Journal of Biomedical Informatics 43 (2010) 159–172

Contents lists available at ScienceDirect

Journal of Biomedical Informatics

journal homepage: www.elsevier.com/locate/yjbin

Methodological Review

The Technology Acceptance Model: Its past and its future in health care

Richard J. Holden [a,b,*], Ben-Tzion Karsh [a]

[a] Department of Industrial and Systems Engineering, University of Wisconsin-Madison, Madison, WI, USA
[b] Department of Psychology, University of Wisconsin-Madison, Madison, WI, USA

ARTICLE INFO

Article history:
Received 28 October 2008
Available online 15 July 2009

Keywords:
Technology use
Behavior
Health information technology
Technology Acceptance Model

ABSTRACT

Increasing interest in end users' reactions to health information technology (IT) has elevated the importance of theories that predict and explain health IT acceptance and use. This paper reviews the application of one such theory, the Technology Acceptance Model (TAM), to health care. We reviewed 16 data sets analyzed in over 20 studies of clinicians using health IT for patient care. Studies differed greatly in samples and settings, health ITs studied, research models, relationships tested, and construct operationalization. Certain TAM relationships were consistently found to be significant, whereas others were inconsistent. Several key relationships were infrequently assessed. Findings show that TAM predicts a substantial portion of the use or acceptance of health IT, but that the theory may benefit from several additions and modifications. Aside from improved study quality, standardization, and theoretically motivated additions to the model, an important future direction for TAM is to adapt the model specifically to the health care context, using beliefs elicitation methods.

1. Introduction

Health information technology (IT) research often focuses on IT design and implementation [1–4], but perhaps not enough on how clinician end users react to already implemented IT. Of course, there is more to health IT "success" than designing or purchasing a reasonably functional technology. Many recent reports of the unintended consequences of health IT [5–13] show that the fit between IT and the clinical work system will lead intended end users to accept or reject the IT, to use it or misuse it, to incorporate it into their routine or work around it [14–19]. In other words, "whether an information system is 'successful' or not is decided on the workfloor ..." [20]. Numerous cases of underuse, resistance, workarounds and overrides, sabotage, and even abandonment are evidence for this claim [21–28]. Yet, many more studies of health IT are about its adoption—that is, whether clinics, hospitals, or clinicians have *purchased* and *installed* IT, and why—than about end-user reactions—e.g., how and why implemented ITs are *used*. Simon et al. [29] noted this trend with respect to studies of electronic health records (EHR):

> Most studies have focused on EHR adoption. Relatively little attention has been paid to the capabilities of those systems and the degree to which physicians with EHRs actually use them. Electronic health records have great potential to improve quality and safety in health care ... but these improvements will occur only if clinicians have access to key functions in EHR systems and use them regularly.

There are, of course, numerous exceptions to implementation-focused research [30,31]. Perhaps most notable is the application of the Technology Acceptance Model (TAM) to the prediction and explanation of end-user reactions to health IT [32]. That this parsimonious theory of IT acceptance and use has penetrated the health IT literature is not surprising. In industries outside of health care, TAM is somewhat of a gold standard, if not a paradigm of its own [33]. As much as 10% of the space allocated to Information Systems publications is claimed by TAM research [34]. Reviews of the most basic version of the theory routinely find that it accounts for 30–40% of IT acceptance, despite its relative simplicity [34–38].

With over twenty studies testing TAM in health care and dozens more empirical and theoretic health IT papers mentioning the theory, TAM is increasingly portrayed as a fitting theory for the health care context. Yet, the TAM is not a model developed specifically in or for the health care context. If used in its generic form, TAM may not capture—or indeed may contradict—some of the unique contextual features of computerized health care delivery. Thus, determining whether TAM is a fitting theory for health care is an empirical question requiring critical examination. Accordingly, the objectives of the present work are (1) to undertake a comprehensive, critical review of studies of TAM with respect to health IT, with particular focus on how, if at all, those studies account for the health care context; (2) to judge the efficacy of TAM and its worth

* Corresponding author. Address: Department of Industrial & Systems Engineering, University of Wisconsin-Madison, 1513 University Avenue, Room 3217, Madison, WI 53706, USA. Fax: +1 608 262 8454.
E-mail address: rholden@wisc.edu (R.J. Holden).

1532-0464/$ - see front matter © 2009 Elsevier Inc. All rights reserved.
doi:10.1016/j.jbi.2009.07.002

Table 1
Definitions of variables in TAM and related models.

Variable	Definition	Models that include the variable
Behavior	The action, specific or general, whose prediction is of interest	TRA/TPB
Use (USE)	One specific behavior of interest performed by individuals with regard to some information technology (IT) system	TAM, TAM2, UTAUT
Behavioral intention (BI)	An individual's motivation or willingness to exert effort to perform the target behavior	TAM, TAM2, UTAUT, TRA/TPB
Attitude (ATT)	An individual's evaluative judgment of the target behavior on some dimension (e.g., good/bad, harmful/beneficial, pleasant/unpleasant)	TAM, TRA/TPB
Perceived ease of use (PEOU)	An individual's perception that using an IT system will be free of effort	TAM, TAM2
Perceived usefulness (PU)	An individual's perception that using an IT system will enhance job performance	TAM, TAM2
Subjective norm (SN)	An individual's perception of the degree to which important other people approve or disapprove of the target behavior	TAM2, TRA/TPB
Perceived behavioral control (PBC)	An individual's perception of how easy or difficult it will be to perform the target behavior (self-efficacy), of factors that impede or facilitate the behavior (facilitating conditions), or of the amount of control that one has over performing the behavior (controllability)	TPB
Effort expectancy	(See PEOU)	UTAUT
Performance expectancy	(See PU)	UTAUT
Social influence	(See SN)	UTAUT
Facilitating conditions	(See PBC)	UTAUT
Image, job relevance, output quality, results demonstrability	Real or perceived characteristics of IT that influence its PU	UTAUT
Behavioral beliefs, normative beliefs, control beliefs	An individual's perceptions about specific positive/negative outcomes of performing the target behavior, specific groups or people who encourage/discourage the behavior, and specific factors or circumstances that make behavior easier/more difficult	TRA/TPB

TAM, Technology Acceptance Model; TAM2, Technology Acceptance Model 2; UTAUT, Universal Theory of Acceptance and Use of Technology; TRA, Theory of Reasoned Action; TPB, Theory of Planned Behavior.

as a theory of health IT acceptance and use; and (3) to propose avenues of change and extension to the theory in an effort to improve its usefulness to researchers, designers, and health care decision-makers.

1.1. Technology Acceptance Model

TAM was developed in the 1980's, in light of concern that workers were not using ITs made available to them [39,40]. Its originators reasoned that the key to increasing use was to first increase acceptance of IT, which could be assessed by asking individuals about their future intentions to use the IT. Knowing the factors that shaped one's intentions would allow organizations to manipulate those factors in order to promote acceptance, and thus increase IT use. Early TAM research discovered that only three factors were needed to explain, predict, and presumably control acceptance.

To arrive at the model, its originators adapted the Theory of Reasoned Action (TRA), a general social-psychological/behavioral theory that had been proven useful for understanding a variety of behaviors such as voting, exercise, and condom use [41]. As was customary for adapting such theory to new contexts [42], a preliminary study took place to determine what would be the appropriate variables to include in order to understand IT use behavior [43]. The variables that were selected, and formed the first version of TAM, are defined in Table 1 and are graphically depicted in Fig. 1a. The most proximal antecedent to IT use is behavioral intention to use it (BI), and this is now commonly what is meant when one refers to acceptance [40,44,45], although another common conceptualization of acceptance is end-user satisfaction [46,47]. Because BI is thought to reliably predict actual use, and the latter is difficult to measure, BI is sometimes the only measured outcome of interest in a study of TAM [48,49]. BI is influenced by one's attitude toward using the IT (ATT). Attitude, in turn, has two determinants: perceived usefulness (PU) and perceived ease of use (PEOU). Additionally, PU is specified to have an independent effect on BI, and PEOU has an effect on PU. The theoretical and practical importance of all of these seemingly esoteric relationships is discussed later in this review. TAM is a theory that has gone through a number of changes. For example, an update called TAM2 [50] (Fig. 1b) removed the ATT component from the model, which originally mediated some of the influence of PU and PEOU. TAM2 also added a variable meant to capture the social influence (e.g., from colleagues or bosses) that compels end users to positively evaluate and accept IT, called subjective norm (SN). Even more recently, an impressive effort to unify the IT acceptance literature resulted in the Unified Theory of Acceptance and Use of Technology (UTAUT), a theory with obvious resemblance to TAM [51]. UTAUT (Fig. 1c) incorporates PU into a performance expectancy construct, PEOU into effort expectancy, and SN into social influence. New to the UTAUT, but not to IT acceptance research generally [52], is the modeling of facilitating conditions as one determinant of BI. UTAUT is a new but promising theory; early tests of UTAUT explained an impressive 70% of the variance in BI and about 50% in actual use.

Finally, some studies use early psychological models of behavior on which TAM was originally based [41,42,53]. These models are the Theory of Reasoned Action (TRA), or, more often, its successor, the Theory of Planned Behavior (TPB). The latter is depicted in Fig. 1d. Variables from TAM and the other mentioned theories are defined in Table 1. As reviewed elsewhere [33,34,54,55], many other revisions have been suggested to TAM and some past revisions have been questioned, but the three TAM descendents described above, and the general TPB, are the most commonly used.

1.2. Technology Acceptance Model in health care

Below we review studies in health care that used TAM and related models described above. In reviewing TAM's application to health care settings, we cannot overlook the excellent recent review by Yarbrough and Smith [30] of various studies of physicians' acceptance and use of health IT, which included four datasets that have been statistically analyzed using TAM as a theoretical base.[1]

[1] Although the authors reviewed eight studies that tested TAM, five of those analyzed the same sample of 408 Hong Kong physicians, and the authors noted this fact.

