

## Unveiling the Digital Frontier: Technological Advances in Pharmacy Research

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### **Abstract:**

This paper explores the transformative impact of digital technologies on the pharmaceutical sector in Europe and America, alongside Bulgaria's initiatives to address challenges such as counterfeit medicines and communication gaps through e-prescriptions and health information platforms. Focusing on drug therapy management, pharmacogenomics, 3D printing of medicines, and personalized care, it highlights how digital innovations are revolutionizing efficiency and patient outcomes. Through survey analyses and pharmacist questionnaires, the paper investigates the acceptance and attitudes of German society toward digital health solutions, providing insights into their adoption within pharmacies. With the total number of pharmacies declining amidst a growing healthcare sector, the study underscores the importance of integrating efficient digital technologies to improve customer experience and maintain competitiveness. By offering actionable recommendations for pharmacies to embrace digitalization and navigate the transition to digital markets, this paper serves as a valuable roadmap for industry stakeholders, ensuring their continued success and relevance in the evolving landscape of Health 4.0.

**Keywords:** *Digital technologies, health 4.0, artificial intelligence, mobile health, ehealth*

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### **Introduction:**

The pharmaceutical industry is experiencing exponential growth, fueled by cutting-edge technological advancements. Drug delivery optimization lies at the heart of this expansion, promising medications with fewer adverse effects and heightened efficacy. This evolution is underpinned by a convergence of innovative technologies including artificial intelligence (AI), digitalization, process automation, novel drug delivery systems, and the scalability of production facilities. With the aid of AI and digitalization, pharmaceutical companies are revolutionizing patient care and drug development. Sophisticated automation and control tools are increasingly employed to streamline manufacturing processes, ensuring consistent quality and safety standards. Concurrently, the adoption of cutting-edge connectivity technologies facilitates seamless communication and data exchange, enhancing collaboration across the industry.[1]

The proliferation of mobile applications and sensors marks a significant advancement, enabling real-time data collection and analysis. These tools play a pivotal role in monitoring the safety and effectiveness of pharmaceutical products, as well as tracking the impact of therapies on patients' daily lives. Through comprehensive data analysis, pharmaceutical companies can pinpoint the most effective treatments and forecast individual patient responses with greater accuracy. Furthermore, the integration of electronic medical records (EMRs) alongside genomic, proteomic, and gene expression data allows for personalized medicine to thrive. By leveraging these vast datasets, healthcare professionals can tailor treatments to individual patients' needs, optimizing outcomes while minimizing risks. This data-driven approach also fosters better patient engagement and information protection, empowering individuals to actively participate in their healthcare journey while safeguarding their privacy.[2]

In the digital age, the exchange of patient health information among various stakeholders is streamlined through digital services, ensuring treatment aligns with patients' preferences and requirements. This facilitates a more patient-centred approach to healthcare delivery, ultimately leading to improved health outcomes and enhanced quality of life. Overall, the pharmaceutical industry's embrace of innovation and technology is reshaping the

landscape of healthcare, promising a future of personalized, effective, and patient-centric treatments. The pharmaceutical landscape has undergone a profound transformation with the advent of digital technologies, reshaping traditional pharmacy practices and ushering in a new era of efficiency, accuracy, and patient-centred care. Digitalization, characterized by the integration of digital technologies into routine operations, has revolutionized various facets of pharmacy practice. One significant advancement is the adoption of electronic prescriptions (e-prescriptions), streamlining the prescribing and dispensing process while reducing errors associated with handwritten prescriptions. This not only enhances patient safety but also optimizes pharmacy workflows. Moreover, tele-pharmacy services have emerged as a valuable tool, particularly in underserved areas, enabling pharmacists to remotely provide medication counselling and monitoring, thus expanding access to care and improving patient outcomes.[3]

The introduction of digital patient records has been instrumental in enhancing the coordination of care and communication among healthcare providers. Electronic health records (EHRs) and electronic medical records (EMRs) offer a comprehensive overview of a patient's medical history, medications, and treatment plans, facilitating more personalized and integrated care. Additionally, automated dispensing systems have transformed medication dispensing by accurately and efficiently managing inventory, dispensing medications, and providing alerts for potential drug interactions or allergies. This automation allows pharmacists to focus more on patient care and counselling, ultimately improving the quality of pharmacy services.

