Assessing Task–Technology Fit in a PACS Upgrade: Do Users’ and Developers’ Appraisals Converge?

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Abstract The purpose of this study was to measure users’ perceived benefits of a picture archiving and communication system (PACS) upgrade, and compare their responses to those predicted by developers. The Task–Technology Fit (TTF) model served as the theoretical framework to study the relation between TTF, utilization, and perceived benefits. A self-administered survey was distributed to radiologists working in a university hospital undergoing a PACS upgrade. Four variables were measured: impact, utilization, TTF, and perceived net benefits. The radiologists were divided into subgroups according to their utilization profiles. Analysis of variance was performed and the hypotheses were tested with regression analysis. Interviews were conducted with developers involved in the PACS upgrade who were asked to predict impact and TTF. Users identified only a moderate fit between the PACS enhancements and their tasks, while developers predicted a high level of TTF. The combination of a moderate fit and an underestimation of the potential impact of changes in the PACS led to a low score for perceived net benefits. Results varied significantly among user subgroups. Globally, the

data support the hypotheses that TTF predicts utilization and perceived net benefits, but not that utilization predicts perceived net benefits. TTF is a valid tool to assess perceived benefits, but it is important to take into account the characteristics of users. In the context of a technology that is rapidly evolving, there needs to be an alignment of what users perceive as a good fit and the functionality developers incorporate into their products.

Keywords Picture archiving and communication system (PACS) · task–technology fit · radiology information systems · technology assessment · questionnaires · organizational innovation · evaluation research · models · theoretical

Introduction

Picture archiving and communications systems (PACS) are a technology that can now be considered mature [1]. The first implementations date to the 1980s. Today, most hospitals in the developed world have a PACS and many have replaced their original systems with either different systems (i.e., different vendors) or updated versions of their original systems. Many studies have been published evaluating the impact of PACS on the radiology department and the hospital [2–10]. Broadly speaking, the evaluations can be divided into two categories: studies measuring productivity and studies analyzing the factors influencing the level of user satisfaction and adoption. The topic of successful implementation of information technology has been tackled in the information management literature and several models have been proposed to understand the relationship between different factors and outcome measures. These models are based on hypotheses concerning the

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influence of different independent variables on specific outcomes related to successful implementation. A few of these models have been applied to the study of health information technology and PACS. The technology acceptance model has been applied to numerous studies of end users' reaction to health information technology [11]. This model has undergone several refinements and modifications, but the main constructs predicting acceptance and use of the technology remain perceived usefulness, as well as perceived ease of use. Although, the idea that the technology must have features that are aligned with the characteristics of the users and their specific task requirements (i.e., fit) is inherent in these models, this is not measured directly. Goodhue argues that an information technology must not only be utilized, but must also be a good fit with the task supported in order to have a beneficial impact on performance [12, 13]. The Task–Technology Fit (TTF) model developed by Goodhue sought to study the relationship between information technology and individual performance. In this model, the TTF construct is explicit in predicting overall performance.

An adaptation of the TTF model has been used to study the introduction of IT in the healthcare setting. Ammenwerth et al. have developed a framework, Fit between Individuals, Task, and Technology, to study the adoption of a computer-based nursing process documentation system [14, 15]. In their study, the authors were able to identify facilitators and barriers to adoption based on an analysis of the three components of the fit framework, namely, individuals, technology, and task. Using the same framework, Tsiknakis et al. were able to study the adoption of IT systems and eHealth services in the context of a regional health information network [16]. From the perspective of PACS evaluation, this model offers an interesting way to incorporate the principle that the technology must be properly aligned with the workflow requirements of the radiologists. An added feature of this model is the possibility to measure fit from the developers' point of view. Utilization and acceptance can only be directly measured at the level of the users, but since the objective of developers of new technology is to produce products that meet users' needs, the concept of TTF can also be evaluated from the developers' perspective.

The studies to date evaluating the success of a PACS implementation have been limited to initial implementations and the conversion from a film-based department to an electronic one. To our knowledge, there is no study of an existing PACS system undergoing an upgrade in order to profit from technology innovations having occurred in the interim. The process by which specific innovations are incorporated into existing technology is complex and involves interaction between users and developers. Both technological imperatives and user demands must be balanced, and the final product is a reflection of this

process. In contrast to an initial implementation, a significant upgrade will elicit responses from users that are affected by experience and familiarity with the technology.

