Do hospital physicians attitudes change during PACS implementation? A cross-sectional acceptance study

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Abstract

Purpose: The purpose of this study is to gain a better insight into the reasons why hospital physicians accept and use a Picture Archiving and Communication System (PACS). Two research questions are put forward, pertaining to (1) factors that contribute to physicians' acceptance of PACS, and (2) whether these factors change as physicians gain experience in using PACS.

Methods: Questionnaires were administered at three moments in time during the PACS implementation process in a private hospital: just before its introduction (T1), four months later (T2), and about fifteen months after the introduction of PACS (T3). The Unified Theory of Acceptance and Use of Technology was chosen as the theoretical framework for this study. Hence, the following scales were measured: *performance expectancy*, *effort expectancy*, *social influence*, *facilitating conditions*, *behavioral intention*, and self-reported frequency of *use*.

Results: Forty-six usable responses were obtained at T1, 52 at T2 and 61 at T3. Three variables directly influenced PACS acceptance (measured as *behavioral intention* and *use* of PACS): *effort expectancy*, *performance expectancy*, and *social influence*; and their influence evolved over time. *Effort expectancy* was of particular importance at T1, whereas *performance expectancy* influenced acceptance at T2 and T3; *social influence* was the only consistent predictor of PACS acceptance at all times. Variance explained in *behavioral intention* ranged from .26 at T1 to .58 at T3.

Conclusions: In this setting, the main motivation for physicians to start using PACS is *effort expectancy*, whereas *performance expectancy* only becomes important after the physicians started using PACS. It is also very important that physicians perceive that their social environment encourages the use of PACS.

1. Introduction

1.1. Clinical Information Systems in healthcare

Technology can facilitate our daily life, just as it can be a burden if it does not work as intended, or while you are still learning to work with a new technology, and do not fully experience its advantages. Although clinical information systems (CIS) have clearly proven their value for health care [1, 2], it took healthcare decision makers longer to acknowledge the beneficial effects of CIS than is typical for commercial or business settings (in which economic efficiency is often the primary motive, unlike in the healthcare sector). These benefits pertain to a wide range of effects, including reduction of report turnaround time, lower number of medication and transcription errors, elimination of adverse drug effects and many others [3-5]. As such, different studies report that CIS ultimately lead to an improved quality of patient care. In view of the potential benefits, it is surprising that only a minority of implemented healthcare information systems may be considered a complete success [6, 7]. This indicates that merely introducing a CIS to users does not automatically lead to the expected benefits. Instead, a prerequisite for success is that the (intended) users actually use the CIS and exploit its features to the full extent [8]. This requires efforts both from users and their organization. Users have to adapt their working method [9] and take the time to learn how to work with the new system in order to make full use of the technology, while the organization needs to provide the necessary conditions to facilitate the use of the new technology, e.g. through training and support [7, 10]. It is the aim of this article to gain more insight into the factors that determine CIS' implementation success, so that the healthcare sector may maximally benefit from their advantages.

1.2. Barriers to the implementation of a Picture Archiving and Communication System

In this paper, the implementation of a Picture Archiving and Communication System (PACS) in a private hospital is studied. In PACS, medical images are collected from the imaging modalities, stored with their corresponding reports, and distributed to the referring physicians. Unlike many other clinical information systems, PACS can be considered a success story [11]; its benefits are considerable [12] and tangible on different levels, going from patients to management [13]. Yet, between the moment when the implementation is considered, and implementation success, there are four threats for a PACS-implementation project [14]:

- project / economic: e.g. funding issues, choice of vendor, timeframe adherence;
- technical: e.g. product / vendor immaturity, server & storage space, network capability;
- organizational: e.g. training issues, organizational resistance, end-user equipment availability;
- behavioral / human: e.g. acceptance and use by the end-user, physician resistance.

Getting end-users to accept and actually use PACS is one of the final obstacles that an organization has to overcome. In view of the financial impact of a PACS project, regardless of whether an entirely new installation or the replacement of an existing PACS is concerned, it is vital to keep the transition phase, in which both systems coexist, as short as possible. Probing users' attitudes towards PACS should give insight into (1) what actions an organization can undertake to speed up the acceptance process when PACS is introduced; and (2) when PACS is already in use, what steps an organization can take to maximize the use of PACS.

1.3. Technology acceptance theories

Building on established social psychology and sociology theories like the Theory of Reasoned Action [15] and the Innovation Diffusion Theory [16], several theoretical models were developed to explain user acceptance of (information) technology, which has been operationalized as *attitude* towards the technology [17], *behavioral intention* to use the technology [18], and / or technology *use* [18]. An overview of models that have been used to study technology acceptance is provided in [18]. The most prominent model in this domain is the Technology Acceptance Model (TAM) [19]. TAM states that a user's *attitude* towards a technology depends on the *perceived usefulness* of that technology and its *perceived ease of use*; *attitude* and *perceived usefulness* then jointly predict a user's intention to use that technology. Several versions of TAM exist, and in many cases *attitude* is omitted from the model. In TAM2, *subjective norms* are added as predictors of intention [20], while TAM3 adds individual differences and system characteristics as antecedents to *perceived usefulness* and *perceived ease of use*, next to constructs relating to *subjective norms* and *facilitating conditions* [21].

