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# Predicting Nurses' Use of Healthcare Technology Using the Technology Acceptance Model

## An Integrative Review

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The benefits of healthcare technologies can only be attained if nurses accept and intend to fully use them. One of the most common models utilized to understand user acceptance of technology is the Technology Acceptance Model. This model and modified versions of it have only recently been applied in the healthcare literature among nurse participants. An integrative literature review was conducted on this topic. Ovid/MEDLINE, PubMed, Google Scholar, and CINAHL were searched yielding a total of 982 references. Upon eliminating duplicates and applying the inclusion and exclusion criteria, the review included a total of four dissertations, three symposium proceedings, and 13 peer-reviewed journal articles. These documents were appraised and reviewed. The results show that a modified Technology Acceptance Model with added variables could provide a better explanation of nurses' acceptance of healthcare technology. These added variables to modified versions of the Technology Acceptance Model are discussed, and the studies' methodologies are critiqued. Limitations of the studies included in the integrative review are also examined.

KEY WORDS

literature review • nursing • patient safety • technology • theoretical models

Technology has been widely adopted in healthcare environments in an effort to improve quality and increase the efficiencies of care delivered to patients.[1–3] Factors influencing adoption in this context include the reduction of organizational expenses and demands from patients for technology to be utilized in their care.[4] In recent years, the uptake of health-related technology at the organizational level has increased at a rapid pace,[5] in an effort to catch up with other industries that have utilized technology for many years.[6,7]

Traditionally, evaluations of healthcare technologies have focused on the implementation of the particular technology, with positive outcomes associated with the successful integration of it into clinical environments.[3,8–10] In addition, much attention has been paid to technical aspects of technology improvement, such as the capability of it to aid healthcare professionals in improving patient safety and the ability of it to fit the users physical and cognitive abilities (human factors).[11,12]

Although advanced technologies may be developed and available in a healthcare environment, little research has been conducted on the appropriate and accurate use of the technology by healthcare professionals.[7,8] The end users can choose to fully use, partially use, or not use the technology available to them.[12]

## Background

The Technology Acceptance Model (TAM) is a theoretical model developed to explain user acceptance of technology in the business and information technology sector.[13] Applications of this model within the healthcare environment have appeared in recent years.[7,8]

Originally the model was developed through an adaption of the Theory of Reasoned Action (TRA) as a way of understanding the behavioral intentions of employees required to use new technologies such as computers and

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This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

*The author has disclosed that she has no significant relationships with, or financial interest in, any commercial companies pertaining to this article.*

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DOI: 10.1097/CIN.0000000000000142

e-mail in the workforce.[14,15] The TRA predicts intention based on a person's attitude and subjective norm toward performing a specific behavior.[16] It is generally accepted by researchers that behavioral intention leads to actual behavior,[17] thus suggesting the usefulness of the theory.

Similar to the TRA, behavioral intention in the TAM is directly predicted by attitude, as well as perceived usefulness and perceived ease of use of the technology.[14,15] In addition, the perceived ease of use is a predictor of perceived usefulness, whereas perceived usefulness is a predictor of attitude[15] (Figure 1). As additional constructs were added and modified from the TRA to create TAM, each construct within the technology context was defined. Perceived usefulness is defined as "the prospective user's subjective probability that using a specific application system will increase his/her job performance within an organizational context."[15(p985)] In addition, perceived ease of use is defined as "the degree to which the prospective user expects the target system to be free of effort"[15(p985)]. Researchers who have worked with the TAM have generally utilized the same definitions for each of the original constructs.[8]

Additional variables have also been tested, and several modified versions of TAM have emerged over time such as the Technology Acceptance Model 2 (TAM2)[18] and the Unified Theory of Acceptance and Use of Technology (UTAUT).[19] In TAM2, attitude has been removed from the model. Added to the model are subjective norm, image, job relevance, output quality, and results demonstrability. These variables are expected to influence perceived usefulness.[18] UTAUT modifies the definition of perceived ease of use to effort expectancy, as well as the definition of perceived usefulness to performance expectancy. Also, UTAUT adds two additional variables: social influence and facilitating conditions. Much like TAM2, UTAUT does not utilize the attitude component of the model seen in the original TAM.[19] These modified versions of TAM were developed to help explain additional variances in behavioral intention that were not explained by the original model.[18,19]