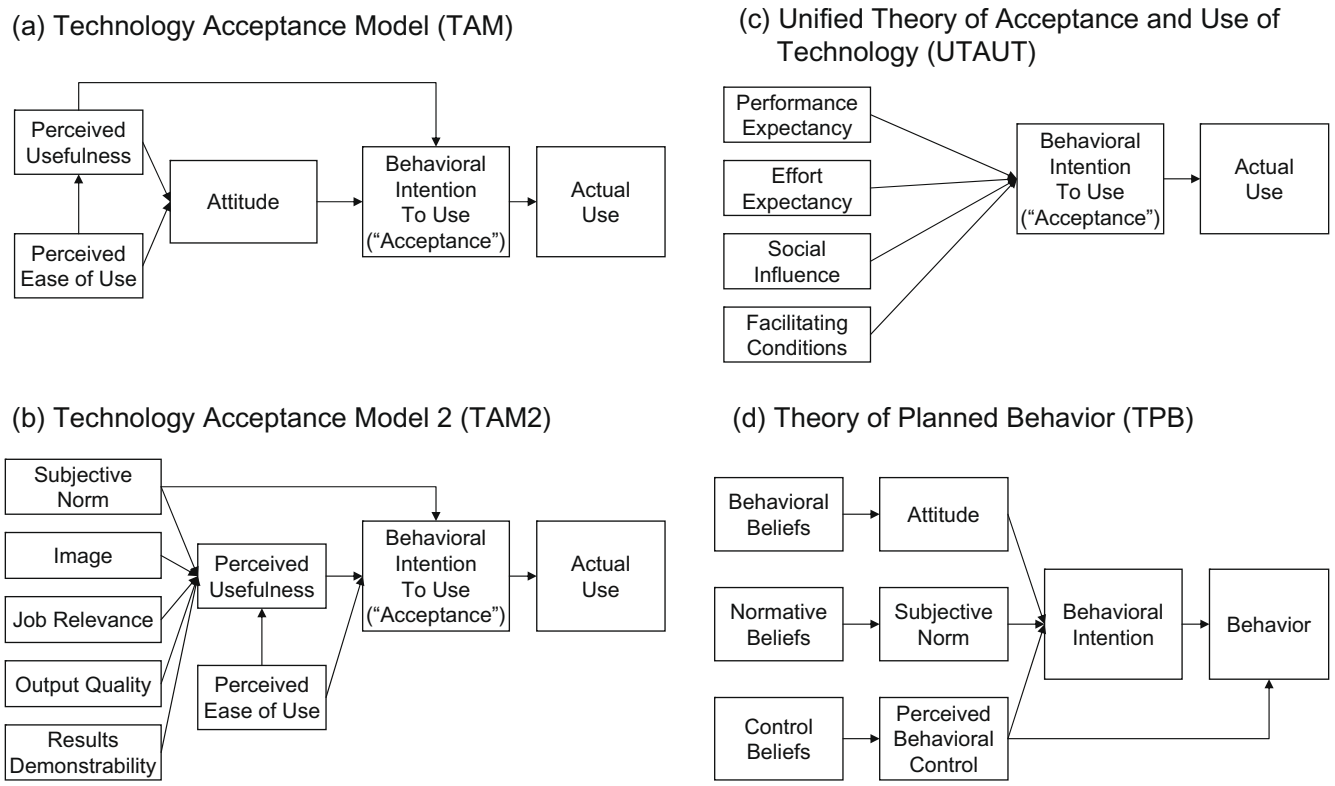

Fig. 1. Illustrations of (a) the Technology Acceptance Model (TAM), and related theories, including (b) TAM2, (c) the Unified Theory of Acceptance and Use of Technology (UTAUT), and (d) the Theory of Planned Behavior (TPB).

That review also contains a discussion of TAM and a proposed research model that builds on TAM, as do recent writings by Holden and Karsh [28,56], Ammenwerth et al. [57], and others [58–62]. The present review differs from Yarbrough and Smith's in several ways. First, it includes only those studies that have quantitatively assessed TAM or a small family of related models. Studies testing only Rogers' Innovation Diffusion Theory [63], for example, are not included in the review. Second, here we review a larger set of 16 data sets analyzed in 22 studies, including ones that were missed by the earlier review and ones that have been published since. Third, the present review includes studies of non-physicians, including studies of nurses, technicians, pharmacists, physician assistants, and physiotherapists. Fourth, and perhaps most importantly, the conclusions and suggested future directions that we will present below differ substantially from those of Yarbrough and Smith.

2. Methods

Studies included in the review had to be published on or before July 2008. They had to quantitatively test relationships between variables specified by TAM. This criterion excluded studies that measured TAM variables but not the relationships between them [64–71] and qualitative studies that used TAM as a framework [72,73]. Unlike Yarbrough and Smith [30], who reviewed qualitative studies of TAM, we were interested specifically in studies of TAM, a model of quantitative relationships between variables. Nevertheless, qualitative TAM studies can be informative. Day et al.'s qualitative interview study of hospice providers' use of videophones showed that providers perceive videophone technology as useful (improved communication, better access to care) but not easy to use (low technical quality, difficult to use for patients), and that ease of use appeared to be a more dominant contributor to intentions to use [73]. Karsh et al.'s study of primary care physicians' and nurses' perceptions of using error reporting systems revealed perceptions of usefulness (improved care, suggestions for improvement) and ease of use (easy and quick to use, minimal extra workload, good instructions), as well as subjective norms (colleagues, supervisors, internal and external organizations) [72].

We also excluded studies that did not use TAM as a theoretical framework but tested one or more relationships specified by TAM [74–76] because those studies do not represent tests of the model. For example, a study that only examined the relationship between PEOU and PU would not have been included. Studies had to focus on health IT use or acceptance (i.e., behavioral intention to use). This excluded studies of nurses' acceptance of tasks or processes [77,78] and studies that used TAM to predict IT adoption by an organization [79]. We defined health IT on the basis of convergence between international definitions of health IT and health/medical informatics. Two illustrative definitions of health IT are:

- "The application of information processing involving both computer hardware and software that deals with the storage, retrieval, sharing, and use of health care information, data, and knowledge for communication and decision-making" [80].
- "The knowledge, skills and tools which enable information to be collected, managed, used and shared to support the delivery of health care and promote health" [81].

Based on such definitions, we restricted the review to studies of technologies that digitized information for the purpose of delivering (direct) patient care. This excluded studies of TAM that focused on web-based learning or online training courses [82–85], clinical decision support knowledge authoring tools [86], and adverse event reporting systems [87]. The end users of the health IT had to be health care professionals providing medical care. This excluded studies of health IT use by patients [88–90] or non-medical

health care providers such as social workers [91]. Those exclusions were made so as to keep our reviewed studies in the same general context. That is, in all of the included studies, the health IT would be affecting the actual work of the clinicians by affecting the care they deliver. Had we included studies of health IT not used for patient care or not used by clinicians, it would have increased the heterogeneity and made drawing conclusions more tenuous.

We excluded unpublished dissertations [92]. Studies had to be published in a language spoken by the authors and accessible to the authors through the University of Wisconsin-Madison library and its comprehensive electronic subscription and interlibrary loan systems. Studies that were excluded because they did not meet our criteria may still provide useful insight for understanding health IT use and acceptance, and should be prime candidates for broader reviews in the future.

Following Yarbrough and Smith [30], we conducted searches of the online database PubMed/MEDLINE with the keywords "Technology Acceptance Model," "TAM," "TAM2," "UTAUT," and "Universal Theory of Acceptance and Use of Technology" and the ABI/INFORM Global database with the same keywords plus "health*," "physician*" and "nurs*" in order to narrow the search to health care settings. Obvious non-health care/non-technology results were removed first, and the abstracts of all remaining results were read. Full versions of all articles that were possibly relevant were retrieved and read. For each retrieved article, we conducted a search of references that might meet inclusion criteria, and retrieved those articles.

For this review we purposely decided not to conduct a quantitative meta-analysis. As others who have reviewed health IT research have pointed out, a meta-analysis would have been inappropriate because of the significant heterogeneity among studies in terms of sample characteristics, specific technologies studied, and functions of those technologies [93,94]. However, we did provide information on the percentage variance explained in the dependent variable (e.g., R^2), for readers to evaluate and compare. Those values must be interpreted with caution, because of the substantial variability in studies.

3. Results

Efforts to apply TAM to health IT date back to the late 1990's, beginning with studies by Hong Kong researchers testing the TAM and, subsequently, different versions of TAM and TPB, in a sample of 408 surveyed physicians with access to telemedicine IT [32,48,49,95]. Their findings were disappointing, and they asserted that TAM was a poor fit for physician acceptance of health IT, perhaps because of professional differences between physicians and other workers who use IT [32]. In total, 16 datasets have been analyzed, and TAM has fared much better in later tests. Reviewed studies are summarized in Table 2 and are discussed below.

3.1. Study samples and settings

Of the 16 data sets analyzed using TAM and related models, seven contained data from all-physician samples. The physician specialties covered were endoscopy [96], pediatrics [97], disability care [98], and some mix of specialists and general practitioners [32,99–101]. In a few studies, participants were nurses [102,103], and physio- [104] or occupational [105] therapists. Five studies collected data from a mix of physicians, nurses, pharmacists, and medical technicians [106–110].

Interestingly, studies of TAM in health care have been conducted in a wide variety of countries. Several studies were set in Taiwan [103,109,110], Hong Kong [32,48,49], the UK [96,104], Australia [102,111], and the mainland US [98,99,106,107] and Hawaii [97]. Others were set in Belgium [108], Finland [100], and Quebec [101].

3.2. Health IT studied

There was variation in the health IT that served as the focus of the study, including telemedicine technology [32], picture archiving and communications systems [108,109], and computerized provider order entry (CPOE) [101] (see Table 2 for full list). In health care and health IT domains, there is currently much interest in clinician use of electronic medical records (EMR) for patient care. Surprisingly, only one set of studies focused on EMR [107], although it was only a trial system that was temporarily evaluated by study participants. Additionally, a study that is not here considered as a study of TAM focused on the perceptions of 51 physicians and 51 midwives toward a planned EMR system [67]. The study used TAM as a theoretical framework to formulate survey questions and then to interpret results, but did not test the relationships between TAM variables.

3.3. Research models tested

The studies mentioned did not test a single, uniformly specified model of relationships between TAM variables. Most studies began with TAM as a conceptual framework and removed [32,102,104] or added predictor variables [49,96,98,100,101,103,106,107,109]. In some cases, added variables were treated as independent predictors of intention to use or actual use of health IT, and in other cases added variables were used to predict TAM variables such as PEOU and PU. For example, several studies tested the effect of health IT compatibility on behavioral intentions [98,100], whereas others tested the effect of compatibility on PEOU and PU [48,49,106], and yet others tested both kinds of effects [103,105,109]. The list of added variables includes various perceived IT system characteristics such as how well the system performs [96,107,112] and how relevant it is to one's job [106], personal characteristics of users [98,105,106], characteristics of the organization such as readiness for IT or technical support [98,105,106,109], and psychological variables such as ownership [101] and trust [103]. One study tested TAM2 [97], two tested UTAUT [108,110], and two tested some hybrid of UTAUT, TAM and TPB [99,105]. Sometimes, the researchers compared TAM to another model, for example, TPB [48,102].

