RELIABILITY AND VALIDITY OF A QUESTIONNAIRE FOR EMPIRICAL ANALYSIS OF FACTORS INFLUENCING IOT-BASED SMART HEALTHCARE

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ABSTRACT: *Quantitative research methods give emphasis to numerical analysis of data collected through questionnaire instrument, which has to be structured for organized surveys. In specific, one of the key validity and reliability issues with quantitative questionnaires is whether the researcher is actually measuring what he/she hopes to assess. Alternatively, then again put another way, are the respondents considering similar things the specialist is the pointing at which they answer the inquiries. Enquiring how the respondents react to draft set of questions will help the researcher interpret whether or not those questions will serve his/her purposes. Validity and reliability are twofold of the most important characteristics of a good research instrument. However, the point of the investigation ponder was to create and survey the validity and reliability of an instrument to empirically analyze the factors influencing IoT-based smart healthcare adoption in Pakistan. In order to understand technological and clinical context the proposed research model of this study was a synthesis of Health Belief Model (HBM) and Unified Theory of Acceptance and Use of Technology (UTAUT), along with trust and doctor-patient relation external factors were adopted from qualitative literature to measure individual and patients' perspective about IoT-based smart healthcare system. The researcher employed principal component analysis method with varimax rotation technique to get the total variance explained and analyze the discriminating validity of the constructs used in this research study. Cronbach's α coefficient reliability statistical technique was applied to measure the internal consistency of each factor in this research study. All constructs were observed with average variance extracted (AVE) above cutoff value 0.5 and construct reliability (CR) above 0.7 estimates validating all the constructs. The most of the factors loaded in significant range of 0.60 to 0.98 with no cross-loading scores proved excellent discriminant validity. Likewise, all factors average reliability calculated 0.822 score-using Cronbach's α coefficient. The study conducted the results of validity and reliability of the incorporated model constructed instrument for empirical analysis of factors influencing the IoT-based smart healthcare adoption. The findings showed the questionnaire was feasible with high reliability and validity.*

Keywords: Smart healthcare, reliable instrument, Internet of Things

I. INTRODUCTION

IoT or the Internet of Things is a standout amongst the most up and coming patterns in innovation starting at now. The use of internet of things has been growing so rapidly that hundreds of thousand devices are connecting to the internet in a minute. According to IDC, approximately 80 billion devices from Wi-Fi enabled the door to smart TVs, to wearable devices, to medical devices, will be part of IoT network by the year 2025. Also, Cisco assesses that "Internet traffic generated by non-PC devices will rise from 40% in 2014 to just under 70% in 2019" [1]. In future broader range of sectors like home and workplace electronics, smarter cities governance, smart traffic management, smart homes and smart healthcare are supposed to be connected and incorporated with IoT technology into their devices, services, procedures and infrastructure, IoT-based-healthcare is one of the significant capacities for bringing community and economic benefits to developing countries like Pakistan [2]. These smart things are visualized to give brilliant metering, e-healthcare coordination, building and home automation, and numerous new use not yet characterized [3].

Locating the existing health and fitness dilemmas it is perceived that future health services could only be upheld by the real-time monitoring and diagnostics of patients using internet of things globally. Therefore, in future IoT-based healthcare is going to equip the traditional healthcare with advanced smart solutions in a new way to assess, assist and treat the patients remotely or wherever the patient may be. By using internet enabled devices like smart health sensors, actuators, beams, Sensor Shield V2.0 (SSV2), and smartphone apps etc. In future, there is a change in the endency of healthcare with the invention of medical wearable devices shift towards patient-centric healthcare from

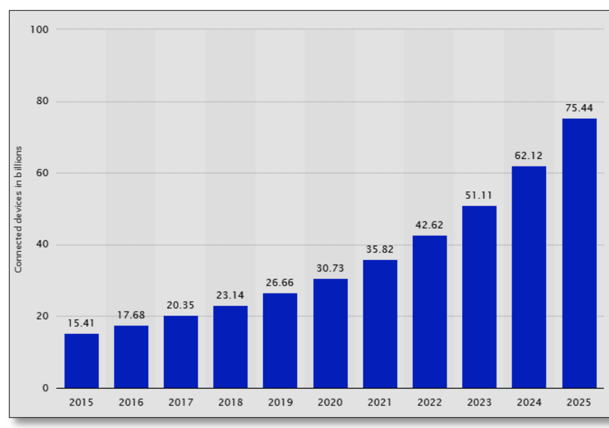

Figure 1 IoT devices connectivity adopted from e-marketer 2017

hospitals to patient wherever he/she may be at home, workplace or on travel [4].