We conducted a survey of the users of a PACS to analyze the concept of fit in the context of a major system upgrade. The purpose of this study was to measure the users' perceived performance impacts of the innovations introduced in the PACS upgrade, and compare their responses to those predicted by developers. The TTF model served as the conceptual framework for the development of the questionnaire and the analysis of the findings.

Methods

Setting Institutional ethics board approval was obtained for the study. This is a case study of an 800 bed, university hospital undergoing a PACS upgrade. The initial system had been in place for 8 years. This study was designed to assess user (i.e., radiologist) perception to changes in the graphical user interface only. Other aspects of the PACS (i.e., server architecture, network architecture) also underwent modifications, but the impacts of these changes were not studied directly. The upgrade took place over several months and was completed in June 2009. The study was conducted 6 months after the upgrade, in January 2010.

Model The TTF model, developed by Goodhue, was used for the purposes of this study (Fig. 1). The model proposed by Goodhue makes explicit the role of fit between a technology and the users' tasks. In addition to recognizing the role of utilization and user attitudes in influencing performance impacts, Goodhue's model emphasizes the role of TTF in understanding how technology influences performance. Since the object of this study was a PACS upgrade, technology in the original model was replaced by technology enhancement. User characteristics included affiliation status within the department (i.e., staff radiologist or resident), years of experience with PACS, and subspecialty affiliation (for staff radiologists only). User tasks were grouped into three categories: organization, analysis, and reporting. A list of enhancements, or innovations, was obtained from the PACS vendor detailing the changes introduced in the current version (Appendix 1).

Questionnaire Development and Pre-test A survey questionnaire was developed using the TTF model as an analytical framework. Questions evaluating the variables of interest were constructed and a pre-test was performed with 10 radiologists. The internal consistency values (α Cronbach) for the variables of interest were as follows: impact of PACS enhancements, 0.78; task–technology fit, 0.89; utilization, 0.62; and perceived net benefits, 0.92.

Fig. 1 An adaptation of the Task–Technology Fit Model and the hypotheses tested in this study. *H1* Task–technology fit predicts utilization. *H2* Task–technology fit predicts perceived net benefits. *H3* Utilization predicts perceived net benefits

Following the pre-test, minor modifications were brought to the questionnaire.

Outcome Measures and Hypothesis Testing A self-administered survey was administered to all the staff radiologists and the residents in training of the radiology department. Respondents were asked to state their professional level (staff or resident), and staff radiologists were asked to specify their area of clinical expertise. All respondents were asked to assess their level of ease with computers and information technology on a Likert scale of 1 to 7 (1 not at all at ease, 7 very much at ease). Four variables (impact, utilization, TTF, and perceived net benefits) were measured. The enhancements or modifications introduced in the upgraded PACS were listed and respondents were asked to assess the perceived impact of these PACS changes on individual workflow. Respondents evaluated the impact on a Likert scale of 1 to 7, where 1 denoted a very negative impact, 4 denoted no impact, and 7 denoted a very positive impact. Utilization was evaluated for the list of enhancements introduced with the PACS upgrade. Although 11 items were identified as innovations in the upgrade (Appendix 1), there were 10 statements for utilization in the questionnaire, since one of the modifications introduced did not permit a choice of use to the user. Utilization was measured on a Likert scale of 1 to 7, with 1 denoting no use and 7 denoting use during every work session. Goodhue et al. validated a number of factors contributing to the measure of TTF. These factors include quality, reliability, locatability, timeliness, and ease of use. Twenty-five statements were developed on the basis of these factors to measure TTF (Appendix 2). For each statement, respondents would indicate on a Likert scale of 1 to 7, whether they strongly disagreed or strongly agreed (1 would indicate a very poor fit, 7 would indicate a very good

fit). Perceived net benefits were measured using eight items drawn from a survey tool developed by Paré et al. in a study of PACS success [9]. This construct is composed of two variables: productivity (five items) and overall quality (three items; Appendix 3).

