Empowerment of Augmented Reality (AR) for Patient Education and Engagement: Medication Adherence Programs' Impact on Public Health Outcomes

Kamlesh Kumar Yadav[1], Dhablia Dharmesh Kirit[2]
[1]*Assistant Professor, Department of CS & IT, Kalinga University, Raipur, India*
[2]*Research Scholar, Department of CS & IT, Kalinga University, Raipur, India*

KEYWORDS

Augmented Reality, Patient Education and Engagement, Medication Adherence Programs, Public Health Outcome

ABSTRACT

The entire effectiveness of pharmacological treatment depends on patients taking their medications as prescribed. Patient education is a vital component of the endeavours to enhance adherence to medications. However, many people still fail to take their prescription pills as prescribed. In addition to having access to healthcare, those who follow their doctors' orders greatly improve their chances of a positive outcome. The unfortunate reality is that many people do not take their medications as prescribed, which has led to deteriorating health, higher healthcare costs, and more overall costs. Hence, this paper presents the Smart Augmented Reality-based Patient Medication Adherence Program (SAR-PMAP) model for effective patient education and engaging medication. The augmented reality spectacles help those with trouble keeping track of their medication, and the model encourages patients to take their prescriptions as prescribed. Users may easily go to their homes with the aid of the navigation functions, and patients with impaired eyesight can benefit from the audio option that gives out the date and time. Given all this data, the Medication Coach Intelligent Agent (MCIA) takes the lead in making comprehensive decisions so patients can get autonomous, individualized, and unobtrusive treatments.

1. Introduction

One of the most important factors influencing medication adherence is patient education, which encompasses people's access to, comprehension of, and use of health information. Worldwide, patients' failure to take their medications as prescribed is a serious health concern [1]. Medication adherence may be enhanced by patient education, compliance aids, appropriate motivation, and support, yet the former is still the most important factor [2]. Within their practice, healthcare providers should seek out methods to increase drug adherence that are feasible and likely to enhance therapeutic results. All parties engaged in pharmaceutical usage should be on board with the multidisciplinary approach needed to carry it out [3]. Inadequate management of blood pressure and avoidance of cardiovascular events may occur when prescription antihypertensive regimens are not adhered to [19]. There are many clinically accessible methods for assessing antihypertensive adherence to medication [5]. The provider's resources dictate the exact measure used for clinical practice, the information's intended purpose, and the method's acceptability and ease for the patient [20].

With the proliferation of mobile devices, Augmented Reality (AR) offers a promising new way to present personalized information and patient education in novel ways, potentially increasing medication adherence and improving patient education overall [7]. Incorporating virtual objects into the physical environment, augmented reality (AR) creates immersive learning environments that are both powerful and contextually relevant [21]. Since augmented reality (AR) has the makings of a useful patient education and health education tool, it is important to take inventory of where the technology is in this area [9]. Research has shown that augmented reality can be useful in a variety of contexts, such as helping patients with medication management and adherence through an app, enhancing tracking techniques in rehabilitation for better physical outcomes, simulating object aids in surgery to better visualize organs, and teaching anatomy to students outside of the traditional classroom setting [10]. Conceptual comprehension of complicated causality and dynamic models may be enhanced using augmented reality technologies, which enable the visualization of unseen or abstract ideas [11]. With the Microsoft HoloLens helmets, patients may use the Coach Intelligent Agent (MCIA) AR software to help them keep track of their drug regimen on their own [8]. The MCIA provides an interactive method of medication management, which also handles patient information such as medication prescriptions and plans [4]. Patients who were semi-independent or who needed expert assistance were the intended recipients [12]. The paper's main contribution is Designing the Smart Augmented Reality-based Patient Medication Adherence Program (SAR-PMAP) model for effective patient education and engaging medication. Introducing the Medication Coach Intelligent Agent (MCIA) leads with holistic decisions to autonomously offer patients personalized and unobtrusive interventions [6]. The experimental outcomes were performed, and the suggested SAR-PMAP model increased the patient recovery time, medication adherence assessment ratio, and patient behaviour prediction ratio compared to other existing systems.