In the case of emergencies, it is easier to get healthcare for the patient himself or herself. In this future framework, patients not only could save their time and money but also reduce patients' load to hospitals in routine checkup and follow-up. In this manner it is earnest that sooner rather than later an inclining innovation should be actualized in the healthcare corporate to create propelled medicinal services strategies and advances and utilize them for the simple checking of physical disorders or illness of patients and their treatment from anyplace [6].

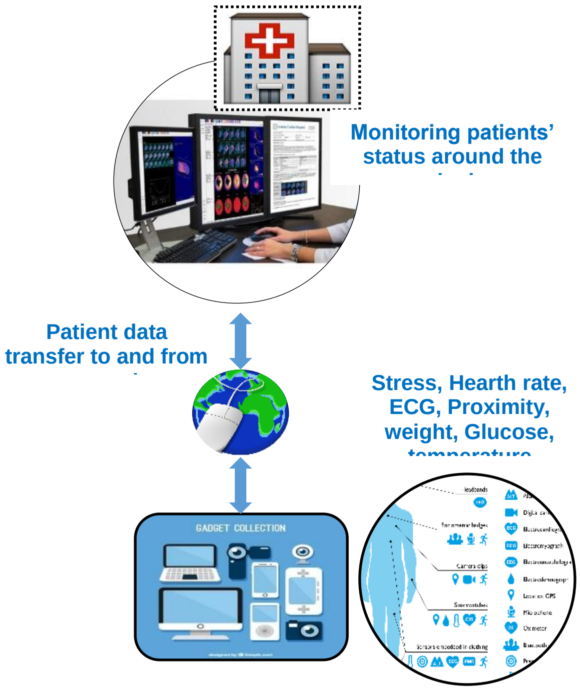

Figure 2 [5]

People in general segment health services units are working regrettably the whole way across the nation and greater part of doctor's facilities are not outfitted with current or technological health framework utilized over the globe for various medical and investigative techniques. Many difficulties are associated with the plan of future health services frameworks for utilization of IoT innovations, especially IoT empower the advancement of new encounters those are not promptly practically identical to healthcare situations that patients or medicinal experts know about. No earlier investigations have been directed up until this point. Henceforth, this requires particular examination with regards to Pakistan to contribute look into in future for a genuine implementation of IoT-based smart healthcare, which may support the provision of remote patients' monitoring and treatment in majority of underserved areas of population in the country.

So, the perseverance of this study is to survey the progress and acceptance of IoT-based healthcare among medical professionals, patients, and the general public for public/private sector hospitals of Pakistan.

II. RESEARCH MODEL

Unified Theory of Acceptance and Use of Technology (UTAUT): The Technological Acceptance Model (TAM) depends on ideas from social psychology research and is an apparatus for characterizing and assessing the goals of consumers to utilize innovation. Besides the health services enterprises, the TAM is utilized as the best quality level [7]. More, advanced version of TAM which is Unified Theory of Acceptance and Use of Technology (UTAUT) has been very much effective in measuring the factors to know the use behavior of technology in healthcare consumers [8]. The UTAUT theory is follow-up of eight theories adopted for acceptance and use of new technology, it complements Innovation Diffusion Theory (IDT), Motivational Model (MM), Theory of Reasoned Action (TRA), Theory of Planned Behavior (TPB), Model of Personal Computer Utilization(MPCU), Social Cognitive Theory (SCT), and TAM [8]. The research study intends to utilize standard constructs of technology acceptance theory to examine its relevance and practicability in the field of smart healthcare.

Health Belief Model (HBM):

Health Belief Model was originally developed in the early 1950s by social psychologists to describe and foresee health behaviors, to know the relationship of health behaviors, and utilize health services and practices systematically. Later, HBM was reviewed to identify and distinguish sickness or disease susceptibility and illness severity from health behavior by including general health motivation. Thus, many researchers have verified HBM, as the furthermost used model for determining and foreseeing preemptive health behavior [9], [10].

Proposed Research Model: Cues-to-usage dependent factor is receiving effect from multiple constructs of two familiar theories from technology and health belief in the proposed hypothetical model. There were three groups of factors: technological context, health context, and individual context, in which factors relate to cues-to-action to use behavior of IoT systems in healthcare. Technological and health context of the study is covered using latent constructs of both HBM and UTAUT theories respectively. Additional constructs were utilized to measure trust and doctor-patient relationship as individual context of medical professionals and general public.

