE is that it uses the percentage difference between the log-transformed actual and predicted values. Small and big differences are treated the same. It should be noted that predictive models are unique to each region since they are trained separately and have their own artificial neural network even though they have the same network architecture. The administrative regions that have visually performed well are: ARMM, CAR, Region 1, 3, 4-A, and 4-B. The predictive models also had inefficiencies in identifying the peak dengue incidence which are evident in Region 2, 5, 10, and ARMM. The worst predictive models are in CARAGA, NCR and Regions 2, 7, 8, 9, 11, and 12.

Predictions made by an artificial neural network are different from statistical or epidemiological modeling. Artificial neural networks utilize a collection of artificial neurons that take the weighted inputs, pass it through an activation function, to produce an output.[28] In this study, there are three inputs: humidity, rainfall, and temperature; and there is one output which is a single value of dengue incidence. Given the three input values, and passing these values to an artificial neural network, what will be the predicted output. The rectified linear unit (ReLU)[29] is the activation function used to avoid having negative values for the dengue incidence. These multiple units and layers of computation can make better predictions.

There are several limitations that were encountered in this study. The study encompasses entire administrative regions, which means micro-climate variability from each city or municipality can be a contributing factor to the dengue incidence. The meteorological variables provided by PAGASA were limited to three (humidity, rainfall, temperature), although the request includes flood occurrence and average sunlight. These three significant meteorological variables appeared in the research studies done in the Philippines: one was done using general additive modeling, SARIMA, random forest, and gradient boosting in the national capital region; while the other one used quasi-Poisson regression combined with distributed lag nonlinear model in Davao region only.[24,30] Flood occurrence may help in dengue incidence prediction because flushing, which occurs when the water levels exceed the mosquito breeding site's threshold and wash away the mosquito larvae, can potentially reduce dengue incidence.[31] Average sunlight has an inconclusive relationship to dengue incidence using statistical model.[32] However, this might be proven otherwise if artificial neural network is used because it does not assume that the data has collinearity or is normally distributed unlike most common statistical models.

The impact of climate change can influence the transmission of dengue to other places other than the tropical and subtropical regions. By the end of this century, dengue epidemic potential for Aedes aegypti could occur in 10 European cities (Madeira, Malaga, Athens, Rome, Nice, Paris, London, Amsterdam, Berlin, Stockholm) with a continued current rate of greenhouse gas emission.[33] The complexities of weather and climate influences on dengue transmission are not easily modelled with a statistical approach[34] which makes an artificial neural network more helpful in predicting dengue incidence more accurately.

4. Conclusion

Close fidelity on the predicted and actual dengue incidence in some administrative regions in the Philippines prove that artificial neural networks can be implemented for predicting dengue. Further work can be done in optimizing the artificial neural network architecture: number of neurons, number of hidden layers, and additional input meteorological variables (flood occurrence, average sunlight). It is recommended that future research be focused on the city or municipal level of dengue cases and the

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Bias – The Achilles Heel of Artificial Intelligence in Healthcare

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ABSTRACT

The field of artificial intelligence (AI) has evolved considerably since the end of the 20th century. While this technology shows great promise and potential to solve daily tasks, the question of fairness of predictions and recommendations decisions by AI models needs to be addressed. There have been examples of AI models performing unfair and creating prejudiced decisions, which has led to a growing need to be able to know 'why' and 'how' these models make decisions. This is particularly important in the healthcare field, where the outcomes of AI models play a decisive role in the well-being of patients with potentially life-or-death impact. In addition, a system for detecting and mitigating biases needs to be developed so that the advantages of AI can be utilized in healthcare. A scoping review was carried out to study the source, nature and impact of biases of AI models. Results showed that bias can be data-driven, algorithmic or introduced by humans. These biases propagate deeply rooted societal inequality, misdiagnose patient groups, and further perpetuate global health inequity. Mitigation of biases is proposed at various stages of the machine learning pipeline. These strategies use techniques such as scrutinizing the way data is collected, better representation of patient groups, optimal training of the model and evaluating model performance. In conclusion, it must be ascertained that AI decisions are free of unwarranted biases and justly fair. Therefore, in an effort to mitigate bias, AI models should adopt systems that contain techniques in which biases can be predicted, measured, explained and then mitigated.