Despite the numerous benefits of digitalization in pharmacy practice, challenges persist. Ensuring the privacy and security of patient data is paramount, requiring pharmacists to adhere to stringent data protection regulations and implement robust security measures. Furthermore, the rapid evolution of digital technologies necessitates ongoing education and training for pharmacists to effectively utilize new tools and stay abreast of advancements. Lifelong learning is essential for pharmacists to navigate the complexities of digital health technologies and provide optimal care to their patients.[4]

In conclusion, the digitalization of pharmacy practice represents a fundamental shift towards more efficient, accurate, and patient-centered healthcare delivery. Through the adoption of digital technologies such as e-prescriptions, tele-pharmacy services, electronic patient records, and automated dispensing systems, pharmacists can enhance patient safety, improve access to care, and optimize pharmacy workflows. While challenges related to data security and professional development exist, embracing digitalization presents pharmacists with unprecedented opportunities to revolutionize healthcare delivery and shape the future of the profession.

### **Entry of Digital Technologies in the Pharmaceutical Sector**

The global pharmaceutical market is driven by innovation and ageism, leading to research into cost savings through digital innovation. Digital technology facilitates informed treatment decisions by enabling instant communication between patients, doctors and pharmacists.[5] Marketing experts analyse the tools needed to update the healthcare industry's business models and processes, improve communication with customers and enable new developments.[6]

Recent digital changes enable patients and healthcare organizations to obtain information about the impact of drug therapy on overall health. Online platforms and mobile applications facilitate communication and follow-up of treatment, providing a better understanding of doctors. Digitalization in the pharmaceutical industry in general is changing operations, communication strategies, and patient care with the aim of improving clinical outcomes and improving overall health.[7]

### **Examples of Application of Digital Technologies in the Pharmaceutical Sector**

- **3D-Printed Drugs/Medical Products:** The first step in pharmacogenomics is 3D printing of drugs. The basis is a unique patented method for the production of products with rapid release of many drugs to achieve improved bioavailability; many flavour enhancing options; and a dose delivered to accurate and effective administration.[8] The 3D printer determines the dosage and prescription for each patient. Additionally, if the patient is diagnosed with multiple chronic diseases, unnecessary drug use can be reduced by combining many medications. In 2016, the US FDA approved the first 3D printed tablet.[9]
- **Medication Therapy Management (MTM):** MTM (Medication Therapy Management) is an online platform in the United States dedicated to delivering digital pharmaceutical care. Pharmacists utilize this platform to comprehensively review all medications prescribed to patients by various healthcare providers,

including over-the-counter drugs, herbs, and supplements. The objective is to identify and resolve any drug-related problems, such as improper medication use, duplication, or the need for additional treatment. Following the review, pharmacists offer training, consultancy, and advice to patients or their caregivers, ensuring proper implementation of therapy.[10] Digital solutions play a pivotal role in providing personalized pharmaceutical care, enabling pharmacists to tailor interventions based on individual patient needs. Digital solutions are essential to the practice of pharmacy because they enable personalized pharmaceutical care. Here are some examples:

- **Video Surveillance of the Drug Action Based on Nanotechnology:** Innovative technologies for video surveillance of drug action in the human body are being developed by the health and IT sectors.[11] The dosage form's incorporation of unique nanoparticles makes it feasible to check the patient's body to see how the medication affects it. An integrated sensor-equipped pill became the first digital medication in history when it was approved by the US Federal Drug Agency (FDA) in 2017.[12] Once the medication is ingested, the sensor starts to send medical data. Following up on treatment compliance is the goal. Privacy: who gets the data and how is it used are the key issues surrounding the "digital pill."
- **Sensors and Digital Services for Personalized Treatment 24/7:** In order to provide round-the-clock care, sensors and digital services are the primary means of achieving personalized care in pharmacy. Certain European nations and the United States offer comparable services.[13] It is anticipated that in the coming years, medications produced by different pharmaceutical companies will be a part of a digital ecosystem that continuously tracks the patient's condition and gives feedback to the multidisciplinary team of caregivers. By adjusting therapy to clinical outcomes and patient needs, this ecosystem will help improve health outcomes. It will also enable remote monitoring of the patient's condition and adherence to therapy by medical professionals. There are a lot of wireless sensors on the market right now that can be used to measure a patient's biophysical performance.[14]
- **Automated Dispensing Units/Cabinet (ADC):** In hospital wards or pharmacies, patients benefit from Automated Dispensing Cabinets (ADCs), decentralized systems for computer-controlled medication storage, dosing, and tracking. Widely utilized in Europe and America, ADCs reduce human errors, prioritizing staff-patient interaction over paperwork. Integration of barcode process automation technology ensures an electronic match between prescribed and dispensed medications, enhancing accuracy and safety in medication management. ADCs streamline processes, minimizing medication errors, and improving overall patient safety and care quality in healthcare settings.



Fig. 1: Components of medication therapy management

- **Medication Reminder Devices Smart Dispenser:** Patients can receive reminders to take their medications via a variety of pharmaceutical devices that are available on the market, along with associated smartphone apps. The application presents data regarding the quantity of dosage units and the timing of their administration. At the push of a button, the device which fits neatly in the palm of your hand releases the tablets and stores the dosage mode.[15] It can send a variety of optical and even acoustic signals when needed. Reminding customers to take their medication until the prescribed dose has been administered is important. Applications that have been developed allow for the accounting of patient compliance.

#### **Healthcare Digitalization: Health 4.0**

There are many terms for the digitalization of healthcare, such as "digital health," "health 4.0," "eHealth," "wireless health," "mobile health," "online health," "smart health," "telemedicine," etc., but no clear definition of this phenomenon has been provided as of yet.[16] To begin with, digitalization in healthcare refers to the incorporation of contemporary information and communication technology into routine medical procedures.[17] The principal objective is to streamline fundamental healthcare procedures across the entire value chain, including medication administration, monitoring, diagnosis, and treatment in healthcare facilities.[18]

Health 4.0 denotes not only the primary emphasis on central patient care but also the increasing interconnectivity between the major healthcare providers of the present and the future. In order to optimize standard procedures and increase the efficiency of previously time-consuming data procurement, it is imperative that data accessibility and value are considered.[19] The Electronic Health Record was created to compile and compile patient records, including vital medical history, demographics, test results, and prescription information, in one location. Therefore, while all patient information is kept private and confidential, data transparency can improve the effectiveness and calibre of individual treatments. In contrast to Austria, which launched its electronic health record system in 2014, the German version of the EHR has been in use since January.[20]

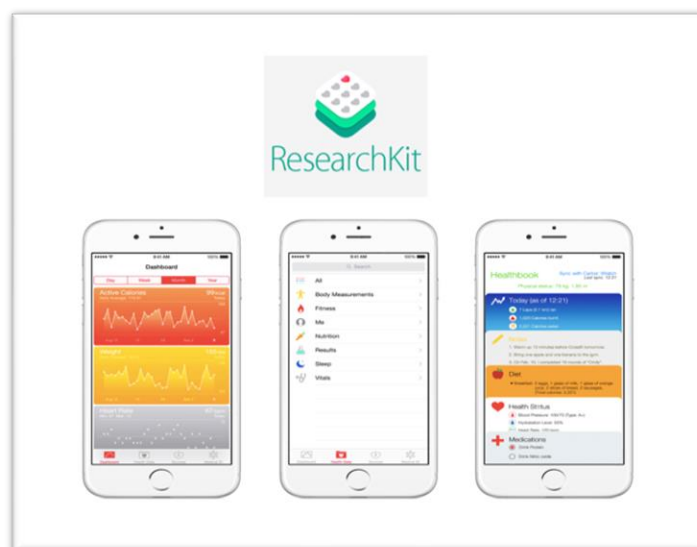
Health 4.0 encompasses advancements categorized into people, design, and technology pillars. New technology and digital processes drive rapid changes in daily healthcare practices for patients and providers, requiring awareness and adaptation among stakeholders. Effective delivery of better services hinges on the willingness of healthcare system participants—physicians, insurers, pharmacies—to embrace these changes. Moreover, sophisticated structure and design of new healthcare products directly influence their efficiency and usability, particularly impacting patients' ease of use. User-friendly healthcare apps like Apple Health and Samsung Health exemplify this, providing users with valuable information. Technology, the third pillar of Health 4.0, is pivotal in driving these advancements and improving healthcare delivery.