Technological Context: Four latent constructs of UTAUT i.e. facilitating conditions, performance expectancy, social influence, and effort expectancy were measured to investigate the influence of technology in an individual's use behavior of IoT-based smart healthcare system as suggested in literature [11].

Health Context: HBM was to analyze health context with perceived health threat composed of perceived severity (PS) and perceived susceptibility (PSS) factors measured the susceptibility and severity of patients' illness that influence the use behavior of an individual towards adoption of new healthcare system [12]**.**

Individual context: Two additional indicators (trust and doctor-patient relation) were merged in proposed model to measure communal influence affecting the positive usage of new system [13]. Trust is a sentiment somebody's dependence on capacity or certainty to accomplish something reasonably [14]. Trust and doctor-patient relationship are the significant factors of society and culture of the community that influence usage behavior of proposed framework for the adoption of IoT-based smart healthcare system.

III. METHODOLOGY

A. Research Approach

Keeping in mind the end goal to achieve the exploration purposes and research hypotheses, the quantitative research procedure was utilized and received an organized poll overview for the collection of data and information about the respondents. This piece of an investigation was finished by looking at the acknowledgment and utilization of IoT and its noteworthiness of function in the health sector by medicinal experts, and patients yet, in addition IT experts. This investigation survey was endorsed formally by concerned authorities of all hospitals and medical institutes at different located cities of Pakistan.

B. Data Collection

Data collection instrument was constructed on the basis of several recommendations suggested in the relevant literature to healthcare, and core constructs of HBM and UTAUT theories utilized in the context of health or medicinal studies. A self-administered questionnaire was dispersed to 500 randomly selected medical doctors, nursing staff, patients and IT professionals who were using electronic health services somehow. The majority of the questions were received from UTAUT and HBM related surveys and the questions were rethought with specific research objectives to meet our survey research context. The questionnaire survey items were grouped into two section to collect demographic information about the potential respondents and measure their general ability of basic usage understanding and know-how about IoT, health apps, and wearables. The second section contained 44 questions related to nine constructs of UTAUT and HBM theories to evaluate the proposed research model. The items in the instrument survey were rated on a seve-point Likert scale from 1 to 7 (strongly disagree, disagree, slightly disagree, neither, slightly agree, agree nor disagree, agree, and strongly agree). All questionnaire items were then tried for reliability in view of the data gathered from the last analysis of 281 responses. The study resulted an excellent reliability value 0.974 of the questionnaire instrument which was above recommended value 0.7 by [15,16,17].

IV. RESULTS AND ANALYSIS

Data Analysis: This research study adopted two different application tools to achieve data analysis of quantitative survey research. For quantitative data, the research utilized Statistical Package for Social Science (SPSS) 23.0 to perform basic descriptive and exploratory data analysis. Explanatory factor analysis (EFA) was also evaluated the construct validity.

Demographic profile of respondents of study: Statistic data exhibited (sex, age, profession, exp., visit-to-doctor) of the members in the survey. The sex appropriation of the respondents demonstrated 67.7% were male, and 32.3% were female. Respondents holding bachelor degree (50.2%) of the sample were young between 25 to 34 years old, demonstrated extraordinary enthusiasm in the study with a feedback of 45% of the sample population. Generally speaking, 79.4% respondents were medicinal experts with 2 to 5 years of medical practice which demonstrated that youthful specialists were more prepared towards the utilization of innovation in health sector.

Background information: Background information about potential respondents and their general ability of basic usage understanding and know-how about smart mobiles, IoT, health apps, and smart wearables is described in this section via table 1.

Table 1 Participant Background Information about Internet of Things (IoT)

S#	Description	Category	Frequency	Percent	Cum Percent
1	IoT awareness	Yes	192	68.3%	68.3%
		No	89	31.7%	100.0%
2	Use of Smart Devices	Yes	280	99.6%	99.6%
		No	1	0.4%	100.0%
3	Web Connectivity	Yes	277	98.6%	98.6%
		No	4	1.4%	100.0%
4	Internet Experience	<1 year	19	6.8%	6.8%
		1-2 years	38	13.5%	20.3%
		3-4 years	109	38.8%	59.1%
		>5 years	113	40.2%	99.3%
		Not ever	2	0.7%	100.0%
5	Familiarity with Mobile /Health sensors	Yes	217	77.2%	77.2%
		No	64	22.8%	100.0%
6	Mobile/Health Sensors	Heart Rate	114	27.9%	40.6%
		Oxygen	18	4.4%	6.4%
		Stress	17	4.2%	6.0%
		SPO2	10	2.5%	3.6%
		Accelerometer	23	5.6%	8.2%
		Proximity	6	1.5%	2.1%
		Others	133	32.6%	47.3%
		None	87	21.3%	31.0%
7	Use of Health Sensors	Regularly	29	10.3%	10.3%
		Weekly	29	10.3%	20.6%
		Monthly	27	9.6%	30.2%
		Rarely	117	41.6%	71.9%
		Never	79	28.1%	100.0%