KEYWORDS

Artificial intelligence, machine learning, bias, explainability, interpretability, explainable AI

1. Introduction

Artificial intelligence (AI) technology is pervasive in many industries today. As the term 'intelligence' rightly suggests, this technology boasts of 'smart machines' performing mundane as well as complicated tasks, otherwise performed by humans. AI technology shows a lot of promise in the healthcare industry and is tasked with performing sensitive operations. When AI is used in the healthcare field, it must perform its operations with impeccable accuracy. However, the existence of bias in AI models thwarts this effort, resulting in distrust and a lack of confidence in their adoption. Therefore, the issue of bias

2. Background

Artificial intelligence (AI) can be seen at work in a plethora of applications in smartphones, the internet of things and much more. The chatbot ChatGPT is an impressive language model in versatility and capability.[1] An overview of some further AI applications in various industries is provided in Table 1.

Table 1: Overview of some applications using artificial intelligence

Field	*Example*
Clinical Medicine	Intelligent assistants in intensive care units that collect and process electronic data including in-hospital mortality, readmission, length of stay[2] Neural networks that detect patterns in radiographic images and H&E stained slides[3]
Transport	Smart traffic sensors that determine traffic conditions, identify the severity of traffic incidents, predict bus arrival times[4] Autonomous vehicles that incorporate AI software[4]
Banking	Algorithms that check genuine credit card transactions, block risky transactions, verify client identity, interact via chatbots, retrieve information from documents and use robo-advisors[5]
Marketing	Technologies that enable voice purchase requests, virtual assistants, authorization of payments through face recognition[6] Digital assistants and chatbots that facilitate decision-making and offer customized online shopping experiences[6]

AI encompasses a group of algorithms which are capable of solving problems that usually require human intelligence. AI includes machine learning (learns without being explicitly programmed) and a further subclass of machine learning includes deep learning (uses artificial neural networks to learn). Due to its wide capability and consistent decision-making, AI performs on par with humans or in some cases, better than humans.[7] AI has a particular role in healthcare that can be divided into administrative and clinical applications. The focus of using AI in healthcare is to enhance the analysis of medical data, improve treatment outcomes and the efficacy of the healthcare industry.[8] While humans are subject to conjecture, tradition, convenience and habit in clinical decision making, decision rules created with AI support a predictable behavior and have shown to reduce clinical error.[3,7] Researchers found that human cognitive biases can lead to poor agreement between operators (due to variance in cognitive reasoning, and different individual experience) and this vulnerability from human bias can be overcome by AI.[9] Therefore, AI can be used for sensitive tasks in healthcare such as clinical prediction, decision-making and public health policymaking for the benefit of society.[7,9] Table 2 lists some of the uses of AI in healthcare.

Table 2: Clinical uses of AI in healthcare [3,8,10]

- Provide recommendations for the prescription of medicines, adherence to clinical practice guidelines
- Analyze CT scans, provide recommendations for radiation treatment
- Diagnose malignancies from photographs, histopathological slides
- Predict eye diseases from retinal scans
- Predict a risk of sepsis
- Assess risk and predict cardiovascular events
- Automate sleep scoring in sleep medicine
- Identify drug-drug interactions and develop personalized treatments
- Improve workflow, reduce healthcare costs, shorten hospital waiting times

AI and the concept of bias:

However, the role of AI is not infallible. There are anecdotal examples of ChatGPT providing faulty answers to relatively simple questions.[11] There have also been a number of case reports where AI systems have been faulty in their decision-making and even suspected of being 'prejudiced'. This bias is defined from two perspectives – statistical (error with the use of statistical analysis) and cognitive (innate or a learned tendency in favor of or against an individual or group, based on preconceived convictions or preferences).[9,12] Due to the potential of AI in a sensitive area such as health, biased AI algorithms can have serious implications on health outcomes. Obermeyer, Powers, Vogeli and Mullainathan[13] reported the case of an algorithm used by health systems and payers (organizations responsible for paying for healthcare services) to determine patients for high-risk care management. The algorithm made use of a proxy 'total medical expenditures' in order to determine the 'health needs' of a patient. However, this relationship is often not true since it is possible that a person in need of healthcare may not have spent on medical expenses in the past. It was found that the bias was detected in black patients who had lesser medical expenses, even though they were as sick as white patients. This led to the conclusion that the prediction of costs led to a racial bias. Other examples include AI systems exhibiting bias at interpreting chest radiographs (trained on gender-imbalanced data) and detecting skin cancers (trained on race-imbalanced data).[14]

It is therefore critical that AI systems are not biased in their outcomes, while providing a distinct advantage in the healthcare field. The sources of bias and their consequences should therefore be studied. Vokinger, Feuerriegel and Kesselheim[15] advocated an approach to check for bias along the machine learning (ML) pipeline that consists of the following stages:

- Collection of clinical data, preparation of data for further steps in model development;
- Training of machine learning models to perform an intended task;
- Evaluation of performance of the machine learning model;
- Authorization and deployment of the machine learning model in clinical practice.

Barclay and Zuanazzi[16] describe additional checkpoints along the machine learning pipeline that include: data collection, annotation, modelling, clinical validation, product integration, certification and deployment & service. Using the machine learning pipeline, it is probable that bias can arise at any of the stages.[15–17] The use of checkpoints along the ML pipeline also serves to provide tools to mitigate the biases at their source. A further concern in using AI for healthcare involves the use of 'black boxes' in deep learning models.[18] Since the working of these 'black boxes' remains esoteric, it further disseminates the notion of bias. There are attempts to introduce techniques of 'explainability' and 'interpretability' in order to be able to understand the functioning of these models. AI models for healthcare do not differ from AI models used in other industries. However, the outcomes of AI models used in healthcare have relatively serious consequences if they are flawed (for example, the case reported by Obermayer et al.[13]). Consequently, any approach to mitigate bias must also be researched in order to apply it to AI models for healthcare. This research was done to determine the source of bias in algorithms designed for healthcare and the possibilities for the mitigation of these biases.

3. Methodology

A scoping review of literature on bias in AI algorithms used in healthcare was carried out to answer the following three questions:

1. What are the sources of bias in AI algorithms designed for healthcare and medicine?

2. What are the consequences and pitfalls of biased AI-based medical solutions in healthcare?

3. Can these biases be located and mitigated?

The databases of Google Scholar, PubMed and Scopus were explored using the following keywords: "bias AND (artificial intelligence OR AI OR machine learning) AND (health OR medicine)". The search was carried out to retrieve articles from the databases from the last five years up to March 2023. The selection of articles was following the PRISMA19 model (Figure 1).

The inclusion criteria encompassed only those articles that delineated the use of AI models for healthcare in accordance with the three research questions. Papers that reviewed the use of AI models for specific clinical use cases and those that provided a view of bias in AI and other ML models, but were not specific to healthcare were excluded.