## THE REVIEW

The primary aim of this integrative review was to review current studies predicting nurses' use of healthcare technology using the TAM and modified versions of the TAM. This was done in an effort to better understand predictors of acceptance that can help inform organizations which have implemented or plan on implementing healthcare technologies among nurses. An integrative review methodology was used to synthesize the findings of the relevant studies. This methodology was chosen because it answers questions related to what is known and what the quality of the literature is regarding what is known. In addition, this method can identify gaps in the literature that may lead to future directions for research. The integrative review process was conducted using Cooper's five stages including (1) problem formulation, (2) literature search, (3) evaluation of data, (4) data analysis, and (5) interpretation and presentation of results.[20]

### Search Methods

Literature was identified through the following electronic databases: Ovid/MEDLINE, PubMed, Google Scholar, and CINAHL. Searches were completed of the electronic databases using the keywords, "TAM," "TAM2," "UTAUT," "nurses," and "Technology Acceptance Model." Hand searching of the reference lists was also conducted.

The definition of technology in the healthcare setting has traditionally been that of "the application of information processing involving both computer hardware and software that deals with the storage, retrieval, sharing, and use of healthcare information, data, and knowledge for communication and decision making."[21 (p38)] The Department of Health in the United Kingdom defines information and communication technology as "the knowledge, skills, and tools that enable information to be collected, managed, used, and shared to support the delivery of healthcare and promote health."[22(p1)] Both definitions account for technologies such as electronic health records, telemonitoring, and PDAs. The technologies used in the reviewed studies were required to meet these definitions.

To be included in the review, studies had to be considered primary research and published since the year 2000. Before the year 2000, technologies available in healthcare settings were less similar and relevant to what is in use today, and therefore literature from this time would be of limited value. Studies were required to use the TAM,

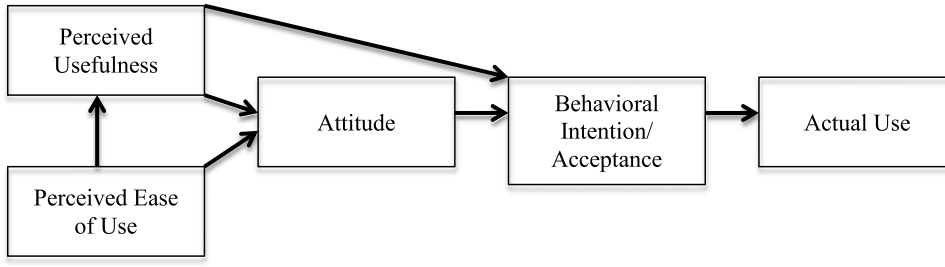


**FIGURE 1.** The Technology Acceptance Model.[8] Reprinted with permission.

TAM2, UTAUT, or a variation of these models to examine nurses' acceptance of healthcare technology. A quantitative research design testing these models was also essential.

## RESULTS

Originally, a total of 982 citations were found within the three electronic databases searched. Duplicate citations were removed; the title, abstract, and text were scanned, and all but 20 studies were eliminated because they did not meet inclusion criteria. Most articles were eliminated because they did not include nurses as the primary users of the healthcare technology or did not conduct primary research. A total of four dissertations, three symposium proceedings, and 13 journal articles were identified for inclusion. One author completed a doctoral dissertation, as well as published the results of the study in a journal, and therefore one was excluded, as the same results were present in both documents.[21,22]

Studies were conducted in nine countries, six done in the United States, three in Spain, and one each in Australia, Canada, Macedonia, Greece, France, and Lebanon.[23–41] In addition, all studies that utilized Bar Coding Administration Systems were done in the United States,[27,32,37] with the exception of 1 study that was completed in Lebanon.[42]

The quality of all 20 studies was assessed utilizing the Critical Appraisal Skills Programme.[43] This program provides resources and workshops for the appraisal of research. A modified checklist was developed based on this program consisting of questions related to the study aim(s), recruitment strategy, methodology and design, data collection, data analysis, value of research, and findings. Although studies varied considerably in their quality, none were eliminated from the review because of quality. Instead, limitations due to concerns of quality were identified, and these are assessed in the Discussion.

### Results of the Studies

A total of 20 studies were reviewed that represented empirical work done on technology acceptance among nurse participants.[23–41] The use of the TAM within nursing populations began in the early 2000s, with work in this area continuing to the present.[29,35] Sixteen studies put forward additional variables to the original TAM, TAM2, or UTAUT in an attempt to capture variance in behavioral intention that was not explained by the original models.[23–35,35,39–41] A summary of the results is shown in Table 1.