3.4. Definitions of key constructs

Studies varied slightly in how key variables were conceptualized, as depicted in Table 3. Perceived usefulness (PU) was defined as health IT use leading to enhancement or gains in job performance. Notably, no study used a broader definition of usefulness, despite the notion that health IT might be useful for not only enhancing performance, but also making performance easier and more satisfying, increasing efficiency and lowering costs, improving quality and safety of care, and more [113–115]. Whereas definitions based on those of Davis's original TAM [39,40] focused on *personal* performance, those based on UTAUT [51] did not, but they also did not explicitly refer to performance benefits for other members of the care team, referring specialists, or patients' families. It was unclear from either definition whether usefulness referred to enhanced performance process (e.g., fewer steps, more information for decision making) or enhanced performance outcomes (e.g., faster care, more accurate decisions) [116].

Perceived ease of use (PEOU) was either defined as the lack of (physical or mental) effort or simply as "ease of use." As with PU, the definitions were somewhat limited (e.g., they do not account for the difficulty of low-*effort* but highly *repetitive* tasks) and

Table 2
Summary of reviewed studies of TAM in health care.

Study[a]	Technology studied	Population studied and setting	Analyzed sample size (*N*)	Response rate	Variance explained[b]
Barker et al.[96]	Prototype of a spoken dialog technology for making observations and notes during endoscopic examinations	Physicians (endoscopists) at James Cook University Hospital, UK	10	Not reported (laboratory study)	—
Chau and Hu, Hu and Chau, Hu et al. [32,48,49,95]	Telemedicine technology	Physicians at public tertiary care hospitals, Hong Kong	408	24%	40–44%
Chen et al. [110]	Radio Frequency Identification (RFID) for improving process quality and safety	Fifty-five emergency room (ER) caregivers (physicians, nurses) and 26 information systems staff, at five hospitals in Taiwan	81	Not reported	62% 56% of actual use
Chismar and Wiley-Patton [97]	Internet and Internet-based health applications	Physicians (pediatricians) in Hawaii	89	43%	54%
Duyck et al. [108]	Future picture archiving and communications system (PACS)	Physicians (radiologists) and radiology technologists at Ghent University Hospital, Belgium	56	60%	48%
Han et al. [100]	Mobile medical information system	Physicians (general practitioners and specialists) in Finland	242	42%	70%
Horan et al. [98]	Online disability evaluation system used for patient assessment	Physicians (disability providers) in the US	141	52%	44%
Liang et al.[c] [106]	Personal digital assistants (PDAs) for health care purposes	Pharmacists, physicians, nurses, managers, and others in the US currently using PDAs	173	14%	62% (of actual use)
Liu and Ma [107,112]	Web-based electronic medical records (EMR)	Senior health care trainees in dental hygiene, physician assistants, and radiology staff at hospitals and clinics in the US	77	86%	52%
Paré et al.[c] [101]	Computerized provider order entry (CPOE)	Physicians (general practitioners) at a regional health care network (13 medical clinics, 1 hospital, and 1 laboratory firm) in Quebec	91	73%	55% (of actual use)
Rawstorne et al. [102]	Computerized nursing care plans	Nurses in a hospital in Australia	61	Not reported	29–30% 0–12% (of actual use)
Schaper and Pervan[d] [105,111]	Information and communication technology (ICT)	Occupational therapists in Australia	1605	25%	63%
Tung et al. [103]	Electronic logistics information systems	Nurses at ten medical centers/ hospitals in Taiwan	252	72%	70%
Van Schaik et al. [104]	Prototype of a portable computerized postural assessment technology	Physio-therapists in the UK	49	Not reported (laboratory study)	39% (of actual use)
Wu et al. [109]	Mobile health care systems (MHS) including mobile Picture Archiving and Communication Systems (PACS) and mobile order systems	Physicians, nurses, and medical technicians at medical centers/ hospitals in Taiwan that had partially or fully implemented a mobile health care systems	123	42%	70%
Yi et al. [99]	Personal digital assistants (PDAs)	Physicians (residents and faculty) in seven family practice residencies in the US	222	74%	57%

[a] Studies that analyzed the same data set are grouped together.
[b] R^2 or similar index for percentage of variance in behavioral intention (unless otherwise noted) accounted for by predictors in the model, if reported.
[c] Attitude, perceived ease of use, and perceived usefulness in these studies were specified to directly affect actual use; there was no inclusion of behavioral intentions.
[d] In one of the two studies, the authors used the same research model to analyze a random subsample ($N = 600$) of their larger sample ($N = 1605$). In that analysis, PU-A and PEOU-BI were significant and ATT-BI and PU-BI were not. Because the samples of the two studies are non-independent and the tests were identical, the findings from the smaller-sample study are not included elsewhere in this review.

generic (e.g., not referring to specific components of usability [117]).

Subjective norm (SN), or social influence, was consistently defined with respect to the opinions of important others about an individual's use of health IT. Although this definition follows the TPB conceptualization of how social influence is directly exerted, the definition ignores other ways that social factors indirectly influence behavior, for example through a culture of health IT use or when people are influenced by vicariously observing the actions and attitudes of others around them, as opposed to being told directly to use or not use health IT [118]. Another open question is whether the social influence is having its effect through compliance, identification, or internalization processes [119], a point that was addressed in only one reviewed study [99].

Perceived behavioral control (PBC), or facilitating conditions, was defined variously as perceptions of existing (a) infrastructure, (b) internal and external resource constraints, or (c) skills, resources, and opportunities necessary to use the system. It is not surprising that definitions differed, given some of the disagreement and variation in how the construct is defined in the psychological literature [120,121].

Some studies did not provide formal construct definitions [32,97,98,102], although all clearly referred to the original TAM or UTAUT, and probably had definitions similar to the above.

To sum up so far, it is a testament to the strength of TAM and related theories that construct definitions were similar. At the same time, using TAM and UTAUT definitions resulted in a limited and generic way of thinking about constructs such as usefulness and social influence. Why such definitions are problematic despite

Table 3
Definitions of key constructs given by reviewed studies.

Construct	Definition of construct	Studies using definition
Perceived usefulness	Perception that using system leads to enhanced personal performance (original TAM definition [39,40])	[96,99–101,103,104,106,107,109]
	Perception that using system will help user attain gains in job performance (UTAUT definition [51])	[108,110,111]
	No formal definition given	[32,97,98,102]
Perceived ease of use	Perception that using system will be free from physical or mental effort (original TAM definition [39,40])	[96,99–101,103,104,106,107,109]
	Perception of the degree of ease associated with using system (UTAUT definition [51])	[108,110,111]
	No formal definition given	[32,97,98,102]
Social influence/subjective norms	Perception of important (or relevant) others' beliefs about person's use of system (TAM2 [50], UTAUT [51], and TPB [42] definition)	[49,97,99,108,110,111]
	No formal definition given	[102]
Perceived behavioral control/facilitating conditions	Perception that organizational and technical infrastructure exists to support using system (UTAUT definition [51])	[108,110,111]
	Perception of internal and external resource constraints on performing behavior (adaptation of TPB [42] definition)	[99]
	Perception of availability of skills, resources, and opportunities necessary for using the technology (adaptation of TPB [42] definition)	[49]
	No formal definition given	[102]

TAM, Technology Acceptance Model; TAM2, Technology Acceptance Model 2; UTAUT, Universal Theory of Acceptance and Use of Technology; TPB, Theory of Planned Behavior.

being seemingly consistent is most clearly illustrated by looking at how key study constructs were measured in reviewed studies.

3.5. Measurement of key constructs

How constructs were operationalized differed greatly between studies, as can be seen in Table 4. Each construct was typically assessed with four or five items. PU was most commonly measured by asking about how much the health IT was "useful to the job" or to a specific task, how much it increased productivity, or how much it increased job effectiveness. Those measures followed the conventional definition of PU as enhancing (personal) job performance, although the productivity and effectiveness dimensions dominated, compared to other useful health IT use outcomes that could be measured, such as efficiency, quality, and so on. Indeed, some studies asked questions specifically about the following outcomes of use: quicker task completion; easier work; increased quality of care or quality of work; improved efficiency; more accurate or more objective accomplishment of tasks; support of critical tasks; increased chances to get a raise; greater control over work; better evidence-based decisions; and improved patient care. Some of those dimensions of usefulness referred to the *process* of performance (e.g., easier work process) and others to the *outcome* (e.g., better quality of care).

PEOU was variously assessed on these dimensions: easy to use; clear and understandable; easy to become skillful with system; easy to get the system to do what one wanted; easy to learn to operate; flexible; requiring low mental effort; easy to do what one wants when using the system; easy to do tasks when using the system; clear; understandable; not demanding of much care and attention; easy navigation; and tasks were easy to remember. It is notable that some of those dimensions reflect specific aspects of usability such as learnability and memorability [117]. Despite the PEOU definitions given in Section 3.4 above, only two studies had questions mentioning effort specifically [96,97].

SN measures were similar to one another in that almost all asked about the degree to which some referents thought the clinician should use the system. What varied widely was the referent's identity, from "People whose opinions I value" to "People who are important to me" to "Pediatricians who influence my behavior" to "Colleagues," "Supervisors," and "Subordinates," as well as other similar permutations. Thus, the direct *route* of social influence—through others having an influential opinion about another's health IT use—was almost always the same, but the *source* of social influence varied in specificity (e.g., "important others" versus "important other pediatricians") and type (e.g., "colleagues" versus "subordinates"). Notably, one study [108] used two questions—about the helpfulness and support of the hospital and management—that did not appear to follow from the study's stated definition of social influence. In general, it was not uncommon that a study's definition for a construct did not match its operationalization.

PBC measures varied as well. Some measures asked about the availability of knowledge or technical assistance for using the system. Others asked generally about being able to use the system at work or for patient care. One study used a question about the dimension of PBC referred to as controllability by psychological theorists [120], which in the case of IT refers to the degree to which using the system is up to the clinician.[2]

3.6. Results of model tests

Table 5 summarizes which relationships specified by TAM and related models (Fig. 1) were significant and non-significant across the studies reviewed here. Only two studies tested the relationship between behavioral intentions and actual use [102,110]. In one study, the relationship was significant [110]. In another, the relationship was only significant for one of two types of use behavior [102]. The effect of ATT on intention to use, as specified by the original TAM, was significant in five out of six tests. The original TAM also specified that PEOU and PU are related, and this was the case

[2] Because of certain theoretical considerations, some of the studies also separately measured voluntariness or mandatoriness of use, which is like controllability. Further, some studies measured self-efficacy, which is a perception of one's own ability to do something [120].