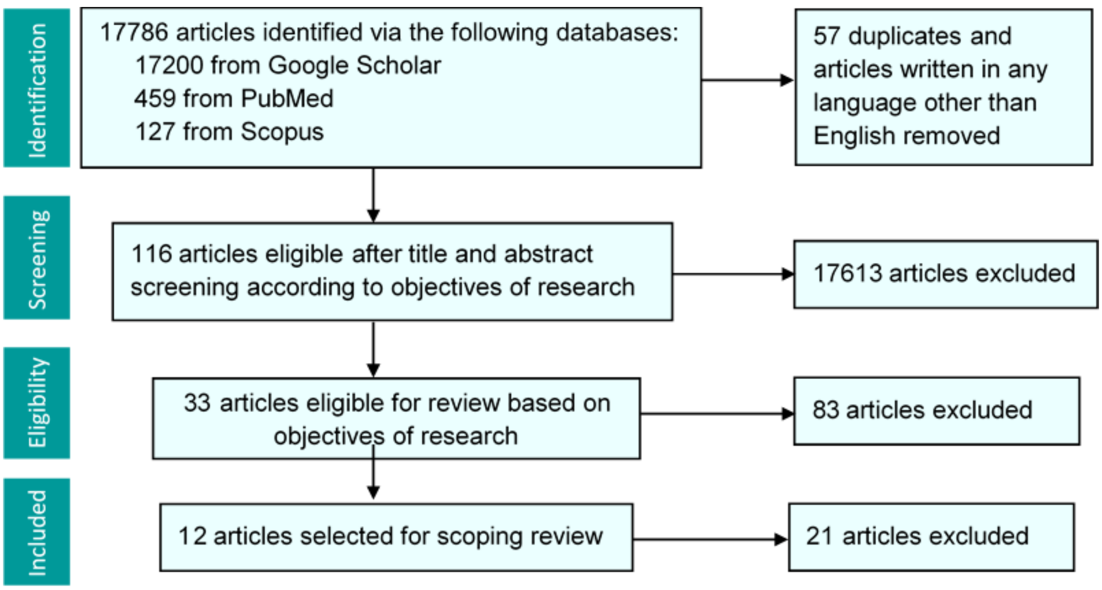

Figure 1: PRISMA model[19] showing the inclusion and exclusion of records

At the step of identification, only articles written in English were selected. If an article was retrieved from more than one database (i.e. a duplicate), only one such article was retained. The selected articles were then screened by analyzing the title and abstract. At this stage, articles that did not contain the keywords in the title and abstract were excluded. An article was then considered as eligible if the content provided information regarding the occurrence of bias in AI in models, their consequences as well as approaches to mitigation of these biases. Articles that did not pertain to answer any of the three research questions were excluded. In the final phase of selection, only those articles were included that provided information to either two or more questions of this study.

The twelve articles that were selected were reviewed and analyzed. In order to answer the question on the source of biases, the different types of biases encountered in AI models were noted. Similarly, the consequences of these biases and the approaches to mitigation were extracted. Retrieved information was categorized according to the three questions of this research, viz. sources of bias in AI algorithms, consequences and pitfalls of biased AI-based medical solutions in healthcare and mitigation of biases. The extracted information was categorized to follow the machine learning pipeline.

4. Results

The analysis of the selected articles revealed the following key points. These points are divided into sources of bias in AI algorithms, consequences and pitfalls of biased AI-based medical solutions in healthcare and location and mitigation of biases. In each of these three sections, the retrieved data is further categorized according to the stages of the machine learning pipeline.

1. **Sources of bias in AI algorithms:**
   The sources of bias in algorithms designed for healthcare can be categorized as shown in Table 3:

Table 3: Sources of bias in AI algorithms for health

Category	*Example*
According to nature of bias[20,21]	Social bias or human-centric elements of bias Statistical bias or methodology-centric elements of bias
According to origin of bias[2,9,20]	Data-driven: Seen in models trained on homogenous / imbalanced / non-representative datasets that suffer from a lack of diversity and missing data Human: Arises from the cognitive ability and accidental behavior that humans are prone to possess Algorithmic: Emerges from outcomes of systematic errors in AI-based systems that affects their ability to classify, estimate risk levels, or make predictions
According to introduction at stages of machine learning pipeline[15]	Stage of data collection Stage of data selection Stage of model development and training Stage of model evaluation Stage of model deployment