The abundance of model development and refinement studies gave rise to the development of an overarching theory, the Unified Theory of Acceptance and Use of Technology (UTAUT) [18]. Venkatesh et al. [18] reviewed models and constructs utilized to study technology acceptance, and carried out an empirical study to test their conclusions. They identified, next to four moderating variables (gender, age, experience with the technology, and perceived voluntariness of use), seven overarching constructs of which only four were withheld as determinants of user acceptance (operationalized as *behavioral intention* and *use*): (a) *performance expectancy*, referring to the usefulness of a technology; (b) *effort expectancy*, referring to the ease of use of a technology; (c) *social influence*, referring to perceived norms in the social environment concerning the use of a technology; and (d) *facilitating conditions*, referring to objective factors that facilitate the use of a technology, such as training, support and compatibility between the new and existing systems.

The main difference between UTAUT and TAM3 is that *social influence* and *facilitating conditions* are modeled as direct predictors of acceptance in UTAUT, whereas in TAM3 they are modeled as antecedents to *perceived usefulness* and *perceived ease of use* [18, 21].

1.4. Technology acceptance in healthcare

A very diverse range of information systems is in use in hospitals, all belonging to one of three clusters: strategic, administrative or clinical [22]. Systems like PACS, electronic patient records and clinical decision support systems belong to the latter category, the clinical information systems (CIS). As these systems can have a profound impact on the quality of patient care, their acceptance and use by physicians is crucial. Below we present the findings of a literature search in the Web-of-Science on quantitative studies of hospital physicians' acceptance of CIS in the time span 2000-2009.

Eleven relevant studies are retrieved and from these studies we learn that just as in business settings [18], the usefulness of the system is the main predictor of physicians' CIS-acceptance [13, 23-30], while the system's ease of use is of minor importance [13, 23, 26]. Although physicians have a large degree of professional autonomy and are considered to independently make technology acceptance decisions, some studies have found that *social influence* is positively associated with CIS-acceptance [13, 26, 31], whereas other studies found no effect of *social influence* [28-30]. Constructs relating to *facilitating conditions* were also important predictors of CIS-acceptance, either directly [13, 26-30] or indirectly through *perceived usefulness* [24, 28-30] or *perceived ease of use* [25].

Furthermore, from this search of the literature we can also conclude that:

- approximately the same factors contribute to physicians' acceptance of CIS as in business settings, with system usefulness as the dominant construct;
- only very few PACS acceptance studies have been conducted: we identified four studies reporting on PACS acceptance in two university hospitals situated in Canada [32] and Belgium [13, 26, 27]. This limited body of research contrasts with the widespread use of the system;
- the most frequent format in the literature is a one-shot approach, in which CIS-acceptance is typically assessed on only one moment in time. Exceptions are [33] who questioned physicians before and about four months after the introduction of speech recognition, and [13, 26] who took questionnaires at the introduction of PACS and about two years later. By taking only one measurement, researchers get a static view of user acceptance, whereas multiple measurements could yield important insights into how user acceptance evolves over time. It can be expected that shortly after the introduction of a new technology, users' attitudes are subject to changes due to insufficient knowledge of, and experience with the new technology. Also, more importantly, only a repeated measurements methodology allows to investigate whether and how the above-mentioned facilitating factors may have differential effects on technology acceptance, in the same physicians, at different moments in time.

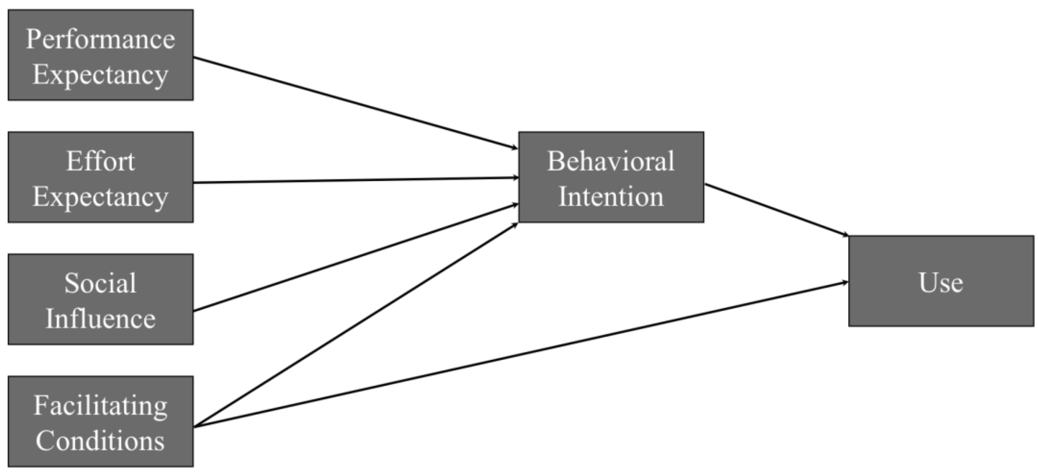
1.5. Purpose

In this study, hospital physicians' PACS acceptance will be assessed at three occasions (before, shortly after and about one year after the introduction of PACS) in a multi-site private hospital. The research model (Figure 1) draws on the Unified Theory of Acceptance and Use of Technology as a theoretical framework. Two research questions are put forward:

RQ1: To what extent can performance expectancy, effort expectancy, social influence and facilitating conditions explain hospital physicians' acceptance of a Picture Archiving and Communication System?