Table 4
Measures of key constructs use by reviewed studies.

Construct	Measurement dimensions of construct	Studies using measure
Perceived usefulness	Useful for job (or task)	[32,96,97,99,100,103,104,106,107,109]
	Increases productivity	[32,96,97,100,103,106–108]
	Enhances effectiveness of job (or work)	[32,96,97,99,104,106,107,109]
	Allows tasks to be accomplished more quickly	[32,99,100,106–108]
	Improves job performance	[99,103,104,107,109]
	Makes it easier to do job/work	[32,100,106,107]
	Increases quality of care	[97,106]
	Increases quality of work	[106]
	Improves work efficiency	[103]
	Allows tasks to be done more accurately	[104]
	Allows tasks to be done more objectively	[104]
	Supports critical aspects of job	[96]
	Increases chance of getting a raise	[108]
	Allows greater control over work	[106]
	Enables decisions based on better evidence	[104]
	Improves patient care and management	[32]
	Not enough information on measurement	[98,101,102,105,110]
Perceived ease of use	Easy to use	[32,97,99,100,103,104,106,108]
	Clear and understandable	[32,96,97,99,103,104,107,108]
	Easy to become skillful with system	[32,100,104,106–109]
	Easy to get it to do what you want it to	[32,96,97,99,104,106,109]
	Easy to learn to operate	[32,104,107–109]
	Flexible to use/interact with	[32,100,104,106]
	Low mental effort	[96,97]
	Easy to do what I want	[103,107]
	Easy to do tasks with system	[96]
	Clear	[106]
	Understandable	[106]
	Does not demand much care and attention	[103]
	Navigation is easy	[107]
	Easy to remember how to perform tasks with system	[99]
	Not enough information on measurement	[98,101,102,105,110]
Social influence/subjective norms	Pediatricians who influence my behavior think I should use system	[97]
	Pediatricians who are important to me think I should use system	[97]
	People who influence my behavior think I should use system	[108]
	People who influence my clinical behavior think I should use system	[49]
	People who are important to me think I should use system	[108]
	People whose opinions I value think I should use system	[99]
	People who are important to my health care services think I should use system	[49]
	People who are important in assessing my patient care and management think I should use	[49]
	Senior management of hospital has been helpful	[108]
	Hospital supported use of system	[108]
	Colleagues who are important to me think I should use system	[99]
	Superiors at work think I should use system	[99]
	Subordinates at work think I should use system	[99]
	Not enough information on measurement	[102,105,110]
Perceived behavioral control/facilitating conditions	Have necessary resources to use system	[49,99,108]
	Have knowledge to use system	[49]
	Compatibility with other systems	[108]
	Availability of technical assistance	[108]
	Able to use system at work	[99]
	Able to use system for patient care and management	[49]
	Using system at work is wise	[99]
	Using system entirely under my control	[49]
	Not enough information on measurement	[102,105,110]

in 10 out of 12 tests. In the studies testing the TAM postulate that PEOU and PU are both related to ATT, PEOU-ATT was significant in one of two tests [101], and PU-ATT was significant in three of three [32,101,105]. Every one of the 16 tests of the relationship between PU and intention to use was significant. The PEOU-intention relationship was much more inconsistent, significant in only seven of 13 tests. The effect of subjective norm on intention was similarly questionable, significant in only four of eight tests. In contrast, all five tests of the PBC-intention relationship were significant.

Some studies, though not all [102,109], attempted to explain the lacking predictive power of PEOU and SN. Some suggested that the lack of effect of PEOU was due to clinicians experience with the IT. One such explanation was that having no actual or little hands-on experience with the IT led to a poorer estimate of PEOU [96,104,108]; a second was that with time and practice, the PEOU of the system became no longer important to acceptance and use [97,100]. Looking across the reviewed studies, there appears to be some evidence for the first explanation, that lack of exposure appears to be associated with non-significant PEOU-ATT and PEOU-BI relationships. Another common explanation was that there was something special about physicians, such as their greater intellect and ability to learn to use technology [49,95,99], their relative disinterest in usability as long as the system is useful [96,97,108], and the availability of support staff to deal with the system for the physician [49,99]. Indeed, of the seven studies with non-significant PEOU-ATT or PEOU-BI relationships, six involved

Table 5
Results of tests of relationships specified by TAM and related models.

Relationship tested[a]	Studies reporting that predicted relationship was statistically significant	Studies reporting that predicted relationship was statistically non-significant	Proportion of tests that were significant
BI-USE	[102,110]	[102]	2/3
ATT-BI	[32,98,101,102,105]	[108]	5/6
PEOU-PU	[96,99,100,101,102,103,104,106,107,109]	[32,97]	10/12
PEOU-ATT	[101]	[32]	1/2
PU-ATT	[32,101,105]	—	3/3
PU-BI	[32,96,97,98,99,100,101,102,103,104,105,106,107,108,109,110]	—	16/16
PEOU-BI	[102,103,105,106,107,109,110]	[96,97,99,100,104,108]	7/13
SN-BI	[99,102,105,110]	[49,97,102,108]	4/8
PBC-BI	[49,99,102,105,108]	—	5/5

USE, actual use; BI, behavioral intention; ATT, attitude; PEOU, perceived ease of use; PU, perceived usefulness; SN, subjective norm; PBC, perceived behavioral control.
[a] For tests of the Universal Theory of Technology Acceptance and Use (UTAUT), the variables performance expectancy, effort expectancy, and social influence were classified here as PU, PEOU, and SN, respectively.

physician users. Of the eight studies with significant relationships, one had an all-physician sample [101], one had a sample of occupational therapists [105], two had all-nurse samples [102,103] and the remaining five had mixed (mostly-non-physician) samples. Note that sample differences in profession were sometimes confounded with sex and age differences (e.g., compare one physician sample of 70% males and 80% in their 40s and 50s [100] to one all-female nurse sample with 98% less than 35 years old [103]). Physician-specific characteristics were also named as reasons for the non-significant effects of SN, namely their independence and general immunity to peer influence [49,97,108]. Indeed, only one of the four studies with a significant SN effect had an all-physician sample [99]. Two studies suggested that the lack of SN effect was due to the system use being mandatory [97,108]. In opposition to that hypothesis, in three of four studies with non-significant SN effects, IT use was voluntary [49,97] or was perceived to be voluntary [108], and IT use was mandatory in two of four studies with significant SN effects [102,110].

Finally, Table 2 gives the percentage of variance explained in the dependent variable (R^2 or an equivalent statistic) by all of the variables tested in each study or set of studies. We caution the reader about too strongly interpreting these values, because of study heterogeneity and other factors that limit comparability. For example, some studies tested as few as two predictors of behavioral intentions [107], resembling the original TAM, whereas others used as many as five predictors [103,105]. Generally speaking, however, the percentage of variance explained in behavioral intentions (or actual use) is reasonably high.

4. Discussion

From the preceding review, it is evident that TAM has had widespread application in explaining health care providers' reactions to health IT. The recent increase in the use of TAM appears justified, with many of the relationships specified by TAM repeatedly validated in health care settings and fairly large proportions of variance explained in the dependent variable (be it intention to use or actual use). Perhaps most impressive is that the relationship between PU and intention to use or actual use of health IT is significant in every test, suggesting that to promote use and acceptance, the health IT must be perceived as useful. But in addition to the apparent strength of TAM in health care studies, there are remaining challenges. Both are addressed next, followed by a discussion of future directions of TAM research in health care.

4.1. Study strengths

On average, the reviewed studies yielded (1) reasonably high R^2 values, (2) frequently large effect sizes (not reported) for relationships between study variables, and (3) some consistently significant relationships. There is strong evidence to conclude that the perceived usefulness of an IT will have some impact on whether clinicians accept and subsequently use a health IT. Whether the IT is perceived to be easy to use may not be as likely to affect acceptance, but it does appear to correlate with usefulness, perhaps reflecting the notion that IT that is difficult to use cannot possibly be perceived as useful [40]. The implication is that design, training, and informational sessions must focus on ensuring that health IT is (or, at least, is perceived to be) capable of improving important outcomes and is not difficult to use. The consistently significant relationship between PBC and acceptance suggests that, regardless of how useful and easy to use the health IT is, steps will need to be taken to ensure that end users feel confident in their ability to use it (self-efficacy), that using the IT is under their volitional control (controllability), and that barriers are removed and sufficient support provided (facilitating conditions).

There were a number of other strengths. Almost every study used well validated questionnaire items from previous studies, something that has been discussed as a major benefit of the penetration of TAM in IT research [32], and of the use of theory in health IT research, generally [28]. Studies also tended to report the psychometric properties of scale items, which were usually reasonable and did not differ substantially between studies. There were, however, cases of measurement misspecification, for example the use of a single-item measure in one study [105], or the measure of the attitude construct using a "heightened enjoyment" scale in another [101], reflecting a common misunderstanding of attitude theory [122]. Other cases of misspecification have to do with the lack of correspondence between construct definitions and operationalizations, discussed in Section 3.5. Many studies included a variety of health care professionals, and some compared the groups [108]. Finally, almost every studied added variables to TAM in an attempt to better understand the antecedents of acceptance or health IT use behavior. This added variables approach, discussed below, represents the growth of the discipline in its incorporation of multiple theories and multiple sources of causality to account for the complexity of health care's socio-technical systems [20,105,123–125].

4.2. Remaining challenges

There were also a number of challenges faced by the body of reviewed studies. As mentioned above, tests of expanded models allowed researchers to test potentially important relationships not specified in the original TAM [87], such as the effect of subjective norm [49,97,99,102,105,108]. At the same time, the variety in model specification—so great that no two studies tested the exact same model—greatly limits quantitative or qualitative comparison

across studies. Perhaps the lack of standardization is due to the variation in TAM research, generally [38], seen in the variations between TAM, TAM2, and UTAUT, or in early influential work testing direct relationships between PU and PEOU on one hand, and actual use on the other [126]. Indeed, some scholars have criticized TAM research for adding variables haphazardly, leading to a progressively less coherent theory [55]. Even the language used in the reviewed studies is not always standardized, with the terms adoption and acceptance used interchangeably and incorrectly. Standardization of the models tested need not be in conflict with the addition of new variables and relationships: researchers can test a standard TAM for comparison, and can separately test expanded models as well.