2. Literature Review

Dominic Pilon et al. [13] suggested Oral Therapies for Medication Adherence Among Patients with Advanced Prostate Cancer (PC). Administrative data was used to identify patients with advanced PC who began treatment with apalutamide, enzalutamide, or abiraterone acetate between October 1, 2014, and September 30, 2019. The author used persistence and adherence six months after starting treatment to assess patient variables and healthcare resource utilization (HRU). Poor adherence/persistence, leading to greater HRU, was connected with being 75 years old or older, being Black, using chemotherapy, and paying more at the pharmacy. Liam J. Wang et al. [14] proposed VR-Based Education (VRE) for Patients Undergoing Radiation Therapy. The author undertook prospective research to ascertain if virtual reality (VR) to provide patients with radiation treatment plans enhances patient education and alleviates treatment anxiety. The number of patients that were enrolled was 43. Questionnaires were given to patients both before and after the encounter. 74% of patients who participated in the virtual reality session said they "strongly agree" that it helped them better comprehend the radiation treatment for their disease [22]. 12, or 57%, reported feeling less anxious about radiation treatment after participating in the VR session.

Benjamin D. Horne et al. [25] recommended the Randomized Controlled Trial (RCT) for Behavioral Nudges as Patient Decision Support for Medication Adherence. Participants in the 12-month, parallel-group, unblinded, randomized controlled experiment were adults seen at cardiology clinics affiliated with Intermountain Healthcare. Being a member of SelectHealth and having a prescription for statins were prerequisites for inclusion [15]. There was an individual ratio of subjects to nudges and controls. The proportion of days covered (PDC) was calculated using claims data from SelectHealth. Zhao Ni et al. [16] discussed the mHealth Intervention with a Randomized Controlled Trial (mhealth-RCT) for improving Health Outcomes and Medication Adherence Among Patients With Coronary Heart Disease. To better health outcomes and medication adherence, this research assessed the efficiency of a mobile health (mHealth) intervention utilizing two mobile applications. The whole study lasted 90 days, with 60 devoted to the mHealth intervention and 30 to follow-up without the intervention. The research coordinator sent educational materials and medication reminders via WeChat and Message Express. A minimum of five drugs were administered to almost half of the subjects (121/196, 61.7%). Xiaolin Wei [17] deliberated the multicentre randomized controlled trial (MCRCT) for electronic medication tracks to improve treatment results among tuberculosis patients. Participants were included if they were at least 15 years old when they began regular TB therapy and if their tuberculosis was drug-susceptible. Based on the survey, there are several issues with existing models in attaining high patient recovery time, patient behaviour prediction, and medication adherence assessment ratio. Hence, this study proposes the Smart Augmented Reality-based Patient Medication Adherence Program (SAR-PMAP) model for effective patient education and engaging medication.

3. Methodology

In all patients with drug-taking behaviour, non-adherence is a regular occurrence. Factors such as patient perspective and traits, disease features, societal environment, and access and service concerns make adherence difficult. Several factors can hinder the proper utilization of medications. These include a lack of understanding between providers and patients regarding the drug and its usage, scepticism regarding the necessity of treatment, anxiety about potential side effects, lengthy drug regimens, complicated regimens involving multiple medications with different dosing schedules, financial constraints, and limited accessibility. Medication efficacy and patient adherence to the therapeutic regimen are the two most important factors in determining the success of a therapy. Medication adherence may be improved by all parties involved in the healthcare system, including patients, physicians, and systems themselves. It is recommended to use a combination of adherence approaches rather than relying on a single strategy to increase drug adherence. An innovative approach has been proposed that utilizes intelligent coaching systems and the AR paradigm. Continuous self-management and the delay or reduction of nurse involvement are made feasible by a smart mHealth app that may aid patients with typical issues associated with medication management. The app can guide users and provide recommendations when filling a pillbox.