#### PERCEIVED EASE OF USE

Perceived ease of use is one of the variables present in the original TAM.[14,15] All studies that conducted model testing included this variable. Results of this review show that perceived ease of use sometimes directly predicts technology acceptance among nurses,[25,27,30] but not always.[26,31] This implies that if a nurse finds a technology easy to use, the nurse is more likely to accept and intend to use the technology. This statement is not true all of the time, and the reasons that ease of use does not predict technology acceptance are unknown.

In addition, this review shows that perceived ease of use is related to perceived usefulness.[25] This means that if a nurse finds a technology easy to use, he/she is more likely to believe it is also useful to his/her work and to patient care. This is an important finding, because it increases the importance placed on "easy-to-use" technologies being available to nurses.

#### PERCEIVED USEFULNESS

Similar to perceived ease of use, perceived usefulness is also one of the variables present in the original TAM.[14,15] All studies that conducted model testing also included this variable. There is strong evidence among the reviewed studies supporting perceived usefulness as a direct predictor of technology acceptance among nurses.[21,22,25–38,42,44] This result was found regardless of the technology or setting and applies not only to nurses, but also to those practicing outside the healthcare setting.[14,15] This suggests that if a nurse believes that a technology is useful, the nurse is more likely to accept it. Nurses can deem a technology useful if it enhances patient safety, improves care quality, or increases efficiencies.

#### PATIENT SAFETY DIMENSIONS

In one of the reviewed studies, the following patient safety dimensions were added as four unique predictors of technology acceptance: (1) teamwork within the hospital unit, (2) communication openness, (3) feedback and communication about errors, and (4) hospital management support for patient safety.[37] Although all dimensions are important elements of establishing a culture of patient safety, "teamwork within hospital units" and "feedback and communication about errors" were found to be significant predictors of both perceived usefulness and perceived ease of use. This suggests that when nurses are informed by a technology that an error or mistake was made, the nurse is able to see immediately how the technology affects their practice. This feature allows nurses to view the technology as useful in preventing errors and enhancing patient safety. It also shows that the team in which a nurse works plays an important role in acceptance and intention to use a technology. The results of this study imply that in teams where there is a strong patient safety culture, technologies that provide feedback about errors to nurses can be strong predictors of their intention to use the technology.

**Table 1**

**Summary of Studies**

| | Technology Studied | Author(s) | Year | Sample Population and Setting | Sample Size (n) | Variables Used |
|---|---|---|---|---|---|---|
| 1 | Hospital information systems | Aggelidis et al[25] | 2009 | Physicians, nurses, and administrators, hospital | 283 | • Individual context<br>Anxiety<br>Self-efficacy[a]<br>Attitude toward use[a]<br>• Technological context<br>Perceived usefulness[a]<br>Ease of use[a]<br>• Implementation context<br>Social influences[a]<br>Training[a]<br>Facilitating conditions[a] |
| 2 | Telemonitoring | Asua et al[26] | 2012 | Nurses, general practitioners, and pediatricians, homecare | 268 | • Individual context<br>Compatibility[a]<br>• Technological context<br>Perceived usefulness[a]<br>Perceived ease of use<br>Habit<br>• Organizational context<br>Facilitators[a]<br>Subjective norm |
| 3 | BCMA system | Bennett[27,32,37] | 2012 | Nurses, hospital | 159 | • Perceived ease of use[a]<br>• Perceived usefulness[a]<br>• Workaround usage[a]<br>• Barcode medication administration satisfaction[a] |
| 4 | PDAs | Chang et al[29] | 2003 | Nurses, hospital | 72 | • Perceived ease of use<br>• Perceived usefulness<br>• Willingness to use |
| 5 | PDAs | Chang et al[28] | 2004 | Nurses and physicians, hospital | 29 | • Perceived ease of use<br>• Perceived usefulness of system<br>• Willingness to use |
| 6 | Medication administration system | Escobar-Rodriquez and Romero-Alonso[30] | 2013 | Nurses, hospital | 118 | • Perceived usefulness[a]<br>• Perceived ease of use[a]<br>• Experience level[a]<br>• Perceived risks[a]<br>• Training[a] |
| 7 | Telemonitoring | Gagnon et al[31] | 2012 | Nurses, physicians, and nurse supervisors, homecare | 93 | • Perceived usefulness[a]<br>• Perceived ease of use<br>• Habits<br>• Compatibility<br>• Attitude<br>• Facilitators[a]<br>• Subjective norm |
| 8 | BCMA system administration system | Holden et al[32] | 2012 | Nurses, hospital | 83 | • Perceived ease of use[a]<br>• Perceived usefulness<br>• Perceived social influence[a]<br>• Perceptions of bar-coding administration training<br>• Perceptions of technical support<br>• Perceived usefulness of patient care[a]<br>• Perceived social influence from patient/family<br>• Age<br>• Experience |

