INDUSTRY 4.0: A Comprehensive Review of Artificial Intelligence, Machine Learning, Big Data and IoT in Psychiatric Health Care

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Abstract It has been quite well known that modern psychiatric treatments bring along certain side effects and current treatment models are unable to precisely address the complexity of mental illness issues. As a result, there has been a major focus to search and adopt applications of information and communication technology (ICT) as a mode for some additional psychological treatment and alternative diagnose with the help of various technologies. Therefore, the objective of this study is to analyze the technological aspects of using virtual reality, artificial intelligence, machine learning, IoT and big data analytics in the mental healthcare industry. In this review paper, we have accumulated some of the remarkable studies and done a comprehensive analysis of various potential technologies in the field of psychiatric health care and the need for these technologies for improving the quality and accuracy of diagnosis for the patients.

Keywords Industry 4.0 · Artificial intelligence · Machine learning · Big data analytics · IoT · Virtual reality · Mental healthcare

1 Introduction

Computers, robots and artificial intelligence have been in existence from the past few decades, but as a result of the industrial revolution and Internet, new opportunities are being introduced in terms of their use and integration. The field of computer science technology has been brimming up with innovation in research using Industry 4.0 and analyzing new opportunities since the stakes are high. All the major sectors of the society have shown interest in adopting it and now healthcare industry is in avid need for the adoption of Industry 4.0. Generation of fast pace lifestyle demands from healthcare industries to find accurate and precise facilities for their patients’ various unmet needs. At times, healthcare industries have faced lawsuits and multiple
backlashes either for not providing proper treatment to the patients or ill-treatment of the patient, altogether due to lack of proper measurement of the patients’ condition [1]. Furthermore, mediocre modes of health treatments are somewhat excessive in nature, such as the use of antibiotics and anticholinergics, leading to difficulty in recovery from certain side effects post-treatment.

In order to transform health in the fourth industrial revolution, technologies like the Internet of things (IoT) uses intelligent sensors and gateways to provide an easy lifestyle in many areas. Examples include tracking and analyzing the mental health state of the patients dealing with a type of disorder [2]. A type of tremendous shift is also taking place in the healthcare industry. The keyword used for the change is “Healthcare 4.0.” The Industry 4.0 revolution has also walked the steps in the field of healthcare, but the practical adoption is still more so in studies. Information and communications technology (ICT) plays a major role in health care to further generate and prove that there are other alternatives or additional modes which can potentially provide personalized care. Henceforth, technological predictions are taking place more and more in this direction. Technologies like machine learning, big data [3, 4] and IoT aid health care by utilizing the data that is already available in the form of images, clinical records and other electronic health records. For example, a machine learning algorithm known as alternating decision trees can accurately predict patterns in late-life depression and treatment response in patients [5].

However, significant gaps continue to occur in the evidence baseline underlying these technologies. In this context, the emphasis of this study is to give a detailed comparative analysis based on the shortcomings and use-case of various existing technologies in the domain of information and communications technology (ICT).

The rest of the paper is categorized in various sections as follows: Sect. 2 illustrates a detailed category wise literature review of various technologies used in mental health care. In Sect. 3, we have done a comparative analysis with the subject of the paper, finally followed by Sect. 4 which explains the conclusion and future work.

## 2 Literature Review

The magnitude of an increase in the rate of a fast-paced lifestyle has made the lives of an average human being much complicated if compared from inception to today. Keeping mental health care in focus, recently there has been a major fascination to promote more research and development using smart technologies for Industry 4.0 revolution in health care which has traditionally been slow in the adoption of this revolution. Also, another alternative solution would be finding a path in applying mindfulness-based cognitive technology (MBCT). Also, many organizations have been fascinated by the idea of bringing both of these areas of subjects (mindfulness using smart technologies for Industry 4.0) together into cutting-edge research for the Industry 4.0 revolution. This, in turn, has led to the evolution of several pieces of research and studies in this background.
Table 1 Research categories and sub-categories

| Research category                                      | Research sub-category                                                                 |
|--------------------------------------------------------|--------------------------------------------------------------------------------------|
| Review of virtual reality, augmented reality and video games for mental health care | VR and AR gaming applications their implications on young adults and future scope for advancement in mental health care |
| Review of AI/ML for mental health care                  | AI/ML-based applications and systems for different mental care problems their shortcomings and design recommendations for the smart health systems |
| Review of big data analytics and IoT for mental health care | Applications of big data analytics and Internet of things (IoT) system designs for the study, analysis, research and diagnosis of mental healthcare issues |

However, for ease of understanding, we have sub-divided this assessment into various categories and their respective sub-categories in Table 1.