Descriptive statistics were obtained for each of the variables, including mean and 95% confidence intervals. The validity of the survey items was assessed with the α Cronbach statistic. Three hypotheses were tested: the higher the level of TTF, the greater the utilization of the innovations; the higher the level of TTF, the greater the perceived net benefits; and the greater the utilization of the innovations, the greater the perceived net benefits.

Subgroup Analysis Recognizing that not all radiologists use PACS in the same way, staff radiologists were divided into two groups. These groups are distinguished by the nature of the image data sets they routinely work with. Group 1 works mostly with cross-sectional imaging studies (e.g., CT, MRI, and ultrasound). They analyze and interpret relatively fewer studies, but these studies contain large data sets. They spend more time per study and interpret fewer studies per day. Group 2 spends a significant portion of its time analyzing and interpreting many studies comprised of small data sets (e.g., chest radiographs and bone radiographs). They interpret many more studies than group 1, but spend less time per study. Residents reflect both work habits, but have less experience with PACS.

Developers Interviews were conducted with developers involved in the PACS upgrade. The names of four key informants who had a global appreciation of the product and who were involved in its development were provided by the PACS vendor. Semi-structured, 2-h long telephone interviews were conducted using the questionnaire as a guide. They were asked to predict the impact of the modifications introduced in the upgraded PACS on the users' workflow. The portion of the questionnaire evaluating TTF was also administered to the developers. The developers were also asked about the relative contribution of end user requests and technological evolution to product enhancements. Finally, they were asked how conflicting user demands were addressed.

Results

Users In all, there were 45 respondents. There were 32 staff radiologists (response rate of 64%), representing all subspecialty groups, and 13 residents (response rate of 33%). Table 1 describes the characteristics of the respondents. There were 16 radiologists in group 1 and 13 in group

Table 1. Respondent characteristics

Professional status	No.	Years experience with PACS (years)	Level of ease with IT (1–7)
Staff			
Abdomen ^a	5	7.4±0.9	5.4±1.5
Neurology ^a	6	6.0±2.9	4.3±1.4
Angiography ^a	5	6.4±3.1	5.4±1.1
Thorax ^b	6	6.8±2.9	4.8±1.2
Musculoskeletal ^b	5	5.4±2.5	4.8±1.1
Mammography ^b	2	6.8±1.8	4.0±0.0
Residents	13	1.9±1.3	5.5±1.3
Total	45	5.2±2.98	5.0±1.26

^a Group 1 users^b Group 2 users

2. On average, the respondents had more than 5 years experience with the previous version of the PACS. The residents had an average of 1.9 years experience. All the respondents felt at ease with IT technology and gave a mean score of 5 out of 7.

The descriptive statistics pertaining to the different variables assessed in this study are summarized in Table 2. The value of α Cronbach varies between 0.72 and 0.88, thus confirming the validity of the questionnaire evaluating these variables. With regards to impact of the enhancements introduced in the PACS upgrade, only a mildly beneficial or positive impact was measured: $5\pm0.72/7$. Utilization (1: never–7: consistently) was measured at $4.6\pm0.99/7$, denoting a level of use that is only moderate. TTF was measured at $4.2\pm0.68/7$ (1: very poor fit–7: very good fit), denoting a moderate fit between the PACS enhancements introduced in the upgrade and the users' tasks. The perceived net benefits

score was $3.3\pm0.98/7$, indicating that users did not judge the upgrade beneficial to their day to day work.

Table 3 summarizes the findings for the subgroup analysis. The only significant difference was seen between radiologists in groups 1 and 2 for utilization. Those radiologists who spend a significant portion of their time analyzing and interpreting many studies comprised of small data sets (group 2), made more use of the PACS enhancements. They also gave the lowest score of perceived net benefits, although the differences with other groups were not statistically significant.

