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Adoption of IoT-based Smart Healthcare: An Empirical Analysis in the Context of Pakistan

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Abstract: Recent smart innovation of Information and Communication Technology (ICT) is available today. The Internet of Things (IoT) is a live information network of smart things equipped with sensing and actuating mechanisms and software code empowering devices and gadgets to apprehend and communicate information. IoT has been conveying remarkable development in IoT-based or smart healthcare with suitable biomedical frameworks that allow medical professionals to remotely collect and assess patients' clinical information through health sensors. This study aims to provide access to medical services in under-served areas for the population living in rural areas and to use proficiently limited healthcare resources in developing countries like Pakistan. However, an investigation is accomplished by developing a successful research framework to know key significant and insignificant factors for adopting IoT-based smart healthcare among medical professionals in Pakistan. The quantitative research findings obtained a significant score of the factors, i.e., performance expectancy (PE), effort expectancy (EE), facilitating conditions (FC), perceived severity (PS) of health risk, and doctor-patient-relation (DPR) that revealed progressive intention of medical professionals in adopting of IoT-based smart healthcare for improving inadequate conditions of healthcare in under-served areas of Pakistan.

Keywords: Internet of Things, smart healthcare, mHealth.

採用基於物聯網的智能醫療保健：巴基斯坦背景下的實證分析

摘要：信息和通信技術的最新智能創新現已上市。物聯網是智能事物的實時信息網絡,配備傳感和執行機制以及軟件代碼，使設備和小工具能夠理解和交流信息。物聯網一直在通過合適的生物醫學框架傳達基於物聯網或智能醫療保健的顯著發展，這些框架允許醫療專業人員通過健康傳感器遠程收集和評估患者的臨床信息。本研究旨在為生活在農村地區的人口提供服務不足地區的醫療服務，並充分利用巴基斯坦等發展中國家有限的醫療資源。然而,一項調查是通過開發一個成功的研究框架來完成的，以了解在巴基斯坦醫療專業人員中採用基於物聯網的智能醫療保健的關鍵重要和不重要因素。定量研究結果獲得了顯著的因素評分,即績效預期、努力預期、便利條件、健康風險的感知嚴重程度和醫患關係這揭示了醫療專業人員採用基於物聯網的智能醫療保健來改善巴基斯坦服務不足地區醫療保健條件不足的進步意圖。

关键词：物聯網、智能醫療、移動醫療。

1. Introduction

The Internet of Things (IoT) has been named a universal miracle and has undoubtedly led to widespread social and monetary change. Smart devices

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utilization has changed the way individuals influence and plans their everyday lives, arrange them socially, and get to informative, business, employment, and healthcare managing opportunities. Modern Information Systems (IS), more specifically the new trend announced these days: The IoT has immense prospects and opportunities in supporting and managing healthcare costs and improving quality of care [1, 2]. IoT is a network of networks in which many smart objects (smartphones, smartwatches, smart glasses, smart TV, etc.), things, sensors, or devices are connected through high-speed networks (4G, 5G) to provide value-added services. IoT and its potential can provide new solutions to almost every aspect of daily activity.

The IoT is the ideal tempest of smart technologies embedded with cutting-edge sensors meshed with live information networks and cloud structures to support smart development in all life zones, i.e., smart urbanization, smart homes, smart industrialization, and smart health [3]. Precisely, the future connected healthcare system may evaluate biological information, including temperature, heart rate, glucose, or blood pressure, and treat patients more intelligently and proactively using biosensors and artificially intelligent robots [4]. The real-time connectivity between patients and hospitals may enhance the health system's capability to deliver foreseeable and proactive services on an extensive range, supporting health information gathering, well-timed decisions, and decreasing medical errors. Hence, the preference of medical care with the development of clinical wearable biosensors may conceivably transfer towards patient-driven medical care from any place anywhere, as depicted in Fig. 1.