Few studies assessed moderators [97,100,105], despite their importance in recent writings on TAM [36,38,51,127]. Among moderating or contextual factors, one worth exploring may be the voluntariness of health IT use [46,50,102,110]. Another is the stage of the health IT; some studies reviewed here studied prototypes [96], trial systems [107], or to-be-implemented systems [108], whereas others studied implemented systems that had been around for different lengths of times. Studies of TAM have shown that over the life course of an IT, the relationships in the model may change; for example, ease of use may be critical at first and less important as time goes by [51,100,128]. Type of health care professional is another moderator deserving of further inquiry [97,103,111]. Although individual or profession-specific differences may not have been possible to study in homogeneous samples, such as those comprised of only young physicians [99,109], all-females [103], or all-males [96], there were studies in which comparisons were possible but not carried out, such as the study aggregating data from physicians, nurses, and information systems department staff [110], one aggregating data from pharmacists, physicians, nurses, top and middle managers, technicians, and more [106], or one aggregating across dental hygiene, physician assistant, and radiology professions [107].

Overall, there was great variability in measures used within and between studies, despite the constructs being similarly defined and the existence of established and validated questionnaires. Evidence of variability certainly challenges the degree to which the different tests of TAM were actually similar enough to compare. It also indicates to us deeper problems with TAM, at least as it is used in health care. The generic definitions of TAM were differently interpreted, a potential sign of lacking theoretical explication of the constructs. At the very least, even if there are theoretic positions on and explanations of constructs, there may be lacking agreement or exposure, because TAM investigators in health care differently interpreted constructs defined the same way. For example, there is work looking at the meaning and makeup of PU [50], and other work suggesting that useful outcomes can be seen at multiple levels—e.g., IT that is useful for the individual versus for the organization [129]—but these theoretical details did not systematically transfer to the studies reviewed here.

Sometimes study investigators used measures that did not fit with their definitions and used measures that are not typically included in studies of TAM. This may be because investigators felt that the established definitions and measures did not match their particular study context. TAM was developed outside of health care, and therefore some of its core concepts and measures may not appear relevant to health care investigators [32]. For example, the focus on personal productivity as a measure of usefulness may not be meaningful, and certainly not sufficient, in a health care context. Thus, some studies incorporate measures of increased quality of care [97,106] and similar health care-specific measures of usefulness [32,104]. Nevertheless, most measures were generic and not health care-specific. Why was this? One possibility is that the health care researchers were not aware of the benefit of contextualizing TAM constructs for health care and the costs of not doing so. Another is that they did not have much basis upon which to determine a priori what would constitute contextualized TAM measures. What does it mean for health IT to be useful to clinicians? What does it mean for health IT to be easy to use? Who are the referents exerting social influence on clinician end users? What kind of barriers and facilitators are important for health IT use? We believe that those kinds of questions are not trivial and require a rigorous, data-driven approach, which we recommend and describe in Section 4.4.

Finally, looking at Table 5, a few other limitations are obvious. First, certain variables such as actual use have been too infrequently measured, precluding tests of several important relationships, such as the one between intention and actual use [102,110]. When the target IT is not yet implemented at the time of the study, measuring variables such as actual use may require longitudinal research, something that is greatly lacking in the reviewed studies. Some relationships have been inconsistent (or consistently weak), raising the possibility of moderating effects or other theoretically important differences between studies. Are the effects of PEOU spurious, given their inconsistent predictive power? Perhaps so, but in some studies, the effect of PEOU is as strong as that of PU [103], if not much stronger [109]. There is also evidence that how strongly PEOU, or other variables for that matter, is related to attitudes, behavioral intentions, or actual use depends on factors such as subject type and technology type [36]. Indeed, the two studies with relatively strong PEOU effects both had young, mostly non-physician samples in Taiwanese medical centers who had hands-on experience with the IT [103,109]. It may also be that the measures of PEOU in the reviewed studies were not sensitive to the ease of use dimensions that are important in health care settings, something that is discussed below.

Given the nascence of TAM research in health care, several future general directions and specific research questions can be suggested. Table 6 provides a non-inclusive list of suggestions, many of which apply to TAM research in general. The first two general directions are next described in more depth.

4.3. The added variables approach

Above we praised what one might call the "added variables" approach to testing TAM in health care settings. Such an approach was commonly taken in the reviewed studies, in order to either better understand the factors that might cause behavioral intentions or actual use of health IT, or to understand the causes of other factors in TAM, such as attitudes or PEOU and PU. As certain variables reappear in models tested in health care, they help researchers, designers, and others to better understand health IT use and acceptance, and there may be benefits to developing general IT theory as well [58,130]. For example, the common addition of variables related to compatibility between the health IT and clinical work processes in the reviewed studies [48,49,98,103,105,106,109] is in line with growing interest in the concept of "fit" as a critical need for successful IT design [131,132], especially in health care [21,28,57,62,72,100,133–135].

The tradition of adding variables is common in research on TAM [51,136,137] and on more general theories of human behavior [138,139]. Theory-based additions to the prediction and explanation of health IT use and acceptance is a welcomed approach [28,56], and it appears to be the approach advocated by some researchers for furthering the use of TAM in health care [30,58,87,99,100,109]. But where will these added variables come from? And what modifications can be proposed for the variables that are already included in TAM? In the following section, we argue for an approach that is complementary to the added variables approach, but that makes explicit how researchers and practitio-

Table 6
Examples of research directions and specific questions for future work on TAM in health care.

General research directions
- Testing additional variables (the added variables approach)
- Beliefs elicitation studies to identify how TAM variables are contextualized in health care settings and to identify important additional variables
- Testing of TAM and related models on large, representative health care samples
- Longitudinal studies of temporal effects and studies comparing TAM between groups and individuals

Specific research questions
- Under what circumstances do different TAM variables—e.g., ease of use, usefulness, subjective norms—have the dominant impact on acceptance and use?
- What are the antecedents/causes of TAM variables? E.g., what is the effect of on-the-job versus classroom training on perceptions of ease of use and usefulness?
- How do TAM relationships differ depending on the stage of health IT implementation (e.g., pre-implementation, first few months, one year post-implementation)?
- What are individual (e.g., computer experience) or group-level (e.g., care specialty) characteristics that affect relationships in TAM?
- What are other outcomes besides intentions and use that are affected by TAM variables (e.g., proximal outcomes such as user satisfaction, effective use, and sustained use, and distal outcomes such as productivity, quality, and safety of care)?
- How does TAM fare against other models of acceptance and use in a health care setting?

ners can better expand and modify TAM for the health care context.

4.4. Beyond the added variables approach: context, evolution, and implications for the future

Those in health care who advocate the use of TAM commonly point out how different physicians and other health care providers are from the users of IT in other studies of TAM, and how the general health care context differs from that of the industries where TAM originated [30,32,58,61,96,98,100]. For example, one writes, "Generally, the essential characteristics of users and technologies in professional health care differ greatly from the customary commercial context ... thus, any model developed for the general public may not apply to a health care environment" [109]. The importance of context cannot be overstated [140]. In a different context, not only may there be differences in the variables needed to understand IT use and acceptance, but also the meaning of variables such as PU and PEOU may be drastically different. The great variability in how reviewed studies interpreted and operationalized TAM constructs was discussed above. We suggested that the variability could be attributed to the lack of systematic contextualization of TAM to health care settings, health care users, and health care tasks. Different health IT researchers may differently interpret what is "useful" about health IT, in the absence of health IT-specific definitions of and measures for usefulness (see Table 4). Similarly, the sources and maybe even the route of social influence may be different in health care compared to in the other industries where TAM was developed and refined. For a physician, social influence might come from patients, patient families, professional groups, regulatory agencies, employing organizations, insurance providers, fellow physicians, referring physicians, nurses, bosses, and others. A *contextualized* version of TAM would allow researchers and practitioners to become aware of the health care-relevant dimensions of PU, PEOU, SN, and PBC. Further, we suspect that part of the reason for the inconsistent predictive power of variables such as PEOU and SN in health care may have to do with a poor match between construct operationalization and the context in which it is measured. For example, the study of Yi et al. [99] is one of few that find an effect of SN, and the authors used three survey items that referred to specific sources of social influence, colleagues, superiors, and subordinates rather than asking general questions (see Table 4). It is difficult to formally assess our suspicion given the limited number of studies and missing information about measures in several studies. Thus, we only tentatively suggest that if contextualized TAM measures replace the practice of using generic measures or specific non-standardized measures based on a particular research group's "common sense" [141], perhaps we will see better predictive power.

There is still the matter of how one can arrive at a contextualized TAM. We propose a specific process for doing so. The process is called *beliefs elicitation* [42,142–145], and it is the preferred method for contextualizing theories of behavior to a specific setting (health care), with a new population (clinicians), and a new behavior of interest (health IT use) [102]. In an elicitation study, researchers find out about the beliefs that participants have about a certain behavior, based on participant responses to open-ended questions. Those beliefs become the basis for subsequent theory. As a matter of fact, beliefs elicitation was the process that Davis and colleagues used in order to fit general behavioral theory to the context of IT use, to form TAM [40]. They found out, based on this preliminary work, that the two key beliefs were PEOU and PU, and they defined those based on what was important to their test population; thus, for example, PU was defined in reference to improvements to personal productivity, as opposed to improvements in patient outcomes, because the participants in Davis' study were college students, not clinicians.

We believe that conducting elicitation studies with clinicians, focusing on the salient aspects of their health IT use in the health care context will lead to better refined, contextualized theories of health IT use and acceptance, just as early studies in other industries led to refined and contextualized theories of IT use and acceptance by students, bank tellers, programmers, and others. Few have done this kind of beliefs elicitation work with respect to health IT [70,72,76,96,102], and none to our knowledge have revised TAM based on such work.[3] Yet guides on how to carry out such work are readily available [42,142,146]. Those guides contain directions for asking about, for example, important others who approve or disapprove of health IT use behavior, in order to determine who specifically is believed to exert social pressure on clinicians.

In the process of carrying out a beliefs elicitation study, the researcher is able to learn not only about what are the salient beliefs held by clinicians, but also the reasons for those beliefs. This has practical implications because knowing the reasons for health IT use beliefs permits designers, policy makers, and others to take action and make changes, a benefit recognized by the authors of two studies reviewed here:

> The major advantages of eliciting beliefs from a sample of the population of interest are that there is a greater guarantee that the beliefs will be relevant to the population ... and that intervention strategies may be properly targeted at the key issues [102].

[3] One study reviewed here [102] found that a contextualized model created using beliefs elicitation slightly outperformed the generic TAM in a health care setting, but did not suggest modifications to TAM. Unfortunately, the study did not provide much detail about differences between the two models or the process and results of the elicitation process, making it difficult to draw independent conclusions.

