A Systematic Review of the Technology Acceptance Model in Health Informatics

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Abstract

Background One common model utilized to understand clinical staff and patients' technology adoption is the technology acceptance model (TAM).

Objective This article reviews published research on TAM use in health information systems development and implementation with regard to application areas and model extensions after its initial introduction.

Method An electronic literature search supplemented by citation searching was conducted on February 2017 of the Web of Science, PubMed, and Scopus databases, yielding a total of 492 references. Upon eliminating duplicates and applying inclusion and exclusion criteria, 134 articles were retained. These articles were appraised and divided into three categories according to research topic: studies using the original TAM, studies using an extended TAM, and acceptance model comparisons including the TAM.

Results The review identified three main information and communication technology (ICT) application areas for the TAM in health services: telemedicine, electronic health records, and mobile applications. The original TAM was found to have been extended to fit dynamic health service environments by integration of components from theoretical frameworks such as the theory of planned behavior and unified theory of acceptance and use of technology, as well as by adding variables in specific contextual settings. These variables frequently reflected the concepts subjective norm and self-efficacy, but also compatibility, experience, training, anxiety, habit, and facilitators were considered.

Conclusion Telemedicine applications were between 1999 and 2017, the ICT application area most frequently studied using the TAM, implying that acceptance of this technology was a major challenge when exploiting ICT to develop health service organizations during this period. A majority of the reviewed articles reported extensions of the original TAM, suggesting that no optimal TAM version for use in health services has been established. Although the review results indicate a continuous progress, there are still areas that can be expanded and improved to increase the predictive performance of the TAM.

Keywords
- technology acceptance model
- literature review
- health information technology
- technology acceptance
- theoretical models
- health informatics

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Background and Significance

New technologies are continuously being adopted in health services.[1,2] Modern information and communication technology (ICT) has been understood to improve service quality in the health service sector in general and in clinical medicine and at hospitals in particular, enhancing patient safety, staff efficiency and effectiveness, and reducing organizational expenses.[3–6] Meanwhile, progress in the life sciences has led to higher medical specialization and needs to exchange health information across institutional borders.[7,8] Despite these needs, health information systems development methods and research have focused on the technical aspects of the system design.[9–13] If the latter efforts are insufficient to meet the needs of progressive health service organizations and individual users, ICT investments will be spent ineffectively, and, potentially, patients put at risk.[14] Therefore, the impact on ICT adoption of different nontechnical and individual-level factors need to be established.[15] In this regard, it is positive that technology acceptance studies at the present are considered to stand as a mature field in information systems research.[16]

During the past 30 years, several theoretical models have been proposed to assess and explain acceptance and behaviors in association with ICT introduction. Robust measures have been developed of how well a technology "fits" with user tasks and have validated these task–technology fit instruments.[17] The best known of these is the technology acceptance model (TAM), which was presented in 1989,[18] and has during this period been applied and empirically tested in a wide spectrum of ICT application areas.[19,20] Also, the TAM is one of the most popular research models to predict use, person's intention to perform a particular behavior, and acceptance of information systems and technology by individual users.[21,22] Originally, the TAM was derived from the social psychological theories of reasonable action (TRA) and planned behavior (TPB),[23] these three models focus on a person's intention to perform the behavior,[24] but the constructs of these three models are different and not exactly the same. The TAM has become the dominant model for investigating factors affecting users' acceptance of novel technical systems.[25] The basic model presumes a mediating role of perceived ease of use and usefulness in association between system characteristics (external variables) and system usage (as shown in ►Fig. 1).[26] Several reviews of TAM use encompassing the ICT field in total have been issued. Accounts of the first decade of TAM-related research and suggestions of future directions were offered in 2003 by Lee et al[27] and Legris et al.[25] The directions included a need for incorporating more variables related to human and social change processes and exploring boundary conditions. At that time, the original TAM had already been modified in the TAM2 version[28] by removal of the "Attitudes" concept and differentiating the "External variables" concept into social influence (subjective norm, voluntariness, and image), cognitive instrumental processes (job relevance, output quality, and result demonstrability), and experience. A few years later, Sharp continued to discuss the relative strengths of perceived usefulness (PU) and perceived ease and the role of attitudes in user acceptance, but also brought to the fore differences between volitional and mandatory use environments.[29] Venkatesh et al proposed a unified model—the unified theory of acceptance and use of technology (UTAUT)—based on studies of eight prominent models (in particular the TAM). The UTAUT is formulated with four core determinants of intentions and usage: performance expectancy, effort expectancy, social influence, and facilitating conditions, together with four moderators of key relationships: gender, age, experience, and voluntariness of use.[16] The same year, King and Jun conducted a statistical meta-analysis of TAM applications in various fields, reporting the TAM to be a valid and robust model that has been widely used.[30] In 2008, the TAM2 was extended with regard to determinants of perceived ease of use (PEOU) (TAM3).[31] The TAM3 is composed of four constructs: PEOU, PU, behavior intention, and use behavior.

Turning the attention from theory building to use environments, Turner et al concluded that care should be taken when using a particular version of the TAM outside the context in which the version originally was validated.[32] Proceeding with the analyses of model validity across use environments, Hsiao and Yang used cocitation analyses to identify three main application contexts for TAM use: (1) task-related systems, (2) e-commerce systems, and (3) "experiential" (or "hedonic") systems.[33]

Task-related systems are designed to improve task performance and efficiency. These systems can be categorized as automation software, office systems, software development, and communication systems such as electronic health record (EHR). Clinical practice guidelines, linked educational content, and patient handouts can be part of the EHR. This may permit finding the answer to a medical question while the

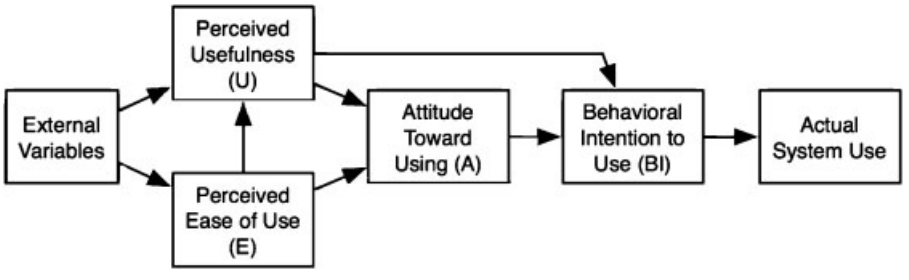

Fig. 1 The basic technology acceptance model.[18]

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patient is still in the examination room.[34] e-Commerce is the activity of buying or selling of products on online services or over the Internet.[35] The "hedonic" information systems are usually connected to home and leisure activities, focusing on the fun or novel aspect of information systems includes online gaming, online surfing, online shopping, and even online learning while perusing enjoyment at the same time.[33]

In 2010, Gagnon et al conducted a systematic review to investigate factors influencing the adoption of ICT by health care professionals. In this review, including all ICT acceptance models in health services, it was concluded that PU of system and PEOU were the two most influential factors.[36] These two factors are the main components of the original TAM.[22] Regarding applications in specific health services areas, Strudwick concluded from a review of TAM applications among nursing practitioners that a modified TAM with variables detailing the health service context and user groups added could provide a better explanation of nurses' acceptance of health care technology.[37] Further, Ahlan and Isma'eel reported from an overview of patient acceptance of ICT that the TAM is one of the most useful models for studying patients' perceptions and behaviors.[38] Also, Garavand et al concluded from their general review of the most widely used acceptance models in health services that the TAM is the most important model used to identify the factors influencing the adoption of information technologies in the health system.[39]

Objective

The objective of this systematic review was to compile published research on TAM use in health information systems development and implementation with regard to application areas and model modifications after its initial introduction, and also to gain understanding of the existing research and debates relevant to a particular topic or area of study. In the present setting, the development of health services requires parallel adjustments of ICT support, and accordingly, of TAMs.

Method

We used systematic search processes to identify all published original articles related to TAM applications in health services from 1989, the year when the TAM was introduced, to February 2017. The PubMed, Scopus, and Web of Science databases were searched and English-only publications selected. The broad keywords used for the initial search are displayed in ►Table 1. The authors, title, journal, year of publication, and abstract for each article were collected in an Excel spreadsheet. First, the publication's titles, and abstracts, were assessed together by two of the four authors, after reviewing all abstracts and eliminating those categorized with exclusion criteria or lacking inclusion criteria; the full texts of the relevant articles were then reviewed by three authors together. The full texts of the remaining articles were read for eligibility, and the qualified publications were retained in a list. A search of the recent reviews and hand-searching references from articles were made to get related articles. The TAM has been used in many technological and geographical contexts. Several major technologies like mobile and telemedicine have variety of applications.[40,41] In a separate phase, the technologies and applications as a subset of major technological contexts and characteristics of each tested model for user groups were identified by three authors together. Finally, the publications in the list were classified into three categories according to their aim and content:

Table 1 Terms used in search

Keyword	Boolean	Additional keywords
Technology acceptance model (TAM)	AND	Healthcare
Technology acceptance model, TAM, hospital information system (HIS), extended technology acceptance model, TAM2, TAM3	AND	Healthcare, medicine, health information system (HIS), telemedicine, telehealth, electronic health record (EHR), computerized physician medication order entry (CPOE), medication system, bar code medication administration (BCMA)

- Original TAM: Applications of the original TAM. In this category, the relationship between the main constructs of the original TAM is examined. These relationships include the relationship between PU and perceived ease to use with intention to use and also the relationship between perceived ease to use and PU.
- Development and Extension of TAM: Reports of new insights related to the core elements of TAM and/or development of new TAM versions by integrating new factors and other acceptance theory variables with the original TAM. These factors incorporate into the constructs of the original TAM as predictive and moderating variables.
- Comparisons of the TAM with other technology acceptance models: The TAM and other theoretical models are compared by examining factors associated with the adoption of a particular technology.