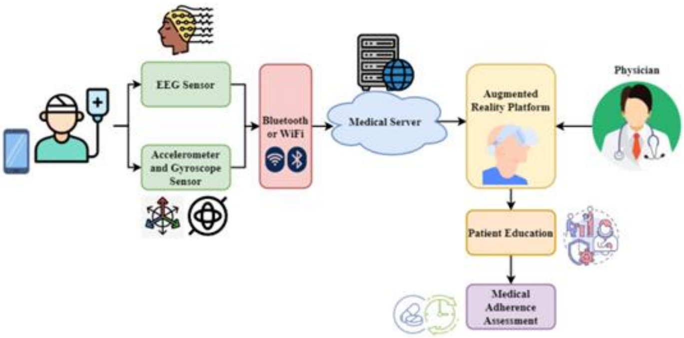

Figure 1. Proposed SAR-PMAP Model

Figure 1 shows the proposed SAR-PMAP model. The data was taken from the virtual patient model assessment [18]. EEG and AR headsets communicate with the command centre, which is responsible for logging all data, receiving and processing the signals, and then adjusting the parameters for the virtual environment. Moreover, the AR goggles can send messages to the carer in case of missed medicine, enhancing the safety net for the user. If the user selects Connect to AR goggles, the mobile application will connect to the goggles using either Bluetooth or Wi-Fi and use the AR goggles to display the medicine data on the mobile. The Bluetooth connection redirects users to a list of available Bluetooth devices where they may select the AR goggles' name to link the smartphone application to the system's microcontroller without needing Wi-Fi. If the user selects no, the mobile application will continue with the medication adherence independently. If the user selects ‘Get Date and Time’, the mobile application will provide the date and time information in an audible format, aiding patients with poor eyesight. Based on the nature of the injury, the doctor or physiotherapist may prescribe an appropriate course of therapy. If the pain is mechanical, for example, treatment should be on mending the affected tissue; if it is non-specific, however, the emphasis will be on educating the patient, getting them moving, and using manual therapy. Clinicians collected anecdotal feedback about the feasibility of using augmented reality computational fluid dynamics (CFD) simulations in a clinical context, whether for research, surgical planning, or patient education/communication.

The proposed scenario includes multiple challenges, such as reading the affective state from an Electroencephalogram (EEG), displaying a virtual environment in real-time at around 90 FPS, and adjusting parameters as quickly as possible; this study depends on the polling rate of each device, the wireless connection speed and interference, and the processing power of the AR headset and the main computer. Therefore, this study preferred a difference system that can swiftly be calculated and still provide a mechanism to reach the goal. A simple first-order linear difference equation (FOLDE) could follow the form $x[m] = \beta_1 x[m-1]$ and then this study solved by inspection as Equation 1 shows, and it became a closed-form definition resulting in $x[m] = x[0]\beta_1^m$.

$$x[m] = \beta_1 x[m-1]$$
$$= \beta_1\left(\beta_1(\beta_1(\beta_1 x[0]))\right)$$
$$= x[0]\beta_1^m \quad (1)$$

After careful analysis, this study noticed that the best approach was a discreet mechanism instead of directly adjusting the values and risking causing discomfort and rejection. This study registered every time the system detected that the selected parameter was below the recorded average baseline for that specific user, as shown in Equation (2).

$$R_y = \begin{cases} +1 & if\ current < \mu_y \\ -1 & otherwise \end{cases} \quad (2)$$

It is important to mention that the report count increases when the value is still below the average, increasing the adjustment's effect. We decided to limit the number of reports from 0 to 10, first to have a quick response and secondly to have a smooth transition where zero has no adjustment, and then this study has ten levels of adjustment to gradually alter the environment. For each given AR acquisition, the following procedures were used to process the x-, y-, and z-axis signals for N1-Chest (or N2-Thumb): first, for the accelerometer (ACC) signal; second, for the gyroscope (GYR) signal. Each signal component was subjected to band-pass (9-13 Hz) second-order Butterworth IIR filters. The magnitude of the overall accelerations (for both the linear and angular elements individually) was determined (Equation (3)).

$$\bar{b} = \sqrt{b_x^2 + b_y^2 + b_z^2} \quad (3)$$

The magnitude vector was then processed utilizing second-order Butterworth filters with a band-pass range of 0.75 to 2.5 Hz. This filter effectively limits heart rate (HR) detection to the 45 to 150 bpm range. The absolute amount of the difference between a quantity's observed and actual values is known as the mean absolute error (MAE). After that, we looked at the absolute disparity between the head-mounted display and the inertial measurement (IMU) readings. Equation (4) was used to compute the MAE of the angular movements:

$$MAE = |Mean\ Head\ Mount\ Display\ Motion - Mean\ inertial\ mesaurement\ unit\ Motion| \quad (4)$$

The MAE percentage (%MAE) has been computed to assess the absolute error with Equation (5):

$$\%MAE = \left(\frac{MAE}{Mean\ IMU\ motion}\right) \times 100 \quad (5)$$

A device's criterion validity might be defined as the extent to which its results adequately represent an ideal. Comparing the IMU and HMD angular displacement using bivariate correlation with the Pearson (r) correlation coefficients allowed us to compute the validity of the criteria. To determine the strength of the connection, we used the following criteria: r < 0.49 was considered poor, r = 0.5-0.75 was measured moderate, and r > 0.76 was measured high. To further illustrate the level of agreement amongst the measurement techniques, limits of agreement (LoA) defined. The HMD with IMU's LoA Equation (3) is:

$$LoA = Mean\ Difference\ \pm 1.96\ Standard\ Deviation \quad (6)$$

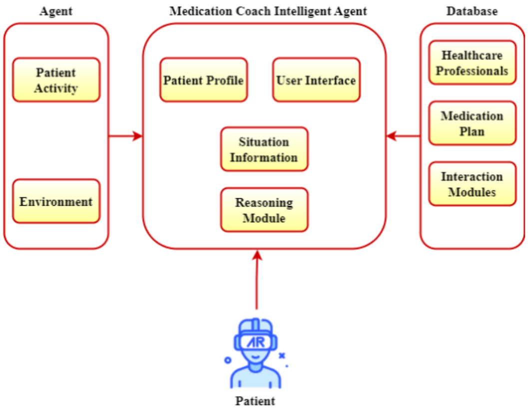

Figure 2. Flowchart of Medication Coach Intelligent Agent for patient education

Figure 2 shows the flowchart of Medication Coach Intelligent Agent for patient education. Planning will occur over a certain time frame, and this plan will be developed every day. This planning session will take place throughout the night for all intents and purposes. So, the user is not concerned about making a new plan for the day when they wake up; all they have to do is re-plan utilizing the event-driven method. Events serve as triggers that alter the MCIA's internal mental state, which is why the process is called event-driven. That is why the MCIA needs to reevaluate the strategy in the event of an incident and make any necessary adjustments. Taking the initiative to accomplish the goals of the MCIA, like reminding the patient, gives rise to proactive behaviour. This study demonstrated the notion using simulated environmental data, even though reminders are time-aware in context. Emerging from the input is reactive behaviour, which may be triggered by the user's vocal instructions or information about their eyesight (via the augmented reality headset). For example, information about medication packs can be shown. For example, if the patient's pill count is lower than it should be given the amount of time that has passed since the prescription was filled it might indicate that they are not taking their medication as prescribed. To determine adherence by counting pills, one may use the following formula (equation 7):

$$\%adherence = \left(\frac{number\ of\ doses\ actually\ taken}{number\ of\ doses\ that\ should\ have\ been\ taken}\right) \times 100 \quad (7)$$

The use of pill count as a measure of adherence is prevalent in clinical trials and practice due to the method's simplicity and cheap cost. There is a possibility that the dispensing date on the medication label does not correspond to when the patient started taking the current drug supply, which might lead to a false assessment of adherence.

4. Results and discussion

The data was taken from the virtual patient model assessment [18]. All aspects of a group of older adults's mental, emotional, and physical well-being are included in this dataset. Data on factors like exercise, diet, exercise limits, balance, depression, and cognition are gathered from medical professionals during clinical evaluations. It contains data from wearable devices, such as daily heart rate averages and average walking speeds. Accompanying this with meticulous data on the frequency of falls, fractures, and disorientation within the sample population might provide light on health trends among the 55 and above.

Patient Recovery time

Patients' physical and mental health, as well as their speed of recovery, may be enhanced by the use of therapeutic play or play therapy while they are hospitalized. Neurological rehabilitation uses a robotic bilateral orthosis to automate locomotor function. Combining a body-weight support system with an augmented reality system, it consists of a treadmill replicating the biomechanics of walking on the ground. The outcome measure known as Mobility Milestones (MM) assesses the time required to complete five mobility milestones: a sitting balancing test, a standing balance test, a 10-step walk, a 10-meter walk, and a 6-minute walk. Figure 3 shows the patient's recovery time.

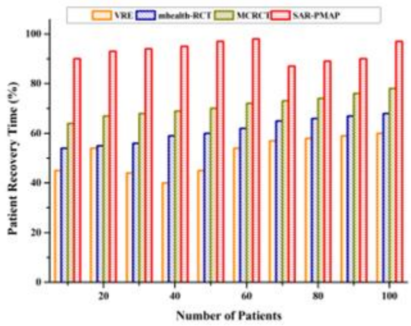

Figure 3. Patient Recovery Time

Medication Adherence Assessment Ratio

To determine the efficacy of medications, identify causes of less-than-ideal adherence and design remedies that work, it is crucial to evaluate medication adherence using management data. The results of this research can potentially improve prescription processes, healthcare worker efficiency, and patient satisfaction via effective analytics on administrative databases that include pharmacy and claims information. Critical insights regarding medication adherence across multiple geographies, ethnicities, and socioeconomic groups are provided by the warehouse's complete analysis of factors such as prescription data, medication records, and health risk assessments. Figure 4 shows the medication adherence assessment ratio.