> In general, beliefs are important not only because they influence subsequent behavior, but also because they are amenable to strategic managerial manipulation through appropriate interventions such as user involvement and user participation ... In the health care context, an understanding of what causes physicians to hold certain beliefs about the target CIS [Clinical Information System] would be of value not only to individuals responsible for overseeing implementation of these systems, but also to researchers interested in explicating the paths through which technology use behavior is manifested [101].

A final benefit of beliefs elicitation is its ability to develop what we call an *evolved* model of health IT use and acceptance. By evolved, we mean a model that is unconstrained by the behavioral theories of the 1960's and 70's on which the original TAM was based [41,147]. Rather, a researcher who asks questions based on more recent theoretical advances in the prediction and explanation of behavior [33,120,122,139,148] can begin to build a theory of health IT use that better parallels current knowledge about why people behave in certain ways, and why they use or do not use certain technologies. An evolved theory may thus incorporate recent distinctions between cognitive and affective causes of behavior, the effect of facilitating conditions versus self-efficacy versus controllability, both external normative and personal normative (e.g., moral/ethical) influences on behavior, and more.

Note that a beliefs elicitation approach is compatible with the added variables approach because elicitation studies can suggest and support additional model variables. The main difference—and the point on which we may disagree with Yarbrough and Smith—is whether new variables or variable modifications should be made solely on the basis of existing theory or on a combination of theory and empirically elicited beliefs. Although a purely theory-based approach—which might for instance add the compatibility variable from Rogers' Innovation Diffusion Theory [63]—can be useful, empirical work may still be necessary to (a) determine whether those variables are relevant to health care, and (b) contextualize these new variables in order to determine, for example, what "compatibility" means in health care [57,135].

5. Conclusion

TAM is a well regarded theory of technology acceptance and use that has been widely researched outside of health care and has lately become an important theoretical tool for health IT research. Designers, purchasers, and others involved with IT projects are routinely advised to use the TAM to aid the design or purchasing process, training and informational sessions, implementation, and other activities. To the extent that the factors predicting acceptance are controllable, they can be strong levers for acceptance and use. TAM has a strong track record in numerous industries; will it be a useful theoretical tool in health care? In this paper, we assessed TAM's future in health care by examining its past. Although TAM did a fair job predicting, and perhaps explaining, clinician end-user acceptance and use of health IT, there is much room for improvement. Aside from a need for standardization, more tests of certain relationships, and better reporting of data, there is also a need to continue exploring new theoretically motivated variables and relationships that can be added to TAM.

More important, researchers should conduct studies for the purpose of identifying salient beliefs that clinicians have about using health IT for at least two reasons. First, this will allow researchers to probe about a wide range of theoretically interesting clinician beliefs, which could make the theory more robust and relevant in health care. Second, and equally important, by contextualizing TAM to health care, there is the opportunity to develop the "left side of the model." That is, contextualization uncovers the specific and, importantly, actionable meaning and causes of generic variables such as usefulness and ease of use, helps determine who are the "important others" of subjective norms and what are the actual barriers and facilitators to IT use. With the US National Research Council concluding in 2009 that current health IT is not designed to adequately support the cognitive work of clinicians [149], the time to begin uncovering specific, contextualized, and actionable constructs is now.

Overall, there is great interest in TAM in health care[4] and ample opportunity for its success, but whether TAM evolves into a theory *of* health IT, as opposed to a theory *for* health IT, is still to be seen.

Conflict of interest

None.

Acknowledgments

Author R.J.H. was supported by a predoctoral training grant from the US National Institutes of Health (TL1 RR025013-01) and a postdoctoral training grant from the US Agency for Healthcare Research and Quality (T32 HS000083-11). The work was also funded in part by grants by the US National Library of Medicine (R01 LM008923) and the US Agency for Healthcare Research and Quality (R01 HS013610) to author B.K. The funding agencies had no involvement with this paper. We appreciate the helpful comments of several anonymous reviewers.

References

[1] Anderson JG. Clearing the way for physicians' use of clinical information systems. Commun ACM 1997;40:83–90.
[2] Jha AK, Ferris TG, Donelan K, DesRoches C, Shields A, Rosenbaum S, et al. How common are electronic health records in the United States? A summary of the evidence. Health Aff 2006;25:w496–507.
[3] Poon EG, Jha AK, Christino M, Honour MM, Fernandopulle R, Middleton B, et al. Assessing the level of healthcare information technology adoption in the United States: a snapshot. BMC Med Inform Decis Mak, 2006; 6. Available from: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=1343543.
[4] Lorenzi NM, Novak LL, Weiss JB, Gadd CS, Unertl KM. Crossing the implementation chasm: a proposal for bold action. J Am Med Inform Assoc 2008;15:290–6.
[5] Ash JS, Berg M, Coiera E. Some unintended consequences of information technology in health care: the nature of patient care information system-related errors. J Am Med Inform Assoc 2004;11:104–12.
[6] Han YY, Carcillo JA, Venkataraman ST, Clark RSB, Watson RS, Nguyen TC, et al. Unexpected increased mortality after implementation of a commercially sold computerized physician order entry system. Pediatrics 2005;116:1506–12.
[7] Koppel R, Leonard CE, Localio AR, Cohen A, Auten R, Strom BL. Identifying and quantifying medication errors: evaluation of rapidly discontinued medication orders submitted to a computerized physician order entry system. J Am Med Inform Assoc 2008;15:461–5.
[8] Koppel R, Metlay JP, Cohen A, Abaluck B, Localio AR, Kimmel SE, et al. Role of computerized physician order entry systems in facilitating medication errors. JAMA 2005;293:1197–203.
[9] McDonald CJ. Computerization can create safety hazards: a barcoding near miss. Ann Intern Med 2006;144:510–6.
[10] Nebeker JR, Hoffman JM, Weir CR, Bennett CL, Hurdle JF. High rates of adverse drug events in a highly computerized hospital. Arch Intern Med 2005;165:1111–6.
[11] Rothschild JM, Keohane CA, Cook EF, Orav EJ, Burdick E, Thompson S, et al. A controlled trial of smart infusion pumps to improve medication safety in critically ill patients. Crit Care Med 2005;33:533–40.
[12] Thompson DA, Duling L, Holzmueller CG, Dorman T, Lubomski LH, Dickman F, et al. Computerized physician order entry, a factor in medication errors: descriptive analysis of events in the intensive care unit safety reporting system. J Clin Outcomes Manag 2005;12:407–12.
[13] Wears RL, Cook RI, Perry SJ. Automation, interaction, complexity, and failure: a case study. Reliab Eng Syst Saf 2006;91:1494–501.
[14] Lapointe L, Rivard S. A multilevel model of resistance to information technology implementation. MIS Q 2005;29:461–91.

[4] In fact, in the one year period following this review, six additional health IT studies of TAM were published [150–155], as were several qualitative/descriptive studies using TAM or a related framework [156–158].