Results

A total of 492 document references were retrieved from the database searches. After removal of 44 duplicates, 448 publications were entered into the selection process. Results of the screening process in the analysis are noted in the flow diagram in ►Fig. 2. First, 448 publications' titles and abstracts were assessed together by two of the four authors. At this stage, 120 articles unrelated to the topic were excluded from the review. The full texts of the relevant

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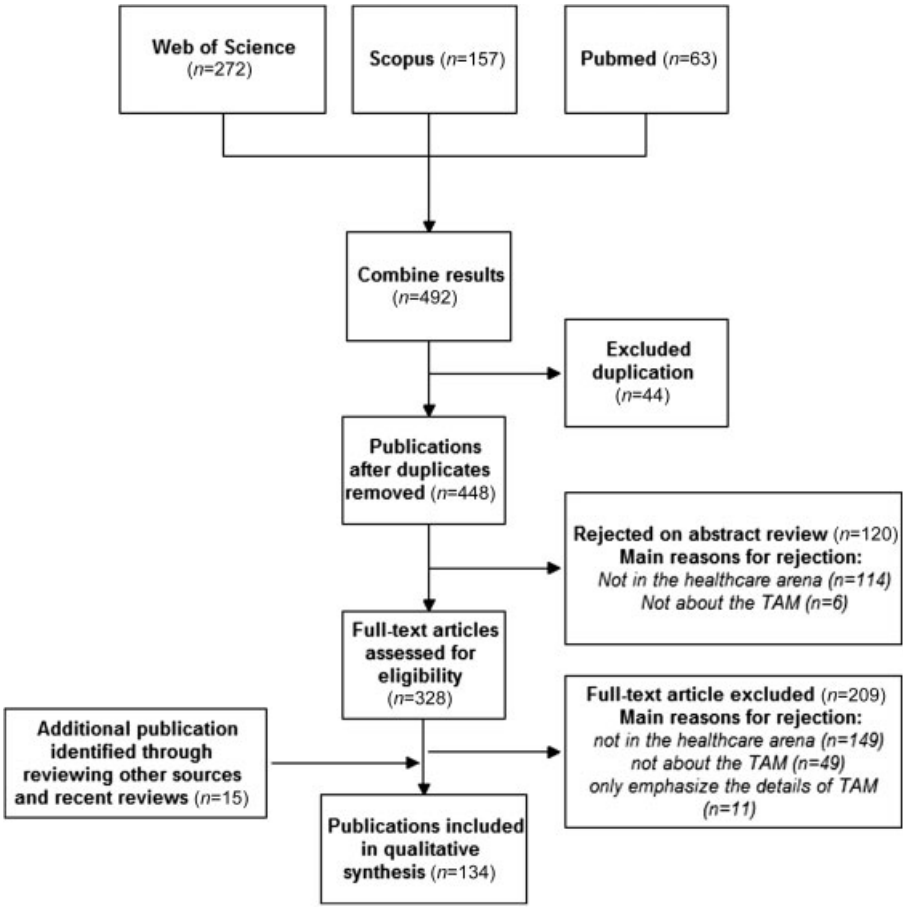

Fig. 2 Flow diagram of the study.

articles were then reviewed by three authors together. The titles and abstracts of the relevant articles were then reviewed by three authors. When the title or abstract was deemed significant for inclusion in the review, the full text was scanned to ensure that the content was relevant. At this stage, 209 articles that were unrelated to acceptance of technology in health care, TAM constructs, or only addressed separate components of the TAM and other acceptance models were excluded. When there was disagreement, the authors evaluated their assessment until consensus was reached. A search of the recent reviews and hand-searching references from articles yielded an additional 15 papers. The systematic search of the literature identified 134 articles that reported original empirical research on the use of the TAM within health services.

Publications dealing with the original TAM had peaked ($n = 3$, 2.2% of all articles) in 2013 and 2015, publications on development and extension of TAM peaked ($n = 16$, 11.9%) in 2013, while publications reporting comparisons of TAMs had peaked ($n = 2$, 1.5%) in years 2010 and 2013 (►Fig. 3). A general increase in reports of TAM use suggests a persisting interest in understanding technology acceptance in health services. Also, there was a noteworthy leap in reports of TAM extensions in 2012 (►Fig. 3), which implies a recent highlighting of the influence from external factors on technology acceptance. The 134 articles reporting on TAM use had been published in 72 scientific journals, and originated from 30 countries; 29 (21.6%) studies from the United States, 28 (20.9%) from Taiwan, 14 (10.4%) from Spain, while the remaining articles originated from countries in Europe, Asia, and Africa. The journals with the highest numbers of articles were International Journal of Medical Informatics with 11 studies (8.14%), Telemedicine and e-Health with 10 studies (7.4%), and BMC Medical Informatics and Decision Making, with 8 studies (5.9%).

The first study of a TAM use in health services was reported in 1999,[42] analyzing physicians' intentions associated with the adoption of the telemedicine technology in a Hong Kong hospital setting. The ICT application area in which the TAM was first more frequently applied was EHR for which a peak in publications was observed in 2009. Publications reporting the TAM applications in telemedicine reached its peak in 2014, while the use of the TAM for analyses of mobile applications did peak in 2015. The first integration of several acceptance models with the TAM in health services was reported from Finland for examining acceptance of mobile systems among physicians.[43] In this study, the TAM was combined with the UTAUT and Personal Innovativeness in the Domain of Information Technology (PIIT) models.

Three main technological contexts were identified for applications of the TAM (►Table 2): (1) Telemedicine with 25 studies (18.6%), (2) EHR with 21 studies (15.7%), and (3)

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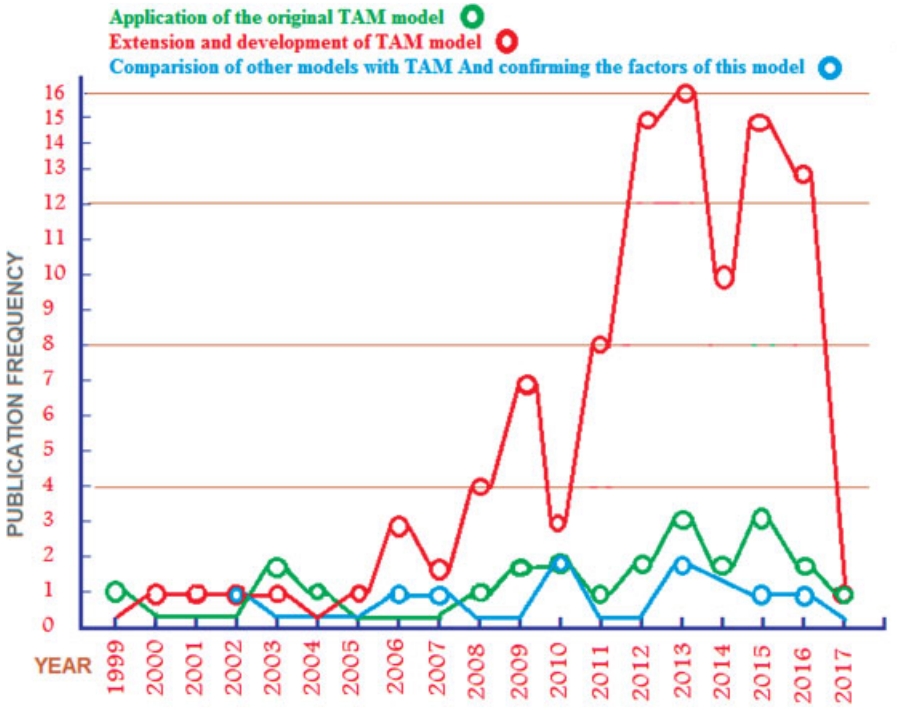

Fig. 3 Frequency of articles reporting technology acceptance model use according to the three study categories displayed by year.

mobile applications with 15 studies (11.2%). Researchers in different countries have focused on different specific technologies: researchers in Taiwan on telemedicine (8 articles), mobile applications ($n = 5$), and hospital information systems (HIS) ($n = 4$); in the United States on EHRs ($n = 8$), computers, handheld (personal digital assistants [PDAs]) ($n = 4$), telemedicine, and personal health records ($n = 2$); and in Spain on telemedicine ($n = 6$), while researchers from Iran have focused on EHR ($n = 3$) technology (►Fig. 4).

Telemedicine, the area where the TAM has been most widely applied, is also the first technology that was studied using the TAM (►Fig. 5). TAM application on mobile technologies was initiated in 2006[43] and these studies peaked in 2015. As shown in ►Table 3, most studies have emphasized the acceptance of physicians ($n = 43$, 32%) and nurses ($n = 34$, 25.3%). Other users of technology acceptance include patients and clients of health services, pharmacists, and other medical professionals.

Applications of the Original TAM

As shown in ►Table 4, 23 (17.1%) of the identified articles reported application of the original TAM. In most studies using the original TAM to assess technology acceptance, the main constructs (i.e., PU and perceived ease to use) of TAM were supported. The most frequent ICT application areas were telemedicine, $n = 6$ (26%) and PDA, $n = 2$ (8.6%). The study participants ranged from 10 to 1,942, with an average of 184. The user category involved in the most studies was nurses ($n = 4$, 17%) followed by physicians and patients (both $n = 3$, 13%).