RQ2: Does experience with PACS moderate the relationships between the independent variables (performance & effort expectancy, social influence, and facilitating conditions) and physicians' acceptance (behavioral intention and use) of PACS?

Figure 1. Research model.



By addressing these questions, our study contributes to the literature in three ways. First, it adds to the literature on factors related to physicians' acceptance of clinical information systems. Second, by taking multiple measurements, it will give more insight into the evolution of users' attitudes towards a technology that is estimated to be very beneficial for its users. In this respect, the measurement shortly after the introduction of PACS should be of particular relevance. Private/non-academic/for-profit (PNF) and university/academic/not-for-profit (UAN) hospitals differ in several respects [6, 24], amongst others on (a) IT infrastructure: UAN hospitals have either a strong [24] or limited and old infrastructure [6]; (b) support: UAN hospitals have either better support [24] or fewer technology-related staff [6] than PNF hospitals; and (c) culture: UAN hospitals have a more pro-technology culture aimed at healthcare education [24]. These differences most likely affect user acceptance of PACS. As the other retrieved PACS acceptance studies were all performed in university hospitals [13, 26, 27, 32], the third contribution of this study is that it is the first empirical study assessing PACS acceptance in a private hospital.

2. Methods

2.1. Instrument development

The questionnaire consisted of six scales that were originally developed by [18]. The items were translated into Dutch and adapted to the study context (hospital setting and PACS). The following scales were included: *performance expectancy*, *effort expectancy*, *social influence*, *facilitating conditions*, and *behavioral intention*. 7-point Likert scales were used, ranging from *completely disagree* ("1") to *completely agree* ("7"). The questionnaires collected post-implementation included an extra item measuring the self-reported frequency of *use* on a scale ranging from *never* ("1") to *daily* ("7"). Next to the acceptance scales, demographic information (gender, age) was also collected.

2.2. Setting

The study setting was a multi-site private hospital with approximately 1100 beds. At the time of data collection, about 2300 people were employed in one of the four locations, among which about 200 physicians and 910 nurses. Originally, the different sites were four distinct hospitals - situated within walking distance in the same city - that merged in the period 1998-2000. In anticipation of the newly-built single site hospital by 2016, the hospital reorganized in 2003 grouping physicians at the same location as a function of their area of expertise.

In the course of May 2006, introductory meetings were organized to announce the introduction of PACS and outline some of its key features. The physicians could start using PACS after these meetings. Following the introductory meetings, follow-up sessions were organized to solve user problems. Hard-copy film printing was largely stopped about four months later; upon request physicians could still receive printed images.

2.3. Data collection

The first questionnaire (T1) was issued to all physicians attending the introductory meetings and was collected at the end of the meeting. The second (T2) and third (T3) questionnaires were issued to and collected from all 200 physicians through the internal mail of the hospital. The second questionnaire was handed out about four months after the first, when users were expected to have a limited experience with PACS, the third was handed out one year after the second, when the users were expected to have extensive experience using PACS. All questionnaires were taken anonymously.

2.4. Data analysis

For the first research question, investigating which factors contribute to physicians' acceptance of PACS, path analysis using AMOS 6.0 is applied. The theoretical overview of technology acceptance models shows that four factors (*performance expectancy* / *perceived usefulness*, *effort expectancy* / *perceived ease of use*, *social influence* / *subjective norms*, *facilitating conditions* / *perceived behavioral control*) contribute to users' acceptance of a particular technology. There is however disagreement as to whether these constructs affect acceptance directly (UTAUT) or rather indirectly through *perceived usefulness* and/or *perceived ease of use* (TAM/TAM3). By performing path analysis, we will be able to model both the direct and indirect effects. To assess goodness-of-fit, the following fit parameters are taken into account: comparative fit index (CFI), goodness of fit index (GFI), root mean square error of approximation (RMSEA), and normed Chi^2. The following thresholds are used: CFI and GFI above .90 [34], RMSEA below .08 [35] and normed Chi^2 below 3.0 [35]. To investigate the second research question, two hierarchical regression analyses are performed, in which Model 1 contains the direct effects (Figure 1), and Model 2 the interaction terms. For the first regression the measurements at T1 and T2 are analyzed together; for the second regression the measurements at T2 and T3. In order to interpret the interaction effects, linear regressions per measurement are performed.

