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RESEARCH ARTICLE

Assessing the Impact of AI: The Case of the Pharmaceutical Industry

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ABSTRACT

The pharmaceutical industry is on the cusp of a transformative era with the advent of Artificial Intelligence (AI). This paper delves into the multifaceted implications of AI in the pharmaceutical sector, encompassing aspects from manufacturing process improvements to drug discovery and personalized medicine. It explores AI's role in reshaping business models, enhancing efficiency, and overcoming traditional challenges in drug development. Additionally, the paper addresses the challenges in adopting AI, such as the need for advanced IT infrastructure and handling unstructured data, underlining the potential of AI to revolutionize pharmaceutical practices.

Keywords: Artificial intelligence (AI), Personalized medicine, Pharmaceutical industry.

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1. Introduction

The actual and potential impact of artificial intelligence (AI) on various industries has been experienced as both a threat and an opportunity by incumbents and would-be entrants. The pharmaceutical industry is no exception. Characterized by research-intensive, complex, and costly development processes, the industry will undoubtedly be impacted by the advent and improvement of AI. However, the exact direction and magnitude of the impact stand to be clarified. This paper analyzes the actual and potential impact of AI on the pharmaceutical industry. The paper also assesses the benefits and challenges that AI can bring to the pharmaceutical industry. In the end, the paper provides a discussion on the trajectory of the development of AI in the pharmaceutical industry.

2. Brief History of AI

Artificial Intelligence, as we know it today, is defined as a system's ability to interpret external data correctly, to learn from such data, and to use those learnings to achieve specific goals and tasks through flexible adaptation (Berlinski, 2000). The concepts origins are in mythology with stories of highly intelligent beings or philosophers that tried to understand the process of human thinking using mechanical symbolism.

In the 1940s, the invention of the digital computer inspired the idea of building an electronic brain, as this device inspired the possibility of human thought being mechanized. It culminated in the summer of 1956 when AI was officially established as an academic discipline. A number of scientists gathered at a workshop at Dartmouth College funded by the Rockefeller Foundation called "Dartmouth Summer Research Project on Artificial Intelligence (DSRPAI)" with the goal of creating an artificial brain. That's where Marvin Minsky and John McCarthy, American computer and cognitive scientists, coined the term "Artificial Intelligence" and targeted research into the creation of machines capable of developing human intelligence (Kaplan, 2022).

Nearly two decades of successful AI development followed. A plethora of new projects led to major advancement in the field, and in 1970, Minsky predicted that a device capable of human intelligence would be in reach within three to eight years. However, major critiques of this optimistic outlook followed, and in 1973, the US and British governments suspended support for AI research. This began what is now known as the First AI Winter (Haenlein & Kaplan, 2019).

During the early 80s, another AI boom was recorded, fueled by the Japanese government aggressively funding its fifth-generation computer project, inspiring the US to increase its AI funding as well, which led to progress in expert systems and connectionism. Nonetheless, the early 1990s recession saw major funding cuts for this field, creating a second AI Winter (Newquist, 1994).

The present-day AI boom started in 2016, with the founding being directed toward utilizing generative AI systems. In late 2022, a number of various AI tools and

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software became available to the general public, generating excitement due to the capabilities that they offered but also eliciting fear because of its disruptive potential. Nevertheless, the opportunities that these AI tools offered, particularly in the business sphere, were so promising that many companies saw this disruptive potential as a resource that should be exploited (Firth-Butterfield, 2023; Kaplan & Haenlein, 2019).

Based on the type of intelligence AI displays, it can be classified into three categories: analytical (cognitive intelligence), human-inspired (emotional intelligence), and humanized (social intelligence). Furthermore, it can also be divided into three categories based on its evolutionary stage: Artificial Narrow, General, and Super Intelligence. However, after AI becomes utilized in the mainstream, all these categories merge due to the AI Effect-the idea that the general public disregards AI as not "real" intelligence or thinking as it relies on mathematical computing (Haenlein & Kaplan, 2019; Fanti *et al*., 2022).