The biases introduced at the various stages of model development were further elaborated as follows:

Biases and factors contributing to risk of bias introduced at the stage of data collection: This first checkpoint is the source of data that were used to train the model. Issues included the exclusion of data from under-represented groups of the human population, other missing data, inaccessible data and metadata.[2,15,20–22] Such data is, therefore, not diversified, incomplete and therefore does not represent the entire population. It was also unclear as to how much data the AI system needs in order to provide a correct decision. 'Sampling bias', on the other hand, referred to the use of an inadequate number of cases in the dataset.[2,12,15,23] There was also the problem of data being collected as 'interesting cases' which cannot represent the percentage of normal and abnormal cases in a population (sample selection bias).[3] Unequal distribution also occurred when some patients access more health services, visit multiple hospitals and patient portals more frequently than others, that constitutes to 'misclassification' and adds to bias introduced at this stage.[2,23] Additionally, it was noted that an inadequate amount of data is partly due to restrictions imposed in the access and collection of data for training of algorithms.[7]

Biases introduced at the stage of data selection: The errors in data selection were shown to have a human factor. The bias and errors introduced by humans were due to errant measurements caused by the intrinsic and unintentional habits of people who handle data.[9] Furthermore, the training of algorithms using such data resulted in 'faulty algorithms' that perpetuated societal, racial, and gender (historical) bias.[9,23] Another aspect was the limited amount of correctly labelled data and consequently the use of data with no ground truth ascribed to it that led to poor reproducibility.[3]

Biases introduced at the stage of model development and training: The stage of model development and training represented a significant number of biases. At first, biases introduced in the stages of data collection and selection were further embedded into algorithms.[9,15] Implicit bias was described as a situation that resulted from unforeseen correlations between variables in a model.[12] The use of a biased proxy or a statistically biased estimator resulted in an incorrect, fallacious prediction that was called 'label choice bias' or 'mislabeling'.[22] Similarly, the uneven distribution of features across different groups caused 'feature selection bias' or 'feature leakage'.[21] The annotation of data also led to bias if there was a consistent error.[21,24] Problems of 'underfitting' of the model resulted in the initial stage when the model was untrained or only partially learning information needed to provide an output.[24] On the other hand, an 'overfitting/overtrained' model included salient features and noise that generated high error rates.[24,25] Apart from these biases, the 'aging' of an algorithm and the passage of time since it was trained deteriorates it and resulted in 'temporal bias'.[3,21,23] Unconscious bias and power imbalances also have a human factor when algorithms were designed to solve apparent problems that are neither necessary to be automated nor are considered to be essential by health providers and patients.[23]

Biases introduced at the stage of model evaluation: The stage of model evaluation is a useful checkpoint for the detection as well as mitigation of bias. However, there are instances when the metrics used to evaluate the model resulted in other biased outcomes. It was noted that the boosting of true-positives and false-negatives resulted in a good model for screening, but did not function well for diagnosis.[3,22] Rebalancing of data was another approach to include an equal number of cases and controls, however, this led to overdiagnosis of cases.[3] Another concern was the 'metric/ranking selection bias' where there was a difference between the metrics used to evaluate the model and ill-defined standards for clinical quality.[21] Machine learning models based on artificial neural networks were considered to be 'black boxes' in that any errors and biases in the predictions of the model were hard to detect. [2,3,23]

Biases introduced at the stage of model deployment: A number of biases were attributed to machine learning models after their deployment and clinical implementation. When a model was applied to a population that had different characteristics from the characteristics of the population that was used to train the model, it was shown to exhibit 'population bias' or 'selection bias'.[25] Other terms to describe these circumstances were 'distributional shift' and 'out of sample input'.[3] Human factors contributing to bias at this stage occurred when operators misinterpreted the algorithm's decision. It was noted that 'automation bias' was a phenomenon where a clinician accepted the decision/prediction of an automated system and avoided looking for confirmation (automation complacency).[3,20]

