Artificial Intelligence in Addiction: Challenges and Opportunities

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Artificial intelligence (AI) involves creating machines, software, and applications to perform functions that would typically require human intelligence, such as tasks that involve understanding natural language, analyzing patterns, and making decisions based on recorded data.[1,2] AI-based tools are increasingly being utilized in the field of healthcare to improve patient outcomes by promoting precision medicine, streamlining service delivery processes, and enhancing the efficiency and quality of medical research.[3] In mental healthcare, the application of AI is slowly gaining momentum, with recent research focusing on exploring predictive diagnostic models, screening tools, telepsychiatry, robot-delivered psychotherapy, and avatar-assisted interventions in various domains of psychiatry, including mood disorders, psychosis, and geriatric mental health.[4]

Among the various mental health conditions, one field that has not received adequate focus in terms of AI-based advancements is addiction, which includes both substance use disorders and addictive behaviors, including gambling disorder and online gaming disorder.[1] According to the United Nations Office on Drugs and Crime (UNODC) report of 2020, more than 250 million people in the world use drugs, and more than 35 million people are affected by substance use disorders.[5] Substance use disorders are a common cause of morbidity and mortality, with significant associations with mental illnesses and communicable diseases, including human immunodeficiency virus (HIV) infection, hepatitis B and C, tuberculosis, and sexually transmitted infections, along with accidental deaths or injuries due to overdose or driving while intoxicated.[6] Global Burden of Disease Study, 2019, estimated age-standardized mortality of 204.7 per 100,000 attributable to substance use from 2009 to 2019.[7] Substance use also incurs heavy social and economic costs related to crime, healthcare, law enforcement, and lost productivity, especially in adolescents and youth population. Moreover, developing nations like India languish under the burden of a huge treatment gap for substance use disorders, mainly due to stigma, inadequate professional workforce, and limitations in healthcare infrastructure for prevention and management initiatives.[8] It is thus imperative that the role of AI be explored for substance use disorders along with other aspects of mental healthcare.

Current Status of Research on the Application of AI in Addiction

Existing studies on the role of AI in the field of addiction are limited in number and focus on AI tools based on machine learning and language learning modules in pattern recognition and prediction models for substance use behavior (**Table 1**). A study comparing the treatment outcome of 12 weeks of cognitive behavioral therapy (CBT) for 780 patients with alcohol use disorder predicted by machine learning models (Fuzzy Unordered Rule Induction Algorithm, among others) with that predicted by treatment providers reported no significant difference between the accuracy of the two.[9] Another study performed 350 facial captures in the thermal energy spectrum by convolutional neural network (CNN) along with Fischer Linear Discriminant (FLD) for dimensionality reduction and identified drunk drivers with 87% accuracy.[10] In a longitudinal study involving more than 700 children and their parents, Jing et al. used the random forest (RF) algorithm to predict

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HOW TO CITE THIS ARTICLE: Suva M, Gayatri Bhatia G. Artificial Intelligence in Addiction: Challenges and Opportunities. *Indian J Psychol Med.* 2024;XX:1–5.

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Submitted: 09 Feb. 2024
Accepted: 30 Jul. 2024
Published Online: xxxx

ACCESS THIS ARTICLE ONLINE
Website: journals.sagepub.com/home/szj
DOI: 10.1177/02537176241274148

TABLE 1.

Current Status of Research on AI in Addiction.

Author (year)	Findings
Symons et al (2019)[9]	There was no significant difference in the predicted treatment outcome of 12 weeks of CBT for alcohol use disorder between machine learning models and addiction therapists.
Menon et al (2019)[10]	Facial capture in the thermal energy spectrum using a CNN identified drunk drivers with 87% accuracy.
Jing et al (2020)[11]	A machine learning model (RF algorithm) could predict substance use in children based on lifestyle variables with an accuracy of 74% at the age of 10 and 86% at 22.
Dou et al (2021)[12]	Machine learning and language processing-based substance use detection systems to detect substance use among homeless youth using social media posts achieved receiver operating characteristic-area under the curve (ROC-AUC) scores of 0.77.
Ebrahimi et al (2021)[13]	A 4-layered, fully connected feed-forward DNN could correctly identify 96, 82, and 89% of normal, hazardous, and harmful drinkers based on electronic health records.
Curtis et al (2023)[14]	Bidirectional Encoder Representations from Transformers (BERT) outperformed standard psychometric assessment in predicting treatment outcomes at 90 days using social media language (risk score for dropout AUC=0.81; p<0.001).