3. A Brief Overview of AI's Impact on Businesses

Historically, AI has primarily been the focus of academic researchers rather than business professionals (Nilsson, 2010). With the latest advances, businesses have recognized the value-creation potential of AI, especially in data-intensive industries (Greenstein, 2001; Åström *et al*., 2022). AI, like similar transformative technology-based tools before, offers a promise of increased efficiency and productivity, but it also stands to fundamentally change how processes are structured and implemented. Henceforth, the disruptive potential of AI is something to assess, along with the benefits it promises.

The alignment of companies' economic objectives, such as enhancing efficiency and reducing costs, plays a crucial role in clarifying the widespread adoption of AI technologies. In manufacturing sectors, the integration of intelligent machines capable of learning and recognizing images and sounds serves to reinforce the trajectory of lean production. A number of channels are in operation, such as (i) reduction of the amount of labor input used in production; (ii) maximization of both human and machines' efficiency in performing their tasks; (iii) new opportunities for machine-assisted human activities; (iv) fixing of bottlenecks and information feedback that allows continuous quality improvement (Rikap & Lundvall, 2021).

As AI progresses, automation and robotization increase the possibility of labor cost-cutting across the board. By stimulating the design, adoption, and use of AI tools, companies can reproduce routine tasks based on specific rules. However, due to its learning systems, AI's ability to evolve into reproducing non-routing complex tasks is unprecedented (Tyson & Zysman, 2022).

For technology-intensive industries, AI is a vital part of their strategies. Relying on learning systems and information processing is a tool for maximizing value by tightening control over all its components (Dosi & Virgillito, 2019). Big Data companies can forecast demand patterns, and machine learning can maintain control of the supply network. This can lead to major reshaping of organizational patterns in the way they interact with customers, suppliers, and competitors (Rikap & Lundvall, 2021; Obschonka & Audretsch, 2020).

There is a great asymmetry between the demand and supply of AI, which has led to a great concentration of companies with resources to develop and control AI technology. What we see is that AI companies operate in very concentrated markets. Because access to digital markets and the ability to digitize processes for increased productivity is becoming integral for competitive advantage, the demand for AI goods is on a sharp rise (UNCTAD, 2021).

Considering the multifaceted and overarching impact of AI and business processes, it is not easy, nor would it be correct, to a priory label AI as having a bidirectional impact on a business, either as a tool for improvement or as a disruptive agent. While optimistic views on AI's contributions to businesses abound, prudent analysis of its adverse effects on the current state of businesses merits thoughtful investigation.

The literature documents the different types of impacts that technology can bring to a particular company. The roots of the competitive advantage of a company are to be found in its resources and capabilities (Grant, 2018). Henceforth, if a competitive advantage of a business is to be impacted by the rise of AI, then this impact will be reflected through the resources and capabilities that the business has.

Technological change that is radical and revolutionary tends to disrupt the incumbent's leading position by rendering its resources and capabilities obsolete (Tushman & Anderson, 1986). The greater the shift in technology, the greater the challenge for the incumbents to adjust or replace their resources and capabilities without losing their competitive position. Companies facing a revolutionary shift in technology tend to adapt better and maintain their competitive edge if the technological shift does not present an architectural but merely a component innovation (Henderson & Clark, 1990). Architectural shift would mean that a major overhaul and redesign of the companies processes and projects is required to exploit the benefits of the new technology. If the new technology can be utilized within the current product or process design, then the incumbents have a faster adoption time. Also, new technology will, in this case, improve a particular part of the problem or phase of the process, subsequently improving the entire product or process.

4. AI in the Pharmaceutical Industry

In the following section, this paper will briefly present different applications of AI within the pharmaceutical industry that can strategically be used to reduce costs and improve efficiency (Patel *et al*., 2021). The findings here are based on in-depth interviews with industry insiders from large pharmaceutical companies.

4.1. Optimizing Healthcare

AI has become integral in various aspects of drug discovery, ranging from designing new molecules to identifying novel biological targets. It plays a crucial role in drug target identification and validation, employing approaches like target-based, phenotypic, and multi-target drug discoveries, as well as drug repurposing and biomarker identification. One significant advantage for pharmaceutical companies lies in AI's potential to expedite drug approval processes and market entry, particularly when integrated into drug trials. This acceleration translates into substantial cost savings, potentially leading to more affordable medications for patients and an expanded array of treatment options. The transformative impact of AI in the pharmaceutical sector not only enhances efficiency but also holds the promise of making healthcare more accessible and diverse.