3. Results

Over the three measurements, a total of 173 questionnaires were collected. Prior to the analysis, 14 questionnaires were excluded because they contained too many missing values on either the dependent or independent variables. This way, 46 (T1), 52 (T2) and

61 (T3) usable responses were retained. The three groups did not differ in terms of gender ($Chi^2(2)=3.777$, $p=.15$) and age ($Chi^2(8)=11.879$, $p=.16$).

3.1. Reliability and descriptives

The reliability (expressed as Cronbach alpha) of the scales is displayed in Table I. Two scales (*performance expectancy* and *behavioral intention*) met the minimal requirements for acceptable reliability (.70) [36]. The reliability of the other scales was below this threshold, especially in the case of *social influence* ($\alpha = .45$). A closer inspection of the latter scale showed that one item did not correlate with all other items. After removal of this item, the reliability increased significantly but remained quite low ($\alpha = .54$). As cronbach alpha is highly dependent of scale length, the reliability might be underestimated. Therefore a multidimensional confirmatory factor analysis (in AMOS 6.0) with the remaining items was conducted. The goodness-of-fit indicators showed a reasonable fit (CFI .937, GFI .903, RMSEA .084), and therefore all scales were withheld for further analysis.

Table I. Reliability and descriptive statistics (Mean and Standard Deviation) of the scales used for this study.

Measurement		T1 (n=46)		T2 (n=52)		T3 (n=61)	
scale	α	M	SD	M	SD	M	SD
Performance expectancy	.78	$4.17^{a,c}$	1.01	$3.22^{a,b}$	1.39	$4.70^{b,c}$	1.51
Effort expectancy	.61	5.41^{a}	0.97	$4.43^{a,b}$	1.59	5.06^{b}	1.65
Social influence$^{\$}$	.54	6.15	0.89	6.14	1.24	5.96	1.34
Facilitating conditions	.61	$5.40^{a,c}$	0.85	4.50^{a}	1.43	4.87^{c}	1.15
Behavioral intention	.94	6.40^{a}	0.74	5.73^{a}	1.66	6.29	1.33
Frequency of use				5.77^{b}	1.64	6.44^{b}	1.18

Notes: Scale means with the same superscript differ on $p<.05$ (independent samples t-test, 2-sided): ^{a} T1 vs. T2; ^{b} T2 vs. T3; ^{c} T1 vs. T3; $^{\$}$ values obtained after removal of the bad item.

In a next step, the scale means and standard deviations were calculated (Table I). Independent samples t-tests were used to compare scale means. The t-tests showed that all mean scale ratings, except on *social influence*, dropped significantly from T1 to T2, and only the ratings on the *performance expectancy* and *effort expectancy* scales improved significantly from T2 to T3. This means that while the physicians were still learning to work with PACS (at T2), they found PACS less useful and easy to use compared to T1, while they also estimated the provision of *facilitating conditions* to be higher at T1. However, when the physicians had become experienced PACS-users (at T3), they found PACS much more useful and easy to use than at T2. This suggests that the T2 results primarily reflect PACS learning efforts.

Comparing T1 and T3, we see that in general the mean scale ratings were higher at T1, although only significantly for the *facilitating conditions* scale, with one exception: the rating on *performance expectancy* was significantly higher at T3 compared to T1. This indicates that at T1, the physicians overestimated the provision of *facilitating conditions*, while they underestimated the usefulness of PACS.

Other findings that stand out are the high ratings on the *social influence* and *behavioral intention* scales and the moderate ratings on the *performance expectancy* scale. This indicates that the physicians strongly intend to start using the system and that their social environment is very supportive concerning the use of PACS, but also that the physicians are not that convinced that use of PACS will have a beneficial influence on their job performance.

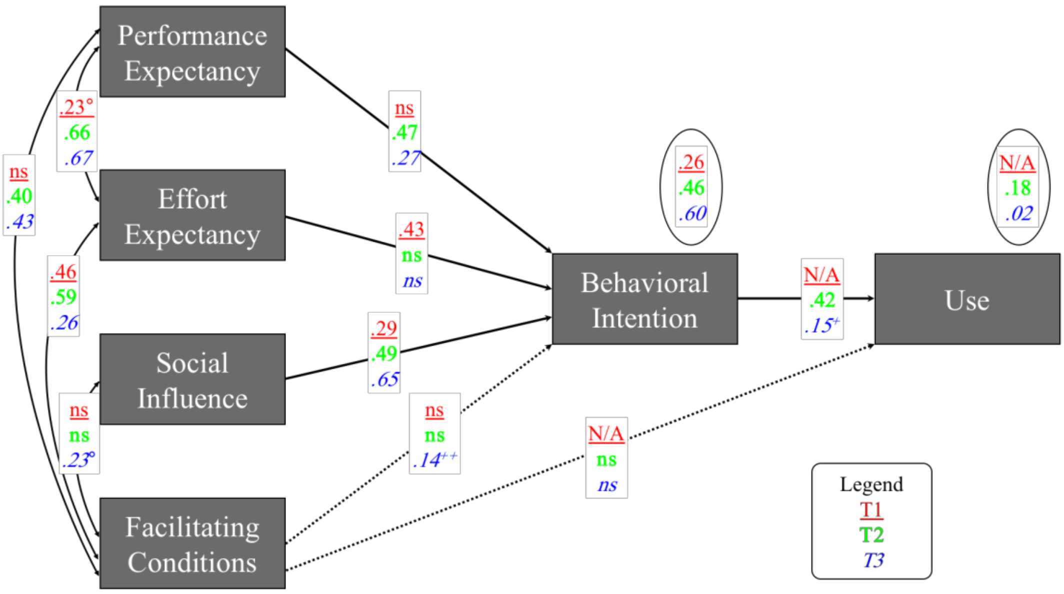
3.2. Research Question 1: explaining acceptance and use