the onset of substance use with an accuracy of 74% in 10-year-olds and 86% in 22-year-olds. The authors identified 30 lifestyle variables that were strongly predictive of future substance use, which shifted from psychological issues and risky health behaviors in late childhood and early adolescence to non-normative social behaviors in late adolescence and early adulthood.[11] Another study developed a machine learning and language processing-based substance use detection system, which was able to identify substance use among homeless youth using social media posts with an accuracy of 77%.[12] A similar study demonstrated the use of deep neural networks (DNN) for identifying patients with alcohol use disorders based on electronic health records, reporting that the method could correctly identify 96, 82, and 89% of normal, hazardous, and harmful drinkers [13] Another recent study assessed the predictive capability of an AI-based digital phenotype recognition model using the social media language of patients receiving treatment for substance use disorders (N = 269). This was done using a deep learning model, Bidirectional Encoder Representations from Transformers (BERT), which generated risk scores using the pre-treatment digital phenotype and medical records to predict the risk of treatment dropout. The authors reported that language phenotypes were significantly superior to standard psychometric assessment in predicting treatment outcomes at three months.[14]

These studies establish a promising role of AI-based tools in the early identification and prediction of treatment outcomes for patients of substance use disorder. However, these studies have relatively smaller sample sizes and a culturally homogenous sample population and have not been reliably replicated, precluding generalizable conclusions. There is a lack of multicenter studies, studies with interdisciplinary collaboration, and research replicating the current findings across varying geographic regions, cultural backgrounds, and socioeconomic statuses. A majority of the studies are based on language learning and pattern recognition, focused only on predictive models, and trials on AI-based interventions or service delivery systems have not yet been attempted. Current literature also appears to have focused on substance use disorders solely, and the potential of AI remains largely unexplored in the field of behavioral addictions, such as online gaming disorder and problematic Internet use, which are a rapidly emerging public health concern.

Potential Applications of AI in Addiction Psychiatry

The potential applications of AI in the context of addiction may be studied under four domains: identification, management, relapse prevention, and prognostication. Early identification of substance use disorders (including screening and recognizing hazardous patterns of substance use and associated high-risk behaviors) results in timely engagement with treatment services before the development of physical or psychosocial complications. Psychological interventions directed at preventing relapse, such as craving management, stress management, and coping skills training, are effective techniques for maintaining long-term abstinence from substances. Based on the current literature, AI-based models are capable of determining specific risk factors for the onset and progression of addictive disorders based on big data analysis and pattern recognition along with their significance, thus predicting personalized risk of developing an addictive disorder in individuals at multiple stages of life, proving their utility in early identification and prediction of treatment outcomes.[14] An added advantage of AI-based predictive models is the ability to automate and scale programs to optimize multiple epidemiologic, geopolitical, and sociocultural variations in the patterns of addictive behaviors. This may significantly enhance the generalizability of the output, and the model may be applied reliably to populations from varied sociodemographic and ethocultural backgrounds.

In the same vein, escalation reduction-based AI programs, like Addicaid and Sobergrid, utilize real-time geographical location monitoring and can alert at-risk individuals, or individuals in treatment, when they get near trigger locations—for example, bars or clubs—where specific substances are known to proliferate. This may prove valuable in relapse prevention programs (16). Based on data collected during treatment, such as an individual's behavioral patterns and thought patterns, AI-based predictive analytics can forecast the risk of relapse with reasonable accuracy.[3] This can be especially useful for behavioral addictions such as Internet gaming disorders and gambling

disorders by monitoring an individual's digital use and/or finances. Furthermore, by identifying potential triggers and vulnerable periods, AI can alert both patients and healthcare professionals, enabling timely interventions, reduced number of lapses, and increased rates of positive treatment outcomes.

In terms of management, even though in-person human-to-human support may remain irreplaceable, AI chatbots and similar virtual assistants allow for instantaneously accessible support to individuals seeking help for addictive behaviors or experiencing an addiction-related crisis. These virtual counselors can be programmed to engage in conversations and role-plays of varying complexities, providing psychological support as per evidence-based interventions such as motivational enhancement, supportive psychotherapy, coping skills training, and behavior change communication, thus providing continuous assistance during the recovery journey and in the long term, reducing the caseload on the exiting addiction treatment services and bridging the treatment gap in addictive disorders, especially in developing countries.

Another important benefit that AI may add to addiction treatment is enabling the healthcare provider to formulate an individualized treatment plan. The AI algorithms can process vast amounts of data expeditiously, including genetic information, medical history, behavioral patterns, multicultural considerations, and treatment outcomes, among other important factors, and generate detailed treatment plans tailored to the unique needs, characteristics, and treatment goals of every individual.[1,14,15] This approach can significantly enhance the effectiveness of addiction recovery programs, as it ensures that treatment plans are designed considering an individual's specific goals and challenges.

The AI-powered database tools may also aid in secure data storage and collation, helping those seeking pharmacological maintenance such as opioid-assisted medical treatment (OAMT) in continuing regular treatment in case of relocation, immigration, hospitalization due to medical causes, or even incarceration. They may also be utilized as efficient reminders to patients for upcoming follow-up visits, which may prove useful for patients with comorbid physical and mental illnesses, including cognitive impairments; may co-ordinate between patients and treatment providers for effective rescheduling of missed appointments; and may alert the healthcare providers for clients lost to follow-up, aiding in outreach-based psychosocial interventions. Identification of overdose and alerting emergency response teams in the event of an overdose are also public health concerns that may be explored for the potential application of AI.

