Digital Health Trends Journal. 2025;1(1):41-48.
doi:10.34172/dhtj.05
https://dhtjournal.ae

Digital Health Trends Journal

Original Article

An Internet of Things-Based Platform for Pharmaceutical Consumption Management and Medication Review: Design and Hedonic/Pragmatic Evaluation

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Abstract

Background: Medication review and management are essential components of high-quality patient care across hospitals, nursing homes, and primary healthcare centers. In addition, drug consumption evaluation (DCE) plays a central role in guiding pharmaceutical interventions and improving patient outcomes. Therefore, this study aimed to design and evaluate an internet of things (IoT)-based platform to facilitate medication reviews and enhance drug consumption management.

Methods: A four-layer architecture was implemented using the open-source Viralink platform. The system incorporated four modules: patient entry/exit control, sleep monitoring, medication cabinet access, and urination frequency tracking. Moreover, the platform was simulated in a laboratory environment using real-world scenarios. Ultimately, an evaluation was conducted using both hedonic and pragmatic measures to assess the user experience.

Results: Overall, the system demonstrated excellent performance in innovation and motivation, acceptable reliability, and above-average scores in attractiveness and transparency, thereby confirming strong user engagement and functional effectiveness.

Conclusion: The proposed IoT-based platform offers a promising solution for improving medication management while reducing drug-related side effects. In addition, its modular design and positive user feedback highlight its potential for integration into clinical and home-care settings.

Keywords: Internet of things, Drug management, Wireless sensor networks, Sensors, Medication review

Received: April 7 , 2025, **Revised:** June 26, 2025, **Accepted:** August 10, 2025, **ePublished:** September 3, 2025

Background

Patient drug safety is one of the most important topics in health care. Every year, preventable medication mistakes lead to thousands of serious adverse reactions and billions of dollars of hospital costs in the United States.[1] This initiative seeks to ameliorate drug management, curtail adverse drug reactions and medication errors, and establish a unified platform for physician collaboration in order to mitigate side effects and harmonize divergent medication orders. Medically, transferring a patient from one treatment center to another can improve patient safety.[2] According to some studies, the use of drug consumption assessment can reduce a number of problems, such as identifying the side effects of drugs, drug costs, and the number of prescribed drugs. In England, it has been proposed as an essential part of primary care.[3,4] Medication regimens should be annually reviewed in elderly patients (with a mean age of 75 years). This review should be conducted every six months for those on regular polypharmacy (defined as four or more medications).[5,6] The simultaneous treatment of multiple chronic diseases often results in multi-drug therapy, thereby increasing the risk of drug interactions, poisoning, side effects, adverse drug events, and non-compliance.[7]

The evaluation of drug consumption is one of the most important and challenging issues in the field of policy making.[8] The use of new methods to improve the evaluation of drug consumption can lead to the improvement of health services, reduction of drug side effects, multi-drug control, control and reduction of the costs related to drugs, and, in general, the management of consumed drugs.[9] Moreover, according to previous research, the automation of this process can decrease problems related to the implementation of drug consumption evaluation (DCE).[10]

The advancement of new technologies has extensively helped the field of medicine.[11] Significant advances in computer and communication technologies, along with low-power, low-cost sensors, actuators, and electronic components, have opened up many opportunities for internet of things (IoT) applications.[12] Studies have shown that investing in the IoT can support the control

and monitoring of behaviors among the elderly, patients, and children. Health-related IoT applications include (1) remote health monitoring systems, (2) tracking of daily activities (e.g., sleep, nutrition, social engagement, mental state, self-care, and household tasks), (3) monitoring of medication adherence, (4) emotion recognition, and (5) improvements in bathroom safety. Additionally, IoT can assist in detecting when medications have been removed or accessed.[13]

According to previous research, drug management systems are highly effective in addressing medication-related challenges, facilitating the rapid identification of medications during emergencies, and supporting patients and their families in maintaining proper adherence. Accordingly, this study aims to design and evaluate an IoT-based platform for medication review.[14]

Materials and Methods

A medication review platform based on the IoT was designed and evaluated in this descriptive study. The study addressed the following research questions:

1. What is the effect of medication review on drug side effects?
2. What is the impact of the IoT on the medication review process?

The present study investigated the scenarios and evaluation methods of IoT-based medication review platforms across multiple databases, including PubMed, Embase, Web of Science, Scopus, Cochrane, IEEE, and Google. The search was conducted without time restrictions using several keywords, such as "IoT", "medication review", "medication management", and "IoMT". Following a comprehensive analysis of existing architectures and their constituent components, the optimal model was selected through iterative testing.

Designing a Medication Review System

In this study, the overall work was on the core of the ESP8266 12e module, which integrates a microcontroller and Wi-Fi capability. The selected module was programmed in C++within the Arduino Integrated Development Environment.[15] This open-source platform was chosen for its extensive suite of IoT-specific libraries, which facilitates the implementation of diverse application scenarios.

