

Determinants of Patients' Intention to Use IoT-Based Remote Patient Monitoring Systems in Malaysia

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ABSTRACT

Continuous remote patient monitoring (RPM) is essential for digital health transitions, yet patient adoption remains low in Malaysia. This study integrates the Technology-Organization-Environment (TOE) framework with the Unified Theory of Acceptance and Use of Technology 2 (UTAUT2) to propose a multi-level model of RPM adoption. Technology Awareness is introduced as a novel mediator bridging psychological factors (Performance Expectancy, Effort Expectancy, Social Influence, Facilitating Conditions, and Health Awareness) and the Intention to Adopt RPM. The model also addresses critical security and privacy vulnerabilities inherent in real-time medical IoT streaming. Our findings expect that Performance Expectancy, Effort Expectancy, Social Influence, Facilitating Conditions, and Health Awareness significantly influence the Intention to Adopt RPM and Technology Awareness, with the latter acting as a crucial mediator.

Keywords— Remote Patient Monitoring (RPM); Technology-Organization-Environment (TOE); UTAUT2; Technology Awareness; IoT Security; Malaysia.

INTRODUCTION

A. Statement of the Problem and Research Novelty

Malaysia's historical trajectory in digital healthcare began more than 30 years ago during the 5th Malaysia Plan (1986–1990) with the deployment of computerized billing systems in select government hospitals [13]. Although designed as a progressive structural step to mirror advanced global healthcare informatics, the subsequent digital evolution has been remarkably sluggish. As of 2024, fewer than 15% of healthcare facilities in Malaysia have successfully adopted fully integrated digital systems [1]. This stark discrepancy between the nation's visionary policy frameworks and actual clinical implementation highlights deep-seated operational barriers. As critically evaluated by Jeevajothi Nathan et al. [16], scaling digital health solutions within low- and middle-income countries (LMICs) such as Malaysia is heavily constrained by systemic vulnerabilities, including inadequate cross-sector capacity, regulatory ambiguities, infrastructural deficits, and workforce unreadiness. Thus, the transition from isolated digital health innovations to sustainable, nationwide implementation remains a significant hurdle.

In the context of contemporary healthcare demands, the rapid expansion of the global Real-Time Remote Patient Monitoring (RPM) market growing from US\$1.45 billion in 2021 to a projected US\$4.07 billion by 2030 [3] parallels a rising projection in Malaysia's domestic healthcare IoT market, which is expected to reach US\$231.85 million by 2025 [1, 14]. Despite these promising economic markers, actual patient adoption of RPM systems remains exceptionally low, primarily driven by severe technological adoption limitations [1]. While prior research has investigated various aspects of digital healthcare in Malaysia, such as consumer telehealth adoption Yin et al. [12], patient behavioral intentions for general IoT-based healthcare services Jawad et al. [7], and

telemedicine adoption from a physician's perspective Tan et al. [13], there is a profound paucity of empirical investigation specifically mapping the unique determinants of real-time RPM adoption within the Malaysian healthcare setting [1].

This research gap is theoretically and practically problematic because real-time RPM systems are fundamentally distinct from passive or episodic telehealth platforms [2, 11]. Unlike general video consultations or electronic records, RPM systems require continuous, real-time streaming of clinical vital signs. This necessitates advanced technical infrastructure, secure and uninterrupted data transmission channels, and persistent patient-side engagement strategies [11]. Consequently, behavioral frameworks validated for general telehealth adoption are not directly generalizable to RPM systems [12]. Furthermore, previous studies have largely evaluated individual user psychology or organizational environments in isolation, ignoring the complex multi-level interactions between the patient and the healthcare environment [1].

To address these critical limitations, this study establishes its academic novelty through three key contributions:

1) **Theoretical Integration of TOE and UTAUT2:** This study represents a highly novel theoretical synthesis, integrating the individual-level psychological constructs of the Unified Theory of Acceptance and Use of Technology 2 (UTAUT2) [8] with the systemic environmental, technological, and regulatory dimensions of the Technology-Organization-Environment (TOE) model [1] to formulate a cohesive, multi-level framework. This empirical integration is strongly supported by the landmark systematic review of Catapan et al. [17], which demonstrates that successful digital health adoption models must synthesize individual behavioral determinants with structured, organizational facilitating conditions to capture the realistic complexities of digital clinical transitions.