In the context of behavioral addictions, machine learning-based individualized early warning mechanisms for Internet addiction symptoms may be installed in smartphones and computers for early identification of Internet addiction symptoms and achieving early prevention on a large scale in vulnerable populations.[16,17] Machine learning tools may monitor online transactions, borrowing, and spending behaviors for patients with gambling disorders, providing personalized feedback, which may enhance treatment seeking.[18] Similar personalized feedback and behavior change communication may be applied to other addictive behaviors such as compulsive shopping, video gaming, and compulsive television viewing.

Challenges in the Utilization of AI in Addiction Psychiatry

Although AI shows promise in the field of addiction medicine, its effective application comes with challenges and ethical issues that lack concrete answers as we stand today. The AI-based prediction models, in order to recognize patterns and make predictions with reasonable accuracy, require a large amount of data to be fed beforehand, which requires detailed past medical records and notes of doctor-patient interaction stored either in physical or electronic form. Not only does digitizing this data require an enormous number of person-hours, but this data needs to be recorded from a wide variety of sociocultural environments in order to ensure applicability to various commonly encountered situations and cues for substance use.[17]

Also, in the context of the principles of ethical practice, sharing in-depth details of patient interaction with a third-party agency, such as developers of the AI applications, may violate the boundaries of physician-patient confidentiality.[19] At present, there is a lack of guidelines and directives that encompass various forms of AI-based assistance and therapeutic services provided by mental health professionals, and existing laws do not precisely define software-developing agencies' accountability for errors or any other adverse incidents that may occur due to technology malfunction.[1,20] At the same time, AI comes with other noteworthy issues, especially related to informed consent and client autonomy, transparency, diagnostic dilemmas and misdiagnosis, misinterpretation of the information provided, and algorithmic bias.[14]

Another pressing issue is the occurrence of algorithmic bias in AI-based predictive models for the diagnosis and prognostication of substance use disorders. Algorithmic bias in the context of healthcare has been defined as the incidences where the application of an algorithm ends up compounding the existing inequities in health service distribution, mainly due to a lack of contextual specificity.[20,21] Thus, AI-based predictive models may not give due concern to bio-psycho-social and geo-cultural variations around the world and may risk providing inaccurate results in under-represented populations, such as ethnic and sexual minorities, due to a lack of adequate data specific to these special population groups.

As per current literature, most AI applications that have been designed and studied provide singular interventions or predictive output along an isolated line. This may prove to be challenging in providing personalized care to patients with substance use disorders in a real-life clinical setting as they require multiple forms of interventions in a combination that may need modification from time to time as per their unique needs and treatment expectations. Also, pilot studies assessing feasibility, acceptability, and applicability on patients of substance use disorders, particularly in developing countries, have yet to be conducted, limiting our understanding of the ground reality to mere conjecture and opinion.

Recommendations and Future Directions

There is a need to address the issues mentioned above in order for AI's potential applications in the management of

addictive disorders to translate effectively from research into clinical practice. Greater research evidence needs to be generated, including large-scale multicenter trials with interdisciplinary collaboration and data collected from various sociocultural settings that are recorded rigorously for accurate analysis and predictions. Emerging aspects of addiction, such as behavioral addictions and real-time monitoring and interventions, also need to be given due focus from research and clinical standpoints. Standard checks on algorithm design from technical, ethical, and clinical authorities need to be conducted regularly in order to mitigate algorithmic bias and generalization of chance findings. Guidelines on data sharing, accountability, transparency, and consent from patients and clinicians need to be developed while keeping in mind the ethical principles of clinical practice. Effective systems for data storage and access permissions need to be developed in order to avoid misuse of confidential records. AI developing agencies may also upgrade existing models to incorporate a greater number of functions so as to enable an integrated approach to the management of addictions and dual diagnoses. Factors such as healthcare infrastructure and resource availability are essential policy-level considerations and need to be upgraded at par with the standards requirements for effective utilization of AI tools, especially in developing nations, which not only face the maximum burden of substance use disorders but also languish under a humongous treatment gap. Last but not least, clinicians may need sensitization to the need for AI application in their routine practice, along with resources to upgrade their knowledge and skills in order to effectively employ AI in the management of healthcare conditions, including substance use disorders.

Conclusion

AI is a promising avenue in the context of addiction treatment, warranting more systematic research and knowledge acquisition for its optimal utilization. AI has a huge potential in early identification, personalized treatment, prediction and prevention of relapse, and maintaining continued and easily accessible support for individuals with addictions. However, it is essential to proceed with caution, ensuring that ethical considerations, privacy concerns, algorithmic bias, and infrastructural challenges are carefully addressed. As AI continues to evolve, collaboration between experts in addiction psychiatry and AI researchers is crucial to access the full potential of this technology and provide the best possible care to those in need.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

Declaration Regarding the Use of Generative AI

The authors did not use AI in any aspect of writing this manuscript. They assume full responsibility for its entire content.

Funding

The authors received no financial support for the research, authorship and/or publication of this article.

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