Motivational Dialogue Systems and Adherence Trajectory Modelling: AI-Driven Platforms for Enhancing Patient Engagement and Therapeutic Adherence

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1. Introduction

Technological innovations, such as artificial intelligence (AI), have found their place in healthcare, with over one third of global investment being committed to developing AI-driven healthcare platforms. The quest, however, for impactful and scalable AI-driven platforms that benefit the patient or healthcare provider continues. An important part of this is patient engagement and, for long-term conditions, adherence. In the UK, more than three quarters of primary care consultations involve patients with one or more long-term conditions, which will eventually cost the NHS around £4 out of every £5 spent. There are many potential interventions that could help, but patients live with their long-term condition all of the time, not just when they encounter healthcare services. The complexity of the best ways to help people living with long-term conditions to have a good life and a healthy future requires a range of expertise that draws on AI for personalization, machine learning to inform the continuous improvement of the system, and the skills and experience of behavioral scientists. AI-based models can be very powerful when they use machine learning to learn about people from the data they generate themselves.

However, recruitment can stay slow, making patients wait and potentially affecting the final results. The topics of ethics and data protection were beyond what could be considered within the scope of the research discussed. Personalized health interventions cannot be developed solely by drawing on single-discipline expertise, but need to pull on a combination of AI, machine learning, and interdisciplinary behavioral science. This is the problem-solving supported by machine learning discussed here. The main goal is to help both researchers and practitioners in the AI domain articulate the need for and potential of AI-based, patient-facing personalization in long-term condition

management. The different types of interventions that are currently available are outlined and the rationale for personalized behavioral support presented. Throughout the process, a range of ethical considerations arise, and these are incorporated into the text at relevant points. The weaknesses of currently available interventions are briefly discussed, and next steps are identified, so as to open up for future work within the domain. The text is structured as follows: first, available interventions are described and issues in their personalization outlined. The rationale for personalizing behavioral support follows, with a discussion of ethics included throughout.

2. Understanding Patient Engagement and Adherence

Patient engagement is typically defined as the individual's involvement in their healthcare in sessions and beyond. Enhanced engagement is thought likely to lead to improved health outcomes, better cost and quality of care, and a reduced demand on services. In a similar manner, adherence is defined as the extent to which a person's behavior – taking medication, following a diet, and/or executing lifestyle changes, corresponds with agreed recommendations from a healthcare provider. In practice, most proposals for interventions to improve patient engagement seek to indirectly improve adherence. Unfortunately, adherence is often poor across a wide range of diseases. Multifaceted approaches to improving it are complicated by it being driven by many factors that interact in a complex manner. Psychological drivers include, for example, apathy, an unwillingness to accept a diagnosis, forgetfulness, depression, and the desire to be in control of one's treatment. Additionally, subjective norms are involved, while patients' individual financial situations have also been shown to increase adherence.

A distinction is sometimes drawn between the degree to which patients are engaged in their care and have the power to make decisions about it, and the subservient involvement when they are dependent on and willing to comply with the expertise of the healthcare practitioner. Professional involvement and support to some extent convey a continuum between the two positions. There is therefore tension involved between the requirement for patient self-management and the need for healthcare professionals to provide professional support. Historically, the patient has usually been at the receiving end of the provision of information, with efforts being directed at increasing knowledge and education, and improving communication between healthcare provider and patient in order to achieve this. Engagement has been widely studied in a range of contexts.

Measurement of adherence and engagement is difficult, with self-report measures often bearing little relationship to the reality.