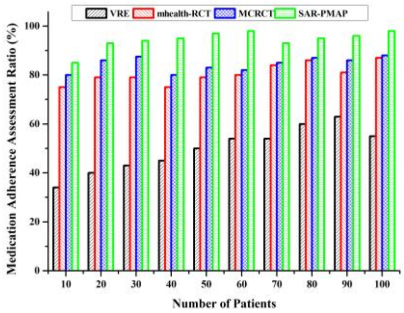

Figure 4. Medication Adherence Assessment Ratio

Patient Behavior Prediction Ratio

The World Health Organization defines medication adherence as the consistency of a patient's behaviour with healthcare provider recommendations, particularly in taking medications. Successful medication management and achieving therapeutic objectives depend on this adherence. A common problem in the treatment of chronic diseases is medication non-adherence, which includes actions like taking more than the recommended dosage or taking less than 80% of the amount as prescribed. Medication behaviour has two components: adherence, which refers to taking the prescription exactly as prescribed and on time, and persistence, which indicates how long one continues to take the medicine. Figure 5 shows the patient behaviour prediction ratio.

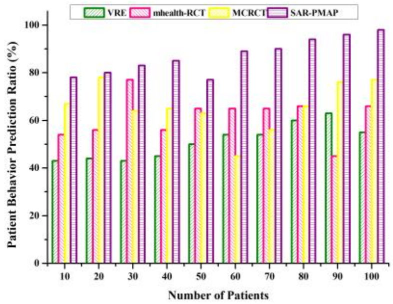

Figure 5. Patient Behavior Prediction Ratio

5. Conclusion and future scope

This study presents the Smart Augmented Reality-based Patient Medication Adherence Program (SAR-PMAP) model for effective patient education and engaging medication. Better health outcomes and general well-being result from patients taking their medications as prescribed. Medication is developed to alleviate abnormal health situations; these abnormalities will persist so long as life exists. Providers, patients, and pharmaceutical companies should all work together to find new and better methods to get people to take their medication as prescribed while addressing the causes of non-adherence. With this idea, users may scan their medicine, get relevant instructions, and then get advice on where to put their medication in their pillbox as part of the onboarding process for novel medication schedules. The experimental outcomes demonstrate that the suggested SAR-PMAP model increases the patient recovery time ratio of 97.8%, medication adherence assessment ratio of 98.4% and patient behaviour prediction ratio of 95.4% compared to other existing models.

Reference

[1] Aremu, T. O., Oluwole, O. E., Adeyinka, K. O., & Schommer, J. C. (2022). Medication adherence and compliance: recipe for improving patient outcomes. *Pharmacy*, *10*(5), 106.

[2] Merks, P., Cameron, J., Bilmin, K., Świeczkowski, D., Chmielewska-Ignatowicz, T., Harężlak, T., ... & Vaillancourt, R. (2021). Medication adherence and the role of pictograms in medication counselling of chronic patients: a review. *Frontiers in pharmacology*, *12*, 582200.

[3] Pietrzykowski, Ł., Kasprzak, M., Michalski, P., Kosobucka, A., Fabiszak, T., & Kubica, A. (2022). The influence of patient expectations on adherence to treatment regimen after myocardial infarction. *Patient education and counseling*, *105*(2), 426-431.

[4] S. Neelima, Manoj Govindaraj, Dr.K. Subramani, Ahmed ALkhayyat, & Dr. Chippy Mohan. (2024). Factors Influencing Data Utilization and Performance of Health Management Information Systems: A Case Study. *Indian Journal of Information Sources and Services*, *14*(2), 146–152. https://doi.org/10.51983/ijiss-2024.14.2.21

[5] Shi, W., Ghisi, G. L., Zhang, L., Hyun, K., Pakosh, M., & Gallagher, R. (2023). Systematic review, meta-analysis and meta-regression to determine the effects of patient education on health behaviour change in adults diagnosed with coronary heart disease. *Journal of Clinical Nursing*, *32*(15-16), 5300-5327.

[6] Alamer, L., Alqahtani, I. M., & Shadadi, E. (2023). Intelligent Health Risk and Disease Prediction Using Optimized Naive Bayes Classifier. *Journal of Internet Services and Information Security*, *13*(1), 01-10.

[7] Urlings, J., Sezer, S., Ter Laan, M., Bartels, R., Maal, T., Boogaarts, J., & Henssen, D. (2022). The role and effectiveness of augmented reality in patient education: A systematic review of the literature. *Patient Education and Counseling*, *105*(7), 1917-1927.