[15] Markus ML. Power, politics, and MIS implementation. Commun ACM 1983;26:430–44.
[16] Zuboff S. In the age of the smart machine. New York: Basic Books; 1988.
[17] Lorenzi NM, Riley RT. Managing change: an overview. J Am Med Inform Assoc 2000;7:116–24.
[18] Smith MJ, Carayon P. New technology, automation, and work organization: stress problems and improved technology implementation strategies. Int J Hum Factors Manuf 1995;5:99–116.
[19] Lærum H, Ellingsen G, Faxvaag A. Doctors' use of electronic medical records systems in hospitals: cross sectional survey. Br Med J 2001;323:1344–8.
[20] Berg M. Implementing information systems in health care organizations: myths and challenges. Int J Med Inform 2001;64:143–56.
[21] Holden RJ, Karsh B. A review of medical error reporting system design considerations and a proposed cross-level system research framework. Hum Factors 2007;49:257–76.
[22] Lapointe L, Rivard S. Getting physicians to accept new information technology: insights from case studies. CMAJ 2006;174:1573–8.
[23] Patterson ES, Rogers ML, Chapman RJ, Render ML. Compliance with intended use of bar code medication administration in acute and long-term care: an observational study. Hum Factors 2006;48:15–22.
[24] Lawler F, Cacy JR, Viviani N, Hamm RM, Cobb SW. Implementation and termination of a computerized medical information system. J Fam Pract 1996;42:233–6.
[25] Koppel R, Wetterneck TB, Telles JL, Karsh B. Workarounds to barcode medication administration systems: their occurrences, causes, and threats to patient safety. J Am Med Inform Assoc 2008;15:408–23.
[26] Weingart SN, Toth M, Sands DZ, Aronson MD, Davis RB, Phillips RS. Physicians' decisions to override computerized drug alerts in primary care. Arch Intern Med 2003;163:2625–31.
[27] Dowling Jr AF. Do hospital staff interfere with computer system implementation? Health Care Manag Rev 1980;5:23–32.
[28] Holden RJ, Karsh B. A theoretical model of health information technology usage behaviour with implications for patient safety. Behav Inf Technol 2009;28:21–38.
[29] Simon SR, Kaushal R, Cleary PD, Jenter CA, Volk LA, Orav EJ, et al. Physicians and electronic health records: a statewide survey. Arch Intern Med 2007;167:507–12.
[30] Yarbrough AK, Smith TB. Technology acceptance among physicians. Med Care Res Rev 2007;64:650–72.
[31] Karsh B, Holden RJ. New technology implementation in health care. In: Carayon P, editor. Handbook of human factors and ergonomics in patient safety. Mahwah, NJ: Lawrence Erlbaum; 2007. p. 391–408.
[32] Hu PJH, Chau PYK, Sheng ORL, Tam KY. Examining the technology acceptance model using physician acceptance of telemedicine technology. J Manag Inform Syst 1999;16:91–112.
[33] Bagozzi RP. The legacy of the technology acceptance model and a proposal for a paradigm shift. J Assoc Inform Syst 2007;8:244–54.
[34] Lee Y, Kozar KA, Larsen KRT. The technology acceptance model: past, present, and future. Commun Am Inform Soc 2003;12:752–80.
[35] Ma Q, Liu L. The technology acceptance model: a meta-analysis of empirical findings. J Organ End User Comput 2004;16:59–72.
[36] Yousafzai SY, Foxall GR, Pallister JG. Technology acceptance: a meta-analysis of the TAM: part 2. J Modell Manag 2007;2:281–304.
[37] King WR, He J. A meta-analysis of the technology acceptance model. Inform Manag 2006;43:740–55.
[38] Legris P, Ingham J, Collerette P. Why do people use information technology? A critical review of the technology acceptance model. Inform Manag 2003;40:191–204.
[39] Davis FD. Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Q 1989;13:319–39.
[40] Davis FD, Bagozzi RP, Warshaw PR. User acceptance of computer technology: a comparison of 2 theoretical models. Manag Sci 1989;35:982–1003.
[41] Fishbein M, Ajzen I. Belief, attitude, intention, and behavior: an introduction to theory and research. Reading, MA: Addison-Wesley; 1975.
[42] Ajzen I, Fishbein M. Understanding attitudes and predicting social behavior. Englewood Cliffs, NJ: Prentice-Hall; 1980.
[43] Davis FD. A technology acceptance model for empirically testing new end-user information systems: theory and results. Doctoral dissertation. Cambridge, MA: Massachusetts Institute of Technology; 1986.
[44] Mathieson K. Predicting user intentions: comparing the technology acceptance model with the theory of planned behavior. Inform Syst Res 1991;2:173–91.
[45] Sjana B. Empirical evaluation of the revised technology acceptance model. Manag Sci 1996;42:85–92.
[46] Brown SA, Massey AP, Montoya-Weiss MM, Burkman JR. Do I really have to? User acceptance of mandated technology. Eur J Inform Syst 2002;11:283–95.
[47] Ives B, Olson MH, Baroudi JJ. The measurement of user information satisfaction. Commun ACM 1983;26:785–93.
[48] Chau PYK, Hu PJH. Information technology acceptance by individual professionals: a model comparison approach. Decision Sci 2001;32:699–719.
[49] Chau PYK, Hu PJH. Examining a model of information technology acceptance by individual professionals: an exploratory study. J Manag Inform Syst 2002;18:191–229.
[50] Venkatesh V, Davis FD. A theoretical extension of the technology acceptance model: four longitudinal field studies. Manag Sci 2000;46:186–204.
[51] Venkatesh V, Morris MG, Davis GB, Davis FD. User acceptance of information technology: toward a unified view. MIS Q 2003;27:425–78.
[52] Taylor S, Todd P. Assessing IT usage: a test of competing models. Inform Syst Res 1995;6:144–76.
[53] Ajzen I, Driver BL. Prediction of leisure participation from behavioural, normative, and control beliefs: an application of the theory of planned behaviour. Leisure Sci 1991;13:185–204.
[54] Yousafzai SY, Foxall GR, Pallister JG. Technology acceptance: a meta-analysis of the TAM: part 1. J Modell Manag 2007;2:251–80.
[55] Benbasat I, Barki H. Quo vadis, TAM? J Assoc Inform Syst 2007;8:211–8.
[56] Karsh B. Beyond usability for patient safety: designing effective technology implementation systems. Qual Saf Health Care 2004;13:388–94.
[57] Ammenwerth E, Iller C, Mahler C. IT-adoption and the interaction of task, technology and individuals: a fit framework and a case study. BMC Med Inform Decis Mak, 2006; 6. Available from: http://www.biomedcentral.com/1472-6947/6/3.
[58] Hennington AH, Janz BD. Information systems and healthcare XVI: physician adoption of electronic medical records: applying the UTAUT model in a healthcare context. Commun Assoc Inform Syst 2007;19:60–80.
[59] Despont-Gros C, Mueller H, Lovis C. Evaluating user interactions with clinical information systems: a model based on human–computer interaction models. J Biomed Inform 2005;38:244–55.
[60] Kukafka R, Johnson SB, Linfante A, Allegrante JP. Grounding a new information technology implementation framework in behavioral science. A systematic analysis of the literature on IT use. J Biomed Inform 2003;36:218–27.
[61] Succi MJ, Walter ZD. Theory of user acceptance of information technologies: an examination of health care professionals. In: Proceedings of the 32nd Hawaii international conference on system sciences; 1999. p. 1–7.
[62] Dixon DR. The behavioral side of information technology. Int J Med Inform 1999;56:117–23.
[63] Rogers EM. Diffusion of innovations. 4th ed. New York: Free Press; 1995.
[64] Chang P, Hsu Y-S, Tzeng Y-M, Hou I-C, Sang Y-Y. Development and pilot evaluation of user acceptance of advanced mass-gathering emergency medical services PDA support systems. Medinfo 2004;11:1421–5.
[65] Chang P, Hsu Y-S, Tzeng Y-M, Sang Y-Y, Hou I-C, Kao W-F. The development of intelligent, triage-based, mass-gathering emergency medical service PDA support systems. J Nurs Res 2004;12:227–35.
[66] Chan P, Tzeng Y-M, Wu S-C, Sang Y-Y, Chen S-S. Development and comparison of user acceptance of advanced comprehensive triage PDA support system with a traditional terminal alternative system. In: Proceedings of the annual symposium of the American medical informatics association; 2003. p. 140–14.
[67] Handy J, Hunter I, Whiddett R. User acceptance of inter-organizational electronic medical records. Health Inform J 2001;7:103–7.
[68] Dillon TW, McDowell D, Salimian F, Conklin D. Perceived ease of use and usefulness of bedeside-computer systems. Comput Nurs 1998;16:151–6.
[69] Sheng ORL, Hu PJH, Chau PYK, Hjelm NM, Tam KY, Wei C-P, et al. A survey of physicians' acceptance of telemedicine. J Telemed Telecare 1998;4:100–2.
[70] Van Schaik P, Flynn D, Wersch AV, Douglass A, Cann P. The acceptance of a computerised decision-support system in primary care: a preliminary investigation. Behav Inf Technol 2004;23:321–6.
[71] Dixon DR, Stewart M. Exploring information technology adoption by family physicians: survey instrument validation. In: Proceedings of the American medical informatics association symposium; 2000. p. 185–9.
[72] Karsh B, Escoto KH, Beasley JW, Holden RJ. Toward a theoretical approach to medical error reporting system research and design. Appl Ergon 2006;37:283–95.
[73] Day M, Demiris G, Oliver DP, Courtney K, Hensel B. Exploring underutilization of videophones in hospice settings. Telemed J E Health 2007;13:25–31.
[74] Gaggioli A, di Carlo S, Mantovani F, Castelnuovo G, Riva G. A telemedicine survey among Milan doctors. J Telemed Telecare 2005;11:29–34.
[75] Lai TYY, Leung GM, Wong IOL, Johnston JM. Do doctors act on their self-reported intention to computerize? A follow-up population-based survey in Hong Kong. Int J Med Inform 2004;73:415–31.
[76] Gagnon MP, Godin G, Gagne C, Fortin JP, Lamothe L, Reinharz D, et al. An adaptation of the theory of interpersonal behaviour to the study of telemedicine adoption by physicians. Int J Med Inform 2003;71:103–15.
[77] Ammenwerth E, Mansmann U, Iller C, Eichstädter R. Factors affecting and affected by user acceptance of computer-based nursing documentation: results of a two-year study. J Am Med Inform Assoc 2003;10:69–84.
[78] Holden RJ, Scanlon MC, Brown RL, Karsh B. What is IT? New conceptualizations and measures of pediatric nurses' acceptance of car-coded medication administration information technology. Annu Meet Human Factors Ergon Soc 2008;52:768–72.
[79] Croteau A-M, Vieru D. Telemedicine adoption by different groups of physicians. In: 35th Hawaii international conference on system sciences; 2002.
[80] Thompson TG, Brailer DJ. The decade of health information technology: delivering consumer-centric and information-rich health care. Framework for strategic action; 2004. Available from: http://www.hhs.gov/healthit/documents/hitframework.pdf.
[81] UK National Health Service. Health informatics defined. NHS connecting for health [cited 2008 August 5]. Available from: http://www.connectingforhealth.nhs.uk/systemsandservices/capability/phi/about/hid.