The integration of AI into healthcare has significantly advanced disease detection and prediction. By amalgamating information from body scans, patient biology, and analytics, AI proves instrumental in identifying diseases, notably cancer, and forecasting potential health issues based on individuals' genetic profiles. Noteworthy is the example of IBM Watson for Oncology, a system that utilizes each patient's medical data and history to propose personalized treatment plans. Beyond diagnostics, AI contributes to the development of tailored drug treatments by analyzing individual test results, past drug reactions, and historical patient data for drug responses. This personalized approach not only enhances the precision of medical interventions but also underscores the transformative potential of AI in ushering in a new era of patient-centric healthcare.

In the pharmaceutical industry, artificial intelligence serves not only to interpret clinical trial data but also to streamline the process of recruiting patients for these trials. Through advanced predictive analytics, AI can delve into genetic information, pinpointing the ideal patient population and determining the optimal sample size for a given trial. Moreover, certain AI technologies have the capability to analyze free-form text entered by patients in clinical trial applications, as well as unstructured data such as doctor's notes and intake documents. This not only expedites the identification of suitable participants but also enhances the efficiency of the overall clinical trial recruitment process, showcasing the multifaceted contributions of AI in advancing pharmaceutical research and development.

In the realm of budget-constrained pharmaceutical companies, the prospect of drug repurposing emerges as a particularly promising domain where AI-based technologies can offer substantial value. The strategy of repurposing entails redirecting known drugs or late-stage drug candidates toward new therapeutic areas. This approach is favored by many biopharmaceutical companies due to its inherent advantages, including a reduced risk of unforeseen toxicity or side effects in human trials, as these drugs have already undergone extensive testing. Additionally, drug repurposing often requires less research and development expenditure, making it an attractive avenue for cost-effective innovation. The integration of AI in this process enhances the identification of potential candidates for repurposing, thereby accelerating the exploration of new therapeutic possibilities without an exhaustive financial burden.

Maintaining compliance with a drug study protocol among voluntary participants in clinical trials poses a significant challenge for pharmaceutical companies. Non-adherence to trial rules by patients can necessitate their removal from the study or, worse, compromise the integrity of the drug study results. Ensuring participants consistently adhere to the prescribed dosage and timing is a critical factor for the success of a drug trial. The importance of having mechanisms to ensure drug adherence is underscored by the potential impact on study outcomes. AI addresses this challenge by employing remote monitoring and algorithmic analysis of test results. Through these methods, AI can effectively distinguish between participants adhering to the protocol and those deviating from it, providing pharmaceutical companies with valuable insights to enhance the reliability and validity of clinical trial data. This integration of AI not only streamlines the monitoring process but also contributes to the overall success and credibility of drug trials.

4.2. Enhancing Business Processes

While the potential applications of AI in pharmaceutical and biotech development are evident, the actual adoption of such technologies often proceeds at a measured pace. The traditional nature of drug development and discovery processes necessitates a gradual adjustment, and the "training" of AI for drug discovery can be a time-consuming endeavor. In contrast to situations where AI receives immediate feedback, such as social media tagging, the evaluation of a new molecule as a drug candidate can take months or even years to validate. Nevertheless, the undeniable trajectory is that AI will play a pivotal role in the pharmaceutical industry's future, and companies embracing new processes will gain a strategic advantage. A pragmatic starting point involves leveraging existing technologies for data analytics, particularly those rooted in multivariate and predictive analytics, providing a foundation for the progressive integration of AI into the intricate landscape of drug development.

Manufacturing process improvement through the integration of AI presents a multitude of opportunities across development and production phases. AI's capabilities extend to enhancing processes such as quality control, design efficiency, material waste reduction, production reuse, and maintenance optimization. AI contributes to increased production efficiency by facilitating faster output and minimizing waste. For instance, tasks traditionally reliant on human intervention for data input or management can be streamlined using Computer Numerical Control (CNC) guided by AI. The incorporation of AI's machine learning algorithms not only ensures precise task execution but also analyzes the overall process to identify areas for further optimization. The outcome is a reduction in material waste, accelerated production timelines, and enhanced adherence to the product's Critical Quality Attributes. This integration underscores the transformative potential of AI in revolutionizing manufacturing practices for increased efficiency and quality outcomes.