Entry and Exit Control

When a radio-frequency identification (RFID) tag is brought into proximity with the RC522 reader, the reader acquires the unique identifier of the tag. This identifier is transmitted to the ESP8266-12e microcontroller via the serial peripheral interface communication protocol. The microcontroller then validates the received data against a predefined list of authorized codes. Upon a successful match, the microcontroller activates the connected relay for one second before deactivating it. Next, the activation of the 12V relay triggers the door unlocking mechanism. Subsequently, the ESP8266-12e module transmits a digital record of this door access event to a cloud-based server for storage. This process generates two distinct data entries per complete trip: one for departure (door opening to exit) and another for return (door opening to re-enter). The relay operated at 12V, while both the RC522 reader and the ESP8266-12e microcontroller were powered at 3.3 V. Consequently, a 12 V DC adapter was employed as the primary power source. A dual-stage voltage regulation circuit was implemented to supply the remaining components. Moreover, a 7805 linear regulator was used to step down the 12 V supply to 5 V, and an AMS1117-3.3 regulator was utilized to further step down the 5 V output to 3.3 V. Then, decoupling capacitors were integrated into the inputs and outputs of these regulators to smooth the voltage and mitigate ripple.

The switching mechanism is controlled by the ESP8266 microcontroller. A designated output pin (labeled OUT in the schematic) drives the base of a negative-positive-negative transistor, which acts as a low-side switch for the 12 V relay coil. When activated, the transistor energizes the relay coil, causing the common contact to change position from the normally closed terminal to the normally open (NO) terminal.

In this configuration, the relay functions as an electronic switch, enabling the low-voltage control circuit (3.3 V from the ESP8266) to safely operate the high-voltage circuit (220 V) required for the electric door lock.

A "Status LED" header pin provides a visual indication of the device's internet connection status. Furthermore, a dedicated "Speaker" header pin supplies power to the ISD1820 audio recorder module. allowing for the playback of pre-recorded auditory feedback (e.g., a "door opened" announcement) upon a change in the state of the door.

Sleep Monitoring Module Design

This system implements a light-sensitive switching mechanism controlled by an ESP8266-12E microcontroller. The core sensing element is a photocell in a voltage divider configuration, whose analog output is converted to a digital value by the microcontroller's analog-to-digital converter. Based on this value, conditional logic triggers a relay via a transistor switch to control a light. The system is powered by a 12 V supply, regulated down to 3.3 V for the microcontroller, which also enables Wi-Fi connectivity for data exchange and status monitoring via LEDs.

Drug Control Module Design

The core of the pharmaceutical control module is an ESP8266-12E microcontroller, selected for its integrated Wi-Fi capability, which enables data exchange with a web server. The module monitors four medicine boxes via micro-switches connected to GPIO pins 4, 5, 9, and 10. The intended pins are configured with internal pull-up resistors, maintaining a logical high state (1) when a switch is open. It is noteworthy that closing a switch (door

opening) connects the pin to ground, pulling the logic state to low (0). This state change is detected by the firmware, triggering the transmission of the corresponding box identifier to the IoT cloud platform.

Auxiliary Alerts and Status Indication

A local alert mechanism is implemented using a buzzer, which is activated by the microcontroller via a transistor switch when a door remains open for a predefined duration. In addition, system status is provided through a multi-LED indicator: a dedicated LED confirms power supply availability, while two additional LEDs connected to GPIO14 (green) and GPIO16 (red) provide visual confirmation of the Wi-Fi connection status (connected or disconnected, respectively).

Power Management and Circuit Implementation

The system is powered by a 5 V DC supply. Considering that the ESP8266-12E requires a 3.3 V operating voltage, an AMS1117-3.3 V low-dropout regulator is employed for voltage conversion. Decoupling capacitors are integrated across the power supply lines to filter noise and ensure stable voltage regulation.

Programming and Device Configuration

Firmware is uploaded to the ESP8266-12E module via a "Program_socket" interface, which connects to a USB-to-Serial converter. To enter programming mode, the module must be hardware-configured and subsequently reset, allowing new code to be flashed to its internal memory.