Development and Extension

Of all studies, 102 (76.1%) studies reported development or extension of the TAM. In these studies, different factors and theories were incorporated to the original TAM (►Table 5). The factors investigated in the most commonly used technological contexts such as health information technology systems in general, telemedicine, EHR, mobile apps, HIS, E-prescription, PDAs, and personal health record are briefly provided. According to the results in various technological contexts, it is possible to draw basic factors that incorporate with the original TAM for each technological context. The most common factors added to the TAM in almost all technological contexts were, in order of importance and frequency of repetition, compatibility, subjective norm, self-efficacy, experience, training, anxiety, habit, and facilitators. These factors can be a basic model for most technological contexts with the incorporation of the original TAM and separate variables regarding a context.

Adding separate variables to develop contextualized TAM versions allows optimizing specific dimensions of the TAM in particular settings and thereby improving predictions in these contexts. A full summary of the additions to the original TAM displayed by technology application area in health services, theories integrated, and new factors and variables inserted is shown in ►Table 6. The most commonly integrated theories were classic acceptance models such as UTAUT, TRA, Diffusion of Innovation theory, and the TPB. In addition to the theories, the conditions and technologies forming the particular context in specific settings have been used to add further concepts and variables, i.e., some factors were not derived from any technology acceptance theory and were instead specific to a certain technology (such as

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Table 2 Numbers of articles analyzing ICT adoption using TAM (main topics according to the MeSH thesaurus)

Main topic (MeSH)	Number	Directions of country based on technology
Telehealth	25	Taiwan (8), Spain (6), United States (2)
Electronic health record	21	United States (8), Iran (3)
Mobile applications	15	Taiwan (5)
HIT systems in general	8	–
Computers, handheld	7	United States (4)
Hospital information systems	6	Taiwan (4)
Decision support systems, clinical	5	–
Electronic prescribing	4	–
Health records, personal	4	United States (2)
Automatic data processing (bar code)	3	–
Radiology information systems	2	–
Medical order entry systems	2	–
Management information systems	2	–
Clinical information system	2	–
Enterprise resources planning	2	–
The remaining of the studies dealt with one technology each		

Abbreviations: CPOE, computerized physician order entry; HIT, health information technology; ICT, information and communication technology; MeSH, Medical Subject Headings; PACS, picture archiving and communication system; PDA, personal digital assistant; TAM, technology acceptance model.
Note: The parenthesized value is number of studies.

technology features, environmental conditions, user types, etc.). Among the 102 articles, only two studies were conducted on the TAM3.

Comparison of Other Technology Acceptance Models with TAM

Nine (6.7%) studies compared TAM with other TAMs. The most common ICT application area for these comparisons was mobile technology, $n = 3$ (33.3%). Typically, Hsiao and Tang[44] used different variables to investigate the introduction of mobile technologies from the perspective of the elderly people in Taiwan. Their results supported the validity of the TAM variables, and also the inclusion of novel factors such as perceived ubiquity, personal health knowledge, and perceived need for health care. Day et al[45] conducted a study to evaluate hospice providers' attitudes and perceptions regarding videophone technology in settings where the technology was introduced but underutilized. Findings indicate that the TAM provides a good framework for an understanding of telehealth underutilization.

In two studies on telemedicine acceptance among physicians in China and the United States, respectively, the TAM and the TPB model were compared. Interestingly, the findings from China suggested that the TAM was more valid than the TPB, while the TPB was more valid than the TAM in the United States.[46,47] Another study comparing the TAM and the UTAUT among physicians concluded that the usage intentions were strongly associated with the performance expectancy on attitude and attitude concepts.[48] Manimaran and Lakshmi[49] formulated an integrated TAM for Health Management Information System and concluded that health workers' innovativeness and voluntariness had a direct and positive influence on these intentions. Similarly, Smith and Motley[50] found that e-prescribing acceptance was predicted by the technological sophistication, operational factors, and maturity factors constructs, i.e., ease-of-use variables derived from the TAM. Liang et al[51] examined whether TAM can be applied to explain physician acceptance of computerized physician order entry (CPOE), and found that data analysis provided support for all relationships predicted by TAM but failed to support the relationship between ease of use and attitude. A follow-up analysis showed that this relationship is moderated by CPOE experience (more details of the nine studies are shown in ►Table 7).

Discussion

The review showed that the TAM initially was applied to task-related ICT systems such as EHRs. These were often connected to educational processes leading to that system's impacts on learning and competence were natural critical influences on use intentions. Since the purpose of task-related systems is to enhance the users' task performance and improve efficiency, educational concepts can be expected to continue to play a dominant role within TAM in this domain. In other words, for the task-related systems such as EHRs, PU and self-efficacy related to learning can be expected to have stronger effects on usage than PEOU,[33] i.e., clinical users are likely to accept a new technology mainly if they recognize that it can help them to improve their work performance and build efficacy.[52] In addition to PU and self-efficacy, system quality, information quality, physicians' autonomy, security and privacy concerns, and cultural and organizational characteristics were found to be important for adoption of task-related technologies, such as EHRs and HISs.

The second aggregation of TAM research was focused on communication systems and telemedicine. The rapid development of worldwide Internet infrastructures has facilitated development of systems in this domain. Telemedicine applications have in particular allowed to introduce new organizational structures in health services[40] and consequently led to an interest in the use of the TAM to facilitate the organizational adaptation. Health care policy makers are still debating why institutionalizing telemedicine applications on a large scale has been so difficult,[53] and why health care

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Fig. 4 Technological contexts in using the technology acceptance model between geographical contexts. The parenthesized value is number of studies.

professionals are often averse or indifferent to telemedicine applications.[40,54] We believe that user rejection is one of the important factors in institutionalizing various types of telemedicine applications. Therefore, it is important to examine the effective factors in accepting telemedicine applications by health care professionals. Consequently, when using the TAM on this category of systems, the validity of analyses with regard to the organizational fit of the novel ICT application is central.[55,56] Other factors commonly associated with technology adoption in this context include subjective norm, security and confidentiality, facilitators, accessibility, and self-efficacy.

Finally, the most recent trend in TAM use—on mobile technologies—is characterized by involving also patients as users. In this setting, the notion of "hedonic" system aspects, denoting factors associated with pleasure or happiness is of

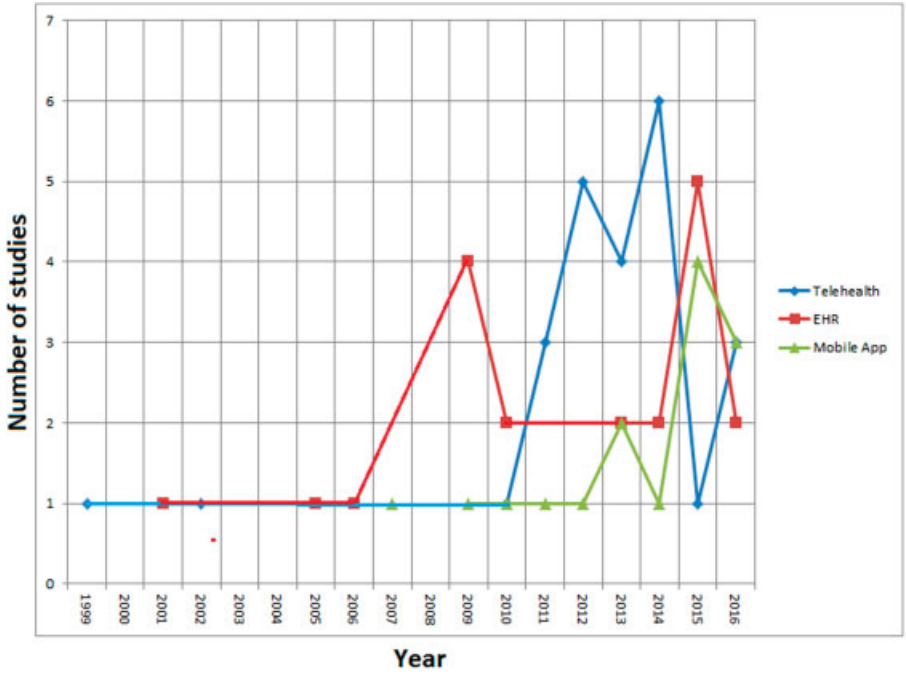

Fig. 5 Distribution of three main technological contexts in using the technology acceptance model by year.

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Table 3 Study user group definitions and the number of studies for each user group

User groups	Number of studies, percentage (%)
Physicians	43 (31.8)
Nurses	34 (25.1)
Patients	17 (13)
Health care professionals	15 (11.1)
Health service staff	13 (9.6)
General population	9 (6.6)
Technology users	8 (5.9)
Managers and providers	4 (2.9)
Students	3 (2.2)
Pharmacists	2 (1.4)
Physiotherapists and midwives each	1 (0.7)

importance.[57] Different from the task-related systems, the concept of hedonic systems focuses on the enjoyable aspect of ICT use and consequently requires other types of factors and variables for analyses of use intentions. Intrinsic motivational factors such as usability and perceived liveliness are in this setting as influential as the PU. The progress from EHRs to mobile technologies in ICT applications has required also the TAM to be dynamically adapted. Based on this, progress of technology introduction in health services cannot be seen to decrease, and a need to modify the TAM to keep up with the new application areas can be also foreseen in the future. Common factors for hedonic such as mobile apps include usability, user satisfaction, reliability, privacy, compatibility, innovativeness, subjective norm, self-efficacy, technical support and training, anxiety, and communication. Also, a theory that integrates with the original TAM to examine the hedonic systems is the self-determination theory (SDT). SDT is a theory of motivation that is concerned with supporting our natural or intrinsic tendencies to behave in effective and healthy ways.[58]

In the extensions of the TAM observed in the review, a wide range of technological context factors and circumstances were