The parameters considered for this categorization in Table 1 are as follows:

- Technology adoption by mental healthcare providers.
- Use-case and acceptance for treatment using these technologies by patients.
- Ethical challenges and shortcomings including a lack of research and design of the system.

2.1 Category 1: A Review of Healthcare Studies Using Virtual Reality or Augmented Reality

As the result of hectic lifestyles, the average stress level in a human being has doubled up as compared from past few decades and the lifestyle has become more complicated on an exponential level leading to which healthcare industries are in an avid need of finding new alternative methods. Due to which, new technological trends have gained more popularity in health care. Henceforth, we are discussing various studies based on AR/VR for the mental healthcare industry scenario.

2.1.1 Virtual Reality Therapy for Public Speaking Anxiety

Cognitive-behavioral therapy is the largely the common cure for public speaking anxiety disorder. Justas and Audrone et al. describe the architectural and technical decisions formed to design a mobile and cloud-based lightweight system that possibly gets adopted by any psychology clinical center [6]. Furthermore, data gathered from 30 participants are further analyzed taken from those gone through a VRET session for the treatment. The objective of this study is to design a standalone cloud-based VRET system which could be useful for the system as a service (SaaS) solution for
people dealing with a public speaking anxiety disorder. The conclusion discussed is that VRET scenarios created a stimulus that is more powerful than that in front of a therapist. Furthermore, this can potentially be introduced as a more universally adaptable virtual reality technique for psychological departments. Scope of the study is further discussed:

- Extract and deliver bio-feedback signal features to the therapist table in real-time.
- Develop a self-treatment online module.
- The system is worn to conduct a complete random clinical test that would consist of the control group.

2.1.2 Virtual Reality Environment and Mindfulness-Based Stress Reduction

This study is based on mindfulness-based stress reduction (MSBR) related to the serious problem known as chronic pain. Tong et al. carried out this conceptual study for the virtual environment system known as “virtual meditative walk” (VMW) to foster patients dealing with chronic pain and help them to direct their attention with ease for mindfulness [7]. The conclusion was a successful discussion on how to design VMW to support and induce learning MBSR techniques. Costa et al. [8] suggested for enhanced immersive environment design to support MSBR in addition to more advancement such as associative nature between three concepts being a presence, meditation depth and perceived restoration about their causal relationship and future scope.

2.2 Category 2: A Review of Healthcare Studies Using AI/ML

Although AI/ML is not a new concept these days. The adoption of these technologies is still limited to some major extent. For example, prescribing the right antidepressant medication for acute or chronic depression to the right patient is not an easy job. Hence, advancements in this region have already been formed by taking some explicitly sensible objectives. Machine learning targets health care by utilizing the images, clinical records and other electronic health records (EHR). This has proven out to be revolutionary and helpful for patients’ evaluation and treatment. This section discusses some studies targeted specifically for mental health care using artificial intelligence and machine learning.

2.2.1 Smart Mental Healthcare Technological Services

A study conducted by Lee et al. [9] for the prime goal to investigate already applicable smart mental healthcare technologies to deduce an artificial intelligence system model which is to be called as a comprehensive mental healthcare stepped-care model
(CMHCSM) [8]. This particular study encourages using various SmartMentalTech as a mode of self-treatment for users. In a conclusion, it was found out that in South Korea and Japan there are a different set of users who uses a specific type of SmartMentalTech. Furthermore, the study encourages future researches to be conducted in the evidence-based analytical study for the same area.

2.2.2 Mobiles, Wearables and Technologies for Mental Health Care

This comprehensive paper by Luxton and June [10] presented study on artificial intelligence-based applications used by smartphones, wearables or gadgets for mental health care [10]. mHealth devices and software applications benefits are discussed followed by AI methods descriptions of mHealth. This study provides design recommendations and ethical considerations for implementations of these smart technologies in mental health care.