Urinary Frequency Control Module

Parts and modules with the ability to connect to the Internet were used since our study was related to the IoT and the connection to the Internet; thus, the esp8266-12e module was used, which is a module with an internal microcontroller. The output of the passive infrared (PIR) sensor was connected to one of the pins of the ESP8266-12e. By reading the status of this pin, one of the other pins of the ESP8266-12e module, which is defined as a logical output, becomes zero or one, and this output pin is controlled by the transistor. It turns on and off a relay, and thus the bathroom light turns on and off. The input of the circuit was supplied from the 12 V adapter and was fixed to 5 V by the 7805 IC regulator because we required 5 V in the parts of the circuit. This regulator was utilized in this study. Then, by the AMS1117-3.3 V IC regulator, the voltage was 3.3 V for the ESP8266-12e module. It was created because the working voltage of this module was 3.3 V. Additionally, the uF100 capacitor smoothed the 3.3V voltage from the AMS1117-3.3 V output. Therefore, if the output signal from the IC has sinusoidal parts, it will be smoothed by this capacitor, and there will be a voltage without noise in the output. The base transistor is stimulated by a 10k resistor and one of the ESP8266-12E module pins, and the transistor has the role of turning on and off the relay. Given that the current and output of the ESP8266 module pin were not enough to turn the relay on and off, a transistor was employed for relay switching. The relay in this circuit turned on and off the lamp in such a way that the relay coil, which contained a coil, pulled the COM contact to the NO contact as a result of being stimulated by the transistor. The NO contact that is connected to the output The COM contact, which has a voltage of 12 V (it can be 220 V: a 12-V lamp is used in this project), is transferred to the output, and thus the lamp turns on. The relay coil had different voltages (e.g., 5, 24, or 12 V), indicating the appropriate voltage for triggering the relay, and a 12-V coil was utilized in this project. The applied diode (in which the anode was connected to the ground, and its cathode was connected to 12 V) is known as a spurious diode. Its task was to remove the induced voltage of the relay used in the circuit. If the load current is suddenly interrupted or reduced, a very strong induced voltage will be created that will damage some circuit parts. A stray diode was employed to discharge this return voltage. In this part, two red and green LEDs were connected to the two pins of the module, demonstrating whether or not it is connected to the internet (green and red mean connected and not connected to Wi-Fi, respectively), and the programmer socket is where the USB converter is located. To upload the written codes from the system (laptop OR PC), a converter was required to convert the USB protocol to serial and write the codes in the module memory. To use this converter, it is necessary to connect the RX module to the TX module and the TX module to the RX module. Furthermore, the GNDs of both modules should be connected. The PIR socket is for connecting the motion sensor whose database is connected to encapsulating security payload and voltage at the common collector (VCC) and GND base. It was connected to 5 V and ground, respectively. The ESP266-12e module needs special hardware settings to be in two program modes and work normally, which, according to the data sheet, should be considered in the hardware design. In this part, the base of GPIO15 was connected to the ground by a 10k ohm resistor, and GPIO2 was connected to VCC by a 10k resistor. Moreover, the GPIO0 was placed in two logic states, 1 and 0, by a switch called FLASH. To apply any of the mentioned modes, it is essential to restart the module by the reset key every time. The EN pin, which is the base of the module's activator, must be connected to VCC; therefore, it is boosted by a 10-kilo resistor. For the practical implementation of the project, it needs to be implemented by parts of this circuit. For this purpose, the printed circuit board design part of this circuit was designed in the Altium environment, and the circuit and scenario were implemented by printing and assembling the parts.

App Usability Evaluation Using a Qualitative Model for Internet of Things Applications

The usability of the system was assessed using a qualitative

model for IoT applications, as proposed by Kim et al,[1,16] which evaluates functionality, reliability, efficiency, and portability. To complement this process, the short version of the User Experience Questionnaire (UEQ) was administered to measure pragmatic (task-oriented) and hedonic (pleasure-oriented) quality dimensions. The UEQ presents respondents with 26 bipolar adjectives, each rated on a 7-point scale, to capture user perceptions of the system. The participant pool for this evaluation consisted of physicians, pharmaceutical specialists, and nurses.

The specific metrics for the qualitative IoT model were defined as follows:

Functionality: This metric evaluates the successful functional connectivity of the system (Formula: $X = A / B$). A represents the number of successful connections to IoT-specific features, and B is the total number of connection attempts within the operational domain. The metric yields a value between 0 and 1, where a higher value indicates a broader and more reliable access range.

Reliability: This metric assesses the seamlessness of the data integrity of the IoT application (Formula: $X = A / B$). A denotes the count of valid input data items, and B is the total number of input items. The result ranges from 0 to 1, with a value of 1 representing optimal reliability, indicating that nearly all data passed validation checks.

Efficiency: This metric gauges the appropriate use of time and resources, with a focus on power management (Formula: $X = A / B$). A represents the achievable battery life under standard usage, and B indicates the user's expected minimum operational time before requiring a recharge. A value of 1 is ideal, signifying that the resource usage of the system perfectly aligns with user expectations for longevity.

Portability: This metric measures the system's adaptability to different operational environments (Formula: $X = A / B$). A and B denote the number of system response requests that can be customized and the total number of user-expected customizable responses, respectively. A value of 1 indicates a highly responsive system that can be tailored to specific user needs (e.g., customizing data streams from IoT sensors for advanced use cases).

Results

Overall, five studies evaluating IoT-based pharmaceutical platforms were identified by searching several databases. Table 1 summarizes the most significant findings in this regard.