2. Consequences and pitfalls of biased AI-based medical solutions in healthcare:

The consequences and pitfalls of biased algorithms at the various stages of model development were described as follows:

Consequences of biases introduced at the stage of data collection and selection: The use of biased AI algorithms in healthcare was found shown to result in a number of untoward consequences. Bias in data collection and selection resulted in the demonstration of inherent, human-associated and hidden societal biases.[3,9] It was observed from the retrieved papers that misrepresentation of patient groups was a common consequence that led to prejudiced outcomes such as misdiagnoses and unequal treatment of these groups.[9,20] Patients with less access to healthcare had insufficient information stored in electronic health records that led to delayed diagnosis.[2,20] With such glaring discrepancies in the diagnoses of patient groups, it was noted that clinical AI for diverse populations is not guaranteed.[7,9,12] A major finding was the disproportion in the retrieval and use of data from all global regions. AI solutions were more applicable to populations from data-rich regions than those populations from data-poor regions.[7,12] Missing data can lead to unsuitable insurance plans, if they are based on misrepresented health records.[2,20] The use of datasets with a small number of datapoints resulted in unreliability of the model.[23] Data-driven biases were further propagated to the training and development stages of the machine learning pipeline and continue to incorporate unfair predictions and decisions which led to inappropriate treatments.[23] Ethical issues may then arise if AI systems (with data-driven biases) autonomously triage patients to access clinical services.[3]

Consequences of biases introduced at the stage of model development and training: The training of models using datasets with missing data had consequences in that it was not beneficial to patients who were not represented in the dataset.[2] The degradation of the quality of algorithms was also found to be invalid in clinical scenarios.[3] Algorithms trained on insufficient data provided only the mean of the cases and did not account for unique cases (underestimation).[2] The use of data from multiple centers had the potential to cause highly biased datasets.[21] Validity was a major turning point in that models that inherited biases from the previous stage were not externally valid. Selection bias was encountered at this stage and had a profound effect on external validity. The outcomes of such biased ML models (that are trained on a particular study population) are not valid when applied to the target population.[25] The use of 'black box' models do not show transparency in their working and, therefore, make the interpretation of decisions difficult. [2,3,25]

Consequences of biases introduced at the stage of model evaluation: In evaluating ML models, the use of metrics such as 'accuracy' may not reflect real-world situations. Therefore, only using the accuracy as a performance metric to optimize the model led to the creation of faulty models.[3] The use of black box models, where there is no transparency of the model, translates to a loss of confidence and lack of trust by users.[23] A model that consistently produces the same set of results with errors can reflect on the quality of care.[23]

Consequences of biases introduced at the stage of model deployment: On clinical deployment, the difference in characteristics of data used for training the AI model and the characteristics of the population for whom the AI system will be used was questioned.[23] Such models perform inefficiently and are not useful. Algorithms that were designed to tackle problems that are not clinically useful or time-saving, resulted in an unnecessary waste of resources.[23] The AI systems were also subject to the individual interpretations of humans which could further introduce more biases and erroneous predictions and decisions. Automation bias when supplemented by previous biases further questions the reliability and validity of the AI systems.[3] Another aspect to consider is the issue of responsibility when biased algorithms are used.[23]

3. Location and mitigation of biases:

The mitigation of biases is best attempted along the stages of the machine learning pipeline. These mitigation strategies were as follows:

Mitigation of biases at the stage of data collection and data selection: A broader inclusion of patient demographic groups in terms of age, gender, race and ethnicity is an attempt to address biased datasets.[2,7,9,20,21] The sharing of data avoids the monopoly of data-rich databases and contribute to a wider representation of the population.[7] There is also the need to define the target population, capture data from diverse populations and normalize data taken from different sources.[2] Use of classifier performance for the dataset can be used to detect representation bias.[22] Some studies recommended the use of reporting tools like the PROBAST (prediction model risk of bias assessment tool) which functions to check the performance level of models, risk of bias and the suitability of its use in a particular population.[15,20]