To examine which factors contributed to physicians' acceptance and use of PACS, two models were tested per measurement: the research model (Figure 1) and a final model in which the fit was maximized. These final models are displayed in Figure 2.

3.2.1. At the introduction of PACS (T1)

The path analysis at T1 (Figure 2) revealed that PACS acceptance was primarily determined by *effort expectancy* and *social influence*, while *performance expectancy* and *facilitating conditions* only indirectly influenced *behavioral intention* through their connections with *social influence* and/or *effort expectancy*. Variance explained in *behavioral intention* was rather low (multiple correlation coefficient [mcc] of .26), but the fit parameters of the final model indicated a good fit between model and data (GFI: .952, CFI: .996, RMSEA: .021, normed chi^2: 1.020).

Figure 2. Results of path analysis: standardized regression coefficients (on the arrows) and multiple correlation coefficients (in the ellipses) per time of measurement (T1: top value; T2: middle value; T3: bottom value).



Notes: ns: nonsignificant relationship (p > .10) removed from model to maximize fit; N/A: not applicable; °p < .10; $^{+}$ p = .25; $^{++}$ p = .13; dotted lines indicate hypothesized relationships that were non-significant on all three measurements

3.2.2. Limited experience with use of PACS (T2)

Path modeling at T2 gave rise to a different final model. Now, *effort expectancy* only had an indirect influence on *behavioral intention* through *performance expectancy*, while *social influence* and *performance expectancy* had a strong direct influence on *behavioral intention*. *Facilitating conditions* did not affect *use* and influenced *behavioral intention* indirectly through *performance expectancy*. Variance explained in *behavioral intention* (mcc .46) was higher than at T1 (mcc .26) while *behavioral intention* explained about one fifth of the variance in *use* (mcc .18). The fit parameters of the final model indicated a good fit between model and data (GFI: .959, CFI: 1.000, RMSEA: 0.000, normed chi^2: .762).

3.2.3. Extensive experience as PACS-user (T3)

At T3, *performance expectancy* and *social influence* determined physicians' *behavioral intention* to use PACS, while *effort expectancy* and *facilitating conditions* only indirectly influenced *behavioral intention* through their connections with respectively *social influence* and *performance expectancy*. Variance explained in *behavioral intention* was high (mcc .58), whereas *use* was hardly associated with *behavioral intention* (ß .15, p = .25, mcc .02). The fit-parameters indicated moderate to good fit (GFI: .952, CFI: .976, RMSEA: .081, normed chi^2: 1.390).

3.2.4. Explaining self-reported frequency of use

The path analyses (Figure 2) showed that *behavioral intention* explained only a small part of the variance in *use*, while *facilitating conditions* were not associated with *use*. This low correlation between *behavioral intention* and *use* can be attributed to the overall high average scores on these scales at T2 and T3 (see Table I). So, this low correlation may be due to a ceiling effect in PACS use, which is confirmed by a deeper inspection of the data showing that at T2 26 (50%) and at T3 46 (75%) physicians used PACS daily (= 7).

3.3. Research Question 2: Moderating effect of experience

Table II reports the results of the regression analyses. Only the beta coefficients of the interaction terms, and of the main effect of experience are relevant for research question 2, while regular linear regressions are needed to interpret the interaction effects. No main effect of experience was found indicating that there was no change in acceptance (*behavioral intention*) from T1 to T2, nor from T2 to T3.

Table II. Results of regression analyses, values reported are standardized regression coefficients (ß).