*(continues)*

**Table 1**

**Summary of Studies, Continued**

| | Technology Studied | Author(s) | Year | Sample Population and Setting | Sample Size (n) | Variables Used |
|---|---|---|---|---|---|---|
| 9 | Hospital information system | Ketikidis et al[33] | 2012 | Nurses and medical doctors, hospital | 133 | • Perceived usefulness<br>• Ease of use[a]<br>• Job relevance[a]<br>• Subjective norms[a]<br>• Computer anxiety<br>• Descriptive norms |
| 10 | Telemedicine/ electronic or remote ICUs | Kowitlawakul[24] | 2011 | Nurses, hospital | 117 | • Perceived usefulness[a]<br>• Perceived ease of use[a]<br>• Years working in hospital[a]<br>• Support from physicians[a]<br>• Support from administrators[a] |
| 11 | Sensor-based medication administration system | Kummer et al[34] | 2013 | Nurses, hospital | 579 | • Subjective norm[a]<br>• Image<br>• Experience[a]<br>• Demonstrability[a]<br>• Voluntariness<br>• Perceived usefulness[a]<br>• Personal innovativeness[a]<br>• Qualitative overload[a]<br>• Quantitative overload[a] |
| 12 | Medication administration system | Kuo et al[35] | 2013 | Nurses, hospital | 665 | • Perceived ease of use[a]<br>• Perceived usefulness[a]<br>• Optimism[a]<br>• Innovativeness[a]<br>• Insecurity[a]<br>• Discomfort[a] |
| 13 | Hospital information system | Lu et al[36] | 2012 | Nurses, hospital | 277 | • Perceived Ease of Use[a]<br>• Perceived Usefulness[a]<br>• System quality[a]<br>• Information quality[a]<br>• Service quality[a] |
| 14 | BCMA system | Marini et al[42] | 2009 | Nurses, hospital | 276 | • Perceived ease of use[a]<br>• Perceived usefulness[a] |
| 15 | Clinical information system | Palm et al[41] | 2006 | Physicians, nurses, and secretaries, hospital | 324 | • Degree of use<br>• Computer experience<br>• Incentive from hierarchy<br>• Perceived use by other colleagues<br>• Sex[a]<br>• Computer information system quality[a]<br>• Service quality[a]<br>• Perceived ease of use[a]<br>• Perceived usefulness[a] |
| 16 | BCMA system | Song[37] | 2007 | Nurses, hospital | 163 | • Patient safety dimensions<br>Teamwork within hospital unit[a]<br>Communication openness<br>Feedback and communication about errors[a]<br>Hospital management support for patient safety[a]<br>• Perceived usefulness[a]<br>• Perceived ease of use[a]<br>• Years of experience using BCMA[a]<br>• Age<br>• Education<br>• Computer skills |

*(continues)*

**Table 1**

**Summary of Studies, Continued**

| | Technology Studied | Author(s) | Year | Sample Population and Setting | Sample Size (n) | Variables Used |
|---|---|---|---|---|---|---|
| 17 | Electronic medical records | Stocker[38] | 2010 | Nurses, hospital | 97 | • Perceived usefulness<br>• Perceived ease of use |
| 18 | Mobile healthcare systems<br>• PDAs<br>• Panel and tablet PCs<br>• Notebooks<br>• Other | Wu et al[39] | 2007 | Physicians, nurses, and medical technicians, hospital | 123 | • Compatibility[a]<br>• Mobile healthcare system self-efficacy[a]<br>• Technical Support and Training<br>• Perceived usefulness[a]<br>• Perceived ease of use[a]<br>• Perceived ease of use[a] |
| 19 | PDAs | Zhang et al[40] | 2010 | Nurses, homecare | 91 | • Perceived usefulness[a]<br>• Subjective norm[a]<br>• Image[a]<br>• Job relevance<br>• Output quality<br>• Results demonstrability |

[a]Significant results.