Table 4 summarizes the findings for the three hypotheses tested in this study for all users combined. Overall results confirmed that TTF predicts both utilization ($r=0.464$, $p=0.001$) and perceived net benefits ($r=0.579$, $p<0.001$), while utilization does not predict the level of perceived net benefits ($r=0.157$, $p=0.316$). When the three subgroups were analyzed separately (Table 5) all hypotheses were confirmed in group 1 (i.e., radiologists interpreting fewer studies containing large data sets), while none were confirmed for group 2 (i.e., radiologists analyzing and interpreting many studies comprised of small data sets). The results for residents were aligned with the results for the three subgroups combined, indicating that their work habits are a combination of the profiles of groups 1 and 2.

Developers Four developers were interviewed for the purposes of the study, but only three completed the portion of the questionnaire predicting TTF. Overall, they predicted a favorable impact of the enhancements on the users' workflow. When divided into the categories of organization, analysis, and interpretation, all predicted that the most favorable impact would be at the level of those enhancements affecting organization, and to a lesser degree, interpretation. They all agreed that the enhancements affecting analysis would be neutral. Developers predicted a strong TTF (mean $5.8/7.0\pm0.77$) and stated that user demands were more important than technological evolution in driving product development. With regards to product development, they stated that it was driven predominantly

Table 2. Descriptive statistics

Construct variables	Items	α	Mean	SD	95% CI
Impact					
Organization	4	0.62	4.89	0.95	4.60–5.18
Analysis	4	0.62	4.88	0.82	4.63–5.13
Interpretation	3	0.75	5.13	0.90	4.85–5.42
Total	11	0.81	4.98	0.72	4.76–5.19
TTF					
Organization	10	0.82	4.37	0.90	4.10–4.64
Analysis	10	0.69	4.20	0.69	3.99–4.41
Interpretation	5	0.68	3.98	1.07	3.65–4.30
Total	25	0.86	4.23	0.68	4.03–4.44
Utilization					
Organization	4	0.63	4.76	1.28	4.38–5.15
Analysis	3	0.04	4.67	0.93	4.38–4.95
Interpretation	3	0.66	4.30	1.36	3.89–4.72
Total	10	0.72	4.62	0.72	4.32–4.92
Perceived net benefits	8	0.88	3.27	0.88	2.97–3.57

 α Cronbach's measure of internal consistency

Table 3. Subgroup analysis

	Group 1 Mean±SD	Group 2 Mean±SD	Residents Mean±SD	ANOVA		
				<i>F</i>	<i>p</i>	<i>R</i> ²
Respondents	16	13	13			
Impact	4.7 ±0.69	5.2±0.75	4.9±0.66	1.53	0.23	0.49
TTF	4.2±0.75	4.2±0.66	4.3±0.63	0.04	0.96	0.47
Utilization	4.2±1.0 ^a	5.2±1.0 ^a	4.5±0.63	4.22	0.02	0.82
Perceived net benefits	3.6±0.93	2.8±0.98	3.3±0.85	2.45	0.10	0.86

ANOVA analysis of variance

^a Tukey's test, *p*=0.018

by user demands. When asked to specify the relative importance of user demands compared to technological innovation, the answers ranged from 50% to 80%. At times, a combination of technology driven changes combined with observation of user work habits were at the source of product changes. When confronted with conflicting user demands, several approaches were invoked. If possible, versatility was introduced into the product to accommodate the different demands; otherwise, only those changes requested by a significant majority of users were adopted.

Discussion

Unlike previous studies, the object of this evaluation was a mature PACS undergoing a significant upgrade in an institution where the users have a well-established experience with the technology in their day to day practice. PACS has become an essential tool in the radiologist's work environment. Medical images can only be accessed, analyzed, and interpreted through the use of this technology. In our view, the concept of fit between task and technology captures the utility the radiologist assigns to PACS in the context of his professional needs. In the context of a technology that is already accepted and widely used, TTF is useful in measuring user response to innovation in the technology. As argued by Goodhue, fit is often missing or only implicit in models focused on utilization. In his view, this is a significant weakness since

utilization may or may not be voluntary, and more utilization of a system does not necessarily lead to better overall performance [13]. As our secondary objective was to compare the users' assessment to that predicted by developers, TTF can also be measured from the developers' perspective.