	T1	T2	T3	T1&T2		T2&T3	
				Model 1	Model 2	Model 1	Model 2
Adj. R^2 (in BI)	.25	.45	.63	.39	.45	.53	.54
Sign. R^2 change$^\$$	N/A	N/A	N/A	N/A	p=.01	N/A	p=.15
Experience				.07	.02	-.03	-.02
PE	-.01	.53***	.18	.34**	.62***	.39***	.64***
EE	.39*	-.19	.13	.01	-.21	-.02	-.19
SI	.27°	.48***	.60***	.42***	.52***	.51***	.54***
FC	.05	.16	.14	.15	.17	.12	.15
PE*Experience					-.33**		.33*
EE*Experience					.26*		-.22°
SI*Experience					-.19°		.03
FC*Experience					-.06		.01

Notes: Columns "T1", "T2" and "T3" report ordinary linear regressions; columns "T1&T2" and "T2&T3" hierarchical *linear regressions, with model 1 only direct effects, and model 2 both direct effects and interactions; empty cells depict relationships that could not be tested; $^\$$significance level of the change in R^2 by adding the interaction terms; N/A: not applicable; ***p<.001; **p<.01; *p<.05; °p<.10; BI: behavioral intention; PE: performance expectancy; EE: effort expectancy; SI: social influence; FC: facilitating conditions*

3.3.1. Evolution in the early stages after PACS-introduction (from T1 to T2)

The first hierarchical linear regression revealed one marginally significant (SI*Experience) and two significant (PE*Experience and EE*Experience) interaction effects. These interaction effects can be interpreted in this way: *performance expectancy* was not important at T1 (ß -.01, ns[1]), but became much more important while the physicians gained experience with PACS (ß .53, $p < .001$). *Effort expectancy* on the other hand was estimated to be very important at T1 (ß .39, $p < .05$), but was of no importance at T2 (ß -.19, ns). The marginal significant interaction between *social influence* and experience (ß .21, $p < .10$) indicates that norms concerning the use of PACS became more important as the physicians started using the system. Adding the interaction terms led to a significant increase of variance explained ($F(4,88) = 3.396$, $p = .01$).

3.3.2. Evolution from limited (T2) to extensive (T3) experience

Only one significant interaction effect was found when pooling T2 and T3: the influence of *performance expectancy* on physicians' *behavioral intention* to use PACS decreased significantly (ß -.33, $p < .05$) from T2 (ß .53, $p < .001$) to T3 (ß .18, ns). The marginally significant interaction between *effort expectancy* and experience (ß .22, $p < .10$) indicates that *effort expectancy* becomes more important again when users gain experience; however, *effort expectancy* influenced *behavioral intention* neither at T2 (ß -.19, ns) nor at T3 (ß .13, ns). Adding the interaction terms did not significantly increase the amount of explained variance ($F(4,103) = 1.742$, $p = .15$).

4. Discussion

In this study, hospital physicians' PACS acceptance was assessed at three moments in time during the implementation process. The Unified Theory of Acceptance and Use of Technology was used as the theoretical framework for this study, aiming to address two research questions: (1) what factors influence PACS-acceptance, and (2) do these

[1] ns = not significant (p-value greater than .10)

factors evolve over time. It was found that PACS acceptance was directly influenced by:

- *performance expectancy*: physicians are more likely to accept PACS if they believe that PACS enhances their job performance;
- *effort expectancy*: physicians are more likely to accept PACS if they believe that they will not have to invest a lot of time in mastering the skills required to do so; and
- *social influence*: physicians are more likely to accept PACS if they believe that their social environment encourages use of PACS.

No consensus exists in the literature as to whether *facilitating conditions* influence acceptance directly [18] or indirectly [21]. Although we did not test the direct influence of *facilitating conditions*, strong correlations were observed between *facilitating conditions* and the three other variables, so *facilitating conditions* most likely exert an indirect influence on acceptance.

We also found some evolution over time, especially in the early stages after the introduction of PACS: *effort expectancy* was of particular importance at T1, but lost significance at T2, while the inverse was observed for *performance expectancy*. No such evolution was observed between T2 and T3.

Getting physicians to accept and use PACS is one of the last hurdles implementers or the organization have to overcome [14] in order to succeed. We will now discuss how the findings of our study can help implementers and/or the organization to overcome physicians' resistance and enhance acceptance and use of PACS. This is followed by a discussion of the contributions and limitations of this study, and options for follow-up research.