3. The Role of AI in Healthcare

Artificial intelligence (AI) and related technologies have the potential to transform healthcare due to advances in machine learning (ML), predictive modeling, robotics, and natural language processing. AI can analyze large and complex datasets quickly, securely, without bias, and with minimal error. AI can handle routine tasks in both clinical care and practice operations, freeing human health professionals for more complex decision-making and interactions with patients. AI's quantitative and data-driven insights have been used for data analytics, predictive modeling, and decision support systems for evidence-based clinical and operational decision-making. In healthcare, ML methods have frequently been used to make predictions for diagnosing conditions and hospital-acquired infections, planning treatments, monitoring patients, and detecting errors. In particular, cognitive AI can identify hidden insights, patterns, and combinatorial relationships at the atomic levels, which can lead to medical breakthroughs and stratified patient-centric care. AI can use personal data to recommend health strategies and treatments based on the conditions or circumstances, genetic factors, family histories, preferences, goals, and other attributes of individual patients. AI-powered cognitive systems can help transform the healthcare user experience and expedite the development of personalized health interventions and behavioral support mechanisms. Since AI has the potential to free clinicians from time-consuming documentation and administrative tasks, they could focus more on providing better healthcare and empathy to their patients. Nevertheless, physicians encounter multiple challenges related to AI applications, including regulatory barriers, lack of interoperability, algorithm bias, lack of technology talent, and training needs. The application of AI to improve patient engagement and minimize non-compliance with medical treatment is also associated with ethical implications such as accountability and transparency for clinical outcomes and social impacts. There remains a significant need to reduce the incidence of avoidable SCD and to seek innovative approaches that could improve the cost-effectiveness and clinical outcomes associated with current healthcare practices.

4. Machine Learning for Personalized Health Interventions

Machine learning engines could develop countless algorithms that determine the best approach for an individual patient. A few of these "statistical whizzes" could identify healthy behavior patterns from large numbers of cases and then predict the outcomes for other similar cases, such as which patients become adherent and healthy. This adaptation of treatment to an individual is something no one is good at without this type of analytical assistance. Think of the machine learning suggested therapy plan as one that is tailored best to work for the individual and the abandonment analytics for those that are unlikely to succeed with adherence after using the assistive tools. Such a personalization process aligns with the rising trend in health called "personalized medicine"—tailoring treatment plans to fit an individual instead of a group. Collecting data to learn about patient variations is the first step toward personalization. Many companies are experimenting with gathering individual patient data from thousands of chronic disease patients using electronic means and studying the impact of diverse therapy approaches. Most of the evidence that patient data can be used to predict the best approaches has been in diabetes because of the substantial amount of patients and data that can easily be captured through mobile apps and cloud data sharing in a compliant manner. Machine learning is the development of algorithms that can find supportive patterns or predict any type of outcome of interest. In short, these engines learn from the data and get smarter and more predictive with each data point. These self-improvers iteratively differentiate the data input into probable categories or predict certain outcomes such as those described above for adaptive and individualized therapies. Such self-improvers continue to cycle through repeated learning tests on the data. This process should be built into the design of the learning healthcare system. If an engine can predict with high confidence that a patient is likely to abandon therapy, they can receive special early attention. There is a commitment in machine learning that it will be designed to be constantly learning and improving to contribute to the evidence.

5. Behavioral Support and AI-Driven Platforms

Use of technology in healthcare is increasingly driven by an understanding of patient behavior. By understanding how and when patients are most likely to engage with different components of technological tools, platforms, and interventions, we can design more impactful interventions. In this sense, behavioral science and technology have a natural boundary. Hence, technology is most suited for population-level interventions,

especially when guided by computational models. At the same time, people still differ in key ways that defy simple randomization, and it is exactly these individually varying components that are important for maximizing the impact, as they tend to influence the degree of engagement with technological tools and interventions. Most importantly, over extended periods of time, investment in personalized support increases the likelihood of adherence, and thereby a limited number of people may sustain full good function of a health enhancer.