Pharmaceutical companies worldwide are actively engaged in the development of sophisticated AI-powered tools and machine learning (ML) algorithms to streamline the drug innovation process. These technological advancements are crafted to discern intricate patterns within vast datasets, offering solutions to challenges associated with complex biological networks. The capability to analyze patterns related to various diseases and identify optimal composite formulations for treating specific symptoms presents a significant opportunity for the pharmaceutical industry. By investing in the research and development of drugs guided by these AI-driven insights, pharmaceutical companies increase their likelihood of successfully addressing and treating various diseases and medical conditions. This not only enhances the efficiency of drug development but also underscores the transformative potential of AI in shaping the future landscape of the pharmaceutical industry.

The pharmaceutical industry, heavily reliant on sales, finds a valuable ally in AI for marketing strategies. AI empowers pharma companies to create distinctive marketing approaches, ensuring high revenues and increased brand awareness. By employing AI to map the customer journey, companies can discern the most effective marketing techniques, allowing a targeted focus on strategies leading to higher conversions and revenue growth. AI tools analyze past marketing campaigns, pinpointing the most profitable ones. This informs the design of present campaigns, optimizing both time and costs. Facilitating the adoption of AI in the pharma sector involves collaborative efforts with academic institutions specializing in AI R&D, partnerships with AI-driven medicine discovery companies for expert guidance, and comprehensive training of R&D and manufacturing teams for effective AI implementation and productivity.

4.3. Artificial Intelligence in Drug Development

Drug development is perhaps the most exciting area where AI could be implemented within pharma. The task of discovering successful new drugs is highly challenging, primarily due to the immense complexity of chemical space, estimated to encompass approximately 10^60 molecules. Artificial Intelligence technologies have evolved into versatile tools applicable across various stages of drug development. These applications include identifying and validating drug targets, designing new drugs, drug repurposing, enhancing research and development (R&D) efficiency, aggregating and analyzing biomedical information, and optimizing patient recruitment for clinical trials-some of which this paper has already outlined.

As mentioned, the process of drug development is highly sophisticated and time-consuming, which this section will try to summarize in a concise manner for the purposes of the research. The iterative and feedback-driven drug development process begins with the assimilation of existing results from diverse sources, including high-throughput screening, computational modeling, and literature reviews. This process involves an alternating cycle of induction and deduction, leading ultimately to the optimization of hit and lead compounds. Automation of specific stages minimizes errors and enhances efficiency. De novo design methods necessitate organic chemistry knowledge for virtual compound synthesis, utilizing screening models as surrogates for biochemical and biological tests. Active learning algorithms contribute to identifying novel compounds with potential activities against specific disease targets.

The initial phase involves identifying compounds with biological activity, known as 'hits,' often discovered through library screening or computer simulations. Leads, the next stage, show promising potential for drug development. Screening in disease-relevant assays and animal models follows to assess efficacy and safety. Once a lead is identified, chemical modifications are undertaken to enhance therapeutic benefits and minimize potential harm. Lead generation involves systematic modifications to improve activity and selectivity and reduce toxicity through hit expansion, a process executed by medicinal chemists using organic chemistry techniques and focusing on specific reactions. Building blocks, possessing reactive functional groups, are assembled to create analogues with interactions at the biological target's active site, visualized through 'lock and key' or 'induced-fit' models. This comprehensive process underscores the intricate and multidisciplinary nature of drug development.

AI aids in refining decision-making processes for patient recruitment in clinical trials. These applications present an opportunity to address inefficiencies and uncertainties in classical drug development methods while minimizing bias and human intervention.

AI's contributions to drug development extend to predicting synthetic routes for drug-like molecules, evaluating pharmacological properties, understanding protein characteristics and efficacy, discerning drug combinations and drug–target associations, and facilitating drug repurposing. Moreover, AI facilitates the identification of new pathways and targets through omics analysis, enabling the generation of novel biomarkers and therapeutic targets. The concept of personalized medicine based on omics markers and the exploration of connections between drugs and diseases are also made possible.