It is clear from the results that the upgrade in question was not deemed a success by the users. Users identified only a moderate fit between the PACS enhancements introduced in the upgrade and their tasks, while developers predicted a high level of TTF. The developers predicted that the most favorable impact would be at the level of those enhancements affecting organization, and to a lesser degree, interpretation. They stated that the enhancements affecting analysis would be neutral. This is not in agreement with the users' perception of impact which was high for organization, analysis, and interpretation, respectively. The combination of a moderate fit and an underestimation of the potential impact of changes in the PACS likely explain the low score for perceived net benefits. Considering the time and investment a PACS provider can devote to product development, it is noteworthy that the appreciation of users in this study fell well short of that predicted by the developers.

In addition to contrasting the users' and developers' appraisals of the upgraded system, we sought to test the hypotheses that TTF can predict utilization and performance. When viewed globally, the data from our study support the hypotheses that TTF predict utilization and perceived net benefits. The hypothesis that utilization

Table 4. Hypothesis testing

Construct variable	TTF predicts utilization		TTF predicts perceived net benefits		Utilization predicts perceived net benefits	
	Pearson correlation	<i>p</i>	Pearson correlation	<i>p</i>	Pearson correlation	<i>p</i>
Organization	0.448	0.002	0.467	0.002	−0.032	0.837
Analysis	0.267	0.077	0.577	<0.001	0.231	0.141
Interpretation	0.334	0.027	0.367	0.017	0.294	0.059
Total	0.464	0.001	0.579	<0.001	0.157	0.316

Linear regression

p denotes bilateral significance

Table 5. Hypothesis testing for the subgroups

Group	TTF predicts utilization		TTF predicts perceived net benefits		Utilization predicts perceived net benefits	
	Pearson correlation	<i>p</i>	Pearson correlation	<i>p</i>	Pearson correlation	<i>p</i>
Group 1	0.738	0.001	0.705	0.003	0.674	0.006
Group 2	0.365	0.221	0.352	0.238	0.041	0.893
Residents	0.393	0.184	0.638	0.026	0.062	0.849

Linear regression

p denotes bilateral significance

predicts perceived net benefits was not confirmed in our study. This supports Goodhue's view that utilization is not necessarily a useful construct in assessing individual performance. It is important to note, however, that usage of PACS as a whole was not voluntary and the users had no choice but to adopt the technology. In this upgrade certain elements were, in essence, built in and mandatory, while others were optional in that alternative tools were available for the radiologists. The study was not designed to differentiate the compulsory tools from the optional ones, but this presents an interesting issue with regards to technological evolution. Namely, should innovations be made compulsory or should they be presented as alternatives, leaving the decision of adoption up to the user.

Subgroup analysis reveals differences among the various users, both with respect to the descriptive statistics and the hypotheses. The difference in level of utilization was significantly different between radiologists who interpreted less studies of greater complexity (i.e., group 1), and radiologists, who interpreted many studies of lesser complexity (i.e., group 2). Group 2 also gave the highest score for impact of the PACS enhancements and the lowest score for perceived net benefits, but the differences were not statistically significant when compared to the other users. In group 1, all three hypotheses tested were confirmed, while none were confirmed in group 2. Data obtained from residents, who work in both paradigms, only confirmed that TTF predicts perceived net benefits. This highlights the fact that users cannot be considered a monolith and that user characteristics are an important variable in studying successful implementation of PACS. One may conclude that when a common set of system enhancements are introduced, not all user subgroups are equally predisposed to appreciate and incorporate the changes. The model was unable to explain the perceived net benefits on the basis of TTF for group 2. It is also possible that the items in the questionnaire defining TTF did not accurately capture the level of fit for this group.