Table 4 Publications addressing the original TAM

Author(s)	Technology studied/Platform	Objective	Year	Sample population and approved factors	Setting	Country
Hu et al[42]	Telemedicine	The applicability of the TAM in explaining physicians' decisions to accept telemedicine technology in the health care context	1999	Physicians $N = 421$/ perceived ease of use not approved	Hospital	Hong Kong
Barker et al[61]	Spoken dialogue system (SDS)	The application of TAM, to use spoken dialogue technology for recording clinical observations during an endoscopic examination	2003	Clinicians ($N = 12$)	Endoscopy center	United Kingdom
Chang et al[62]	Triage-based emergency medical service (EMS) personal digital assistant (PDA) support systems	Developing triage-based EMS (PDA) support systems among nurses and physicians by TAM	2004	Physicians, nurses ($N = 29$)	Emergency medical center	Taiwan
Chang et al[63]	Emergency medical service PDA support systems	Extending well-developed, triage-based, EMS (PDA) support systems to cover prehospital emergency medical services	2004	Physicians, nurses ($N = 29$)	Hospital	Taiwan
Chen et al[64]	Web-based learning system	Understanding PHNs' BI toward Web-based learning based on the technology acceptance model (TAM)	2008	Nurses ($N = 202$)	Health centers	Taiwan

(*Continued*)

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Table 4 (*Continued*)

Author(s)	Technology studied/Platform	Objective	Year	Sample population and approved factors	Setting	Country
Wilkins[65]	Electronic health records (EHR)	Examining factors that may influence the adoption of electronic health records by TAM	2009	Health information managers ($N = 94$)	Hospital	United States
Marini et al[66]	BCMA system	Using the TAM to determine the level of nurses' readiness to use IT for medication administration	2009	Nurses ($N = 276$)	Hospital	Lebanon
Van Schaik et al[67]	Portable system for postural assessment	Assessing the TAM for the new system	2002	Physiotherapists ($N = 49$)	Spinal unit	United Kingdom
Huser et al[68]	A prototype of a flowchart-based analytical framework (RetroGuide)	Exploring acceptance of query systems called RetroGuide for retrieval EHR data	2010	Human subjects ($N = 18$)	Laboratory	United States
Cranen et al[69]	Web-based telemedicine service	The patients' perceptions regarding a Web-based telemedicine service with TAM among patient	2011	Patients ($N = 30$)	Homecare	The Netherlands
Hung and Jen[70]	Mobile health management services (MHMS)	This study introduces MHMS and employs the TAM to explore the intention of students in Executive Master of Business Management programs to adopt mobile health management technology	2012	Students ($N = 170$)	University	Taiwan
Aldosari[71]	Picture archiving and communication system (PACS)	The TAM was used to assess the level of acceptance of the host PACS by staff in the radiology department	2012	Staffs ($N = 89$)	Radiology department	Saudi Arabia
Noblin et al[72]	Personal health record	The TAM was used to evaluate to adopt personal health record	2013	Patients ($N = 10$)	Hospital	United States
Martínez-García et al[73]	Social network component	Assessing acceptance and use of the social network component (web 2.0) to enable the adoption of shared decisions among health professionals (this is highly relevant for multimorbidity patients care) using TAM	2013	Health care professionals ($N = 10$)	Health care center	Spain
Monthuy-Blanc et al[74]	Telemental health (psychotherapy delivered via videoconferencing)	Understanding the role of mental health service providers' attitudes and perceptions of psychotherapy delivered via videoconferencing on their intention to use this technology with their patients	2013	Providers of health care ($N = 205$)	Center of Telemental	Canada

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Table 4 (*Continued*)

Author(s)	Technology studied/Platform	Objective	Year	Sample population and approved factors	Setting	Country
Abdekhoda et al[75]	Health information management system	The acceptance of information technology in the context of health information management (HIM) by utilizing TAM	2014	Worker of medical record ($N = 187$)	Hospital	Iran
Cilliers and Stephen[76]	Telemedicine	Using of the TAM to identify the factors that influence the user acceptance of telemedicine among health care workers	2014	Health care workers ($n = 75$)	Hospital and clinic	South Africa
Ologeanu-Taddei et al[77]	Hospital information system (HIS)	Examining key factors of a HIS acceptance for the care staff, based on the main concepts of TAM	2015	Staffs ($N = 1,942$)	Hospital	France
Money et al[78]	Computerized 3D interior design applications (CIDAs)	Exploring the perceptions of community dwelling older adults with regards to adopting and using CIDAs with TAM	2015	Older adult ($N = 10$)	Homecare	United Kingdom
Faruque et al[79]	*Geoinformatics technology in disaster disease surveillance*	Assessing the feasibility of using geoinformatics technology in disaster disease surveillance uses by self-administration based on the technology acceptance model (TAM)	2015	Personnel ($N = 50$)	Health centers	Iran
Kivekäs et al[80]	Electronic prescription (e-prescription) system	Assessing general practitioners' (GP) experience of an electronic prescription (e-prescription) system and the use of a national prescription center	2016	General practitioners ($N = 269$)	Hospital	Finland
Abdullah et al[81]	Telemonitoring of home blood pressure (BP)	Exploring patients' acceptance of a BP telemonitoring service delivered in primary care based on the technology acceptance model (TAM)	2016	Patients ($N = 17$)	Homecare	Malaysia
Hanauer et al[82]	Computer-based query recommendation algorithm	Assessing computer-based query recommendation algorithm as part of a search engine that facilitates retrieval of information from EHRs using TAM	2017	Clinicians, staffs ($N = 33$)	Hospital	United States

Abbreviations: BCMA, bar code medication administration; BI, business intelligence; EHR, electronic health record; IT, information technology; PHN, public health nurse; TAM, technology acceptance model.

introduced. Examples of such factors include physicians' autonomy, doctor–patient relationship, project team competency, clinical safely, job fit, and optimism, as well as patient user group,[59] voluntariness of the ICT use, and whether the ICT systems were prototypes, trial systems, to-be-implemented systems, or implemented systems. Other revisions had more to do with explicitly stating contextual circumstances, rather than extensions per se. For instance, over the life course of an ICT application, the relationships in the TAM may change, e.g., usability may initially be critical but less important later on. Two methods to add novel concepts and variables to the TAM were highlighted in this review. The first, theory-based

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Table 5 Publications addressing extension and development of TAM

Author(s)	Technology studied	Main topic	Years	Sample	Setting/*Incorporated theories and variable with the TAM*	Country
Rawstorne et al[83]	Patient care information system	Identifying the relevant issues necessary for applying the technology acceptance model and the theory of planned behavior to the prediction and explanation of mandated IS usage	2000	Nurses ($N = 61$)	Hospital/theory of planned behavior (TPB)	Australia
Handy et al[84]	Electronic medical records (EMR)	Studying primary care practitioners' views of an electronic medical records (EMR) system for maternity patients	2001	Physicians and midwives ($N = 167$)	Hospital/*System acceptability, system characteristics, organizational characteristics, individual characteristics*	New Zealand
Chismar and Sonja[85]	Internet and Internet-based health applications	Testing the extension to a widely used model in the information systems especially Internet in pediatrics	2002	Pediatri-cians ($N = 89$)	Hospital/*the TAM2 theory*	United States
Liang et al[86]	Personal digital assistants (PDAs)	Predicting TAM to actual PDA usage	2003	Health care profession-als ($N = 173$)	–/*compatibility, support, personal innovativeness, job relevance*	United States
Liu and Ma[87]	Service-oriented medical records	Extending TAM by embedding perceived service level (PSL) as a causal antecedent for health care workers' willingness to use application service-oriented medical records	2005	Health care worker ($N = 79$)	Hospital/*Perceived service level*	United States
Han et al[43]	Mobile system	Examining acceptance of mobile system among physicians with the aid from mainly TAM, UTAUT and Personal Innovativeness in the Domain of Information Technology (PIIT) models	2006	Physicians ($N = 151$)	Health care sector/ *gender, experience, age, personal innovativeness, compatibility, social influence*	Finland
Liu and Ma[88]	Electronic medical records (EMR)	Introducing the notion of perceived system performance (PSP) to extend the TAM	2006	Medical profession-als ($N = 77$)	Hospital/*Perceived system performance*	United States
Palm et al[89]	Clinical information system (CIS)	Designing an electronic survey instrument from two theoretical models (Delone and McLean, and TAM) to assess the acceptability of an integrated CIS	2006	Physicians, nurses, and secretaries ($N = 324$)	Hospital/*Building on the TAM and the DeLone and McLean ISS models*	France
Kim and Chang[90]		Identifying the core functional factors in	2007	Users ($N = 228$)	Home/*Information search, usage support,*	South Korea

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Table 5 (*Continued*)