#### **eHealth**

The healthcare industry has not been significantly impacted by the Internet of Things, despite the fact that it has changed many aspects of life. Because most people frequently use the internet to Google specific disease symptoms, Google Flu Trends is able to predict the course of the illness earlier than most physicians. Nevertheless, there are currently insufficient applications in the healthcare industry to fully utilize Big Data and digital technology.[21] Apple ResearchKit, one of the most well-liked Big Data healthcare solutions, was introduced by the company in 2015. It makes it apparent how far digital health solutions can advance in the future (Figure 2).[22] Generally speaking, ResearchKit functions as an Open Source Framework that allows individual users of particular iOS applications to gather a vast amount of medical data about health and chronic diseases. This has made it possible for various apps, like the EpiWatch App, to create personalized seizure detectors for people with epilepsy, and other apps have been used to identify autism in children as early as age 5.[23]

The general term for the digitalized version of the central healthcare system is eHealth, and it encompasses the modernization of the real "old" telematic healthcare infrastructure, like the EHR. An additional focus is on any and all advancements related to novel patient care and treatment options made feasible by the utilization of contemporary information and communication technology, including the internet. Hence, the idea of smart health, to which both of the previously mentioned examples belong, constitutes a smaller portion of the all-encompassing eHealth term. The term "smart health" refers to the creation of fresh, creative business models for the healthcare industry that make use of the many online resources. Therefore, the objective of both eHealth and smart health is to link contemporary digital healthcare technologies (EHR, E-Recipe, mobile applications, etc.) with stationary healthcare ecosystems (hospitals, pharmacies, doctor's offices, retirement homes, etc.).

Additionally, this resemblance highlights the primary distinction between this concept of health and the one that follows, which is called mobile health.[24]