Although not as disruptive as an initial PACS implementation in a film-based environment, a PACS upgrade can still be relatively disruptive. We conducted the study

less than 6 months after the completion of the upgrade to better capture the initial perception of fit and evaluate its impact on adoption and user satisfaction, as measured by the perceived net benefits. Researchers have shown that users can sometimes adapt to a poor-fitting technology; therefore, it was important, in our view, to measure the initial user perception. Fuller and Dennis, in a study designed to evaluate the performance of groups of senior undergraduate accounting students using an information system to select potential applicants, found that fit can predict performance soon after a technology is adopted [17]. Beyond first use, however, they found that the teams using a poor-fitting technology innovated and adapted to the technology, eventually improving their performance. In light of this, they argued that the concept of fit should be re-evaluated to take into account the impact of continued use. PACS is a complex technology, and appropriation can take a significant amount of time [5]. In a study of PACS benefits, namely, shortened dictation turnaround time and increased productivity, significant improvements were evident 1 year after PACS implementation. In the immediate post-PACS period, however, results were mixed with slight improvement in productivity and efficiency for some tasks and significant deterioration in others. It would be interesting to assess the evolution of fit over time for a system such as PACS.

There are some limitations in this case study. The launch of the upgraded version was delayed several times due to technical issues. Some of these hardware and network issues persisted for some time and overlapped the survey period done for this study. Although the purpose of our study was to study the graphical user interface only, it was often impossible to dissociate other factors (e.g., hardware or network) from the end user's overall perception of the system. The constructs measured in this study, namely, impact, task–technology fit, utilization, and perceived net benefits all had a high level of internal consistency. When broken down into the categories of organization, analysis, and interpretation, however, this was not the case. This is likely due to the lower number of survey items per category. So, although the overall assessment of the

constructs was valid, it was difficult to draw conclusions for specific dimensions.

In conclusion, task–technology fit is a valid tool to assess perceived net benefits, but it is important to take into account the individual characteristics of users. Other studies on PACS have noted differences among various group of users such as radiologists, technicians, and clinicians. Our study showed that there are different classes of users with different perceptions within the radiology community and these should be taken into account. This lends support to the modification proposed to the model by Ammenwerth et al. to include individual characteristics of users [14]. Task–technology fit is also a useful construct to measure in developers, since their avowed aim is to provide a product that meets the users' requirements. In the context of a technology that is rapidly evolving, there needs to be an alignment of what users perceive as a good fit and the functionality developers incorporate into their products.

Appendix 1. System enhancements

Organization

- New graphical user layout
- Worklist building tool
- Scheduled worklist tool
- Multiple patient display

Analysis

- Toolkit icon presentation
- Data compression option
- Integrated 3D tools
- Internet access

Reporting

- Automated workflow
- Creating subset of noteworthy images
- Teaching tools

Appendix 2. Survey questionnaire items assessing TTF

Organization

1. Patient data is current and up to date (quality)
2. The patient data displayed is pertinent (quality)
3. There is sufficient detail (quality)
4. The data is easily accessible (locatability)
5. The patient data interface is user friendly (ease of use)

6. Queries are answered rapidly (timeliness)
7. There are few system crashes while accessing patient data (reliability)
8. Training for the patient data interface was useful (ease of use)
9. The interface with the radiology information system is useful (ease of use)
10. The interface with the radiology information system is reliable (reliability)

Analysis

11. Pertinent image data is displayed (quality)
12. Images are of diagnostic quality (quality)
13. Image manipulation tools are easily accessible (locatability)
14. Images are displayed quickly (timeliness)
15. Image sets scroll quickly (timeliness)
16. There are few system crashes while viewing images (reliability)
17. The image display interface is user friendly (ease of use)
18. The 3D tools are easily accessible (locatability)
19. The 3D tools facilitate image analysis (ease of use)
20. Training for the image display interface was useful (ease of use)

Interpretation

21. The dictation interface is reliable (reliability)
22. The teaching tools are easy to use (ease of use)
23. The WEB access is useful (ease of use)
24. It is easy to save images of interest (ease of use)
25. It is easy to incorporate the results of 3D analysis (ease of use)

Appendix 3. Survey questionnaire items assessing perceived net benefits

1. My overall efficiency has increased since the upgrade (productivity)
2. I can interpret more studies per work session (productivity)
3. My professional quality of life has improved (quality)
4. I waste less time searching or waiting to interpret images (productivity)
5. I waste less time searching or waiting to consult images (productivity)
6. The time needed to interpret each study has decreased (productivity)
7. The new tools available facilitate consultations with clinicians (quality)
8. The quality of my diagnosis has increased since the upgrade (quality)

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