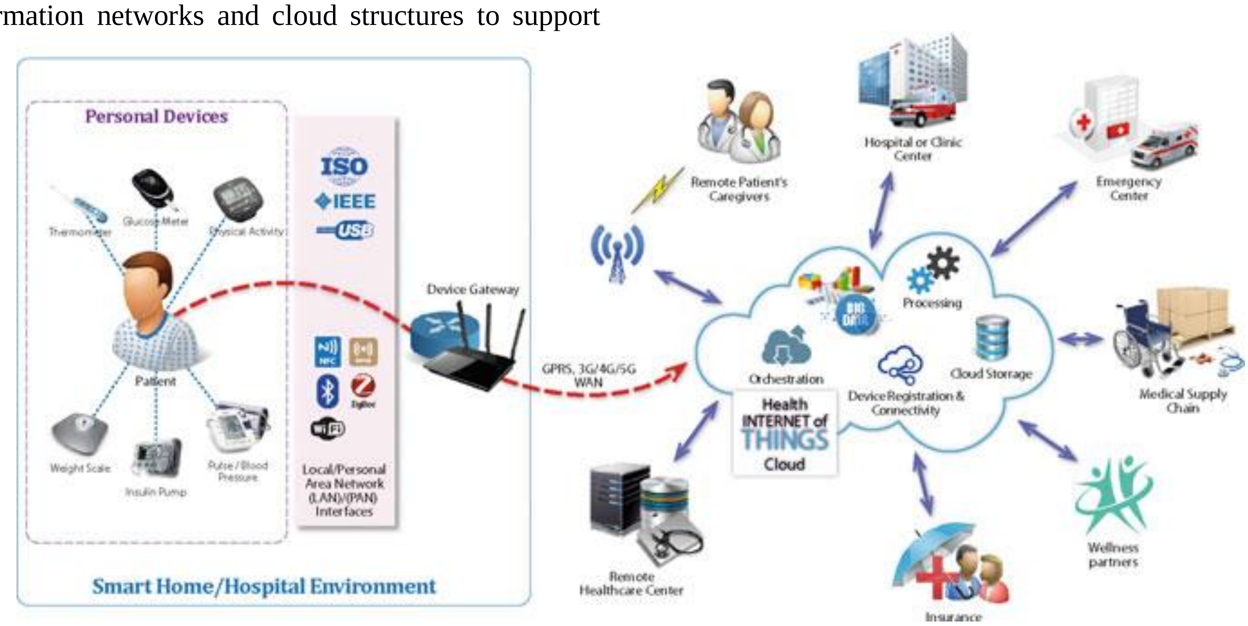

Fig. 1 Smart home/hospital environment [4]

2. Background

2.1. IoT in Healthcare

The combination of ICT and the medical sector formed a sub-field e-health, telemedicine, or mobile health to enhance the access, efficacy, and quality of medical and business practices adopted by hospitals, physicians, and patients. In conjunction with many other services, comprising of managing patients' appointments, keeping digital records, and managing workflows, IoT-based smart healthcare may have infinite prospects to transform the digital age with smart healthcare, including biosensors and health wearables focusing on prevention and proactive health management providing instantaneous monitoring of critical patients' health more frequently to control the probability of health incidents. However, the sensor instruction, actuators, beams, and software may breed artificial intelligence into the Internet of Things to act completely independently, autonomous or self-directed. In IoT, 'Things' can be wise and mindful of other 'Things'. Subsequently, at times, smart things should speak with different items. One 'Thing' may discover the area of a related or intriguing 'Thing' and start an exchange, accumulate data from each other, and impart ramifications of that data to some chiefs via cloud computing [5].

Both public and private sectors are serving the population of Pakistan in healthcare. Largely, private healthcare practitioners and medical care centers serve the population with 78 percent, and the remaining 22 percent is covered by public healthcare networks throughout the country [6]. Reasonably, the number of medical professionals (physicians, medical staff) and the number of hospitals has increased during the last few years yet, the population and health facilities proportion, each doctor and each hospital bed are serving more than 1593 patients [7], which states meager operational conditions of public health service across the country. Therefore, the advancement and elevation of healthcare are one of the main targets of the government and private sector stakeholders. Leveraging ICT and IoT technologies in the health sector may ensure smart healthcare benefits across the country anywhere.

3. Proposed Research Model and Research Hypotheses

By the arrival of ICT and commercial network in the late 1990s, e-Health, mHealth, telemedicine, and smart health has been under research focus, and a big number of researchers have contributed to the adoption of e-Health, mHealth, telehealth, and smart health. Consequently, additional digital services and advanced medical care have been added to modern healthcare. Many researchers have successfully utilized Unified Theory of Acceptance and Use of Technology (UTAUT) and Health Belief Model (HBM) theories in advanced healthcare adoption. Hence, a combined research framework is formulated with additional factors chosen after an extensive qualitative literature review to analyze individual patient points of view for IoT-based healthcare adoption. More, a mediating factor is injected to observe, as shown in Fig. 2.