Table 2 provides the results of the most related studies on existing architectures and the identification of architectural components.

Following an examination of common IoT architectures, such as the three-level (perception, transit, and cloud), four-level, and five-level models, a four-layer architecture was selected based on the features extracted in the prior phase.

Case Study: Performance Verification

A case study was designed to verify system performance in a realistic clinical scenario involving a 70-year-old patient with diabetes, hypertension, cardiovascular disease, and Alzheimer's. The system was tasked with monitoring several health-related activities as follows:

- Medication adherence: A smart cabinet with four compartments tracks the removal of specific drugs.

Table 1. A Description of the Most Relevant Studies About the Evaluation Methods of IoT-Based Pharmaceutical Review and Management Platforms

Authors	Country	Year	Description
Salami and Yari[17]	Iran	2018	Based on reliability studies, data acquisition delay and data dissemination rate were selected as the key metrics for evaluation across the three platforms.
Ismail et al[18]	Egypt	2018	Two platforms were evaluated based on their scalability, measured by throughput and average response time, and their stability, assessed through resource usage and robustness.
Akhtar Qureshi[19]	Australia	2018	A comprehensive evaluation method was proposed for the platforms, comprising four distinct assessments: technical evaluation (based on TPC-IoT criteria), usability/sustainability interaction, and market competence.
Mazhelis and Tyrväinen[20]	Finland	2014	Twelve platforms were evaluated across three key dimensions: design, implementation, and performance.
Kim et al[16]	Korea	2016	A qualitative model was established to evaluate the performance, reliability, portability, and efficiency of IoT-based systems.
Ferreira et al[21]	Brazil	2022	TpM-Pro is a flexible, technology-independent framework specifically designed for developing and evaluating IoT solutions. It originated in academia and was later adapted for corporate use.

Note. IoT: Internet of Things; TPC: Processing Performance Council; TpM-Pro: Three-Phase Methodology for Project Development.

Table 2. Studies Related to Existing Architectures and the Identification of Architectural Components

Authors/Source	Year	Description
Li[22]	2017	Proposing a four-layer architecture comprising sensor, network, service, and interface layers, with a focus on security evaluation
Cisco	2023	Presenting a four-layer architecture consisting of sensor, port, network, management, and application layers, tailored for enterprise IoT systems
Rawas[23]	2024	Suggesting a personalized medication management framework using IoMT and machine learning, structured around patient-specific data, real-time monitoring, and AI-driven decision support
Yadegari and Asosheh[24]	2025	Introducing a unified IoT architecture for smart hospitals with five horizontal layers (perception, network, IoT gateway, knowledge, and application) and three vertical aspects (security, management, and cloud platforms)

Note. IoMT: The Internet of Medical Things; AI: Artificial intelligence; IoT: Internet of Things.

The time and identity of the accessed drug are transmitted to the Viralink platform. An integrated alarm alerts the user if a cabinet door is left open.

- Bathroom visits: A PIR sensor detects bathroom entry, providing a proxy metric for urination frequency. The data are transmitted to the platform with a latency of two seconds.
- Sleep monitoring: Sleep patterns are monitored via a photocell sensor that activates when the bedroom light is turned off, triggering the collection and transmission of sleep data.
- Location safety: To address safety concerns related to the patient's Alzheimer's, an RFID tag on the user's key reports door openings to Viralink, notifying caregivers of potential unsupervised egress.

The evaluation results for this scenario, based on the metrics of functionality, reliability, efficiency, and portability, are detailed in Table 3.

The UEQ was administered to a cohort of 25 healthcare professionals, including physicians, nurses, and pharmacists. Table 4 presents the descriptive statistics for the questionnaire items, categorized into scales of pragmatic quality (quality of use) and hedonic quality (quality of design).

Table 5 summarizes the results for the pragmatic quality (quality of use) and hedonic quality (quality of design) categories, including the mean values for each scale.

The pragmatic quality (quality of use) score of 0.82 fell below the benchmark average. In contrast, the hedonic quality (quality of design) score of 0.89 exceeded the benchmark. The overall score of 0.86 remained below the average compared to the standard dataset (Figure 1).

Table 6 presents the 95% confidence intervals for the mean scores of the aggregated scales.

The average values and overall variance for these six scales are listed in Table 7 and visualized in Figure 2.

All evaluated scales scored above average. The scales of motivation (2.33), innovation (2.30), and efficiency (1.97) achieved an "excellent" rating, while attractiveness (1.49), reliability (1.69), and transparency (1.68) were rated "above average" (Figure 2).