4.1. Managerial implications

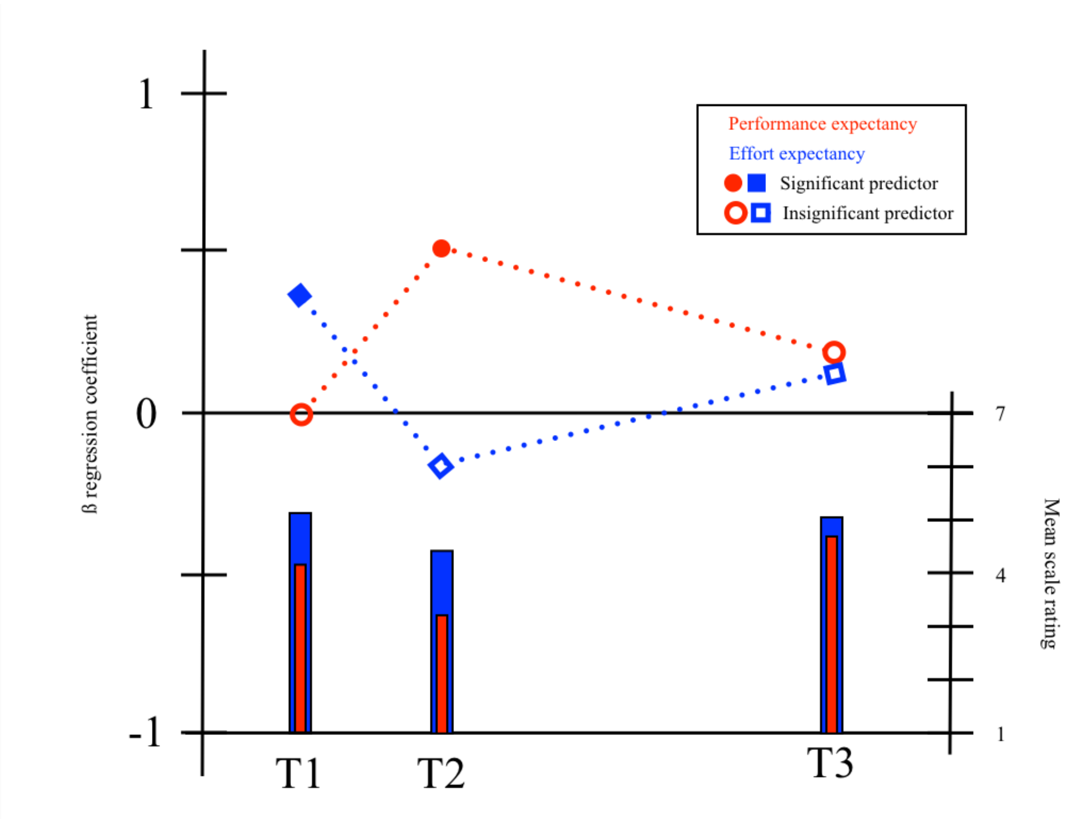
By probing physicians' attitudes towards PACS we aimed to address two questions (see §1.2): (1) what actions to take to speed up PACS-acceptance from the beginning onwards; and (2) when PACS is already in use, how to maximize the use of PACS. These questions are addressed in the action plan below. The assumption underlying this action plan is that physicians see no need to change their workflow to a new way of working.

a. Create an environment in which use of PACS is strongly supported. Although pressuring physicians to (start to) use a technology could lead to adverse reactions [37], In the organization under study, strong pressure to (start to) use PACS was exerted, and this positively effected PACS acceptance.

b. Adjust training strategy while physicians are still learning to work with PACS. Major shifts in significance were found between T1 and T2, but not between T2 and T3; and only the significance level of *performance* and *effort expectancy* varied depending on the time of measurement (see Table II). Therefore, at the introduction of PACS, training should be focused on ease of use (*effort expectancy*), thus on mastering the "basic" tasks, the tasks that physicians already perform on radiological images on the negatoscope. Training should then gradually shift to increasingly harder tasks involving advanced functionalities that make the true gain of PACS. In the setting under study, an opportunity was missed to maximize acceptance and use of PACS as illustrated in Figure 3. In Figure 3, the observed mean scale ratings (Table I) on *performance* and *effort expectancy* are coupled to the corresponding ß standardized regression coefficients (Table II), per time of measurement. We found that despite the strong influence of *performance expectancy* on *behavioral intention* at T2, physicians' mean rating on *performance expectancy* was quite low (M=3.22). So the organization or implementers should have focused on highlighting the usefulness of PACS: a theoretical increase of *performance expectancy* by one unit would result in an increase of .63 on *behavioral intention*.

c. Provide *facilitating conditions*. We did not explicitly investigate the causal effect of *facilitating conditions* on the other independent variables, as proposed in [21]. Yet, from the correlations we can conclude that setting up a good training program and providing adequate support and compatible systems should positively influence perceptions of system usefulness (*performance expectancy*) and ease of use (*effort expectancy*), while physicians would also feel more supported and encouraged by their social environment to use PACS. Which would ultimately lead to an enhancement of physicians' acceptance of PACS.

Figure 3. Graphical representation of the mean scale ratings (bars; for exact values see Table II) and beta regression coefficients (squares and circles) of performance (in red) and effort expectancy (in blue) per time of measurement.



Note: dotted lines connecting the squares and circles do not imply linearity, but were inserted for clarity and aesthetic reasons

4.2. Study contributions

As stated in §1.5, our study should contribute to the literature in three respects: (1) come to a better understanding of the factors that influence physicians' acceptance of a CIS, in this case PACS; (2) gain insight into the dynamics underlying acceptance by taking multiple measurements; and (3) give insight in the acceptance process in a private hospital.

4.2.1. **Factors influencing physicians' acceptance of PACS**

The Unified Theory of Acceptance and Use of Technology was used as a theoretical framework, and as stated above, three out of four constructs directly influenced physicians' *behavioral intention* to use PACS, while *facilitating conditions* might exert an indirect influence.

4.2.2. Multiple measurements

By taking multiple measurements, we found that the determinants for physicians' acceptance of PACS vary over time. This was especially the case in the early stages after the introduction of PACS.