2.2.3 Machine Learning in Depression Prediction

This recommended [11] study aims to calculate correct prediction patterns for late-life depression (LLD) diagnosis so that medical care is done more precisely rather than conventional trial and error based on behavioral signs and the symptoms. The machine learning approach known as alternating decision trees predicts a highest accuracy for LLD (87.27%) and treatment response (89.47%). As a result, a combination of multi-modal imaging and/or no-imaging helps in effective prediction for the LLD diagnosis [11].

2.3 Category 3: A Review of Healthcare Studies Using Big Data Analytics and IoT

2.3.1 IoT System to Track Mental Stability in Patients

A paper proposed by Hayati and Suryanegara [2] introduced an IoT-based system design called LoRa system which is short for the long-range radio system can be applied for tracking and monitoring mental stability of the patient. The system is a combination of a tracker device and gateway to be installed on the patient and hospitals and other locations, respectively. A LoRa end-device that has the Dragino LoRa shield wireless, Arduino Uno board, GPS sensor and Wi-Fi module that is deployed in a microcontroller are the constituents of the system. To conclude, parameters considered are feasible based on system efficiency, battery life and adaptability. The future scope is to engineer this design prototype for a real-time system [12].
2.3.2 IoT System for Post-Traumatic Stress Disorder (PTSD)

McWhorter and Brown et al. [12] proposed a comprehensive paper for a wearable monitoring system that is used for tracking sleep patterns, nightmares signs and in the attempt to control them or awaken the patient peacefully [13]. This may help out a patient’s lifestyle dealing with post-traumatic stress disorder (PTSD). The conclusion describes that this system is feasible in the long run in an attempt to benefit people suffering from PTSD and reduce their pain, anxiety, depression and hopefully the number of suicide rates.

2.3.3 IoT-Based Affective State Mining

Alam and Abedin et al. [13] proposed an Internet of medical things-based system for emotion detection. Psychophysiological outcomes are acquired via electromyography (EMG), electro-dermal activity (EDA), an electrocardiogram (ECG) medical sensor and calculated with the help of the convolutional neural network (CNN) [14]. This study concludes that this type of state mining method guarantees better results as compared to the previous method.

2.3.4 Big Data Analytics in Predicting Mental Illness

Social media is a goldmine for big data analytics and it can be extremely beneficial for future research conducted as a basis for any type of mental disorder. A study by Thorstad and Wolff [14] investigates the signs present in people’s everyday language containing significant phrases or indications to smartly analyze and predict the mental illness for present or future scenario. Social media Web site Reddit is a source for data collection [15]. The conclusion from this study was exactly resulting to deduce various types of psychiatric disorders (ADHD, anxiety, depression, etc.).

3 Comparative Analysis

The following comparative analysis is a comprehensive attempt to describe various studies proposed or applied in the healthcare sector for Industry 4.0. Selected technologies in the comparative analysis such as VR, ML and IoT are in trend in the year 2020 and will surely be used for future developments for the healthcare Industry 4.0.

It has been found from the comparative that there is still a lack of research in these fields but the future scope is definitely possible. Table 2 is a comparative analysis based on various technologies to promote more research in mental health care. These ICT-based wearables, gadgets and sensor systems would aid in more person-centered or personalized experience in the diagnosis of various issues regarding mental health.