Discussion

This study presented a robust and clinically relevant IoT-based health monitoring system designed to support medication adherence, behavioral tracking, and safety assurance in elderly patients with complex comorbidities. The system was evaluated through a case study involving a 70-year-old patient diagnosed with diabetes, hypertension, cardiovascular disease, and Alzheimer's, conditions that generally demand continuous and multifaceted monitoring. Matayong et al conducted a comprehensive systematic review of 54 peer-reviewed studies focusing on IoT-based systems for elderly healthcare. Their findings revealed that health rehabilitation and fall detection were the most commonly addressed healthcare categories, with a significant emphasis on system design, infrastructure, and data analytics. Compared to our system, which emphasizes medication adherence, sleep tracking, and location safety, the reviewed studies leaned more toward physical risk prevention and mobility monitoring.[25]

The system architecture was built upon a four-layer model, integrating hardware, communication, data processing, and application layers. At its core, the ESP8266-12E microcontroller served as the central node, selected for its low power consumption, wireless capabilities, and compatibility with diverse sensor modules. Moreover, four monitoring modules (i.e., medication adherence, sleep tracking, bathroom visits, and entry/exit control) were implemented using a combination of RFID, PIR, photocell, and compartmentalized cabinet sensors. Each

Table 3. Evaluation Results of the Scenario

Items	Expected number	Obtained number from the scenario	Answer
Functionality	7	7	1
Reliability	7	6	0.8571
Efficiency	7	6.6	0.9429
portability	7	6	0.8571

Table 5. The Descriptive Table of Aggregation of Questionnaire Scales

Short UEQ Scales	
Quality of use	0.820
Quality of design	0.890
Overall	0.855

Note. UEQ: User Experience Questionnaire.

Table 4. Descriptive Statistics for Questionnaire Items

Item	Mean	Variance	SD	No.	Negative	Positive	Scale
1	2.5	0.3	0.5	25	Disruptive	Supportive	Quality of use
2	0.9	0.5	0.7	25	Complicated	Easy	Quality of use
3	2.1	0.6	0.8	25	Inadequacy	Adequate	Quality of use
4	2.2	0.7	0.9	25	Confusing	Clear	Quality of use
5	2.3	0.5	0.7	25	Tedious	Attractive	Quality of design
6	2.2	0.8	0.9	25	Lack of attractiveness	Attractive	Quality of design
7	-2.5	0.5	0.7	25	Customary/traditional	Innovation/innovator	Quality of design
8	1.5	0.7	0.8	25	Normal	A leader in technology	Quality of design

Note. SD: Standard deviation.

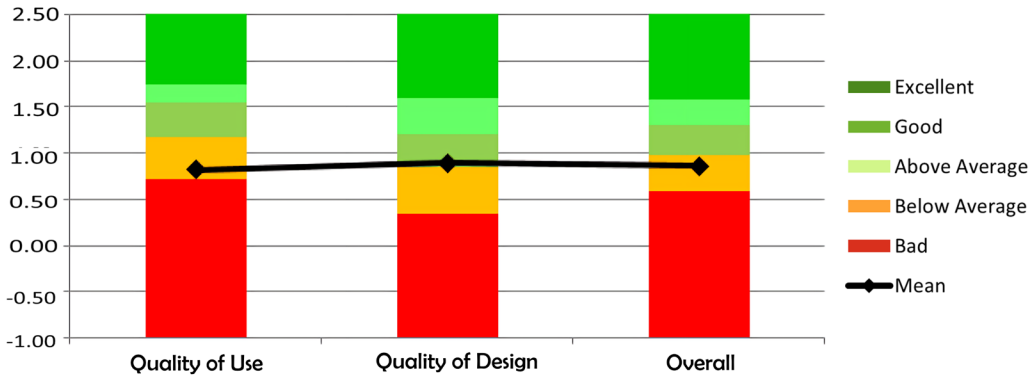

Figure 1. The Bar Chart for Quality of Design and Quality of Use

Table 6. Calculated Confidence Intervals for Measures

Confidence intervals ($P=0.05$) per scale						
Scale	**Mean**	**SD**	**N**	**Confidence**	**Confidence interval**	
Quality of use	0.820	0.255	25	0.100	0.720	0.920
Design quality	0.890	0.421	25	0.165	0.725	1.055
Overall	0.855	0.254	25	0.100	0.755	0.955

Note. SD: Standard deviation.

Table 7. The Descriptive Table of Aggregation of Questionnaire Scales

UEQ Scales	Mean	Variance
Attractiveness	1.493	0.08
Transparency	1.680	0.17
Efficiency	1.970	0.37
Reliability	1.690	0.22
Motivation	2.330	0.16
Innovation	2.300	0.16

Note. UEQ: User Experience Questionnaire.

module was designed to capture specific health-related behaviors and transmit structured data to the Viralink platform for real-time analysis.

Clinical Scenario Validation

The case study demonstrated the ability of the system to effectively operate in a realistic home-care setting. Medication adherence was tracked via a smart cabinet with four compartments, each capable of identifying drug removal events and alerting the user if a door remained open. Additionally, sleep monitoring was achieved through a photocell sensor that detected light-off events, serving as a proxy for sleep initiation. Bathroom visits were also monitored using a PIR sensor, providing indirect metrics for urination frequency, an important indicator in geriatric care. Finally, the entry/exit module utilized RFID-based door tracking to notify caregivers of potential unsupervised egress, addressing critical safety concerns for patients with cognitive impairments.