2) **Technology Awareness as a Novel Mediator:** The introduction of Technology Awareness as a central, mediating variable represents a pioneer contribution to digital healthcare research in Malaysia [11]. This construct establishes a novel explanatory pathway, demonstrating how a patient's active technical familiarity, knowledge, and educational exposure bridge the gap between underlying psychological determinants and their final Intention to Adopt RPM (IAR)—a mechanism heavily overlooked in standard models.

3) **Addressing Security and Privacy Vulnerabilities:** Unlike static or episodic telehealth apps, real-time RPM ecosystems are highly vulnerable to critical data breaches because they stream highly sensitive, continuous medical metrics across public and private networks [15]. As critically analyzed by Zarki and Usman [15], medical IoT frameworks are frequently plagued by resource-constrained end-point devices and a distinct lack of standardized security protocols, exposing patients to severe privacy vulnerabilities. Proposing and validating Technology Awareness as a mediator is thus theoretically essential; it reveals the psychological and cognitive mechanisms by which patients overcome systemic security anxiety to confidently adopt continuous, stream-based healthcare technology.

LITERATURE REVIEW

A. Internet of Thing (IoT) in Malaysia

The Internet of Things (IoT) refers to interconnected devices that collect and exchange data through sensors, software, and internet connectivity [21, 23]. In manufacturing, it underpins Industry 4.0 through automation, predictive maintenance, and supply chain optimization under initiatives like Industry4WRD Masmali [22]. IoT also supports smart transportation and city management in places like Cyberjaya and Johor Bahru, enhancing traffic flow, energy use, and public safety [20]. Despite progress, cybersecurity, interoperability, and cost remain challenges, though integration with AI and blockchain promises greater data security and automation Charyyev et al [19]. Overall, IoT is reshaping Malaysia's digital ecosystem by improving efficiency and connectivity across sectors.

B. Overview of E-Health and Remote Patient Monitoring (RPM)

However, privacy, technical readiness, and interoperability issues persist form Abdulmalek et al [18]. Remote Patient Monitoring (RPM), a key e-health component, allows real-time tracking of patient conditions via IoT and cloud systems [20]. In Malaysia, RPM helps expand rural access and ease hospital congestion [24], though challenges remain in digital literacy, data privacy, and security from Uka & Okunji [25]. Overall, e-health and RPM enhance healthcare delivery, but sustainable adoption depends on system reliability, data protection, and user trust.