Given these points, personalizing behavioral support is crucial. Tools employing machine learning will play a crucial role here. A number of AI tools are especially good at this personalized probability problem. Chatbots, for example, may determine the best timing for reminders based on an individual's behavioral patterns. Similarly, intelligent virtual health coaches can incorporate information about an individual's social context and use effective motivational interviewing to help people set realistic goals and enhance self-efficacy. Similarly, machine learning tools can be harnessed to guide and time behavioral nudges that help to steer behavior, for example, by promoting motivation and self-efficacy. However, as we integrate behavioral science principles within AI platforms, it is also important to consider human factors that play a large role in determining user acceptability, reach, scalability, and adaptability; the product must engage the user. Items from the user interface to strategies to enhance engagement need to be evidence-based. These areas continue to require further research and testing within an mHealth context.

6. Challenges and Ethical Considerations

Operating AI-driven health interventions is fraught with a number of difficulties and ethical factors. The use of healthcare data raises concerns around the privacy and trust of patient information and is subject to statutory and regulatory regulations designed to protect individuals. Sensitive data is a potentially lucrative target for malfeasance. The use of clinical and patient-generated data to create detailed health psycho-trees may lead to potential discrimination, "blackballing," and the potential leakage of this information to other, less salubrious actors. Furthermore, it is indicated that, while AI systems that promote medication compliance could be useful, they must be held to the same ethical standards of "rigor and robustness" as the drugs they supplant.

Issues around the potential perpetuation of unequal health outcomes due to the misinterpretation of data or biased AI health systems have been discussed. The "accountability challenge," which entails allocating blame and punishment if an AI system makes a grave mistake, is increased exponentially in the context of AI as a 'virtual practitioner.' Resistance from healthcare professionals and patients could inhibit adoption. It is seen as not only legally wise to consider individual perspectives in the use of healthcare data and AI in medicine but morally wise too, as a disregard of such an approach may dent public trust. Finally, there are ethical consequences associated with the informed consent possible in the formal setting of PPI. Current discussions within the AI and medical communities argue for a balanced approach that sees the deployment of theoretical guidelines and practical toolsets within the development lifecycle of AI-driven health interventions.

7. Case Studies and Success Stories

7.1. Human-Level AI in Patient Care and Monitoring Treatments

7.1.1. Introduction Below are some examples of applications, use cases, and success stories that illustrate the value and impact of AI-driven platforms in healthcare. Each case study addresses a different angle of patient engagement (outcomes achieved, engagement rates, adherence rates, etc.), as well as highlights a variety of healthcare domains to which AI-driven, patient-specific personalized health interventions and behavioral support can be applied, from chronic care diseases to preventive care.

7.1.2. Summary The most meaningful insights and lessons learned include the effectiveness of the patient outcome gain assessed via pilot and clinical trials, while the ease of use and patient engagement can be evaluated in parallel for scalability and cost-effectiveness. It is important for any AI-driven feature to demonstrate its gains in the context of the standard of care, where the standard may need to be adjusted to absorb the new functionality and show complementarity (rather than substitutability) of the intervention. The examples below are presented here in a more detailed and representative way and are not intended to be an exhaustive list.

7.1.3. Success Stories - Development in pediatric cardiology and ICU of augmenting decision-making in cardiac rehabilitation units in the mid-care setting from the real-world evidence. - Predictive model for patient adherence in stroke prevention care. - A

platform campaign for the MI cohort. - AI-driven integrated treatment plan for home-based stroke prevention. - Digital twin.

Future Outlook A broader adoption of these AI solutions has the potential to greatly reduce healthcare costs and hospital admissions, but this can only be proven with further application and with the global amalgamation of real replication projects.

8. Future Directions and Opportunities

The purpose of this paper is to introduce the concept of AI-driven platforms for building patient engagement and adherence strategies. We believe that technology platforms should drive continuous improvement of optimization models and shape design thinking to facilitate and foster innovative and efficient solutions. The AI community could offer a unique biomedical perspective on personalized medicine and ways to deliver tailored interventions. Furthermore, there exist emerging technologies not yet widely used in the precision health domain which could be offered to patients for educational purposes, enhancing the rationale and patient preferences regarding the behavioral part of the interventions. They may provide additional mechanisms and customize nudge strategies.