Author(s)	Technology studied	Main topic	Years	Sample	Setting/*Incorporated theories and variable with the TAM*	Country
	Health information Web sites	designing and operating health information Web sites			*customization, purchase, and security*	
Wu et al[91]	Mobile health care systems	Examining determines mobile health care systems (MHS) acceptance by health care professionals based on revised TAM	2007	Physicians, nurses, and medical technicians ($N = 137$)	Hospital/*MHS self-efficacy, technical support and training, compatibility*	Taiwan
Tung et al[92]	Electronic logistics information system	Nurses' acceptance of the electronic logistics information system with new hybrid TAM	2008	Nurses ($N = 258$)	Hospital/*Perceived financial cost, compatibility, trust*	Taiwan
Lai et al[93]	Tailored Interventions for management of DEpressive Symptoms (TIDES)	Designing Tailored Interventions for management of DEpressive Symptoms (TIDES) program based on an extension of the TAM	2008	Patients ($N = 32$)	Clinics/*framework based on TAM2 (subjective norm, job relevance, experience) and modified TAM (socio-demo, adjustment, job relevance)*	United States
Wu et al[94]	Adverse event reporting system	Investigating determines acceptance of adverse event reporting systems by health care professionals with extending TAM that integrates variables connoting trust and management support into the model	2008	Health care professionals ($N = 290$)	Hospital/*trust, management support, subjective norm*	Taiwan
Yu et al[95]	Health information technology applications	Applying a modified version of the TAM2 to examine the factors determining the acceptance of health IT applications	2009	Staff members from long-term care facilities ($N = 134$)	Long-term care/*age, subjective norm, image, job level, work experience, computer skills, voluntariness*	Australia
Dasgupta et al[96]	Personal digital assistants (PDAs)	Evaluating pharmacists' behavioral intention to use PDAs with TAM2	2009	Pharmacists ($N = 295$)	Hospital and community pharmacies/*The TAM2 theory*	United States
Ilie et al[97]	Electronic medical record (EMR)	Examining physicians' responses to uses of EMR bases on TAM	2009	Physicians ($N = 199$)	Hospital/*System accessibility*	United States
Trimmer et al[98]	Electronic medical records (EMRs)	Application models TAM, UTAUT, and organizational culture in several different phase for acceptance EMR	2009	Physicians ($N = –$)	Residency in family medicine/*Derived from TAM, UTAUT, and organizational culture*	United States
Lin and Yang[99]	Asthma care mobile service (ACMS) = mobile phone	Integrating TAM and "subjective norm" and "innovativeness" in acceptance ACMS	2009	Patients ($N = 229$)	Remote areas/*person-centered, communication*	China
Aggelidis and	Hospital information system (HIS)	Examining HIS acceptance by hospital	2009	Hospital personnel ($N = 283$)	Hospital/*Derived based on UTAUT and TAM (Compatibility, training,*	Greece

(*Continued*)

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Table 5 (*Continued*)

Author(s)	Technology studied	Main topic	Years	Sample	Setting/*Incorporated theories and variable with the TAM*	Country
Chatzoglou[100]		personnel bases on TAM			*social influence, facilitating condition, self-efficiency, anxiety)*	
Hyun et al[101]	Structured narrative electronic health record (EHR) model (electronic nursing documentation system)	Applying theory-based (combined technology acceptance model and task-technology fit model) and user-centered methods to explore nurses' perceptions of functional requirements for an electronic nursing documentation system	2009	Nurses ($N = 17$)	Hospital/*Combined TAM and task-technology fit (TTF) model*	United States
Vishwanath et al[102]	Personal digital assistant (PDA)	Exploring the determinants of personal digital assistant (PDA) adoption in health care with TAM	2009	Physicians ($N = 215$)	Hospital/*age, position in hospital, cluster ownership, specialty*	United States
Morton and Susan[103]	Electronic health record (EHR)	Adopting of an interoperable EHR in ambulatory card uses innovation diffusion theory and the TAM	2010	Physicians ($N = 802$)	University/*Combining innovation diffusion theory (IDT) and the TAM*	United States
Zhang et al[104]	Mobile homecare nursing	Applying TAM2 in mobile homecare nursing	2010	Nurses ($N = 91$)	Home/*The TAM2 theory*	Canada
Stocker[105]	Electronic medical records (EMRs)	Evaluating the TAM relevance of the intention of nurses to use electronic medical records in acute health care settings	2010	Nurses ($N = 97$)	Hospital/*Environment or context, nurse characteristics, EHR characteristic*	United States
Lim et al[106]	Mobile phones	Women's acceptance of using mobile phones to seek health information basis on TAM	2011	Women ($N = 175$)	Home care/*Self-efficacy, anxiety, prior experience*	Singapore
Schnall and Bakken[107]	Continuity of care record (CCR)	Assessing the applicability of TAM constructs in explaining HIV case managers' behavioral intention to use a CCR	2011	Managers ($N = 94$)	Center of HIV care/ *Perceived barriers to use*	United States
Kowitlawakul[108]	Telemedicine/ electronic or remote technology (eICU)	Determining factors and predictors that influence nurses' intention to use the eICU technology bases on TAM	2011	Nurses ($N = 117$)	Hospital/*Support from physicians, years working in the hospital, support from administrator*	United States
Egea and González[109]	Electronic health care records (EHCR)	Explaining physicians' acceptance for electronic health care records (EHCR systems)	2011	Physicians ($N = 254$)	Hospital/*Perceptions of institutional trust, perceived risk, information integrity*	Spain

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Table 5 (*Continued*)

Author(s)	Technology studied	Main topic	Years	Sample	Setting/*Incorporated theories and variable with the TAM*	Country
Hsiao et al[110]	Hospital information systems (HIS)	The application of TAM for evaluate HIS in among nursing personnel	2011	Nurses ($N = 501$)	Hospital/*system quality, information quality, user self-efficacy, compatibility, top management support, and project team competency*	Taiwan
Orruño et al[111]	Teledermatology	Examining intention of physicians to use teledermatology using a modified TAM	2011	Physicians ($N = 171$)	Home/*Subjective norm, facilitator, habit, compatibility*	Spain
Melas et al[112]	Clinical information systems	Explaining intention to use clinical information systems based on TAM	2011	Medical staff (total [$N = 604$], physicians- $= 534$)	Hospital/*Physician specialty, ICT knowledge, ICT feature demand*	Greece
Pai and Kai[113]	Health care information systems	Adopting the system and services based on Model proposed by DeLone and Mclean and TAM	2011	Nurses, head directors, and other related personnel ($N = 366$)	Hospital/Model proposed by DeLone and Mclean and TAM	Taiwan
Jimoh et al[114]	Information and communication technology (ICT)	Using modified TAM in among maternal and child health workers	2012	Health workers ($N = 200$)	Rural regions/ knowledge, *endemic barriers* (knowledge a separate factor from attitude)	Nigeria
Lu et al[115]	Hospital information system (HIS)	Exploring factors influencing the acceptance of HISs by nurses with derived model from TAM	2012	Nurses ($N = 277$)	Hospital/*Information system success model*	Taiwan
Lakshmi and Rajaram[116]	Information technology (IT) applications and innovativeness	Analyzing the influence of IT applications and innovativeness on the acceptance of rural health care services uses by TAM	2012	Health personnel ($N = 465$)	Rural centers/ *Information technology exposure, innovativeness, online information dependence*	India
Jian et al[117]	USB-based personal health records (PHRs)	Factors that influencing consumer adoption of USB-based personal health records by TAM	2012	Patients ($N =$- 1,465)	Hospital/*Subjective norm*	Taiwan
Escobar-Rodríguez et al[118]	e-Prescriptions and automated medication management systems	Investigating health care personnel to use e-prescriptions and automated medication management systems with extensive TAM	2012	Physicians, nurses ($N = 209$)	Hospital/*perceived compatibility*, *perceived usefulness* to enhance control systems, *training*, *perceived risks*	Spain
Ketikidis et al[119]	HIT systems	Applying modified TAM in acceptance of HIT systems in health care personnel	2012	Health professionals (nurses and medical doctors) ($N = 133$)	Hospital/*Computer anxiety*, *relevance*, *self-efficacy*, *subjective and descriptive norms*, *familiarity/ use of computers*	Greece

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Table 5 (*Continued*)

Author(s)	Technology studied	Main topic	Years	Sample	Setting/*Incorporated theories and variable with the TAM*	Country
Chen and Hsiao[120]	Hospital information system (HIS)	Examining acceptance of hospital information systems (HIS) by physicians	2012	Physicians ($N = 81$)	Hospital/*System quality, information quality, service quality*	Taiwan
Kim and Park[121]	Health information technology (HIT)	Developing and verify the extended technology acceptance model (TAM) in health care	2012	Health consumers ($n = 728$)	Home/*Incorporating the Health Belief Model (HBM) and theory of planned behavior (TPB), along with the TAM*	South Korea
Parra et al[122]	Care service for the treatment of acute stroke patients based on telemedicine (TeleStroke)	Development, implementation, and evaluation of a care service for the treatment of acute stroke patients based on telemedicine (TeleStroke) using a TAM	2012	Medical professionals ($N = 34$)	Hospital/*Subjective norm, facilitating conditions*	Spain
Gagnon et al[123]	*Telemonitoring system*	Using a modified TAM to evaluate health care professionals' adoption of a new telemonitoring system	2012	Health care professionals ($N = 234$)	Hospital/*habit, compatibility, facilitators, subjective norm*	Spain
Wangia[124]	Immunization registry	Extending with contextual factors (contextualized TAM) to test hypotheses about immunization registry usage	2012	Immunization registry end-users ($n = 100$)	Unit of immunization registry/*job-task change, commitment to change, system interface characteristic, subjective norm, computer self-efficacy*	United States
Wong et al[125]	Intelligent Comprehensive Interactive Care (ICIC) system (Telemedical)	Evaluating the users' intention using a modified technological acceptance model (TAM)	2012	Elderly people ($N = 121$)	Elderly care/*The TAM2 theory and enjoyment factor*	Taiwan
Holden et al[126]	Bar-coded medication administration (BCMA)	Identifying predictors of nurses' acceptance of bar-coded medication administration (BCMA)	2012	Nurses ($N = 83$)	Hospital/*Social influence, training, technical support, age, experience, satisfaction*	United States
Dünnebeil et al[127]	Electronic health (e-health) in ambulatory care (Telemedicine)	Extending technology acceptance models (TAMs) for electronic health (e-health) in ambulatory care settings by physicians	2012	Physicians ($N = 117$)	Ambulatory care/*building based on TAM and UTAUT (process orientation, importance of standardization, e-health knowledge, importance of documentation, importance of data security, intensity of IT utilization*)	Germany
Asua et al[128]	Telemonitoring	Examining the psychosocial factors related to telemonitoring acceptance among	2012	Nurses, general practitioners, and	Homecare/*Habit, compatibility, facilitator,* subjective norm	Spain