## TRAINING

One of the added variables in several studies was training.[25,30,32,39] Within the literature, it is somewhat unusual for training to be considered an independent variable as it is usually included within the concept of facilitating conditions (the conditions in which the technology is implemented).[25] It seems likely that the delivery of high-quality training should predict higher levels of perceived usefulness, perceived ease of use, and technology acceptance. Through training, nurses should come to understand the features and benefits of the technology that make it useful. Training should also familiarize the nurse with the technology, making it easier to use.

Of the four studies that added training as a variable,[24,28,30,37] only two found it to be statistically significant.[25,30] This may be due to the quality of the training provided, although details on the training program were not provided in either of the studies.

## FACILITATING CONDITIONS

Facilitating conditions are the physical and technical infrastructures that support the use of the specified technology.[25] Two studies found that nurses who believed their organization had high levels of facilitating conditions had significantly higher levels of technology acceptance.[25,26] This suggests that nurses who believe their organizations remove barriers to being able to successfully utilize the healthcare technology available to them have higher levels of technology acceptance. Examples of facilitating conditions include enhanced support during the implementation of a technology, new equipment for nurses to utilize, available equipment, adequate help and technical support, and end-user involvement in the decision-making process.[26] Further research that explores the elements of facilitating conditions that are the most important would be valuable.

## PERSONALITY TRAITS

Optimism, innovativeness, insecurity, and discomfort are personality traits that were added as variables within the TAM in one study.[35] Personality traits have been included in the TAM in the business and information technology literature previously, but never previously with nurse participants. In this nursing study, optimism was a significant predictor of perceived ease of use, as well as perceived usefulness of the technology. This implies that nurses who have a positive attitude about the future are more likely to believe a technology is useful and easy to use. The result is congruent with research done outside the nursing context.[35]

Innovativeness was also a significant predictor of perceived ease of use, but not perceived usefulness, which is consistent with research conducted outside nursing. This finding indicates that those who are innovative are more likely to adopt a technology sooner and be able to work more easily within any constraints of the technology. In addition, nurses who have higher levels of personal innovativeness may also be more likely to adopt a technology even when the usefulness of the technology has not been fully realized.[33]

Insecurity had a significantly negative impact on perceived ease of use and no relationship at all to perceived usefulness.[35] Lastly, discomfort also had a significantly negative impact on perceived ease of use and no relationship to perceived usefulness.[35] These results are congruent

with the notion that nurses who are worried and stressed about the use of a technology are less likely to want to utilize a technology.

### COMPUTER ANXIETY, SELF-EFFICACY, AND EXPERIENCE

Two studies included computer anxiety in their models.[25,33] The technologies being studied were hospital information systems that required nurses to input information through a computer. Computer anxiety was defined as the individuals' apprehension when faced with the possibility of using computers in their practice.[25] No significant relationship between this variable and technology acceptance was found.[25,33] This suggests that computer anxiety likely had no impact on whether a nurse would or would not accept a particular technology.

Computer self-efficacy was also added to a model and was found to be significant in predicting behavioral intention.[25] In this case, computer self-efficacy was defined as an individual's perception of his/her ability to use computers in the accomplishment of a task.[25] This may indicate that although computer anxiety is not a predictor of technology acceptance, a nurse's confidence in his/her ability to achieve a desired outcome while using a computer does predict technology acceptance. When nurses do not display this confidence, they may be less likely to accept the technology.

Two other studies explored elements of the relationship between computers and nurses. In one study, the variable "computer skills" was utilized; however, this study did not find a significant relationship among the variables.[37] In addition, one study utilized the variable "computer experience," but also found no significant relationship among the variables.[41] Computer skills and computer experience, in addition to computer anxiety, have therefore not shown to impact the acceptance of technology by nurses.

### JOB RELEVANCE

Two studies utilized job relevance as an independent predictor of technology acceptance.[33,40] One study was conducted in a hospital setting with computer-based technology and showed that job relevance predicted technology acceptance.[33] The second study was conducted in a homecare setting with PDAs and found no significant relationship between the variables.[40] As only two studies have investigated this concept, further research into how and if job relevance impacts the acceptance of technology may be required.