[82] Tung F-C, Chang S-C. A new hybrid model for exploring the adoption of online nursing courses. Nurs Edu Today 2008;28:293–300.
[83] Tung F-C, Chang S-C. Nursing students' behavioral intention to use online 1062 courses: a questionnaire survey. Int J Nurs Stud 2008;45:1299–309.
[84] Chen IJ, Yang K-F, Tang F-I, Huang C-H, Yu S. Applying the technology acceptance model to explore public health nurses' intentions towards web-based learning: a cross-sectional questionnaire survey. Int J Nurs Stud 2008;45:869–78.
[85] Rutkowski A-F, Spanjers RWL. Optimising e-learning in healthcare for nurses. Int J Healthcare Technol Manag 2007;8:354–69.
[86] Hulse NC, Del Fiol G, Rocha RA. Modeling end-users' acceptance of a knowledge authoring tool. Methods Inf Med 2006;45:528–35.
[87] Wu J-H, Shen W-S, Lin L-M, Greenes RA, Bates DW. Testing the technology acceptance model for evaluating healthcare professionals' intention to use an adverse event reporting system. Int J Qual Health Care 2008;20:123–9.
[88] Kim D, Chang H. Key functional characteristics in designing and operating health information websites for user satisfaction: an application of the extended technology acceptance model. Int J Med Inform 2007;76: 790–800.
[89] Klein R. An empirical examination of patient–physician portal acceptance. Eur J Inform Syst 2007;16:751–60.
[90] Lanseng EJ, Andreassen TW. Electronic healthcare: a study of people's readiness and attitude toward performing self-diagnosis. Int J Serv Industry Manag 2007;18:394–417.
[91] Zhang W, Gutierrez O. Information technology acceptance in the social services sector context: an exploration. Soc Work 2007;52:221–31.
[92] Fisher ME. Using the technology acceptance model to measure pediatrician acceptance of practice management information systems. Doctoral dissertation. Fort Lauderdale-Davie, FL: Nova Southeastern University; 2002.
[93] Berlin A, Sorani M, Sim I. A taxonomic description of computer-based clinical decision support systems. J Biomed Inform 2006;39:656–67.
[94] Door D, Bonner LM, Cohen AN, Shoair RS, Perrin R, Chaney E, et al. Informatics systems to promote improved care for chronic illness: a literature review. J Am Med Inform Assoc 2007;14:156–63.
[95] Hu PJH, Chau PYK. Physician acceptance of telemedicine technology: an empirical investigation. Top Health Inform Manag 1999;19:20–35.
[96] Barker DJ, van Schaik P, Simpson DS, Corbett WA. Evaluating a spoken dialogue system for recording clinical observations during an endoscopic examination. Med Inform Internet Med 2003;28:85–97.
[97] Chismar WG, Wiley-Patton S. Test of the technology acceptance model for the internet in pediatrics. In: Proceedings of the annual symposium of the American medical informatics association; 2002. p. 155–9.
[98] Horan TA, Tulu B, Hilton B, Burton J. Use of online systems in clinical medical assessments: an analysis of physician acceptance of online disability evaluation systems. In: Proceedings of the 37th Hawaii international conference on system sciences; 2004. p. 1–10.
[99] Yi MY, Jackson JD, Park JS, Probst JC. Understanding information technology acceptance by individual professionals: toward an integrative view. Inform Manag 2006;43:350–63.
[100] Han S, Mustonen P, Seppänen M, Kallio M. Does fragmenting of working time and working space influence the acceptance of mobile technology? A case of Finnish physicians. Turku Centre for Computer Science; 2005.
[101] Paré G, Sicotte C, Jacques H. The effects of creating psychological ownership on physicians' acceptance of clinical information systems. J Am Med Inform Assoc 2006;13:197–205.
[102] Rawstorne P, Jayasuriya R, Caputi P. Issues in predicting and explaining usage behaviors with the technology acceptance model and the theory of planned behavior when usage is mandatory. In: Proceedings of the 21st international conference on information systems; 2000. p. 35–44.
[103] Tung F-C, Chang S-C, Chou C-M. An extension of trust and TAM model with IDT in the adoption of the electronic logistics information system in HIS in the medical industry. Int J Med Inform 2008;77:324–35.
[104] Van Schaik P, Bettany-Saltikov JAB, Warren JG. Clinical acceptance of a low-cost portable system for postural assessment. Behav Inf Technol 2002;21:47–57.
[105] Schaper LK, Pervan GP. ICTs & OTs: a model of information and communications technology acceptance and utilisation by occupational therapists (part 2). Stud Health Technol Inform 2007;130:91–101.
[106] Liang H, Xue Y, Byrd TA. PDA usage in healthcare professionals: testing an extended technology acceptance model. Int J Mobile Commun 2003;1:372–89.
[107] Liu L, Ma Q. Perceived system performance: a test of an extended technology acceptance model. Database Adv Inform Syst 2006;37:51–9.
[108] Duyck P, Pynoo B, Devolder P, Voet T, Adang L, Vercruysse J. User acceptance of a picture archiving and communication system. Applying the unified theory of acceptance and use of technology in a radiological setting. Methods Inf Med 2008;47:149–56.
[109] Wu J-H, Wang S-C, Lin L-M. Mobile computing acceptance factors in the healthcare industry: a structural equation model. Int J Med Inform 2007;76:66–77.
[110] Chen CC, Wu J, Crandall RE. Obstacles to the adoption of radio frequency identification technology in the emergency rooms of hospitals. Int J Electron Healthcare 2007;3:193–207.
[111] Schaper LK, Pervan GP. ICT and OTs: a model of information and communication technology acceptance and utilisation by occupational therapists. Int J Med Inform 2007;76:S212–21.
[112] Liu L, Ma Q. The impact of service level on the acceptance of application service oriented medical records. Inform Manag 2005;42:1121–35.
[113] RAND Corporation. Health information technology: can HIT lower costs and improve quality?; 2005.
[114] Chaudhry B, Wu S, Maglione M, Mojica W, Roth E, Morton SC, et al. Systematic review: impact of health information technology on quality, efficiency, and costs of medical care. Ann Intern Med 2006;144:E12–22.
[115] Shekelle PG, Morton SC, Keeler EB. Costs and benefits of health information technology. Evidence Report/Technology Assessment No. 132. Rockville, MD: Agency for Healthcare Research and Quality; 2006.
[116] Karsh B, Holden RJ, Alper SJ, Or CKL. A human factors engineering paradigm for patient safety—designing to support the performance of the health care professional. Qual Saf Health Care 2006;15:i59–65.
[117] Nielsen J. Usability engineering. Boston: Academic Press; 1993.
[118] Bandura A. Social foundations of thought and action. Englewood Cliffs, NJ: Prentice-Hall; 1986.
[119] Kelman HC. Compliance, identification, and internalization: three process of attitude change. J Confl Resolut 1958;2:51–60.
[120] Ajzen I. Perceived behavioral control, self-efficacy, locus of control, and the theory of planned behavior. J Appl Soc Psychol 2002;32:665–83.
[121] Armitage CJ, Conner M. Distinguishing perceptions of control from self-efficacy: predicting consumption of a low-fat diet using the theory of planned behavior. J Appl Soc Psychol 1999;29:72–90.
[122] Ajzen I. Nature and operation of attitudes. Annu Rev Psychol 2001;52:27–58.
[123] Berg M. Patient care information systems and health care work: a sociotechnical approach. Int J Med Inform 1999;55:87–101.
[124] Berg M, Aarts J, Van Der Lei J. ICT in health care: sociotechnical approaches. Methods Inf Med 2003;42:297–301.
[125] Kaplan B. Addressing organizational issues into the evaluation of medical systems. J Am Med Inform Assoc 1997;4:94–101.
[126] Adams DA, Nelson RR, Todd PA. Perceived usefulness, ease of use, and usage of information technology: a replication. MIS Q 1992;16:227–47.
[127] Sun H, Zhang P. The role of moderating factors in user technology acceptance. Int J Hum Comput Stud 2006;64:53–78.
[128] Agarwal R, Prasad J. The role of innovation characteristics and perceived voluntariness in the acceptance of information technologies. Decision Sci 1997;28:557–82.
[129] DeLone WH, McLean ER. The DeLone and McLean model of information systems success: a ten-year update. J Manag Inform Syst 2003;19:9–30.
[130] Chiasson MW, Davidson E. Pushing the contextual envelope: developing and diffusing IS theory for health information systems research. Inform Organ 2004;14:155–88.
[131] Goodhue DL. Comment on Benbasat and Barki's "Quo Vadis TAM" article. J Assoc Inform Syst 2007;8:219–22.
[132] Goodhue DL, Thompson RL. Task-technology fit and individual performance. MIS Q 1995;19:213–36.
[133] Ludwig DA, Doucette J. Adopting electronic medical records in primary care: lessons learned from health information systems implementation experience in seven countries. Int J Med Inform. 2009;78:22–31.
[134] Karsh B, Holden RJ, Escoto KH, Alper SJ, Scanlon MC, Arnold J, et al. Do beliefs about hospital technologies predict nurses' perceptions of quality of care? A study of task-technology fit in two pediatric hospitals. Int J Hum Comput Interact 2009;25:374–89.
[135] Kaplan B. Evaluating informatics applications—some alternative approaches: theory, social interactionism, and call for methodological pluralism. Int J Med Inform 2001;64:39–56.
[136] Moore GC, Benbasat I. Development of an instrument to measure the perceptions of adopting an information technology innovation. Inform Syst Res 1991;2:192–221.
[137] Venkatesh V. Determinants of perceived ease of use: integrating control, intrinsic motivation, and emotion into the technology acceptance model. Inform Syst Res 2000;11:342–65.
[138] Langdridge D, Sheeran P, Connolly KJ. Analyzing additional variables in the theory of reasoned action. J Appl Soc Psychol 2007;37:1884–913.
[139] Conner M, Armitage CJ. Extending the theory of planned behavior: a review and avenues for further research. J Appl Soc Psychol 1998;28:1429–64.
[140] Gammon D, Johannessen LK, Sørensen T, Wynn R, Whitten P. An overview and analysis of theories employed in telemedicine studies. Methods Inform Med 2008;47:260–9.
[141] Zaidi STR, Marriott JL, Nation RL. The role of perceptions of clinicians in their adoption of a web-based antibiotic approval system: do perceptions translate into actions? Int J Med Inform 2008;77:33–40.
[142] Francis JJ, Eccles MP, Johnston M, Walker A, Grimshaw J, Foy R, et al. Constructing questionnaires based on the theory of planned behaviour: a manual for health services researchers. Newcastle upon Tyne, UK: Centre for Health Services Research, University of Newcastle; 2004.
[143] Darker CD, French DP, Longdon S, Morris K, Eves FF. Are beliefs elicited biased by question order? A theory of planned behaviour belief elicitation study about walking in the UK general population. Br J Health Psychol 2007;12:93–110.
[144] Sutton S, French DP, Hennings SJ, Mitchell J, Wareham NJ, Griffin S, et al. Eliciting salient beliefs in research on the theory of planned behaviour: the effect of question wording. Curr Psychol 2003;22:234–51.
[145] Downs DS, Hausenblas HA. Elicitation studies and the theory of planned behavior: a systematic review of exercise beliefs. Psychol Sports Exerc 2005;6:1–31.

[146] Ajzen I. Constructing a TpB questionnaire: conceptual and methodological considerations; 2002 [cited 2005 May 27]. Available from: http://people.umass.edu/aizen/pdf/tpb.measurement.pdf.
[147] Fishbein M. A behavior theory approach to the relations between beliefs about an object and the attitude toward the object. In: Fishbein M, editor. Readings in attitude theory and measurement. New York: John Wiley; 1967. p. 389–400.
[148] Eagly AH, Chaiken S. The psychology of attitudes. Belmont, CA: Wadsworth; 1993.
[149] Stead WW, Lin HS, editors. Computational technology for effective health care: immediate steps and strategic directions. Washington, DC: National Academies Press; 2009.
[150] Aggelidis VP, Chatzoglou PD. Using a modified technology acceptance model in hospitals. Int J Med Inform 2009;78:115–26.
[151] Kijsanayotin B, Pannarunothai S, Speedie SM. Factors influencing health information technology adoption in Thailand's community health centers: applying the UTAUT model. Int J Med Inform 2009;78:404–16.
[152] Lishan X, Chiuan YC, Choolani M, Chuan CH. The perception and intention to adopt female-focused healthcare applications (FHA): a comparison between healthcare workers and non-healthcare workers. Int J Med Inform 2009;78:248–58.
[153] McDowell DE, Dillon TW, Lending D. Perceived quality benefits influenced by usefulness and documentation accuracy of information systems. Comput Inform Nurs 2008;26:350–7.
[154] Tao D. Understanding intention to use electronic information resources: a theoretical extension of the technology acceptance model (TAM). In: Proceedings of the American medical informatics association symposium; 2008. p. 717–21.
[155] Yu P, Li H, Gagnon M-P. Health IT acceptance factors in long-term care facilities: a cross-sectional survey. Int J Med Inform 2009;78:219–29.
[156] Hyun S, Johnson SB, Stetson PD, Bakken S. Development and evaluation of nursing user interface screens using multiple methods. J Biomed Inform 2009;42:1004–12.
[157] Huser V, Narus SP, Rocha RA. Evaluation of a flowchart-based EHR query system: a case study of RetroGuide. J Biomed Inform 2010;43:41–50.
[158] Whitten P, Holtz B, Meyer E, Nazione S. Telehospice: reasons for slow adoption in home hospice care. J Telemed Telecare 2009;15:187–90.