4.2.3. Private (vs University) setting

The findings of this study differ remarkably from previous studies that identified *perceived usefulness* or *performance expectancy* as the main driver for physicians to accept and use a CIS [13, 23-30]. As pointed out by [6, 24], private and public hospitals differ fundamentally in several respects, for instance in terms of staffing, IT infrastructure and education. The focus in private hospitals is rather on the impact of a technology on raising efficiency: in the hospital under study, physicians are paid on a fee-for-service basis and therefore using a new technology should be as effortless and fast as possible, hence the primary importance of *effort expectancy*. In a university setting such as in [10], where physicians receive a fixed salary and in which a physician should fulfill, next to caring for and curing patients, other duties (such as educating physicians in training, and participating in scientific research); the applicability of a technology is evaluated in a wider perspective, e.g. in respect to its added value as a training or instruction tool, hence the primary importance of *perceived usefulness* or *performance expectancy.* Moreover, with respect to *facilitating conditions*, it is worth mentioning that the physicians in this setting were responsible for acquiring their own personal computers on which they had to consult PACS. This is not always the case in university hospitals, e.g. [10]. These differences offer a plausible explanation for the divergent results obtained in this study, which is the first to investigate PACS acceptance in a private hospital.

4.3. Limitations

The main limitation of this study pertains to the relatively low number of respondents, necessarily associated with the relatively small population in this setting. Fortunately, the response rate (25-30%) was comparable to or higher than in other studies involving hospital physicians [24-26, 28-32], so that we may be confident about the validity of our results. A larger number of respondents would also have benefited scale reliability. Another limitation of this study lies in the tradeoff between social desirability and the degree to which evolutions may be traced among participants. In order to avoid socially desirable answers (e.g. caused by hospital management pressure), questionnaires were taken anonymously, leading to a cross-sectional instead of a longitudinal design.

Although we estimate that our study led to some valuable insights, a longitudinal study is better in dissociating experience effects from between-subject variability.

4.4. Directions for further research

This study also raised some issues that can be addressed in follow-up research. First, the differences between our study and previous studies were striking and can possibly be attributed to differences between private and public hospitals [6, 24]. As most studies are performed in university or teaching hospitals, more research should be performed in private hospitals, or preferably even comparing both types of settings.

From a theoretical point of view, our study also raised questions concerning the operationalization of user acceptance. We found a ceiling effect when trying to explain *use*. It is of course an excellent finding that such a large proportion of the physicians used PACS daily, but use of PACS was mandatory so they had no other option than to use PACS to perform their job. The necessity of PACS use (does a physicians use PACS whenever possible, or only if absolutely necessary) is at this time not taken into account. So, follow-up research should aim at identifying alternatives for self-reported frequency of *use* in which the necessity of a technology is taken into account.

5. Conclusion

In this study, physicians' acceptance of PACS was assessed on three occasions in a private hospital. Findings differed heavily from similar studies in university hospitals. First of all, *social influence* was identified as a major influencing variable: pressuring physicians to use PACS in this case positively effected PACS-acceptance. Second, physicians primary focus was on ease of use while usefulness of PACS became only later important.

When introducing PACS in a private hospital, the organization or implementers should create an environment in which use of PACS is strongly supported. Training should first focus on the tasks a physician already performs, introducing only later on the more advanced functionalities that make up the true gain of a PACS.

Our study demonstrated the added value of taking multiple measurements. It should be an onset to deeper research into the differences between private and university settings.

Author contributions

BP contributed to the design of the study and to all aspects of data acquisition, analysis and interpretation. He coordinated between the authors and prepared the final manuscript.

PDe contributed to the design of the study and the processing of the questionnaires, and in revising the first drafts of the final manuscript.

WD and JvB contributed to the analysis and interpretation of the data, and in the preparation of the final manuscript.

BS contributed to the reinterpretation of the data and in reviewing and revising the final manuscript.

PDu led the conception and design of the study, and critically revised the first drafts and final manuscript.

All authors approved the final version of the manuscript.

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Conflicts of interest statement

No conflicts of interest occurred

***Summary points**

Summary table

What was already known	What this study added to our knowledge
* physicians' acceptance of clinical information systems is mainly determined by the technology's usefulness * only few studies investigate physicians' acceptance of PACS * most studies take a one-shot approach	* the main driver for physicians to start using PACS is *effort expectancy* and not *performance expectancy* * it is important that physicians feel supported by their social environment concerning their use of PACS * taking multiple measurements uncovers some dynamic underlying physicians' acceptance of PACS * the factors influencing PACS acceptance vary over time and are especially in the early stages after the introduction susceptible to changes.

Research highlights

- PACS' ease of use is the main driver for physicians to start using PACS
- The drivers for PACS acceptance vary over time
- Support by peers and hospital management is very important for PACS-acceptance
- Focus training first on basic tasks; introduce advanced functionalities gradually
- Multiple measurements uncover dynamics underlying acceptance process

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