System Performance Evaluation

System performance was quantitatively evaluated using four key metrics: functionality, reliability, efficiency, and portability. Based on the results (Table 3), the system achieved full marks in functionality (1.00), indicating that all expected features were successfully implemented and were operational. Nonetheless, reliability (0.86) and portability (0.86) were slightly below the ideal threshold, suggesting minor inconsistencies in sensor responsiveness and deployment flexibility. Efficiency scored 0.94, reflecting the ability of the system to process and transmit data with minimal latency and resource consumption.

User Experience Assessment

To assess usability and design quality, the UEQ was administered to 25 healthcare professionals, including physicians, nurses, and pharmacists. The results revealed a nuanced picture. While the pragmatic quality (quality of use) scored 0.82, slightly below the benchmark average, the hedonic quality (quality of design) achieved a score of 0.89, surpassing the benchmark. This implies that although some users found the system moderately complex or confusing in certain aspects, the overall design was perceived as innovative, attractive, and well-aligned with modern healthcare technology standards. Another study by HealthSciencePub explored the design challenges and user-centric considerations in IoT-enabled health monitoring systems for elderly care.[27] Key concerns included interoperability, privacy, and ease of use, which were all echoed in our user experience evaluation. Notably, our system achieved high scores in motivation (2.33) and innovation (2.30), aligning with the emphasis on engaging and forward-thinking design found in comparative studies. However, the slightly lower score in pragmatic quality (0.82) suggests room for improvement in usability and clarity, which is consistent with broader challenges reported in the literature.

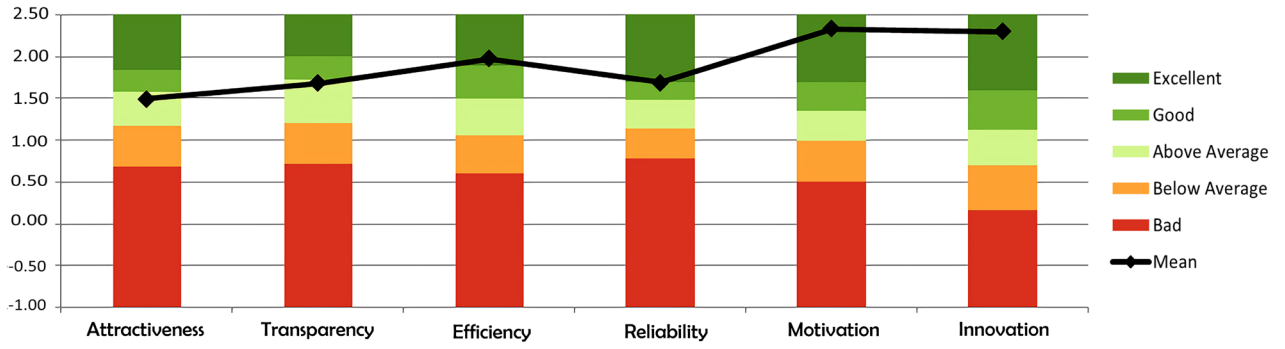

Figure 2. The Bar Chart for Attractiveness, Transparency, Efficiency, Reliability, Motivation, and Innovation

Confidence intervals calculated for individual items and aggregated scales (Tables 6 and 7) were narrow, reinforcing the statistical reliability of the evaluation. The overall confidence interval of ± 0.10 suggests high precision in the reported mean scores.

Further breakdown of UEQ scales highlighted motivation (2.33), innovation (2.30), and efficiency (1.97) as the top-performing dimensions, each receiving an "excellent" rating. Attractiveness (1.49), reliability (1.69), and transparency (1.68) were rated "above average," indicating strong but improvable user perceptions in those areas. These findings are visually supported by Figures 1 and 2, which illustrate the distribution and clustering of user feedback across multiple dimensions.

Challenges and Future Directions

Despite its promising performance, the system faces several challenges common to emerging IoT-based healthcare technologies. They include

- Data security and patient privacy concerns, especially in cloud-based environments
- Device safety and physical reliability, particularly in long-term home use
- Lack of interoperability and standardization across platforms and sensor types
- Complexity in system setup and scalability, which may hinder adoption in resource-limited settings
- Socioeconomic implications, such as caregiver displacement and cost barriers

To address these limitations, future iterations of the system will incorporate additional health metrics, including continuous blood pressure monitoring, body temperature tracking, and facial expression analysis for pain or distress detection. These enhancements aim to provide a more holistic view of patient well-being and enable proactive interventions.