Familiarity with Internet of Things: According to background study of respondents about the Internet of Things, 70% were well acquainted with the innovation with while 30% were unacquainted to the innovation. The entire majority was among the young professionals.

Smart Devices and Internet Usage: As per the review comes about, the standard of the respondents (99.6%) had internet-enabled gadgets. The most noteworthy rate (40%) of respondents had been utilizing these gadgets for over five years and (38.8%) respondents had been utilizing internet-enabled gadgets for 2 to 4 years. While not very many respondents had neither the internet-enabled gadgets nor access to the internet which was (0.4%) and (0.7%) separately.

Familiarity to Health Sensors/ Health App Usage: Specific types of sensors, which are commonly used in smart phones, were enquired in the survey to respondents. Thick response of 77.2% showed that majority of sample population was well acquainted to health or biosensors and (78.7%) of the population was practicing numerous sensors.

10.3% of the population was utilizing biosensors via mobile apps frequently, while (41.6%) of the respondents were utilizing biosensors/mobile apps seldom. Table 2 demonstrates the use of sensors.

Table 2 Health Sensors Utilization

S#	Sensors	Respondents	Percent%	Percent% of Cases
1	Heart Rate	114	27.9	40.6
2	Oxygen	18	4.4	6.4
3	Stress	17	4.2	6.0
4	SPO2	10	2.5	3.6
5	Accelerometer	23	5.6	8.2
6	Proximity	6	1.5	2.1
7	Others	133	32.6	47.3
8	None	87	21.3	31.0
9	Total	408	100.0	145.2

Reliability of Constructs: In order to test the steadiness of the questionnaire responses for each construct[18]reliability coefficient was calculated for all constructs using formula 5.1 [19][20]. The estimation of the coefficient was over the base satisfactory level of 0.7 as recommended.

$$CR = \frac{(\sum \lambda_i)^2}{(\sum \lambda_i)^2 + (\sum \epsilon_i)}$$

Formula 1: Reliability of Constructs

Note: λ (lambda): standardized factor loading, i: number of items, ε: error variance term of each latent construct.

Reliability test result of each construct is tabulated in Table 3. The estimation of the coefficient was over the base satisfactory level of 0.7 for all constructs that indicated good measurement of the constructs. For example, the dependability scale of CTU (0.942) demonstrated high inner consistency and satisfactory unwavering reliability.

Table 3 Reliability Coefficient of Latent Variables

Constructs	Mean	Std. Deviation	Reliability
	Statistic	Statistic	Statistics(>0.7)
Cue-to-Usage (CTU)	4.88	1.77	0.942
Performance Expectancy (PE)	5.16	1.38	0.835
Effort Expectancy (EE)	4.81	1.77	0.906
Social Influence (SI)	4.06	1.02	0.804
Facilitating Condition (FC)	5.08	1.57	0.861
rust (TR)	4.08	1.19	0.853
Doctor-patient Relation (DPR)	4.88	1.71	0.893
Perceived Susceptibility (PSS)	4.46	1.79	0.789
Perceived Severity (PS)	4.62	1.42	0.885

Average Variance Extracted (AVE): Average variance extracted is measurement of total variance that is reserved by the construct in link to the degree of variance because of estimate error. In any case, a more exact other option to reliability, as a scale of convergent validity may be an AVE of 0.5 or above. Along these lines, satisfactory convergent validity may be recommended by reliabilities of 0.8 or higher, and exhibited by an AVE over 0.5. Formula 2 was utilized to compute the AVE [19][20]. Table 4 describes AVE calculated for each construct.

$$AVE = \frac{\sum_{i=1}^{n} \lambda_i^2}{n}$$

Formula 2: AVE Measurement

Table 4 Average Variance Extracted

S#	Construct	AVE(>0.5)
1	CTU	0.732
2	PE	0.675
3	EE	0.709
4	SI	0.518
5	FC	0.700
6	TR	0.596
7	DPR	0.628
8	PSS	0.548
9	PS	0.502