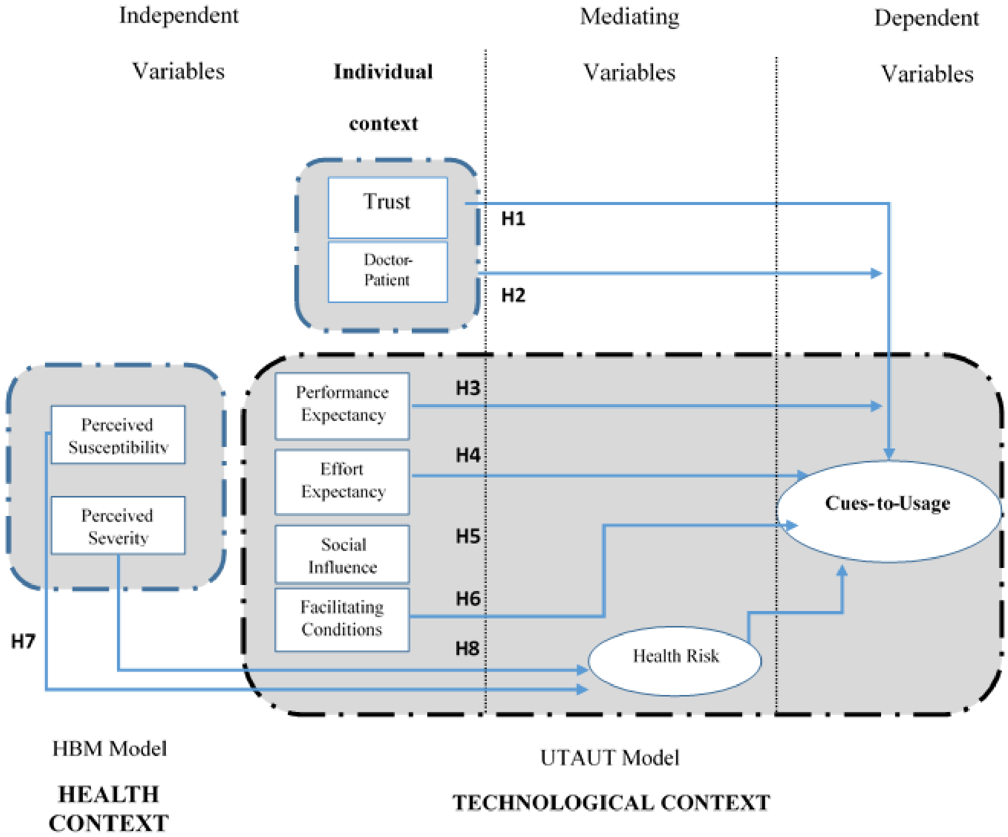

Fig. 2 Proposed research model

Both UTAUT and HBM model theories have been among the extensively utilized models in research studies of Health Information Technology (HIT). Both models are most appreciated, which enabled researchers to identify the adoption or rejection of the innovation. Several studies have employed UTAUT and HBM research models in measuring health system operational support, interactive support, and system credibility in managing elderly patients' health issues via mobile health systems [7]. The outcome of the study presented that the proposed model factors were positively significant on users' intention. The empirical results indicated that the UTAUT with HBM factors had been the most suitable model to convince the elderly to live with healthiness using mobile healthcare technology. Hence, the author found these studies and the methods utilized in the study most relevant to an investigation of factors of IoT-based healthcare adoption in the context of Pakistan as well.