Moreover, the integration of machine learning and deep learning algorithms represents a transformative opportunity. By leveraging predictive analytics and personalized modeling, the system can evolve from passive monitoring to intelligent decision support, thereby empowering clinicians with actionable insights and improving patient outcomes. Prior research demonstrated the efficacy of such approaches in disease prediction, anomaly detection, and behavioral analysis, making this a logical and impactful extension of the current work. Ali et al proposed an innovative IoT and edge intelligence framework that uses non-wearable sensors and machine learning algorithms (e.g., isolation forest and long short-term memory) to detect behavioral anomalies in elderly patients.[26] Their system processes data locally to minimize latency and privacy concerns, offering real-time alerts and longitudinal trend analysis. In contrast, our system transmits data to a centralized cloud platform (Viralink, https://github.com/viralinkio), which may introduce latency but allows for broader integration and remote access. While both systems prioritize early detection of health risks, the model suggested by Ali et al emphasizes predictive analytics, whereas our current implementation focuses on event-based tracking with plans to integrate intelligent algorithms in future iterations.[27]

Conclusion

This study addressed a gap in the literature by designing and evaluating an IoT-based platform for DCE. The system, built on a four-layer architecture and the Viralink platform, used four monitoring modules to automate DCE. It was evaluated for both usability (pragmatic) and user experience (hedonic) quality, representing a significant step toward remote medication management and reducing drug-related adverse events, though clinical trials are needed to confirm its effectiveness.

Authors' Contribution

Conceptualization: Maryam Shadman.
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Formal analysis: Sepideh Sepahi.
Funding acquisition: Maryam Shadman.
Investigation: Maryam Shadman.
Methodology: Sepideh Sepahi.
Project administration: Maryam Shadman.
Resources: Maryam Shadman
Software: Maryam Shadman
Supervision: Maryam Shadman
Validation: Sepideh Sepahi
Visualization: Not applicable.
Writing–original draft: Maryam Shadman.
Writing–review & editing: Sepideh Sepahi.

Competing Interests

There is no conflict of interests.

Ethical Approval

All procedures were performed in accordance with relevant guidelines and regulations, especially in artificial intelligence-related studies. Before the study, all participants received an information statement about the study and provided written consent to participate. Moreover, this study was approved by the Ethics Committee of Tabriz University of Medical Sciences (IR.TBZMED.REC.1399.821).

Funding

This study was self-funded by the authors and received no external financial support from any funding organization.

Intelligence Use Disclosure

The authors used Gemini for grammar correction and language editing to improve manuscript readability. All AI-generated language suggestions were reviewed and edited by the authors.