**Fig. 2:** ResearchKit as an example of intelligent digital healthcare solutions

### Mobile Health

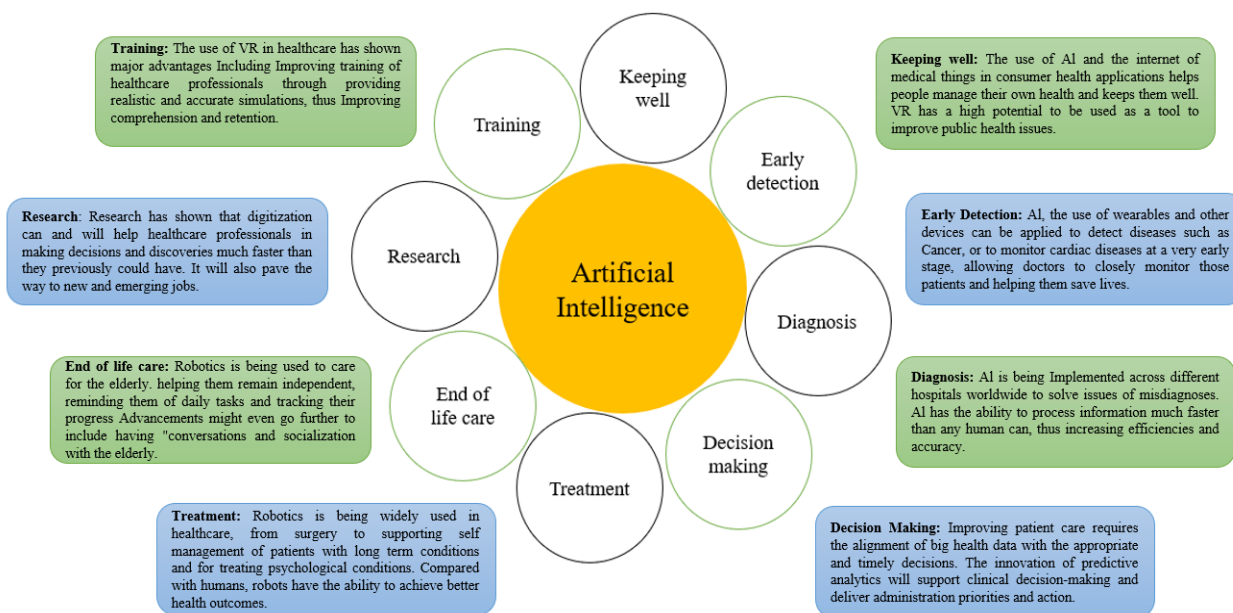
The term "mobile health," or "mHealth," refers to the use of different health-related apps on portable electronics like tablets, smartphones, and other PHAs. Put differently, mHealth is what happens when mobile devices and mHealth/smart health come together.[25] Users of these personal health-related mobile technologies may be able to oversee non-critical care in their communities on their own. Patients can thus easily lower their risk of acute hospitalization, save money on their care, and enhance their quality of life on a daily basis.[26] It is crucial to stress that the only foundation of mobile health (mHealth) is mobility within healthcare solutions, setting it apart from the other concepts discussed above. MHealth can, but need not, share any points of overlap with physical healthcare ecosystems, like pharmacies.

The global population's increasing ownership of mobile devices, like smartphones, is contributing to the growing importance of mHealth. The global count of smartphone subscriptions crossed 6 billion in 2021, and it is expected that this figure will rise steadily going forward. In all, more than 350,000 mHealth apps, including both medical and health and fitness apps, were accessible in the major app stores in 2020. Due to rising smartphone adoption and continuous significant investment in the digital health space, the number of apps available has nearly doubled since 2015.[27]

### Artificial Intelligence

From the turn of the 20th century, extensive research has been conducted on the enormous potential of the global artificial intelligence healthcare market. Figure 3 illustrates that the global AI market for healthcare was estimated to be worth USD 6.7 billion in 2020, whereas the market only began in 2016 with a total value of USD 660.7 million.[28] AI is anticipated to grow at a compound annual growth rate of 41.8% between 2021 and 2028 as a result of this remarkable market expansion.[29]

According to definitions, artificial intelligence is the "ability of a digital computer or computer-controlled robot to perform tasks commonly associated with intelligent beings." Determining whether a system is intelligent or not can be challenging, as the definition of human intelligence is broad. Consequently, a variety of assessments have been created employing straightforward techniques to gauge computer systems' intelligence. Originally known as the imitation game, Alan Turing created one of the earliest and most user-friendly test procedures in 1950.[30] Today, it is commonly referred to as the "Turing Test." In this test, an actual person uses a keyboard and screen to conduct an interview with a machine and another human who are unknown to him and have no visual or auditory contact. The computer system passes the Turing Test and is regarded as having intellectual capacity comparable to that of a human brain if the interviewer is unable to identify which of the two is a machine by the end of the test.



**Fig. 3:** Applications of artificial intelligence in the medical field. Reprinted in 2020, Springer Nature, with permission.