Mitigation of biases at the stage of model development and training: Imbalanced data can be rectified at the stage of model development through the use of 'adversarial debiasing' or 'oversampling', simulated datasets that include missing variables, counterfactual simulations and 'continual learning'.[20,25] These methods generate synthetic data in an attempt to increase the representation of underrepresented classes. Additionally, 'selection bias' can be overcome by the application of an "independent external dataset" to check the suitability of the study population used to train the model with the target population.[25] Furthermore, it was recommended to test and tune models to perform optimally in all population groups and at all stages using the ground truth as a proxy.[2,9,12,20,24] Bias brought about by overfitting can be improved by regularization techniques, cross validation, and data augmentation.[25] Continued monitoring, follow-up, use of feedback loops and retraining the model are necessary to check the results of the machine learning models.[2,3,23]

Mitigation of biases at the stage of model evaluation: The common methods during the stage of model evaluation include the use of performance metrics such as accuracy and F1 score. Models should be trained with the consequences of false negatives (missed diagnoses) and false positives (over-diagnoses).[2,22,23] Methods for testing algorithm performance are detailed in CLAIM (Checklist for Artificial Intelligence in Medical Imaging) and can be applied to detect selection bias.[25] AI algorithms can also be employed to flag decisions that require to be checked.[20,21] Other techniques used are interpretability and explainability. These techniques are specifically introduced to allow human users to understand the results produced by machine learning algorithms. In the field of medical imaging, visual-based methods for explainability include 'saliency maps' that attempt to identify areas and features that contributed to the prediction of the algorithm.[3,22,23]

Mitigation of biases at the stage of model deployment: The first step to mitigate biases at this stage is to have fail-safe methods that will check if socio-demographic characteristics of patients (for whom the model will be used) are representative of the patients included in the training data. This includes 'field-testing' to assess the performance of algorithms in different population groups and clinical settings. Unwanted bias must be recognized from feedback loops, namely transparency and justification of levels of bias for future avoidance and removal.[21] Finally, it needs to be ascertained that clinically useful and meaningful algorithms are designed that are beneficial to the patient, the healthcare provider and to the whole healthcare system through the improvement of outcomes.[2,23]

5. Discussion

Knowledge of the origin or source of bias in the AI algorithm is critical. There are many examples where faulty algorithms were rectified by identifying the source. Recognition of the possible sources of biases at the outset leads to an efficient model development. However, machine learning algorithms that are based on artificial neural networks are subject to 'black-box decision-making'. These are models where it is difficult to detect biases and other errors, prompting researchers to devise techniques in order to evaluate these models. The present research identified three probable sources of bias that are linked to – a) data, b) model design and development, and c) human involvement. Once these sources have been recognized, it is important to check at which stage of the machine learning pipeline they can be introduced. Vokinger, Feuerriegel and Kesselheim[15] in 2021 demonstrated this strategy as well as the possible mitigation techniques at each stage. By using the machine learning pipeline, it was concurred that bias can arise at any of the four stages, propagate along the pipeline and then exacerbate the bias at the final stage. Igoe[17] described this phenomenon as a "trickle-down effect". An ideal workflow would be at first to recognize all possible biases that could arise in the development of a model and apply mitigation techniques right from the start of the machine learning pipeline. Waeed and Omlin[26] utilized the phases of the ML pipeline to demonstrate that XAI can be used to detect, prevent and even mitigate bias. During the course of model development, it is advisable to use techniques (derived from prior knowledge of bias origin) to mitigate expected biases.