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Table 5 (*Continued*)

Author(s)	Technology studied	Main topic	Years	Sample	Setting/*Incorporated theories and variable with the TAM*	Country
		health care based on TAM2		pediatricians ($N = 268$)		
Kummer et al[129]	Sensor-based medication administration systems	Usage of professional ward nurses toward sensor-based medication systems based on an TAM2	2013	Nurses ($N = 579$)	Health associations/ *Qualitative overload, quantitative overload, personal innovativeness*	Australia
Sedlmayr et al[130]	Clinical decision support systems for medication	Testing acceptance of system by ED physicians with TAM2	2013	Physicians ($N = 9$)	Hospital/*Resistance to change(RTC), compatibility (COM)*	Germany
Abu-Dalbouh[131]	Mobile health applications	Using TAM to evaluate the system mobile tracking model	2013	Health care professionals ($N = –$)	–/*User satisfaction, attribute of usability*	Saudi Arabia
Tavakoli et al[132]	Electronic medical record (EMR)	Investigating the TAM using EMR	2013	Users of EMR ($n =$ census)	Central Polyclinic Oil Industry/data quality, user interface	Iran
Buenestado et al[133]	Clinical decision support systems (CDSS) based on computerized clinical guidelines and protocols (CCGP)	Determining acceptance of initial disposition of physicians toward the use of CDSS based on (CCGP)	2013	Physicians ($N = 8$)	Hospital/ *compatibility, habits, facilitators, subjective norm*	Spain
Escobar-Rodriguez and Bartual-Sopena[134]	Enterprise resources planning (ERP) systems	Analyzing the attitude of health care personnel toward the use of an ERP system in public hospital	2013	Health care personnel ($n = 59$)	Hospital/*Experience with IT, training, support, age*	Spain
Su et al[135]	Telecare systems	Integrating patient trust with the TAM to explore the usage intention model of Telecare systems	2013	Patients ($N = 365$)	Hospital/Patient trust *(including Social Trust, Institutional Trust)*	Taiwan
Alali and Juhana[136]	*Virtual communities of practice (VCoPs)*	Exploring VCoPs satisfaction based on the technology acceptance model (TAM) and DeLone and McLean IS success model	2013	Practitioners ($N = 112$)	Hospital/*Developing from TAM and DeLone and McLean IS success models (knowledge quality [KQ], system quality [SyQ], service quality [SeQ], satisfaction [SAT])*	Malaysia
Wang et al[137]	*Telecare system*	Using telecare system to construct medication safety mechanisms for remote area elderly uses TAM	2013	Elderly patients ($N = 271$)	Remote areas/*Person-centered caring, communication*	Taiwan
Chen et al[138]		Understanding the influence on	2013	Citizens ($N = 334$)	Home/*Relationship quality (including trust,*	Taiwan

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Table 5 (*Continued*)

Author(s)	Technology studied	Main topic	Years	Sample	Setting/*Incorporated theories and variable with the TAM*	Country
	Hospital e-appointment system	continuance intention in the hospital e-appointment system based on extended TAM			*satisfaction), continuance intention*	
Sicotte et al[139]	Electronic prescribing	Identifying the factors that can predict physicians' use of electronic prescribing bases on expansion of the technology acceptance model (TAM)	2013	Physicians ($N = 61$)	City region/*Social influence, practice characteristics, physician characteristics*	Canada
Liu et al[140]	Web-based personal health record system	Extending TAM that integrates the physician–patient relationship (PPR) construct into TAM's original constructs for acceptance of Web-based personal health record system	2013	Patients ($N = 50$)	Medical center/*Physician–patient relationship (PPR)*	Taiwan
Ma et al[141]	Blended e-learning systems (BELS)	Integrating task-technology fit (TTF), computer self-efficacy, the technology acceptance model and user satisfaction to hypothesize a theoretical model, to explain and predict user's behavioral intention to use a BELS	2013	Nurses ($N = 650$)	Hospitals and medical centers/*Integrating the TAM and task-technology fit (TTF)*	Taiwan
Escobar-Rodríguez and Romero-Alonso[142]	Automated unit-based medication storage and distribution systems	Identifying attitude of nurses toward the use of automated unit-based medication storage and distribution systems and influencing factors bases on TAM	2013	Nurses ($N = 118$)	Hospital/*Training, perceived risk, experience level*	Spain
Huang [143]	Telecare	Exploring people's intention to use telecare with aid from structural equation modeling (SEM) technique that is a modification of TAM	2013	People ($N = 369$)	City region/*Innovativeness, subjective norm*	Taiwan
Portela et al[144]	Pervasive Intelligent Decision Support System (PIDSS)	Adopting of INTCare system making use of TAM3 in the ICU	2013	Nurses ($N = 14$)	ICU/*The TAM3 theory*	Portugal
Johnson et al[145]	Evidence-adaptive clinical decision	Acceptance of evidence-adaptive clinical decision support system associated with an	2014	Internal medicine residents ($N = 44$)	Hospital/User satisfaction, computer knowledge, general optimism, self-reported usage, usage trajectory	United States

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Table 5 (*Continued*)

Author(s)	Technology studied	Main topic	Years	Sample	Setting/*Incorporated theories and variable with the TAM*	Country
	support system	electronic health record system using TAM			group, institutionalized use	
Zhang et al[146]	Mobile health	Assessment and acceptance between privacy and using mobile health with aid from TAM	2014	Patients ($N = 489$)	Hospital/*Personalization, privacy*	China
Andrews et al[147]	Personally controlled electronic health record (PCEHR)	Examining how individuals in the general population perceive the promoted idea of having a PCEHR	2014	Patients ($N = 750$)	Homecare/Social norm, privacy concern, trust, perceived risk, controllability, Web self-efficacy, compatibility, perceived value	Australia
Gagnon et al[148]	Electronic health record (EHR)	Identifying the main determinants of physician acceptance of EHR in a sample of general practitioners and specialists	2014	Physicians ($N = 157$)	Hospital/*Integrating original TAM, extended TAM, psychosocial model*	Canada
Hwang et al[149]	Prehospital telemetry	Factors influencing the acceptance of telemetry by emergency medical technicians in ambulances uses by extended TAM	2014	Emergency medical technicians ($n = 136$)	Hospital/*Job fit, loyalty, organizational facilitation, subjective norm, expectation confirmation, clinical factors, nonclinical factors*	South Korea
Tsai[150]	Telehealth system	Integrating extended TAM and health belief model (HBM) for to identify factors that influence patients' adoption to use telehealth	2014	Patients ($N = 365$)	Home/*Integrating extended technology acceptance model (extended TAM) and health belief model (HBM)*	Taiwan
Rho et al[151]	Telemedicine	Developing telemedicine service acceptance model based on the TAM with the inclusion of three predictive constructs from the previously published telemedicine literature: (1) accessibility of medical records and of patients as clinical factors, (2) self-efficacy as an individual factor, and (3) perceived incentives as regulatory factors	2014	Physicians ($N = 183$)	Medical centers and hospitals/*Self-efficacy, accessibility, perceived incentives*	South Korea
Tsai[152]	Telehealth	Developing a comprehensive behavioral model for analyzing the relationships among social capital factors (social capital theory), technological factors	2014	End users of a telehealth system ($N = 365$)	City region/*Integrating social capital theory (social trust, institutional trust, social participation), social cognitive theory (system self-efficacy) and TAM*	Taiwan

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Table 5 (*Continued*)

Author(s)	Technology studied	Main topic	Years	Sample	Setting/*Incorporated theories and variable with the TAM*	Country
		(TAM), and system self-efficacy (social cognitive theory) in telehealth				
Horan et al[153]	Online disability evaluation system	Developing a conceptual model for physician acceptance based on the TAM	2004	Physicians ($N = 141$)	Hospital/*Organizational readiness, technical readiness, perceived readiness, work practice compatibility, social demographics*	United States
Saigí-Rubió et al[154]	Telemedicine	Analyzing the determinants of telemedicine use in the three countries with TAM	2014	Physicians ($N = 510$)	Hospital, health care centers of the urban and rural/*Optimism, propensity to innovate, level of ICT use*	Spain, Colombia, and Bolivia
Steininger and Barbara[155]	Electronic health record (EHR)	Examining and extending factors influence acceptance levels among physicians, uses a modified (TAM)	2015	Physicians ($N = 204$)	Hospital/*Social impact, HIT experience, privacy concerns*	Austria
Basak et al[156]	Personal digital assistant (PDA)	Using an extended TAM for exploring intention to use personal digital assistant (PDA) technology among physicians	2015	Physicians ($N = 339$)	Hospital/*Integrating the TAM and DeLone and McLean IS success models (knowledge quality, system quality, service quality and user satisfaction)*	Turkey
Al-Adwan and Hilary[157]	Electronic health record (EHR)	Applying a modified version of the revised TAM to examine EHR acceptance and utilization by physicians	2015	Physicians ($N = 227$)	Hospital/*Compatibility, habit, subjective norm, facilitators*	Jordan
Kowitlawakul et al[158]	Electronic health record for nursing education (EHRNE)	Investigating the factors influencing nursing students' acceptance of the EHRs in nursing education using the extended TAM with self-efficacy as a conceptual framework	2015	Students ($N = 212$)	Clinics/*Self-efficacy*	Singapore
Michel-Verkerke et al.[59]	Patient record development (EPR)	Developing a model derived from the DOI and TAM theory for predicting EPR	2015	Patients ($N = –$)	–/*Derived from DOI and TAM theory*	The Netherlands
Lin[160]	Hospital information system (HIS)	Using the perspective of TAM; national cultural differences in terms of masculinity/femininity, individualism/collectivism, power distance, and uncertainty avoidance are incorporated into the TAM as moderators	2015	Nurses ($N = 261$)	Hospital/*Power distance, uncertainly avoidance, masculinity or femininity, individualism or collectivism, time orientation*	Taiwan