AI-based technologies could be used in healthcare to the benefit of all parties involved. Artificial intelligence applications in healthcare ecosystems have the potential to lower healthcare costs while improving care quality. Scientists have recently been searching for tools and methods to integrate and analyse this unstructured data mass because the healthcare industry already generates a huge amount of potentially useful data, e.g., sensors, trackers, sleep patterns, diagnosis, treatments, etc. Figure 3 demonstrates the wide range of applications of AI in the healthcare industry, ranging from IoT devices and sensors to more sophisticated systems that use machine learning and natural language processing.[31] The most common application of AI technologies is in primary and direct patient care processes, which allow for quicker and more precise treatment.

Due to a shortage of doctors relative to the population's health concerns, many individuals face delays or even inability to access timely medical consultations. In response, medical chatbots have been developed, offering additional support by providing detailed symptom information and more accurate diagnoses. Moreover, artificial intelligence extends its impact beyond direct patient care, contributing to medication and vaccine development, exemplified by the Johnson & Johnson COVID-19 vaccine. Collaborative efforts, like the DELPHI model by MIT and Janssen R&D Data Science, leverage AI to predict future COVID-19 hotspots, demonstrating its broader application in addressing public health challenges.

#### Pharmacy 4.0 - Future Pharmacy Concept

Future pharmacy concepts could take many different forms, given the volume and rate of changes that have occurred within pharmacies over the past ten years. Based on various modifications to Health 4.0, the brief outlook that follows outlines the most succinct development opportunities for pharmacies of the future. The text that follows is split into two primary sections to provide it with a little bit more organization. In the first section, "Pharmacists' Next Steps," potential technologies that might be incorporated into pharmacy systems in the near future are covered. More futuristic concepts and developments pertaining to patient care and health can be found in the second section, "The Future Pharmacy." In any case, the two sections solely concentrate on aspects of the pharmaceutical delivery process that increase efficiency for patients and customers. Both sections also largely omit background processes like purchasing, administration, etc.

#### Pharmacies' Next Step

The official strategy adopted by pharmacists to keep up with the latest advancements in healthcare and to ensure the quality of their services is outlined in the concept "Pharmacy 2030." Relentlessly prosperous in the pharmacy

industry. Since this concept was first developed in 2015, numerous new and additional changes have been made to provide a clear, current picture of the pharmacy of the future. Therefore, it follows that the two main facets of pharmacists' daily jobs going forward will continue to be giving patients specific advice on medications and selling specific pharmaceuticals. A systematic medication management system must unavoidably be implemented in order to provide each individual customer with long-term, effective, and safe drug treatments.

It is critical for pharmacies to offer online and offline access to their full range of goods and services, as mobile health becomes more and more significant in the healthcare industry. That's why Walgreens, the second-biggest pharmacy chain in America, carried out a significant study on the subject of digital sales tactics in the pharmacy industry. The surprising finding was that three and a half times as many Walgreens customers will purchase products directly from the store and that 70% of Walgreens customers already interact with the company through mobile applications.

Therefore, mobile purchases account for more than half of Walgreen's total digital sales, demonstrating the significant influence that mobile solution integration can have on well-established businesses. The German version of Walgreens, called Gesund.de, already connects more than 7000 pharmacies into a single mobile application and plans to grow even more in 2022 by adding more healthcare providers. Given that gesund.de was only introduced to the German market in the third quarter of 2021 and already boasts over 100,000 users, it is evident that the platform's growth potential is only expected to increase with further digitization.

This suggests that in the future, a significant portion of pharmacy sales may come from mobile devices.

### **Future Pharmacy**

AI holds significant potential to enhance the role of pharmacists by streamlining tasks like medication management, inventory control, and patient counselling. While it can optimize processes and improve healthcare outcomes, the complete replacement of human pharmacists seems improbable due to the need for personalized care and complex decision-making. Instead, AI will likely serve as a valuable tool, augmenting human expertise and enabling pharmacists to provide more intensive and tailored healthcare services to patients, especially in the context of an aging population with increasing medical needs.[32]

Pharmacies currently utilize basic AI, like pharmacy management systems, to store patient data and aid in clinical decision support. Integrating these systems with healthcare data could revolutionize pharmacy technology, reducing medication errors and workload for pharmacists. This would allow for more thorough patient consultations while enhancing patient safety through timely identification of drug-related issues.