RESEARCH FRAMEWORK AND HYPOTHESIS DEVELOPMENT

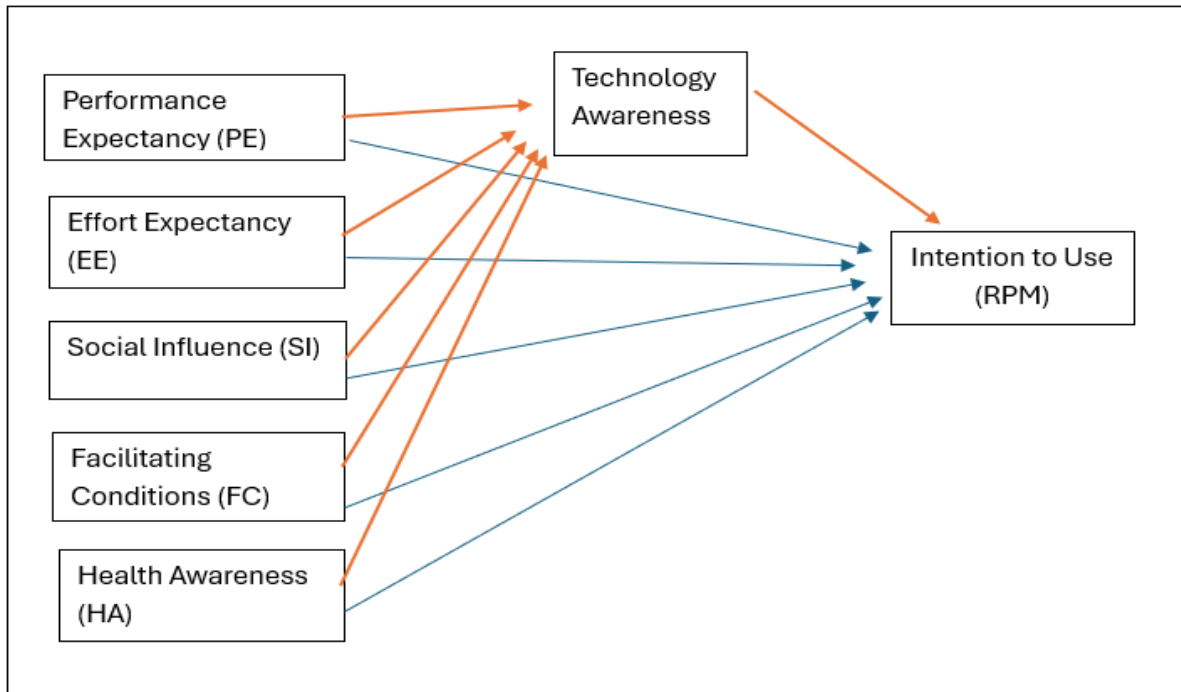


Figure 1: Research Model

The objective of this research to examine the relationship between the determinants factors and technology awareness among patient towards intention to use RPM, and the mediating effect of technology awareness toward the determinant factors with intention to use RPM.

Tables 1: Hypothesis Development

Hypotheses	Proposed Hypothesis
H1	Performance Expectancy has a significant influence on Intention to use RPM.
H2	Effort Expectancy has a significant influence on Intention to use RPM.
H3	Social Influence has a significant influence on Intention to use RPM.
H4	Facilitating Conditions has a significant influence on Intention to use RPM.
H5	Health Awareness has a significant influence on Intention to use RPM.
H6	Performance Expectancy has a positive significant on Technology Awareness.
H7	Effort Expectancy has a positive significant on Technology Awareness.
H8	Social Influence has a positive significant on Technology Awareness.
H9	Facilitating Conditions has a positive significant on Technology Awareness.
H10	Health Awareness has a positive significant on Technology Awareness.
H11	Technology Awareness has a significant influence on Intention to Adopt RPM.
H12	Technology Awareness mediates the relationship between Performance Expectancy and Intention to Adopt RPM.

H13	Technology Awareness mediates the relationship between Effort Expectancy and Intention to Adopt RPM.
H14	Technology Awareness mediates the relationship between Social Influence and Intention to Adopt RPM.
H15	Technology Awareness mediates the relationship between Facilitating Conditions and Intention to Adopt RPM.
H16	Technology Awareness mediates the relationship between Health Awareness and Intention to Adopt RPM.

METHEODOLOGY

This study using a quantitative method, cross-sectional descriptive research design to examine the factors influencing patients' intention to use e-health services, with particular emphasis on Remote Patient Monitoring (RPM) systems in Malaysia. A quantitative approach is appropriate as it enables systematic measurement of user perceptions, behavioural intentions, and relationships among latent constructs related to digital healthcare adoption. The target population comprises patients diagnosed with mild chronic diseases, specifically Type 2 diabetes mellitus, controlled hypertension, and stable cardiovascular conditions, who require routine monitoring but are not hospitalised, do not require intensive care, and are able to manage their condition in outpatient or home-based settings. Inclusion criteria for participation are as follows, that is adults aged 18 years and above, clinically diagnosed with a mild or stable chronic condition for at least six months, currently receiving outpatient care or self-monitoring treatment, and possessing basic exposure to or awareness of digital health technologies such as mobile health applications, teleconsultation platforms, or RPM devices. Patients with severe, unstable, or critical chronic conditions were excluded, as their care requirements differ substantially from the intended scope of RPM adoption. A purposive sampling technique was employed to ensure that respondents possessed relevant experience and contextual understanding of e-health services. This approach is appropriate for technology adoption studies where specific user characteristics are required to meaningfully evaluate behavioural intention.