[8] Ramana, R.H.V., & Ravisankar, V. (2024). Precision in Prostate Cancer Diagnosis: A Comprehensive Study on Neural Networks. Journal of Wireless Mobile Networks, Ubiquitous Computing, and Dependable Applications (JoWUA), 15(2), 109-122. https://doi.org/10.58346/JOWUA.2024.I2.008

[9] Moro, C., Smith, J., & Finch, E. (2021). Improving stroke education with augmented reality: A randomized control trial. *Computers and Education Open*, *2*, 100032.

[10] Yang, S., Pang, X., & He, X. (2021, July). A novel mobile application for medication adherence supervision based on AR and OpenCV designed for elderly patients. In *International Conference on Human-Computer Interaction* (pp. 335-347). Cham: Springer International Publishing.

[11] Kapp, K., Sivén, M., Laurén, P., Virtanen, S., Katajavuori, N., & Södervik, I. (2022). Design and usability testing of an augmented reality (AR) environment in pharmacy education—presenting a pilot study on comparison between AR smart glasses and a mobile device in a laboratory course. *Education Sciences*, *12*(12), 854.

[12] Urlings, J., de Jong, G., Maal, T., & Henssen, D. (2023). Views on Augmented Reality, Virtual Reality, and 3D Printing in Modern Medicine and Education: A Qualitative Exploration of Expert Opinion. *Journal of Digital Imaging*, *36*(4), 1930-1939.

[13] Pilon, D., LaMori, J., Rossi, C., Durkin, M., Ghelerter, I., Ke, X., ... & Lefebvre, P. (2022). Medication adherence among patients with advanced prostate cancer using oral therapies. *Future Oncology*, *18*(2), 231-243.

[14] Wang, L. J., Casto, B., Luh, J. Y., & Wang, S. J. (2022). Virtual reality-based education for patients undergoing radiation therapy. *Journal of Cancer Education*, *37*(3), 694-700.

[15] Allin Geo A.V., et.al Application of data mining/strategic CRM for Indian public sector banks, World Applied Sciences Journal, V-29, I-14, PP:96-101, 2014.

[16] Horne, B. D., Muhlestein, J. B., Lappé, D. L., May, H. T., Le, V. T., Bair, T. L., ... & Anderson, J. L. (2022). Behavioral nudges as patient decision support for medication adherence: the ENCOURAGE randomized controlled trial. *American Heart Journal*, *244*, 125-134.

[17] Ni, Z., Wu, B., Yang, Q., Yan, L. L., Liu, C., & Shaw, R. J. (2022). An mHealth intervention to improve medication adherence and health outcomes among patients with coronary heart disease: randomized controlled trial. *Journal of medical Internet research*, *24*(3), e27202.

[18] Wei, X., Hicks, J. P., Zhang, Z., Haldane, V., Pasang, P., Li, L., ... & Hu, J. (2024). Effectiveness of a comprehensive package based on electronic medication monitors at improving treatment outcomes among tuberculosis patients in Tibet: a multicentre randomized controlled trial. *The Lancet*, *403*(10430), 913-923.

[19] https://www.kaggle.com/datasets/thedevastator/virtual-patient-model-assessment

[20] Arad, M., Goli, R., Parizad, N., Vahabzadeh, D., & Baghaei, R. (2021). Do the patient education program and nurse-led telephone follow-up improve treatment adherence in hemodialysis patients? A randomized controlled trial. *BMC nephrology*, *22*, 1-13.

[21] Paczkowska, A., Hoffmann, K., Kus, K., Kopciuch, D., Zaprutko, T., Ratajczak, P., ... & Bryl, W. (2021). Impact of patient knowledge on hypertension treatment adherence and efficacy: A single-centre study in Poland. *International journal of medical sciences*, *18*(3), 852.

[22] Adetunji, R. O., Strydom, M. A., Herselman, M. E., & Botha, A. (2022). Augmented reality technology: A systematic review on gaming strategy for medication adherence. *Recent innovations in artificial intelligence and smart applications*, 47-66.

[23] Kutlu, Y., & Camgözlü, Y. (2021). Detection of coronavirus disease (COVID-19) from X-ray images using deep convolutional neural networks. *Natural and Engineering Sciences*, *6*(1), 60-74.

[24] Allin Geo A.V., et.al Application of data mining/strategic CRM for Indian public sector banks, World Applied Sciences Journal, V-29, I-14, PP:96-101, 2014.