Pharmacies can leverage natural language processing for efficient customer communication. For example, a medical AI assistant could handle phone orders and inquiries, freeing pharmacists from routine tasks. With increasing transparency of health data, AI technologies can provide personalized assistance and streamline operations without compromising data security, ensuring that smart devices and health services can collaborate effectively in managing vast amounts of health data.

### **Future Directions and Emerging Trends in Digitalized Pharmacy Practice**

The field of pharmacy practice is expected to change even more as digital technologies advance. The pharmaceutical industry faces both opportunities and challenges as a result of emerging trends and innovations that have the potential to improve the effectiveness, accessibility, and quality of pharmaceutical care.

- **Wearable Technology Integration**

The practice of pharmacy is incorporating wearable health technologies, like fitness trackers and smartwatches, more and more. These devices can track a patient's vital signs, level of physical activity, and adherence to medication. They can also provide pharmacists with real-time data to help with medication management and lifestyle counselling. Predictive and tailored patient care will be made possible by the incorporation of wearable technology data into pharmacy management systems, which is consistent with the general movement toward precision medicine.

- **Extension and Regulation of Tele-pharmacies**

Due to the convenience of remote services and the need for increased healthcare access in underserved areas, tele-pharmacy is expected to continue expanding. In order to guarantee that remote pharmacy services maintain the same standard of care as traditional settings, regulatory frameworks pertaining to licensure, reimbursement, and quality standards will need to change as tele-pharmacy becomes more popular.



Furthermore, tele-pharmacy's capabilities will be further enhanced by developments in digital communication technologies, allowing for more interactive and customized patient consultations.

- **Artificial Intelligence and Machine Learning**

Emerging trends in pharmacy practice are led by artificial intelligence (AI) and machine learning. These technologies have the power to completely transform the industry in a number of areas, including personalized medication management and drug discovery and development. In order to improve patient safety and treatment outcomes, artificial intelligence (AI) algorithms can evaluate large datasets in order to forecast drug interactions, optimize prescription regimens, and identify possible adverse drug reactions. Furthermore, machine learning models can forecast prescription demand and simplify inventory management, increasing the effectiveness of pharmacy operations.

- **Blockchain Technology for Safe Data Processing**

Blockchain technology is becoming more and more popular as a way to improve the efficiency, security, and transparency of data management in pharmacy practice. Blockchain can secure the exchange of patient data, prescription data, and supply chain logistics by establishing a decentralized, tamper-proof ledger of transactions, reducing the risk of data breaches and fake drugs. Additionally, this technology has the potential to enhance medication traceability, guaranteeing the genuineness and security of pharmaceuticals from production to distribution.

- **The Challenges and Ethical Issues**

Pharmacies will confront issues with data privacy, ethical AI use, and the digital divide as these technologies develop. Realizing the full potential of digitalization in pharmacy practice will depend on ensuring the equitable distribution of digital health benefits and addressing inequalities in access to technology. Furthermore, in order to guarantee that these technologies are used in a way that puts patient welfare and professional integrity first, stakeholders will need to continue having discussions and reaching consensus on ethical issues pertaining to the use of AI and automation.

### **Conclusion:**

Digitalization presents both opportunities and risks for Germany's stationary pharmacies. As the healthcare sector expands, the number of traditional pharmacies is declining, while online pharmaceutical suppliers are on the rise. Pharmacies embracing basic digital tools gain a competitive edge, starting with improved websites, online sales integration, and efficient stock management systems driven by Big Data. Automation streamlines processes, enabling 24/7 sales counters and freeing pharmacists for personalized consultations. Mobile apps and Big Data analytics further enhance customer engagement and digital sales. To thrive, pharmacies must prioritize digitalization, leveraging AI and technology to enhance efficiency and customer service, ensuring their relevance in the evolving healthcare landscape.

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