Table 1 Key constructs of the model

Theory	Construct	Description of perception
UTAUT	Performance Expectancy (PE)	Measures perception about proposed system may increase efficacy of operation [8]
	Effort Expectancy (EE)	Measures perception about proposed system may increase ease of operation [8]
	Social Influence (SI)	Measures social persuasion or peer pressure to adopt the proposed system [2]
	Facilitating Conditions (FC)	Measures the perception about the disposal of administrative and technical setup to

Theory	Construct	Description of perception
		adopt proposed system [8]
HBM	Perceived Susceptibility (PSS)	"It refers to the people's evaluation of his or her probability of being exposed to the malicious threats" [9]
	Perceived Severity (PS)	Refers to the "beliefs a person holds concerning the effects a given disease or condition would have on one's state of affairs" [9], [10], [11]
	Perceived Health Risk (PHR)	Perceived health risk is obtained by perceived susceptibility, perceived seriousness triggering cues to action [12] and [13]
External Factors	Trust (Tr)	"Accumulation of trust beliefs: integrity, benevolence, and ability that relate with the adoption of proposed system" [14].
	Doctor-patient-relation (DPR)	"Patient-doctor- relation has been compliance between patient and doctor about identification of disease, information, causes, and proper follow-up of the disease treatment" [15].
Dependent Variable	Cues-to-Action (CTA)	Consists of Cues to Action from HBM theory and Use Behavior latent variables from UTAUT theory [16].

Table 2 Constructs hypothetical relationship

RH#	Research Hypotheses	Hypothetical Relation
H1	Performance Expectancy affects positively on Cues-to-Action	PE➔CTA
H2	Effort Expectancy positively affects on Cues-to-Action	EE ➔CTA
H3	Social Influence positively affects on Cues-to-Action	SI➔CTA
H4	Facilitating conditions affects positively on Cues-to-Action	FC➔CTA
H5	Perceived susceptibility will raise health risks and affects positively on Cues-to- Action	PSS➔ PHR➔ CTA
H6	Perceived severity will raise health risks and affects positively on Cues-to-Action	PS ➔PHR➔CTA
H7	Trust affects positively on Cues-to-Action	Trust➔ CTA
H8	The doctor-patient relationship affects positively on Cues-to- Action	DPR➔CTA

4. Research Methodology

4.1. Instrumentation and Data Collection Tools

The structured questionnaire survey was utilized for data collection from medical professionals, paramedical staff, IT professionals employed in the health sector, and few patients currently under specialized care. The cluster sampling technique was consumed because the population was spread over the area's geographic location under research [17]. Five public and private sector hospitals of dispersed geographic locations in the Sindh province of Pakistan, i.e., the main cities, namely Karachi, Hyderabad, Nawabshah, Sukkur, and Khairpur, were identified as clusters to get a good representation of the whole population. After finalizing the sampling from the target population, the next step was developing an instrument for collecting data that involved an appropriate selection of measurement scales, survey items, phrasing sentences, item contents, response format, and sequence of items. The questionnaire was written in the simple and coherent English language to be understood easily by the participants. Due to the quantitative nature of the research, both computerized and paper-based survey forms were followed by all guidelines of the robust instrument as recommended in the literature [18]. Hence, the survey questionnaire design ensured the accuracy and comprehensiveness of the research problem [19]. All of the items were scored on a seven-point Likert scale. Questionnaire items included three sections to cover demographics, perception of the Internet of Things in general, smart devices (smartphones, smart health fitness trackers), and health sensors.

4.2. Data Collection

In this research, study data were collected using a combination of the above methods. Almost most of the surveys were collected via favorite social media mobile apps, WhatsApp and Facebook, because target respondents were too overbooked with patients to check their mailboxes or switch to computers during their work hours at healthcare units. Therefore, having acknowledged potential users who were proficient in using the Internet and were aware of smart health devices (smartwatches, wearables, fitness and health trackers, smart glasses, smart jewelry, and smart clothes), the questionnaires were distributed to them. Almost all respondents felt it easier to respond using a web-based survey questionnaire due to their appointments scheduled with patients and emphasized the researcher to share the web-based link of the survey questionnaire on their social accounts. The sample of this research study was a wide blend of medicinal experts. Therefore, this synthesis contributed a decent cross-area of the sample population to gather information and their remarks and understanding about the worthy utilization of the innovation in medical sciences.

5. Data Analysis and Results

5.1. Demographics

The sample data collected showed a fair distribution between urban (58.4%) and rural (41.6%) represented actual population ratio of inhabitants. Surveys revealed (79.4%) that the young population aged between 25 to 34 years old were more positive to adopt smart healthcare and responsive to innovation in the sector. Similarly, male (69%) participants were more than female (31%), reflecting the actual employment ratio of gender tendency in the population. The experience of the respondents showed that most of the young medical professionals (68.3%) were acquainted with the Internet of Things (IoT), while (31.7%) respondents were unacquainted with IoT.