The parameters considered for this categorization in Table 2 are as follows:
| References                  | Type | Primary findings                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Shortcomings and real-time use                                                                                                                                                                                                                     |
|-----------------------------|------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Šalkevičius and Miškinytė [6] | VR   | During the experimental analysis of this study, the system used by patients for VR solution was VR GEAR and by psychologists was WebGL. The objective of this is to create a VR system specifically for the SaaS solution. After the VR session, results have shown that the VRET session is better than a therapist for public speaking anxiety disorder (PTSD).                                                                                                                                                                                                                       | Cost-ineffectiveness of the software VRET on cloud comes with benefits of user-friendliness and cover a larger diameter in terms of reach as compared to standard VR or just a therapist It can be used as an additional tool for the treatment |
| Patel and Anderson et al. [11] | ML   | An ML-based method, alternating decision trees estimates the highest prediction. Wherein, depression patients \(n = 33\) and non-diagnosed patients \(n = 35\) compared based on cognitive levels. Conclusion from the diagnosis is that the prediction would be more effective if multi-modal imaging is used (with or without a non-imaging)                                                                                                                                                                                                                       | One of the major shortcomings came in the form of a small sub-sample size for the treatment response prediction The outcomes may help practitioners to understand LLD in a better way rather than going for a conventional trial and error method for the treatment |
| Alam and Abedin et al. [13] | IoT  | During the experimental study, a benchmark dataset (DEAP) calculates the efficiency of the IASM framework by using a neural network (CNN) and a testbed. The Lua language along with Torch 7.0 deep learning framework is applied for developing CNN using a testbed, Lua-JIT is installed after the Torch 7.0. The conclusion comes out to be that, it provides higher accuracy of 87.5% in contrast to the physiology-based recognition methods                                                                                                                                                                                                                       | Despite having a specific hardware requirement, the system is not 100% accurate to predict State mining can help in proving additional help for early health practitioners who have maybe less experience in psychiatry or those who may need it                                                                                                                                 |

(continued)
Table 2 (continued)

| References                                    | Type | Primary findings                                                                 | Shortcomings and real-time use                                                                                                                                 |
|------------------------------------------------|------|----------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|
| McWhorter and Brown et al. [12]               | IoT  | Smart wearable technology like Fitbit charge HR is considered along with the integration of ML-based proposed system which can be deployed in a home automation device carrying HUB like INSTEON that comprises of intelligent outlets, oil diffusers, audio systems, etc. Furthermore, the conclusion of this study provides ongoing comfort and treatment to the users dealing with PTSD | Despite being cheap and easy to deploy, this proposed system can arise some issues like the security of user data and privacy breach due to Bluetooth service as a mode of data transfer. The system can be used by healthcare providers as alternative/additional modes for treatment. Cheap and easy to use possibly help in preventing any greater concern to the patients. |

- Type of technologies such as VR, ML and IoT in psychiatric health care.
- Primary findings based on the selected study.
- Shortcomings and uses based on the selected study.

This is how Industry 4.0 is being promoted for psychiatric health care. We found out that IoT could be an efficient approach in the future developments for psychiatric health care. However, there is a huge scope for future advancements to be made and in more common adoption of these technological services by the mental health care with respect to Industry 4.0.

4 Conclusion and Future Work

This study contributes to emphasizing the most dominating challenges faced by psychiatric healthcare industries about how the technological revolution Industry 4.0 can resolve all their concerns. By performing a comparative analysis, we can say that there is an avid demand for health care or psychiatric healthcare industry to adopt these technologies in action. To conclude our study, we have described the use of Industry 4.0 based on its significance to end-users.

1. **Patients**: AI, AR and VR are able to provide comfortable, affordable and convenience rather than going for regular visits to a professional as it would be easily accessible from a smartphone or computer.

2. **Health practitioners and Therapists**: Alternative treatments in the form of virtual reality, faster approach and better measurement and monitoring of the patients’ condition through machine learning, IoT and big data analytics.
3. **Research and Development**: Big data analytics and IoT being a goldmine of research and development [16], it would be beneficial for new generation of researchers to further dive into new developments for future. Furthermore, it would open up vast opportunities for the next generation of mental health.

4. **Academics**: Psychology institutional departments and universities will be able to improve the quality and value of academic pool of knowledge and education by introducing new technologies such as big data analytics, IoT and VR based systems to carefully scale up and broaden the horizons to more practical-based knowledge and understanding of the concept.

Finally, we can say that there is a vast potential for research and development in the recently explored area like big data and IoT and the scope of Industry 4.0 revolution for psychiatric health care in high. For a future work of this study, we hope to propose a study aimed at integrating healthcare 4.0 like big data analytics, machine learning and data science for Internet of medical things (IoMT) in analyzing the sleeping patterns of students to analyze any mental health issue caused by lack of sleep and proper rest such as hallucinations, depression, stress, anxiety and post-COVID-19 pandemic.

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