### SOCIAL INFLUENCE

Nurses can be influenced by their physician, administrator, and peer colleagues, as well as by patients and their families.[32] Support from physicians and administrators was found to be significant predictors of behavioral intention to use remote ICUs/telemonitoring in one study.[24] In another study, perceived social influence from patient/family was not found to predict intentions.[32] Social influences that included all types of influencers were tested in one study and were found to be significant.[25]

### EXPERIENCE

Experience working as a nurse was examined as a predictor in three studies.[23,30,34] One study examining telemedicine technology showed a significant relationship between experience and behavioral intention.[23,24] The two other studies that were conducted investigated medication administration systems and also showed significant relationships between the variables.[30,34] This indicates that the experience level of the nurse is likely an important predictor of use for various healthcare technologies.

## Study Conclusions

The reviewed studies varied in the results reported. For studies that tested for model fit using a modified version of the TAM, TAM2, or UTAUT, the amount of variance that was explained by the overall model ranged from 24% to 87%.[25,32,36,39–41] The model that accounted for 87% of the variance utilized variables that fell into three main contexts: individual, technological, and implementation.[25] In this study of Greek physicians, nurses, and administrators on acceptance of a hospital information system, the individual, technological, and implementation context variables directly predicted behavioral intention.

In addition, there were studies that reported that the proposed modified model was partially supported. In a study done of nurses' acceptance of a Medication Administration System in Taiwan, all paths in the proposed model were supported except insecurity, innovativeness, and discomfort on perceived usefulness.[35] A study examining the use of PDAs among homecare nurses in Canada reported that several paths within the proposed model were not significant including job relevance, output quality, and results demonstrability on perceived usefulness.[40] As the questionnaire was given to nurses who had minimal experience over 4 weeks of use of the PDA, it is difficult to know if nurses were still learning how to use the device at the time the questionnaire was administered.[40] Studies investigating how the relationships between the variables within the TAM may or may not change before, during, and after technology implementation, as well as with increased usage, would therefore be of value.

Several studies did not evaluate model fit. In these studies, the TAM was utilized to either evaluate user satisfaction of the technology or predict nurses completing workaround behaviors.[27–29] Three studies in this review

reported positive user satisfaction with the technology.[28,29,36] In a 2012 study of nurses' use of a bar-coding medication administration (BCMA) system, nurses with more experience completed more workarounds. In addition, those nurses who had computers in their home environment completed less workarounds.[27] Although these findings are not in support of a specific TAM or modified TAM, they are of value to organizations that are implementing technologies in which workarounds are possible. In addition, insight into the parameters in which technology is accepted by nurses can be learned.

## DISCUSSION

### Nurse Choice in Use of Technology

Optimal and appropriate use of healthcare technology are ways that nurses can ensure safe and quality care. One of the critiques of the TAM is the usefulness of the model in predicting technology acceptance in environments where nurses are required to use a technology and do not have the ability to make a choice regarding its use.[8] In this particular case, the model is still applicable, but is best applied to nurses' optimal use of the technology and may be understood through their use of workarounds.[27] A workaround in the healthcare context has been explained as the "healthcare provider developing an alternate route to bypass a block in workflow."[27] An example of a workaround in the healthcare setting is an employee circumventing the use of a drug library when using a "smart" IV pump. In this case, the TAM is applicable as the behavioral intention of the employee to utilize the "smart" IV pump properly can be predicted by the model. Studies included in this review did not discuss whether the technology being utilized to test the model was optional or mandatory. In addition, only one study examined workarounds.[27] Given that quality and safety parameters are functions that are traditionally bypassed by nurses when a workaround is conducted, future research that investigates predictors of proper technology use would be of value.

### External Variables Influence on Behavior Intention

One critique of the original TAM is that it does not account for external variables that may influence behavioral intention.[23,24] This review discovered that tests of the model have shown that the majority of variance in technology acceptance comes from the variables already included in the original TAM.[32] However, researchers who have included external contextual variables have been able to explain additional variances, thus suggesting that there may be external variables that do influence behavioral intention.[24,31] In a 2011 study, three external variables were significant in the proposed model. Number of years working in the hospital, support from physicians, and support from administrators were significant predictors of perceived ease of use.[24] External variables are therefore likely an important part of explaining contextual specific information that is essential in the prediction of behavioral intention.