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Table 5 (*Continued*)

Author(s)	Technology studied	Main topic	Years	Sample	Setting/*Incorporated theories and variable with the TAM*	Country
Abdekhoda et al[59]	Electronic medical records (EMRs)	Assessing physicians' attitudes toward EMRs' adoption by a conceptual path model of TAM and organizational context variables	2015	Physicians ($N = 330$)	Hospital/*Management support, training, physicians' involvement, physicians' autonomy, doctor–patient relationship*	Iran
Gartrell et al[161]	Electronic personal health records (ePHRs)	Using a modified technology acceptance model on nurses' personal use of ePHRs	2015	Nurses ($N = 847$)	Hospital/*Perceived data privacy and security protection, perceived health-promoting role model*	United States
Carrera and Lambooij[162]	Out-of-office blood pressure monitoring	Developing an analytical framework based on the TAM, the theory of planned behavior, and the model of personal computing utilization to guide the implementation of out-of-office BP monitoring methods	2015	Patients, physicians ($N = 6$)	–/Framework *based on the TAM, the TPB (including self-efficiency, social norm), and the model of personal computing utilization (including enabling conditions)*	The Netherlands
Sieverdes et al[163]	Mobile technology	Investigating kidney transplant patients attitudes and perceptions toward mobile technology with aid from the technology acceptance model and self-determination theory	2015	Patients ($N = 57$)	Medical center/ *Frameworks from the TAM and self-determination theory (SDT)*	United States
Song et al[164]	Bar code medication administration technology	Using bar code medication administration technology among nurses in hospitals with TAM	2015	Nurses ($N = 163$)	Hospital/*Feedback and communication about errors, age, teamwork within hospital units, hospital management support for patient safety, nursing shift, education, computer skills, technology length of use*	United States
Jeon and Park[165]	Mobile obesity-management applications (apps)	The acceptance of mobile obesity-management applications (apps) by the public were analyzed using a mobile health care system (MHS) (TAM)	2015	Public (health consumer) ($N = 94$)	Homecare/ *Compatibility, self-efficacy, technical support and training*	South Korea
Alrawabdeh et al[166]	Electronic health record (EHR)	The revealing factors that affect the adoption of EHR	2015	Final users ($N = 6$)	Health sector of NHS/ *Clinical safety, security, integration, and information sharing*	United Kingdom
Escobar-Rodríguez and Lourdes [167]	Enterprise resources planning (ERP)	Impact of cultural factors on user attitudes toward ERP use in public hospitals and identifying	2015	Users ($N = 59$)	Hospital/*Resistance to be controlled, perceived risks, resistance to change*	Spain

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Table 5 (*Continued*)

Author(s)	Technology studied	Main topic	Years	Sample	Setting/*Incorporated theories and variable with the TAM*	Country
		influencing factors uses by TAM				
Briz-Ponce and García-Peñalvo[168]	Mobile technology and "apps"	Measurement and explain the acceptance of mobile technology and "apps" in medical education	2015	Students, medical professionals ($N = 124$)	University/*Reliability, social influence, facilitating conditions, self-efficacy, anxiety, recommendation*	Spain
Lai et al[169]	Mobile hospital registration system	The use of the mobile hospital registration system	2015	Patients ($N = 501$)	Hospital/*Information technology experience (ITE)*	Taiwan
Al-Nassar et al[170]	Computerized physician order entry (CPOE)	Behavior of CPOE among physicians in hospitals based on the technology acceptance model (TAM)	2016	physicians ($N = –$)	Hospital/*Instability of new software providers, software quality*	Jordan
Lin et al[171]	Devices for monitoring elderly people's postures and activities	Designing and development of a novel, textile-based, intelligent wearable vest for real-time posture monitoring and emergency warnings	2016	Elderly people ($N = 50$)	Homecare/*Technology anxiety*	Taiwan
Suresh et al[172]	Health information technology (HIT)	Analyzing the application of the technology acceptance model (TAM) by outpatients	2016	Patients ($N = 200$)	Hospital/*Customized information, trustworthiness*	India
Ifinedo[173]	Information systems (ISs)	The moderating effects of demographic and individual characteristics on nurses' acceptance of information systems (IS)	2016	Nurses ($N = 197$)	Hospital/*Education, computer knowledge*	Canada
Goodarzi et al[174]	Picture archiving and communication system (PACS)	The TAM has been used to measure the acceptance level of PACS in the emergency department	2016	Users ($N =$ census)	Hospital/*Change*	Iran
Abdekhoda et al[175]	Electronic medical records (EMRs)	Integrating a model to explore physicians' attitudes toward using and accepting EMR in health care	2016	Physicians ($N = 330$)	Hospital/*Integrated TAM and diffusion of innovation theory (DOI) model*	Iran
Strudwick et al[176]	Electronic health record (EHR)	Developing integrated TAM using theory of reasoned action, theory of planned behavior, and the TAM to explain behavior among nurses	2016	Nurses ($N = –$)	–/*Combining three different models theory of reasoned action (TRA), theory of planned behavior (TPB), and TAM*	Canada
Hsiao and Chen[177]	Computerized clinical practice guidelines	Investigating critical factors influencing physicians' intention through an integrative model of activity theory, and the	2016	Physicians ($N = 238$)	*Hospital/ incorporating activity theory (three dimensions of factors) with TAM concepts (intention as dependent variable)*	Taiwan

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Table 5 (*Continued*)

Author(s)	Technology studied	Main topic	Years	Sample	Setting/*Incorporated theories and variable with the TAM*	Country
		technology acceptance model				
Saigi-Rubió et al[178]	Telemedicine	Investigating determinants of telemedicine use in clinical practice among medical professionals using the TAM2 and microdata	2016	Physicians ($N = 96$)	*Health care institution/ Security and confidentiality, subjective norm, physician's relationship with ICTs*	Spain
Lin et al[179]	Nursing information system (NIS)	Developing a conceptual framework that is based on the technology acceptance model 3 (TAM3) and behavior theory	2016	Nurses ($N = 245$)	Hospital/*Framework that is based on the TAM3 and behavior theory (prior experience)*	Taiwan
Ducey and Coovert[180]	Tablet computer	Evaluating practicing pediatricians to use of tablet based on extended technology acceptance model	2016	Pediatricians (physicians) ($N = 261$)	Hospital/*Subjective norm, compatibility, reliability*	United States
Holden et al[181]	Novel health IT, the large customizable interactive monitor	Examining pediatric intensive care unit nurses' perceptions, acceptance, and use of a novel health IT, the large customizable interactive monitor bases on TAM2	2016	Nurses ($N = 167$)	Hospital/*Social influence, perceived training on system, satisfaction with system, complete use of system*	United States
Omar et al[182]	Prescribing decision support systems (EPDSS)	Investigating perception and use of EPDSS at a tertiary care using TAM2	2017	Physicians (pediatricians) ($N = –$)	Hospital/*The TAM2 theory*	Sweden

Abbreviations: DOI, diffusion of innovation; HIV, human immunodeficiency virus; ICT, information and communication technology; ICU, intensive care unit; IS, information system; IT, information technology; NHS, National Health Service; USB, Universal Serial Bus; UTAUT, unified theory of acceptance and use of technology.

additions can be expected to allow comparisons between ICT application areas and harmonization between ICT applications and different organizational processes.

However, it has been suggested that a main reason for inconsistent predictive performance of the TAM in health services is the poor match between construct operationalization and the context in which the construct is measured,[29] The second method to expand the TAM is to add contextualized TAM concepts that increase predictive power. One method to derive such contextualized concepts is belief elicitation[60] which was also the process used to fit general behavioral theory to the ICT context when developing the TAM.[20] However, this step-wise method is less suitable for comparisons between application areas and analyses of the organizational fit of new ICT applications from a general health service perspective. The results of this review suggest that consensus is needed upon how the TAM extension processes should be designed for uses in health services.