Obviously, iterative fast improvement should happen; nevertheless, only a small portion of protocols will achieve the possibility of an increased improvement. Finally, the combination of drugs versus placebo and platform-led RCTs are also of interest for hybrid palliative interventions. Participants also noted several other areas for potential expansion through future research. In terms of methods, while technology and technical requirements are evolving rapidly, several stakeholders expressed concerns about current patient engagement and adherence strategies. There was recognition that they are time-consuming, often not evidence-based, and usually take the form of a paper-based resource. The time taken to develop new patient interventions can also be prohibitively long, and some participants felt that a move towards the AI-driven approach should also see a shift from paper-based to digital interventions. The use of AI and existing learning algorithms can also be applied to healthcare use cases to develop potential solutions to some of these challenges. A common theme from attendees was the potential of these strategies for supporting and underpinning personalized medicine. The use of AI could model pretrial likely patient responses for patient engagement and adherence interventions, utilizing demographic, cultural, and healthcare data. AI could

also move beyond personalized medicine and explore what has worked in other disease areas while tailoring solutions to local populations. In agreement with participant views, the use of AI could help to ensure and uncover effectiveness in different populations, but could also uncover inefficiencies in sticking to a cookie-cutter protocol strategy. However, it was also noted among participants that the use of AI could potentially raise regulatory and ethical issues in areas of efficacy, replication, and effectiveness, and that questions about the evidence required to provide novel interventions were raised. An attendee also noted that there would be a steep learning curve to integrate AI into the healthcare system. It may be less of a challenge for us to develop drugs but to get healthcare professionals to change their behavior and adopt these changes. Therefore, there is an interesting area to explore using AI to stratify patient knowledge. Research next steps using a more AI- and business-focused approach include diving into the technical/business cases for the development of these algorithms and discussing with the public, patients, and experts how to ensure AI can be used in a responsible manner.

9. Conclusion

AI-driven platforms are capable of overcoming a range of issues that undermine patient engagement and adherence. One such mechanism is through facilitating the delivery of personalized health interventions and behavioral support by applying sophisticated machine learning techniques to predict individual health trajectories. The software and systems described have a number of advantages over the current use of digital health interventions, which are of a 'one size fits all' design. They can be tailored and can more effectively stimulate engagement in users who require them. However, it must be acknowledged that delivering behavioral interventions at scale, such as in the context of national treatment guidelines, poses a multitude of challenges that demand significant further exploration and research.

As AI-driven platforms become more sophisticated, they can be trained to predict the effect that any given behavior change—however complex or subtle—can have on an individual's health. Turning these causal predictions into decision-making support for clinical services presents two major opportunities. Firstly, such systems can identify the remains of safety and harmfulness within a treatment option to create a more accurate and personalized recommendation for a patient. Secondly, when additional energy may

be expected to lead to improvements in health at both the individual and community or 'public' scale, such systems can be combined to form a public health recommendation.

Merging personalized and public health causal recommendations, however, comes with many important ethical and governance questions, spanning from the local clinical system to the international. Here, a brief summary and a call for further discussion and work in a field where the technology can be harnessed to benefit health and well-being is provided. As healthcare increases its reliance on various technologies, careful consideration must be given to the development of a decision-making framework that takes into account the full context of the person accessing care, which is possible only while integrating human judgment at multiple points of the care pathway. This presents a new direction in patient-centered AI, in which the weaknesses of purely machine-led recommendations can be augmented through integrating these with human expertise.

Concluding remarks: The field of personalized recommendation for behavior change is clearly advancing quickly. Healthcare is an area evolving towards greater digitization and will increasingly see application through software and algorithms to solve complex human problems. However, to benefit from these technologies and methodologies being described, academia, policymakers, health professionals, and industry stakeholders need to work together. Ensuring AI recommendations integrate both rigorous scientific and ethical principles, while acknowledging the importance of issues including privacy, equitable access, and the quality of data, is crucial to delivering positive patient and public outcomes.