### Physical Limitations

A limitation of the TAM is that it cannot account for the physical limitations of technology, such as lack of available resources.[7,44] If a nurse is not able to use a technology, as it is not available, or is in use by another nurse, all predictors of behavioral intention are not meaningful. Assumptions regarding the availability of the technology and appropriate infrastructure to support the technology, such as having adequate power supply, must be made when using the TAM.[8]

### Methodological Issues

The quality of the reviewed studies varied. Most studies had small sample sizes and/or response rates, and some did not state the response rate. All studies reviewed the results of nurse participants; however, in some, the nurses and other healthcare professionals were lumped together.[25,26] In these cases, it is difficult to understand how individual professional differences may have had an impact on model fit. It was, however, decided that including these articles in the review would still offer some value.

Minimal theoretical rationale was provided for the inclusion of specific variables in most of the studies that utilized an added variable approach.[41] Definitions of new variables were not always included, which made it difficult to understand exactly what was being hypothesized and measured.[31] This also made it difficult to understand the difference between similarly labeled variables from different studies, for example, anxiety versus computer anxiety.[25,33] In addition, without knowing the definition and meaning of a variable, it is difficult to know if the method for operationalizing the variable was appropriate.[25] Previously developed and tested instruments were generally modified and utilized among the participants.[39] Given that not all variables were defined, the instruments chosen to test the variables may or may not be appropriate.

In addition to concerns related to the instruments used to test variables, issues related to the timing of the data collection and the ability for the participants to utilize the technology in their practice were also noted. Data either were collected before,[33] during,[28,40] or after a new technology was implemented[25,26] or were collected after a simulation activity. Data collected before and during technology

implementation may provide limited information as participants may be hypothesizing what they might do or may be still learning how to utilize the technology effectively. Data collected after implementation has to be conducted long enough after the participants have had a chance to become comfortable utilizing the technology among real clinical scenarios. Data collection before this time would not provide an accurate measure of nurses' true technology acceptance. It may be that relationships within the TAM change during different stages of technology implementation.

Data collected from simulation exercises may not provide an accurate insight into technology acceptance by nurses given that the scenarios can never be fully analogous to the real world. In addition, participants would not have the same opportunity as they would in the clinical setting to become comfortable with technology use over time.

## Limitations

Limitations of the reviewed studies include sample sizes that were either not discussed or low,[29,38] the use of instruments that are not always adequately explained that test the proposed variables,[39] and a generally low level of rigor in conducting the studies.[29] While the behavioral intention of the nurse to utilize a technology was measured, no measurement of actual use was completed in several examples. Studies that were reviewed from symposium proceedings were of low quality,[28,29,41] and studies that did not test model fit were of limited value.[28,29] Those that did complete model testing were generally done in a single setting and were not repeated.[26,35,40] At this time, generalizability of the studies is therefore limited.

Four studies utilized TAM or a modified version of this model as a theoretical basis for the evaluation of a newly implemented technology.[27–29,38] No model testing is completed in these studies; therefore, they do not provide insight into the usefulness of the model within the nursing context. In addition, these studies do not seek to understand if existing variables that predict behavioral intention to utilize technology in current models are appropriate. In the future, research of this kind should be minimized as the value it brings to both the organization, and the broader nursing community is limited.

## CONCLUSION

Given the complex environment in which nurses work, modified TAMs that include additional variables have been most frequently examined in the literature. It appears that by adding these variables, a more holistic understanding of nurses' use of healthcare technology can be accomplished. The implications of this work are most applicable to organizations implementing healthcare technologies and vendors of healthcare technologies, as well as researchers. Organizations implementing healthcare technologies can conduct an assessment of their own unique contextual and end-user characteristics and plan technology implementation appropriately. In addition, nurse input at the time of technology selection is an important part of ensuring technology acceptance. Vendors of technology should recognize the most significant contextual factors that impact the acceptance and appropriate use of their technology and develop appropriate supports accordingly. Given the rate of technology implementation in healthcare, rigorous research is required to identify the most appropriate model to explain technology acceptance among unique technologies and clinical settings. Future studies investigating whether factors predicting workarounds differ from factors predicting user acceptance may be of value.


## Acknowledgment

The author thanks her supervisor, Dr Linda McGillis Hall, for her guidance in the development of this article and for editing several drafts.


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