The primary threats to the validity of this review are concerned with the search strategy employed. First, it may be possible that we have not identified all relevant publications. The completeness of the search is dependent upon the search criteria used and the scope of the search, and is also influenced by the limitations of the search engines used. Publication bias is possibly a further threat to validity, in that we were primarily searching for literature available in the major computing digital libraries. It is possible that, as a result, we included more studies reporting positive results of the TAM as those publications reporting negative results are less likely to be published. Since we have been unable to undertake a formal meta-analysis, we are equally unable to undertake a funnel analysis—using a series of events that lead toward a defined goal—to investigate the possible extent of publication bias. Finally, it must be remembered that the TAM does not measure the benefit of ICT use,[57] implying that measures of

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Table 6 The factors, variables, and theories used in common technological contexts in studies (respectively, repetition and importance)

Technology area	Factors (variables) and intention-based theories incorporated to original TAM based on different user groups and technological contexts			
	User groups	Factors and variables	Intention-based theories	Extended TAM version used
HIT systems in general	Health care professionals	Knowledge, endemic barriers, anxiety, relevance, self-efficacy, subjective and descriptive norms, age, image, job level, work experience, computer skills, voluntariness, information technology exposure, innovativeness, online information dependence	DeLone and McLean IS success model	–
	Nurses	Social influence, perceived training on system, satisfaction with system, complete use of system	–	–
	Patients	Customized information, trustworthiness.	Health belief model (HBM), TPB	–
Hospital information system (HIS)	Physicians	System quality, information quality, service quality	–	TAM3
	Health care professionals	Compatibility, training, social influence, facilitating condition, self-efficiency, anxiety	UTAUT	–
	Nurses	Power distance, uncertainly avoidance, masculinity or femininity, individualism or collectivism, time orientation, prior experience, system quality, information quality, self-efficacy, compatibility, top management support, project team competency	Information system success model	TAM3
Electronic health record (EHR)	Physicians	System acceptability, system characteristics, organizational characteristics, individual characteristics, system accessibility, organizational cultural, perceptions of institutional trust, perceived risk, information integrity, social impact, HIT experience, privacy concerns, compatibility, habit, subjective norm, facilitators, management support, training, physicians' involvement, physicians' autonomy, doctor–patient relationship	DOI, IDT, UTAUT	TAM2
	Health care professionals	Perceived service level, perceived system performance, data quality, user interface, self-efficacy, clinical safety, security, integration and information sharing	–	–
	Nurses	Environment or context, nurse characteristics, EHR characteristic	TRA, TPB, TTF	
e-Prescription systems	Physicians	Social influence, practice characteristics, physician characteristics, perceived compatibility, perceived usefulness to enhance control systems, training, perceived risks	–	–
	Nurses	Perceived compatibility, perceived usefulness to enhance control systems, training, perceived risks	–	–
Computers, handheld (PDAs)	Physicians	Subjective norm, compatibility, reliability, knowledge quality, system quality, service quality, user satisfaction, age, position in hospital, cluster ownership, specialty	DeLone and McLean IS success model	–

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Table 6 (*Continued*)

Technology area	Factors (variables) and intention-based theories incorporated to original TAM based on different user groups and technological contexts			
	User groups	**Factors and variables**	**Intention-based theories**	**Extended TAM version used**
	Health care professionals	Compatibility, support, personal innovativeness, job relevance	–	–
	Nurses	–	–	–
	Pharmacists	Subjective norm, image, output quality, result demonstrability, job relevance, experience, voluntariness	–	TAM2
Telemedicine	Physicians	Security and confidentiality, relationship with ICTs, subjective norm, facilitators, habit, compatibility, self-efficacy, accessibility, perceived incentives, process orientation, importance of standardization, e-health knowledge, importance of documentation, importance of data, propensity to innovate, organizational readiness, technical readiness, social demographics, optimism, propensity to innovate, enabling conditions	UTAUT, TPB, personal computing utilization	TAM2
	Health care professionals	Subjective norm, job fit, loyalty, expectation confirmation, clinical factors, nonclinical factors, habit, compatibility, facilitators	–	–
	Patients	Patient trust, person-centered caring, communication, enjoyment factor, social and institutional trust, social participation, self-efficacy, innovativeness, subjective norm, social norm, enabling conditions, technology anxiety	HBM, social capital theory, social cognitive theory, TPB, personal computing utilization	TAM2
	Nurses	Support from physicians, experience, support from administrator.	–	–
Mobile applications	Physicians	Gender, experience, age, personal innovativeness, compatibility, social influence	–	–
	Health care professionals	Reliability, social Influence, facilitating conditions, self-efficacy, anxiety, recommendation, user satisfaction, attribute of usability, technical support and training, compatibility	–	–
	Nurses	Subjective norm, image, output quality, result demonstrability, job relevance, experience, voluntariness	–	TAM2
	Patients	Information technology experience (ITE), compatibility, self-efficacy, technical support and training, personalization, privacy, anxiety, prior experience, person-centered, communication	Self-determination theory (SDT)	–
Personal health record (PHR)	Patients	Subjective norm, physician–patient relationship (PPR), social norm, privacy concern, trust, perceived risk, controllability, self-efficacy, compatibility, perceived value	DOI	–

Abbreviations: DOI, diffusion of innovation; HIT, health information technology; ICT, information and communication technology; IDT, innovation diffusion theory; IS, information system; PDA, personal digital assistant; TAM, technology acceptance model; TPB, theory of planned behavior; TRA, theories of reasonable action; TTF, task-technology fit; UTAUT, unified theory of acceptance and use of technology.

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Table 7 Other models' comparison with TAM and confirmation of suitability of the TAM factors

Author(s)	Technology studied	Main topic	Years	Sample	Setting	Country
Chau and Jen-Hwa[46]	Telemedicine	Comparing different models, including TAM, the theory of planned behavior (TPB), and an integrated model for acceptance telmedicine	2002	Physicians ($N > 400$)	Hospital	China
Liang et al[51]	Computerized physician order entry (CPOE)	Examining whether the TAM can be applied to explain physician acceptance of CPOE	2006	Physicians ($N = 200$)	Hospital	China
Day et al[45]	Videophone technology	Evaluating hospice providers∋ attitudes and perceptions regarding videophone technology in the hospice setting in the context of the TAM	2007	Providers ($N = 17$)	Hospice	Colombia
Smith and Motley[50]	Electronic prescribing	The degree of e-prescribing acceptance is highly predictable by factors that are very stable ease-of-use variables derived from the TAM	2010	Pharma-cists ($N = 50$)	Pharma-ceutical company's supply	United States
Kim et al[47]	Telehomecare (telemedicine)	Comparing two theories of technology adoption, the technology acceptance model and the theory of planned behavior, to explain and predict physicians' acceptance and use of the telehomecare technology	2010	Physicians ($N = 40$)	Homecare	United States
Kuo et al[183]	Mobile electronic medical record (MEMR) systems	Confirming relationships between the TAM components, and behavioral intention in the technology acceptance model toward MEMR usage	2013	Nurses ($N = 665$)	Hospital	Taiwan
Manimaran and Lakshmi[49]	Health management information system (HMIS)	Formulating a model of technology acceptance of health management information system (HMIS) that features the TAM was confirmed	2013	Health workers ($N = 960$)	Rural health care	India
Hsiao and Tang[44]	Mobile health care devices	The use intention of mobile health care devices from the perspectives of elderly people	2015	Elderly people ($N = 338$)	–	Taiwan
Kim et al[48]	Mobile electronic health records (EMR) system	Confirming the factors that influence users' intentions to utilize a mobile electronic health records (EMR) system with TAM	2016	Health care profession-als ($N = 942$)	Hospital	South Korea

Abbreviation: TAM, technology acceptance model.

technology acceptance and use intentions should not be mistaken for measures of technology value. Separate studies using measures of effectiveness or productivity are needed to assess the organizational value of the new technology.

The review was limited to those articles describing only the TAM and its application in health care service. By restricting our review to a narrow segment of this literature, we may have inadvertently eliminated meaningful details from other acceptance models and factors in health technologies acceptance. Also, there are books and book chapters that deal with the TAM in health care. These types of publications are not included in our review, but may contain information relevant to this review. Finally, our review includes only articles in English language and languages other than English might have information about the TAM in health care.

Conclusion

The result showed that telemedicine applications peaked between 1999 and 2017 and is the ICT application area most frequently studied using the TAM, implying that acceptance of telemedicine applications during this period was a major challenge when exploiting ICT to develop health service organizations. A majority of the reviewed articles reported extensions of the original TAM, suggesting that no optimal TAM version for use in health services has been established. Although the review results indicate a continuous progress, there are still areas that can be expanded and improved to increase the predictive performance of the TAM. Finally, it is suggested that the common investigated factors in the previous studies (►Table 6), for each technological contexts and user groups, should tested empirically in real settings. If these factors confirmed, it is recommended that they will be

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applied as a basic model for each technological contexts and user groups.

Clinical Relevance statement

This systematic review showed that between 1999 and 2016, telemedicine applications were the ICT application area most frequently studied using the TAM, implying that acceptance of the telemedicine technology during this period was a major challenge for health service organizations. The construct validity of the model is showcased by its broad applicability to various technologies in health care. With the increasing number of technologies in the health care environment, the use of technology acceptance models is needed to guide implementation processes across health service contexts and user groups. This review has indicated continuous progress in revealing new aspects critical for ICT implementation having significant influence on health service processes and outcomes.

Multiple Choice Questions

1. Which of the following options are three main technological contexts using the TAM in health care ICTs?
   a. (1) Hospital information system (HIS), (2) mobile applications, and (3) electronic health record (EHR).
   b. (1) Telemedicine, (2) hospital information system (HIS), and (3) computers, handheld (PDAs).
   c. (1) Telemedicine, (2) electronic health record (EHR), and (3) mobile applications.
   d. (1) Electronic health record (EHR), (2) e-prescription systems, and (3) hospital information system (HIS).

   Correct Answer: The correct answer is option c. The study identified three main technological contexts for using TAM in health care: (1) Telemedicine, (2) electronic health records (EHR), and (3) mobile applications. The geographical contexts of using TAM between different countries: Taiwan (telemedicine and mobile applications), U.S. and Iran (EHR), and Spain (telemedicine).

2. What variables can be added to the original TAM as a basis for model application in a variety of technological contexts?
   a. Subjective norm, self-efficacy, compatibility, experience, training, anxiety, habit, and facilitators.
   b. Job relevance, age, communication, image, information quality, and uncertainty avoidance.
   c. Power distance, time orientation, project team competency, acceptability, and organizational characteristics.
   d. Training, management support, user interface, autonomy, cluster ownership, personal innovativeness, and loyalty.

   Correct Answer: The correct answer is option a. The most common factors added to the original TAM in almost all technological contexts were, in order of importance and frequency of repetition, compatibility, subjective norm, self-efficacy, experience, training, anxiety, habit, and facilitators.

Protection of Human and Animal Subjects
Not applicable.

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Conflict of Interest
None.

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