5.2. Measurement Model Analysis Results

Internal reliability, Convergent Validity (CV), and Discriminant Validity (DV) score touched the recommended threshold, which confirmed the measurement model correctness of model fit as recommended. Cronbach's alpha and Composite Reliability (CR) established the internal reliability of all constructs. The average Variance Extracted (AVE) score confirmed the convergent validity. The most frequently used evaluation grades: Cronbach's alpha, CR, AVE, and item loading collection, are presented in Table 3 Construct Reliability Results.

Table 3 Reliability coefficient of the observed variables

Construct	Items Loadings	CR	Cronbach α	AVE
Cues-To-Usage	0.73-0.84	0.942	0.941	0.732
Performance Expectancy	0.78-0.89	0.912	0.835	0.675
Effort Expectancy	0.72-0.81	0.907	0.906	0.709
Social Influence	0.72-0.82	0.810	0.807	0.518
Facilitating Conditions	0.81-0.85	0.875	0.867	0.700
Trust	0.79-0.85	0.855	0.855	0.596
Doctor-patient relation	0.70-0.82	0.894	0.893	0.628
Perceived Susceptibility	0.72-0.85	0.782	0.778	0.548
Perceived Severity	0.68-0.84	0.826	0.885	0.512

Note: AVE - average variance extracted; CR - composite reliability

In Table 3, the findings examined the consistency of the responses to all items of each factor loading ranges from 0.68 to 0.89, which evidenced well construct reliability, and accordingly higher than the recommended ranks [20]. Cronbach's alpha values extended from 0.78 to 0.94, and CR values extended from 0.77 to 0.94 verified solid construct internal reliability. Thus, all constructs surpassed the recommended threshold of 0.7 [21]. As shown in Table 3, the loadings of all the items are above the threshold of 0.5, and AVE ranged from 0.51 (PS) to 0.73 (CTA), signifying that each construct has high convergent validity. Accordingly, AVE supported the analysis of DV by comparing the square root of each latent construct with Squared Inter-Construct Correlation (SIC). Usually, the square root of the AVE of the construct should be greater than its correlations with another construct for good DV [22]. Table 4 (with diagonal values) and Table 5 present results of discriminant validity and SIC.

Table 3 Discriminant validity

	SI	CTU	DPR	PE	FC	PS	EE	TR	PSS
SI	**0.719**								
CTU	-0.107	**0.855**							
DPR	0.016	0.566	**0.792**						
PE	-0.049	0.113	0.031	**0.821**					
FC	-0.010	0.589	0.332	-0.027	**0.837**				
PS	0.149	0.139	0.126	-0.065	-0.009	**0.709**			
EE	-0.123	0.630	0.608	0.015	0.329	0.093	**0.842**		
TR	-0.140	0.020	0.031	0.023	0.022	-0.153	0.098	**0.772**	
PSS	0.007	0.119	0.032	0.055	0.027	0.038	0.049	-0.025	**0.740**

Note: Diagonal values are AVE and off diagonal are inter-construct squared correlations

Table 5 Inter-construct correlations

	CTU	PE	EE	SI	FC	TR	DPR	PSS	PS
CTU	1.000								
PE	.080	1.000							
EE	.581	-.014	1.000						
SI	-.099	-.011	-.101	1.000					
FC	.717	-.013	.410	-.027	1.000				
TR	.014	.035	.088	-.131	.009	1.000			
DPR	.521	.005	.557	.015	.390	.029	1.000		
PSS	.107	.055	.070	.007	.039	.029	.002	1.000	.
PS	.137	-.059	.071	.106	.046	-.119	.136	.033	1.000

5.3. Structural Model Analysis

A large number of researchers have utilized

Structural Equation Modeling (SEM) in healthcare, e.g. [23], telecare, e.g. [24], adoption of mobile electronic records [25]. Consequently, Structural Equation Modeling (SEM) was assessed to test hypotheses about causal relationships between dependent and independent variables distinctly [26]. SEM tested the causal relationship between latent factors, validation of each measure by validating the measures underlying the structural model using initial and final confirmatory factor analysis. The standardized regression weight for all measurement items was above the recommended level of 0.7 [26]. Thus, the goodness of fit (GoF) and the proposed research framework's overall quality were based on absolute, incremental, and parsimonious fit indices, baseline values of path coefficients, and coefficient of determination (R2). In Table 6 displays the final structural model, goodness-of-fit indices showing measures: (X2/Df = 1.802, RMSEA = 0.054) absolute fit, (NFI= 0.841, CFI= 0.921 and TLI = 0.9127) incremental fit, and (AGFI = .808) parsimony fit as recommended [27].