A significant emphasis is placed on the data that is used for training algorithms for healthcare. The lack of diversity in datasets is partially due to the limitations in the sharing of medical data. These may be due to privacy laws as well as the lack of interoperability between systems.[14] The use of electronic Health Information Exchange (HIE) is a solution to make large amounts of data accessible to machine learning.[18]

The most obvious consequences of biased AI algorithms are exclusion, unfair allotment of resources, misdiagnoses, fatal outcomes, and lack of external validity. These are largely due to imbalanced data that is used to train the algorithms. Even though one is aware of this fact, the perceived usefulness of AI is once again in doubt, as it cannot be used for broader populations, thus perpetuating global health inequity and existing health disparities. If underrepresented groups are susceptible to the impact of bias, it needs to be addressed in order that AI in health care is applicable to the United Nations Sustainable Development Goal, i.e. 'AI for Good'. An ideal scenario would be to improve the collection of high-quality and correctly labelled data. Kaushal, Altman and Langlotz[14] call for the implementation of a strong infrastructure in terms of technology, regulation, economic and the privacy and safety of data.

The mitigation of biases should be attempted by first diligence in data handling and during model development. Potential biases should be anticipated and their mitigation employed. A diverse team approach consisting of engineering and biomedical teams may also be intuitive.[23] A recent approach to mitigation involves the use of interpretability and explainability (XAI) techniques used especially for 'black-box' models. If XAI techniques bring to light the features that influence the outcome of a ML model decision, it will be a tool with direct benefit for the user. Models that are transparent and understandable by humans instill confidence in their utilization, thus encouraging their use. Therefore, a combination of quality mitigation techniques and XAI techniques integrated into algorithms may be the probable solution to the Achilles Heel of artificial intelligence. A list of recommendations to overcome biases in AI algorithms is outlined in Table 4.

Table 4: Recommendations to overcome biases in AI Algorithms

Approach through the collection and selection of data: The collection of better data is first and foremost the most important step to avoid disparities in datasets. These include: • Datasets should be representative of diverse population groups (address race, gender, age and socio-economic); • Databases should be improved by addressing the imbalance of country-wise distribution of databases; • Sharing of data and interoperability should be encouraged.

Approach through best practices in algorithm development: The development of algorithms and the way data is used is critical in determining the usefulness of the model. Best practices include:

- An algorithm should be designed to fulfill the need of clinicians;
- The intended use of the algorithm must be determined;
- Underfitting and overfitting must be considered while training the algorithm;
- Proxies and related labels must be judiciously chosen and rechecked for potential biases;

Approach through best practices in algorithm evaluation: The evaluation phase is a critical checkpoint to find potential biases. Strategies include:

- Performance metrics must be applied to evaluate the model;
- Interpretability and explainability techniques should be used to instill trust in the user;
- Basic criteria of appropriateness, fairness, and bias should be used for evaluation

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Approach at the stage of clinical deployment: The final stage includes the following:

- External validation and model re-calibration should be carried out prior to clinical implementation (match the algorithm training sets to the target context and population);
- Manufacturers should be transparent in providing datasheets of the AI system.

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6. Conclusion

Artificial intelligence (AI) has a distinct advantage over traditional algorithmic methods. However, just like the metaphorical ‘Achilles Heel’, AI is vulnerable despite its strong capabilities and apparent invincibility with weaknesses of which bias is one. This aspect is of particular concern when using AI in healthcare. Biases originate from data, during model development and evaluation, and after deployment. The existence of these biases challenges the notion of trustworthiness of using AI technology. Bias is a concern to the field of AI, and it is the major reason for its slow adoption despite its promises. Explainability and interpretability must be valid, consistent and reproducible if they are to instill principles of inclusivity, openness, and user trust. They may also be sensible approaches for bias detection and mitigation; however, there still exists the need for further validation and evaluation of these methods. Future research should be focused on further capabilities of XAI methods to be able to detect and hence mitigate bias. In this regard, it is recommended that metrics play a larger role not only in the evaluation of AI algorithms, but also in the evaluation of XAI methods.

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