Validity: The validity mentions that how much an instrument really measures the factors of the model that are expected to be measured. According to Campbell and Fiske (1959), validity is categorized as convergent and discriminating validity. Convergent validity is reflected by reliabilities of 0.8 or higher and exhibited by an AVE 0.5 or higher value [21]. The widely held investigations on digital or smart healthcare, the components and research models utilized as a part of these investigations are conducted in settings of developed countries almost; where the healthcare delivery is absolutely more enhanced from the setting of

Pakistan. Thusly, it was felt vital to reevaluate the validity of the factors to supplement the investigation literature befittingly. Likewise, EFA was performed to check the robust correlation of all data items to a qualified factor. Additionally, convergent and discriminant validity tests were performed to statistically validate the constructs.

Convergent Validity: All constructs were observed with average variance extracted (AVE) above cutoff value 0.5 and construct reliability (CR) above 0.7 estimates validating all the constructs using formula 1 and formula 2. That proved excellent convergent validity in Table 5 where column one CR value is greater than AVE score and AVE is greater than 0.5 cutoff value[20].

Table 5 Convergent validity

S #	Construct	CR (>0.7)	AVE (>0.5)	MSV (<AVE)	ASV (<MSV)
1	CTU	0.942	0.73	0.40	0.14
2	PE	0.835	0.68	0.01	0.00
3	EE	0.906	0.71	0.40	0.11
4	SI	0.804	0.52	0.02	0.01
5	FC	0.861	0.70	0.35	0.07
6	TR	0.853	0.60	0.02	0.01
7	DPR	0.893	0.63	0.37	0.10
8	PSS	0.789	0.55	0.01	0.00
9	PS	0.885	0.50	0.02	0.01

ASV- Average Shared Validity
MVS- Maximum Shared Squared Variance

Discriminant Validity: The degree of uniqueness and negative correlation of factors is referred as discriminant validity, it shows only strong correlation among variables of the same factor. Discriminant validity is determined with significant loading of variables only on unique factor during exploratory factor analysis (EFA). Variables may cross-load on multiple factors with more than 0.2 difference in pattern matrix for acceptable discriminant validity[22]. Furthermore, "the discriminant validity was tested among all constructs by comparing the average variance extracted (AVE) of each construct with the squared correlation of that construct and all the other constructs"[23]. Reliability analysis and discriminant validity of all factors were justifiable because MSV and ASV score was less than AVE score for each factor in Table 5 [24] and [25].

Table 6 Discriminant Validity

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

Note: AVE was extracted from square multiple correlation estimate using formula 2.

Kaiser-Meyer-Olkin (MKO) test was performed to verify and validate the sample acceptability before PCA factor analysis. Which was sufficient (0.825) closer to 1.0 enough to perform factor analysis (Verma, 2013). Table 7 depicts the KMO test results significant at 0.000 score which is less than $p<0.05$ (Verma 2013).

Table 7 KMO Statistics and Bartlett's Test of Sphericity

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.825
Bartlett's Test of Sphericity	Approx. Chi-Square	7795.805
	df	820
	Sig.	.000

V. CONCLUSION

Potential outcomes are unending as Pakistan is a developing ICT business sector, which is including large digit of internet clients consistently, and they anticipate the eventual fate of IoT with certainty. As IoT is very novel innovation and not readily existing in exercise of patients or medical professionals in Pakistan. So, designing and development of IoT-based smart healthcare may involve several challenges in future. This research study was also preferred to fill that gap and contribute to the literature finding the empirical study of smart healthcare adoption in the setting of developing countries like Pakistan before its real implementation.

The study presented the psychometric properties UTAUT and HBM based on survey questionnaire for assessing perception and significant factors influencing medical professionals and patients to adopt IoT-based smart healthcare in Pakistan. Having reviewed systematic literature and professionals' recommendations, the instrument was completed to collect data. The significant reliability and validity tests validated and proved the instrument based on UTAUT and HBM theories was adequately fit for empirical analysis of factors influencing IoT-based smart healthcare adoption by medical professionals and patients in Pakistan. This research is limited to reevaluate validity test with big sample size and different perspective of the study. More, confirmatory factor analysis (CFA) and structural equation modeling (SEM) may be performed to analyze factor correlations and path analysis.

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