Table 6 Model fit indices of structural model

Measure indices	Fit indices	Results	Cutoff	Reference
Absolute fit measure	X^2	1198.026		
	DF	780		
	X^2/DF	1.802	$1<X^2/Df<5$	[28]
	RMSEA	0.054	< = 0.08	[29]
Incremental fit measure	NFI	0.841	> = 0.90	[30], [31]
	TLI	0.912	> = 0.90	[30], [32]
	CFI	0.921	> = 0.90	[30], [33]
Parsimony fit measures	AGFI	0.808	> = .80	[31], [34]

Note: $\chi 2$ - Chi-square; df - degree of freedom; GFI - Goodness of fit index; RMSEA - Root mean square error of approximation; NFI - Normated fit index; CFI - Comparative fit index; AGFI - Adjusted GoF index; TLI - Tucker-Lewis coefficient

5.4. Confirmation of Hypotheses

Finally, the critical ratio (CR or t-value) values and path estimates of the factors verified the causal paths by using path coefficient (β) and t statistics as the method proposed by [31]. The empirical analysis revealed that five hypothetical relationships (H1, H2, H3, H4, H5) were highly significant (i.e., the p-value is <0.001) and highly significant path coefficient (β) and t statistics between FC and CTA (β-value = 0.51, t-value = 7.43). However, the least positive path coefficient (β) path is between PE and CTA (β-value = 0.14, t-value = 2.51). Subsequently, (H6, H7, and H8) were non-significant. Fig. 3 shows the proposed research framework supported by empirical data in Table 7.

Table 4 Hypotheses testing results

Construct	Code	Hypotheses	Causal path	β-value	*t*-value	Result
Trust	CTU	H1	TR➔CTU	-0.040	-.566	Rejected
Doctor-patient relation	DPR	H2	DPR➔ CTU	0.232	3.246	Accepted
Performance Expectancy	PE	H3	PE➔CTU	0.144	2.519	Accepted
Effort Expectancy	EE	H4	EE ➔ CTU	0.333	5.575	Accepted
Social Influence	SI	H5	SI➔ CTU	-0.170	-1.577	Rejected
Facilitating Condition	FC	H6	FC➔ CTU	0.516	7.430	Accepted
Perceived Susceptibility	PSS	H7	PSS➔HR➔CTU	0.086	1.609	Rejected
Perceived Severity	PS	H8	PS➔HR➔CTU	0.117	2.062	Accepted

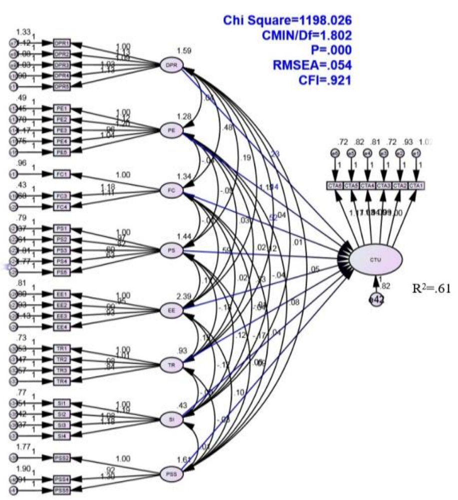

Fig. 3. Structural equation model

6. Discussion

This research study investigated ways to find success factors to adopt IoT-based smart healthcare in Pakistan. The study provided empirically fit data and a model to validate the hypotheses using organized research methodology. The research revealed that both HBM and UTAUT models are suitable to forecast the usage compliance behavior of IoT-based smart healthcare. Based on the information system adoption viewpoint, several healthcare studies (e-health, telemedicine, telehealth, mHealth) have utilized the technology acceptance model and UTAUT individually to demonstrate predictors of healthcare system adoption and usage [27], [35], [36], [37].