References

1. Chen CL, Deng YY, Li CT, Zhu S, Chiu YJ, Chen PZ. An IoT-based traceable drug anti-counterfeiting management system. IEEE Access. 2020;8:224532-48. doi: 10.1109/access.2020.3036832.
2. Jara AJ, Zamora MA, Skarmeta AF. Drug identification and interaction checker based on IoT to minimize adverse drug reactions and improve drug compliance. Pers Ubiquitous Comput. 2014;18(1):5-17. doi: 10.1007/s00779-012-0622-2.
3. McHale SA, Pereira E, Weishmann U, Hall M, Fang H. An IoT approach to personalised remote monitoring and management of epilepsy. In: 2017 14th International Symposium on Pervasive Systems, Algorithms and Networks & 2017 11th International Conference on Frontier of Computer Science and Technology & 2017 Third International Symposium of Creative Computing (ISPAN-FCST-ISCC). Exeter, UK: IEEE; 2017. doi: 10.1109/ispan-fcst-iscc.2017.34.
4. Yang G, Xie L, Mäntysalo M, Zhou X, Pang Z, Da Xu L, et al. A health-IoT platform based on the integration of intelligent packaging, unobtrusive bio-sensor, and intelligent medicine box. IEEE Trans Industr Inform. 2014;10(4):2180-91. doi: 10.1109/tii.2014.2307795.
5. Lee GB, Etherton-Beer C, Hosking SM, Pasco JA, Page AT. The patterns and implications of potentially suboptimal medicine regimens among older adults: a narrative review. Ther Adv Drug Saf. 2022;13:20420986221100117. doi: 10.1177/20420986221100117.
6. Wang J, Shen JY, Conwell Y, Podsiadly EJ, Caprio TV, Nathan K, et al. Implementation considerations of deprescribing interventions: a scoping review. J Intern Med. 2024;295(4):436-507. doi: 10.1111/joim.13599.
7. Rodrigues AR, Teixeira-Lemos E, Mascarenhas-Melo F, Lemos LP, Bell V. Pharmacist intervention in Portuguese older adult care. Healthcare (Basel). 2022;10(10):1833. doi: 10.3390/healthcare10101833.
8. Hager P, Jungmann F, Holland R, Bhagat K, Hubrecht I, Knauer M, et al. Evaluation and mitigation of the limitations of large language models in clinical decision-making. Nat Med. 2024;30(9):2613-22. doi: 10.1038/s41591-024-03097-1.
9. Pan X, Lin X, Cao D, Zeng X, Yu PS, He L, et al. Deep learning for drug repurposing: methods, databases, and applications. Wiley Interdiscip Rev Comput Mol Sci. 2022;12(4):e1597. doi: 10.1002/wcms.1597.
10. Zheng WY, Lichtner V, Van Dort BA, Baysari MT. The impact of introducing automated dispensing cabinets, barcode medication administration, and closed-loop electronic medication management systems on work processes and safety of controlled medications in hospitals: a systematic review. Res Social Adm Pharm. 2021;17(5):832-41. doi: 10.1016/j.sapharm.2020.08.001.
11. Al-Worafi YM. Technology for Drug Safety: Current Status and Future Developments. Springer; 2023.
12. Abdulhussain SH, Mahmmod BM, Alwhelat A, Shehada D, Shihab ZI, Mohammed HJ, et al. A Comprehensive review of sensor technologies in IoT: technical aspects, challenges, and future directions. Computers. 2025;14(8):342. doi: 10.3390/computers14080342.
13. Yang Q, Al Mamun A, Wu M, Naznen F. Strengthening health monitoring: intention and adoption of Internet of Things-enabled wearable healthcare devices. Digit Health. 2024;10:20552076241279199. doi: 10.1177/20552076241279199.
14. Alyazeedi A, Stewart C, Soiza RL, Stewart D, Awaisu A, Ryan C, et al. Enhancing medication management of older adults in Qatar: healthcare professionals' perspectives on challenges, barriers and enabling solutions. Ther Adv Drug Saf. 2024;15:20420986241272846. doi: 10.1177/20420986241272846.
15. Mitu NS, Vassilev V, Tabany MR. Low cost, easy-to-use, IoT and cloud-based real-time environment monitoring system using ESP8266 microcontroller. Int J Internet Things Web Serv. 2021;6:30-44.
16. 16-Kim M, Park JH, Lee NY. A quality model for IoT service. In: International Conference on Computer Science and its Applications. Singapore: Springer; 2016. p. 497-504.
17. Salami A, Yari A. A framework for comparing quantitative and qualitative criteria of IoT platforms. In: 2018 4th International Conference on Web Research (ICWR). Tehran: IEEE; 2018. doi: 10.1109/icwr.2018.8387234.
18. Ismail AA, Hamza HS, Kotb AM. Performance evaluation of open source IoT platforms. In: 2018 IEEE Global Conference on Internet of Things (GCIoT). Alexandria, Egypt: IEEE; 2018. doi: 10.1109/GCIoT.2018.8620130.
19. Akhtar Qureshi D. Performance Evaluation of IoT Platforms in Green ICT Applications [dissertation]. Luleå Tekniska Universitet; 2018.
20. Mazhelis O, Tyrväinen P. A framework for evaluating internet of things platforms: application provider viewpoint. In: 2014 IEEE World Forum on Internet of Things (WF-IoT). Seoul: IEEE; 2014. doi: 10.1109/WF-IoT.2014.6803137.
21. Ferreira LC, Chaves PR, Assumpção RM, Branquinho OC, Fruett F, Cardieri P. The three-phase methodology for IoT project development. Internet Things (Amst). 2022;20:100624. doi: 10.1016/j.iot.2022.100624.
22. Li S. Security requirements in IoT architecture. In: Li S, Xu LD, eds. Securing the Internet of Things. Boston: Syngress; 2017. p. 97-108. doi: 10.1016/b978-0-12-804458-2.00005-6.
23. Rawas S. Transforming healthcare delivery: next-generation medication management in smart hospitals through IoMT and ML. Discov Artif Intell. 2024;4(1):31. doi: 10.1007/s44163-024-00128-1.
24. Yadegari F, Asosheh A. A unified IoT architectural model for smart hospitals: enhancing interoperability, security, and efficiency through clinical information systems (CIS). J Big Data. 2025;12(1):149. doi: 10.1186/s40537-025-01197-4.
25. Matayong S, Jetwanna KW, Choksuchat C, Choosawang S, Trakulmaykee N, Limsuwan S, et al. IoT-based systems and applications for elderly healthcare: a systematic review. Univers Access Inf Soc. 2025;24(1):99-125. doi: 10.1007/s10209-023-01055-1.
26. Ali A, Montanaro T, Sergi I, Carrisi S, Galli D, Distante C, et al. An innovative IoT and edge intelligence framework for monitoring elderly people using anomaly detection on data from non-wearable sensors. Sensors (Basel). 2025;25(6):1735. doi: 10.3390/s25061735.
27. Iqbal S. Artificial intelligence tools and applications for elderly healthcare-review. In: Proceedings of the 2023 9th International Conference on Computing and Artificial Intelligence. New York: Association for Computing Machinery; 2023. p. 394-7. doi: 10.1145/3594315.3594347.