Deep learning (DL) stands out for its exceptional success in proposing potent drug candidates and accurately predicting their properties and potential toxicity risks. AI methods have overcome historical challenges in drug development, including the analysis of large datasets, laborious compound screening, and the significant time and cost requirements exceeding US$2.5 billion over a decade. With AI technology, new studies can be conducted to assist in identifying novel drug targets, rational drug design, and drug repurposing (Kit-Kay & Mallikarjuna, 2019).

5. Discussion on Challenges of AI Adoption in the Pharmaceutical Industry

There are a lot of challenges when it comes to AI adoption within the pharmaceutical industry. Here, we present three main ones that pharmaceutical companies are currently facing and are trying to find strategies that will let them implement AI technology within their operations while minimizing the costs associated with this new development.

The adoption of artificial intelligence in the pharmaceutical industry is hindered by the unfamiliarity and perceived complexity of the technology. For many pharmaceutical companies, AI remains somewhat of a "black box" due to its relatively recent introduction and esoteric nature. The intricate algorithms and processes that power AI systems can be challenging for professionals in the industry to fully comprehend, leading to hesitancy in embracing this transformative technology. Additionally, the rapid advancements in AI can contribute to a sense of unfamiliarity, making it challenging for pharmaceutical companies to keep pace with the latest developments. As AI becomes increasingly integral to various aspects of the pharmaceutical sector, there is a growing need for targeted education and training programs to demystify AI, enhance understanding, and encourage more widespread adoption. Bridging this knowledge gap is crucial for unlocking the full potential of AI in pharmaceuticals, enabling companies to harness its capabilities for improved drug discovery, development, and overall operational efficiency.

The limited adoption of artificial intelligence in the pharmaceutical industry is further exacerbated by a lack of suitable IT infrastructure. Many existing IT applications and infrastructure in use within pharmaceutical companies were not originally developed or designed with the integration of AI in mind. This misalignment poses a significant challenge as AI often requires specialized infrastructure to function optimally. Consequently, pharmaceutical firms find themselves in the position of having to invest substantial financial resources to upgrade their IT systems to accommodate AI technologies. This process is not only costly but also time-consuming, as it involves not just the implementation of new AI-compatible hardware and software but also the integration of these components into the existing IT ecosystem. Overcoming this hurdle necessitates strategic planning and significant financial commitment from pharmaceutical companies to modernize their IT infrastructure, aligning it with the evolving landscape of AI applications in the industry. This investment, though demanding, is essential for unlocking the full potential of AI in pharmaceuticals and ensuring a seamless and efficient integration into existing workflows.

The pervasive presence of unstructured data, often in free text format, presents a formidable challenge for pharmaceutical companies looking to leverage artificial intelligence. Extracting meaningful insights from such data demands substantial effort, as companies must go above and beyond to organize and convert this diverse information into a format suitable for analysis. The inherent complexity of free text data, coupled with the need for meticulous curation, poses a time-consuming and resource-intensive task. Despite these challenges, it is undeniable that AI is already reshaping the landscape of biotech and pharma. The transformative potential of AI is evidenced in its ability to navigate and derive valuable insights from the vast and diverse datasets inherent in the pharmaceutical domain. From drug discovery to clinical trials and marketing strategies, AI is playing a pivotal role in streamlining processes, enhancing decision-making, and driving innovation. While overcoming the obstacles posed by unstructured data requires significant investment and strategic planning, the industry is witnessing a paradigm shift as AI continues to redefine the possibilities and efficiencies within biotech and pharmaceutical research and development (Patel *et al*., 2021).

6. Conclusion

The exploration of Artificial Intelligence in the pharmaceutical industry reveals a landscape ripe for transformation. AI's integration into various aspects of pharmaceutical operations, from drug development to marketing strategies, signifies a paradigm shift in how the industry operates. While challenges such as technological familiarity, infrastructure readiness, and data management persist, the potential benefits of AI, including enhanced efficiency, cost-effectiveness, and innovation, are undeniable. As the industry moves forward, AI stands as a pivotal tool in revolutionizing pharmaceutical practices, heralding a new era of efficiency and innovation.

Conflict of Interest

The authors declare that they do not have any conflict of interest.

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