The proposed research model explained 61.8%

variance in Cues-to-Action (CTA) dependent variable. The most factors that influenced CTA were DPR, PE, EE, FC, and PS to adopt smart healthcare. All these factors were used as direct determinants of CTA. DPR was argued in literature and adopted from [37], [38], [39], [40] by the researcher. As suggested in the literature, DPR was found to impact the CTA in this research directly. FC, PE, and EE factors have been consistently determined significant in prior research studies as well [37], [37], [41], [40], [42], [43], [12], [42]. Several previous researchers have empirically examined the positive effect of perceived severity PS on CTA behavior as well [43], [43], [44], [37]. PS causal relation was used to measure the health risk severity that either someone was suffering from chronic disease or getting progressed in a specific disease with high severity, and needed long term sustainable self-managed healthcare with the regular clinical diagnosis. Therefore, PS had affected significantly on CTA.

The consequences of this investigation were predictable with these hypotheses discoveries based on prior research studies. Several research studies empirically verified that DPR, PE, EE, FC, and PS have a significant influence on behavior when using innovation. However, trust, social influence, and perceived susceptibility have been found non-significant determinants frequently in the same context. The aim of the proposed research was intensive to developing countries like Pakistan, and the research findings can be applied straightforwardly to similar populations. There was no prior contribution found in the literature similar to healthcare scenarios in Pakistan. Thus, this research study developed a new experience that can deepen the understanding and outspread the knowledge related to the Internet of Things innovation adoption developments in developing countries like Pakistan. Moreover, this research has examined the possibility of different theories and concepts of the Internet of Things innovation adoption and diffusion, which were established previously only for developed nations.

7. Conclusion

The extraordinary increase in the smart Internet-enabled devices (IoT devices) and their benefits, i.e. (smartwatches, wearables, fitness and health trackers, smart glasses, smart jewelry, smart clothes, smart biomedical equipment, and health sensors) are convincing private, and public sector enhances and upgrades current healthcare system in Pakistan to provide basic health service access to all, anytime and anyplace, and maintain patient to doctor relationship. Health organizations can provide an opportunity for physicians, healthcare facilities, and patients to benefit from aggregated health data of smart wearables in staying proactive in disease management [45]. In few years, society would be full of digital natives who truthfully would never see people without smartphones or smart devices and the Internet. In the coming few years, extensive adoption of health fitness, preventive healthcare products, and applications will be supported by IoT [46]. This huge investment might touch the total potential of smart IoT devices, valuing trillions of dollars by 2025 [4]. Therefore, extremely desirable research findings have been revealed and developed a successful hybrid research framework identifying technological, health beliefs, and doctor-patient trust relationship factors for adopting IoT-based healthcare systems for future health units. Hence, they could effectively prioritize their resources to ensure universal healthcare. The findings may help health organizations ensure 24/7 availability and enhancement of health services and develop user-friendly and easy-to-use health apps in the future.

Scholastically, the research investigation utilized extensively esteemed exploration theories as a fused study structure to center innovation, healthcare, and individual judgment in receiving IoT-based medical care. It likewise conceded to most predominant elements to be applied for other IoT-based stages in areas of health and different future innovation receptions like savvy medical clinics, smart homes, schools, cities, smart traffic, and others. Accordingly, this exploration contributed fundamentally to the scientific literature by validating the research framework using a systematized methodology measurement model and structural equation model. Past, a few explorations considers (electronic healthcare, telehealth, telemedicine, mHealth, e-medicine) have used the same theories like TAM (Technology Acceptance Model), UTAUT (unified theory of acceptance, and use of technology), and HBM (Health Belief Model) one by one to exhibit the indicators of embracing and utilizing innovation in medical care as debated in the prior section. The point of the proposed research was escalated to evolving nations like Pakistan, and the discoveries of the analysis might be applied clearly to the comparable populaces. The outcomes are empowering and favorable yet have a few limits straightforwardly identified with the exact piece of data collected group. Regardless, the data collected was cross-sectional, which is conducted in a single phase limited time. However, it merits worried because of the health services kind of study. So the outcomes may not cover the whole parent populace, and the example representativeness might be restricted. Therefore, future investigations might be coordinated to perform a longitudinal review. Ultimately, notice that no earlier investigation had been directed so far with regards to Pakistan. Consequently, the research attempted to include those who were vigorously profound and had a strong innovative base to present their feedback. Thus, future studies might be revised over time because of the tendency and inclination of the overall population towards innovation norms explicitly in fitness and medical services.

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