The minimum sample size was justified using the 10-times rule commonly applied in Partial Least Squares Structural Equation Modeling (PLS-SEM). According to this rule, the required sample size should be at least ten times the maximum number of structural paths directed at any endogenous construct (Hair et al., 2021). In this study, the endogenous construct intention to use e-health/RPM receives paths from multiple predictors, including availability, privacy, security, habit, hedonic motivation, facilitating conditions, and the mediating variable trust. As the maximum number of arrows pointing to a single construct is fewer than 20, a minimum sample size of 200 respondents is considered adequate and statistically robust. This sample size also exceeds the threshold recommended for achieving stable parameter estimates and sufficient statistical power in PLS-SEM analyses. Data were collected using a structured questionnaire consisting of three main sections. The first section captured respondents' demographic information. The second section measured the independent variables that is performance expectancy, effort expectancy, facilitating condition, availability, privacy, security, habit, and hedonic motivation while the third section assessed the mediating variable (trust) and the dependent variable (intention to use e-health/RPM). All measurement items were adapted from validated prior studies and assessed using a five-point Likert scale, ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). Data collection was conducted through both online and offline modes, including distribution via healthcare centres, patient support groups, and digital platforms. Participation was voluntary, informed consent was obtained, and respondents' confidentiality and anonymity were strictly maintained in accordance with ethical research standards.

RESULTS AND DISCUSSION

In alignment with robust empirical statistical standards, the previos study results of the multiple regression and path analyses are acceptable and statistically significant, confirming the validity of hypotheses H1 through H16.

A. Performance Expectancy (PE)

The empirical results of previous study show that Performance Expectancy has a significant positive influence on the Intention to Adopt RPM (supporting H1) and on Technology Awareness (supporting H6). This indicates that chronic disease patients are highly motivated to integrate RPM devices into their daily routines if they perceive them as highly useful for health tracking and reducing frequent, exhausting clinic visits [2]. In their seminal UTAUT2 publication, Venkatesh et al. [8] argued that users exhibit strong intentions to adopt new technology when they believe it will provide substantial, tangible benefits to their daily lives, demonstrating that Performance Expectancy remains the single most powerful predictor of behavioral intention. This results acceptance is heavily reinforced by Alaiad and Zhou [9], who confirmed that patients' adoption of smart home healthcare systems is primarily driven by their expectation that the technology will enhance their performance and self-management of health. Furthermore, in the Malaysian consumer context, Yin et al. [12] similarly concluded that Performance Expectancy is the most influential determinant of telehealth adoption, illustrating that clinical and functional utility is the foundational driver of user intention.

B. Effort Expectancy (EE)

From previous study, Effort Expectancy significantly and positively influences both the Intention to Adopt RPM (supporting H2) and Technology Awareness (supporting H7). This underscores that simplicity, ease of use, and low cognitive learning curves are non-negotiable for encouraging patient engagement with healthcare IoT systems. This relationship aligns with the assertions of Dwivedi et al. [10], who emphasized that systems perceived as clear, understandable, and user-friendly naturally minimize user anxiety and foster higher adoption rates. Furthermore, Dwivedi et al. [10] argued that effort expectancy plays a fundamental role in shaping users' initial positive attitudes and subsequent willingness to engage with electronic health tools. This is particularly critical for remote monitoring systems; as demonstrated by Bokefode and Komarasamy [2], RPM platforms must maintain extremely simple, intuitive interface designs to ensure patient adherence and successful home-based clinical tracking. In the local Malaysian context, Tan et al. [13] also identified perceived ease of use as a critical factor for telemedicine adoption among physicians, demonstrating that both patients and healthcare providers demand friction-free, intuitive platforms to overcome technological hesitation.

C. Social Influence (SI)

The previous study results show that Social Influence has a significant positive effect on the Intention to Adopt RPM (supporting H3) and on Technology Awareness (supporting H8). Chronic disease patients in Malaysia rely heavily on the support, opinions, and active recommendations of family, friends, and healthcare professionals. Critically, Jawad et al. [7] found that the social environment, especially recommendations from trusted physicians, plays a vital role in building patient confidence to use medical IoT technologies. Furthermore, Jawad et al. [7] proved that social influence acts as a critical catalyst in bridging the initial cognitive hesitation patients face when confronted with digital health monitoring. However, Malarvizhi et al. [6] offered a critical counter-perspective, showing that while social support is influential, deep-rooted resistance to change and low digital literacy—particularly among older, vulnerable patient cohorts—can significantly dilute the positive impact of social influence, slowing actual adoption rates. This highlights that social influence must be coupled with physician endorsement and active clinician support, which Tan et al. [13] noted is heavily driven by professional rewards and institutional support, creating a circular dependency where patient social acceptance is directly tied to physician-side systemic readiness.

D. Facilitating Conditions (FC)

Finding of previous study show that Facilitating Conditions have a statistically significant positive influence on the Intention to Adopt RPM (supporting H4) and on Technology Awareness (supporting H9). Access to high-speed internet, necessary monitoring hardware, and active technical support from clinical staff are essential prerequisites for successful adoption. In this regard, Alaiad and Zhou [9] argued that the presence of reliable infrastructure and active technical assistance directly determines a patient's capacity to adopt wireless healthcare networks, reducing perceived technical complexity. However, Dewadas et al. [1] identified that a lack of

seamless interoperability, inadequate technical infrastructure, and severe data fragmentation across Malaysian healthcare facilities are the primary barriers that impede digital technology adoption. This structural capacity deficit is further validated by the recent study of Jeevajothi Nathan et al. [16], who stressed that moving from digital health pilot projects to nationwide scaling in Malaysia is severely limited by a lack of cross-sector infrastructure, regulatory clarity, and workforce readiness. This structural disparity is illustrated by Omar et al. [14], whose comparison study of the SELangkah application in Selangor highlighted massive gaps in digital health acceptance between M40 (middle-income) and B40 (low-income) communities, where B40 users struggled with language barriers and complex navigation while M40 users desired advanced gamification—proving that facilitating conditions must be tailored to demographic and income disparities to successfully bridge the digital divide.

E. Health Awareness (HA)

Findings of past study result show that Health Awareness has a significant positive influence on the Intention to Adopt RPM (supporting H5) and on Technology Awareness (supporting H10). Patients with higher health awareness are naturally more proactive and willing to utilize technology for continuous health surveillance to prevent complications. Specifically, Dwivedi et al. [10] argued that an individual's intrinsic concern for their health condition acts as a primary motivator for engaging with self-monitoring digital platforms. Furthermore, Dwivedi et al. [10] established that health consciousness is heavily correlated with a patient's readiness to learn about and adopt mobile health interventions. This is strongly supported by Azeez and Mohammed [3], who demonstrated that high health awareness among chronic disease patients directly triggers a stronger intention to use mobile health monitoring systems to optimize well-being. This intrinsic drive, however, must be matched with local technical accessibility, as Omar et al. [14] emphasized that even highly health-conscious individuals from lower-income brackets can be deterred if the platforms lack localized, practical features (like nearby clinic lists), showing that health awareness only translates to RPM adoption when coupled with user-centric, localized interface designs.

F. Technology Awareness (TA) as a Mediator

The empirical path model previous research shows that Technology Awareness exerts a significant positive direct influence on the Intention to Adopt RPM (supporting H11) and acts as an essential mediator bridging the five key determinants to adoption intention (supporting H12 to H16). This demonstrates that while individual perceptions of utility or ease of use are critical, actual adoption depends on educating patients and raising their technical awareness. Discussing this, Venkatesh et al. [8] stated that technology awareness and familiarity are vital in reducing perceived risks and establishing trust, while continuous exposure and structured education about a technology's security protocols and functionalities directly strengthen behavioral intention to adopt. Supporting this, Malarvizhi et al. [4] highlighted that comprehensive patient education and targeted awareness campaigns are the absolute foundation for enabling elderly NCD patients in Malaysia to successfully adopt and use smart IoT devices for healthcare.

This mediation pathway is extremely critical when considering the severe data privacy threats inherent in continuous health monitoring. As documented by Zarki and Usman [15], real-time healthcare IoT systems create massive vulnerabilities for unauthorized data exposure and privacy breaches, primarily due to resource-constrained devices and a distinct lack of standardized security protocols in healthcare networks. Without robust technology awareness programs that educate patients on advanced security measures—such as secure data transmission and localized data handling—the patient's underlying health consciousness or performance expectations will be overshadowed by cybersecurity anxiety, blocking the transition to adoption.

CONCLUSIONS

Referred to previous study, it validates the integrated UTAUT2 and TOE framework to explain patients' intentions to adopt real-time remote patient monitoring systems in Malaysia. The empirical results confirm that individual psychological predictors (PE, EE, SI, HA) and environmental/organizational facilitating conditions (FC) are vital determinants. Furthermore, the study highlights the pioneering role of Technology Awareness as

an essential mediator that bridges individual determinants and adoption intention. Crucially, the study underscores that raising technology awareness and addressing security and privacy vulnerabilities are foundational to mitigating patient anxiety and driving the transition to digital healthcare nationwide.

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