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Going Mobile: An Empirical Model for Explaining Successful Information Logistics in Ward Rounds

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Abstract. Background: Medical ward rounds are critical focal points of inpatient care that call for uniquely flexible solutions to provide clinical information at the bedside. While this fact is undoubted, adoption rates of mobile IT solutions remain rather low. Objectives: Our goal was to investigate if and how mobile IT solutions influence successful information provision at the bedside, i.e. clinical information logistics, as well as to shed light at socio-organizational factors that facilitate adoption rates from a user-centered perspective. Methods: Survey data were collected from 373 medical and nursing directors of German, Austrian and Swiss hospitals and analyzed using variance-based Structural Equation Modelling (SEM). Results: The adoption of mobile IT solutions explains large portions of clinical information logistics and is in itself associated with an organizational culture of innovation and end user participation. Conclusion: Results should encourage decision makers to understand mobility as a core constituent of information logistics and thus to promote close end-user participation as well as to work towards building a culture of innovation.

Keywords. mHealth, Organizational Culture, Diffusion of Innovation, Patients' Rooms, Clinical Rounds, Electronic Health Records

1. Introduction

Ward rounds are uniquely information intense workflows as they are arguably the most important focal points for medical decision making in secondary care [1,2]. This poses unique challenges to hospital IT-systems in terms of flexible and effective information provision in close proximity to the point of care. It also holds promises with respect to efficiency gains [3], enhanced access to information [4] and increasing quality of care [5]. Meeting key requirements of successful clinical information logistics [6] in ward rounds in terms of providing the right information for the right person, at the right time and in the right quality, requires innovative and mobile IT solutions to be applied. Although there has been rising adoption and increased attention in research towards mobile solutions following the society-wide uptake of tablet and smartphone usage, adoption rates in hospital settings remain surprisingly low [7]. This poses questions about their efficiency and usefulness in clinical environments. Benefits might be considerably hampered by negative externalities such as distractions from physician-patient interactions [8,9], usability issues [4] as well as security concerns that might outweigh potential benefits.

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In accordance with modest adoption rates, workflow support through IT in ward rounds is often perceived significantly poorer compared to other clinical core processes such as clinical admission and pre- and post-surgery workflows or discharge [10]. Thus, we were interested in researching current adoption rates of mobile IT solutions in ward rounds across hospitals in the DACH-region (Germany-Austria-Switzerland) and in investigating the association between adoption rates and the perceived quality of workflow support from a user perspective. Successful clinical information logistics was thereby regarded as the manifestation of effective workflow support [11].

We furthermore aimed at gaining insights on how hospitals can bring innovative health IT such as mobile IT solutions into practice, i.e. what socio-organizational factors distinguish adopters from non-adopters. In times of increasingly fast innovation cycles in health IT, hospitals need to be able to flexibly adopt innovations within clinical workflows in order to be able to deliver high quality care and stay competitive [12]. Building on previous works we specifically considered the degree of user participation in the different stages of IT projects (in strategy development, implementation, evaluation etc.) and an innovation-friendly culture created by the top management to be possible antecedents of higher adoption rates of mobile IT solutions as both are regarded as key components of an organization's innovation capabilities [13-15]. The main goal therefore was to elaborate and test a generalizable framework from a user perspective that maps out preconditions and consequences of mobility and successful information logistics in ward rounds on a large scale.

2. Methods

2.1. Material

Data used in the analyses were obtained in the context of the international initiative "IT Report Healthcare" that aimed amongst others to assess the perceived IT-usage, IT-workflow-support, IT-quality and engagement of clinical staff in IT-projects. Most items were developed on the basis of existing surveys and scales [10,13,16] whereas scales for measuring information logistics in ward rounds as well as indicators of participation were newly developed and pretested in two iterations by a total of 14 experts (including health IT scientists, statisticians, management researchers, executive health professionals and one psychologist). The questionnaire targeted clinical users in German, Austrian and Swiss hospitals. In order to yield an overview of the entire hospital, the medical and nursing directors, as representatives of their hospital, were asked to provide answers that represent the prevailing view of the front-line clinicians. Data were collected via an online questionnaire between June and September 2017. We received fully completed responses from 373 out of a total of 2421 hospitals contacted (response rate: 15.4%). 85.2% of responses came from Germany, 7.0% from Austria and 7.8% from Switzerland.

2.2. Data Analysis

Since we aimed at statistically explaining both, antecedents and consequences of mobile IT solutions in order to work towards a comprehensive and more generalizable model, we applied structural equation modelling (SEM). SEM is the most common family of statistical methods available for testing complex cause-effect relationships, especially when latent variables (i.e. variables, that are not directly observed) are involved [17].

The model was specified to explain the variance in the endogenous variable "mobility" by the degrees of "innovation culture" and "participation" as well as to explain the variance in "clinical information logistics" by all other variables through direct and indirect effects, mediated by the degree of mobility (Fig. 1). All four variables were specified as latent variables, reflected by their respective indicators from the survey (Tab. 1). Thus, four reflective measurement models were combined in one structural model.

SEM offers a variety of possible techniques and algorithms with covariance-based SEM (CB-SEM) techniques being the most common [18]. CB-SEM has a primarily confirmatory character in that it focusses on model-fit and is therefore mostly used to test and confirm existing models within theory development. In contrast to CB-SEM, variance-based SEM, known as partial least squares (PLS-SEM) has a stronger focus on predicting target constructs and on the identification of key drivers with a more exploratory character [19]. However, in recent years a modified algorithm based on PLS has been developed that produces results largely consistent with CB-SEM, called consistent partial least squares (cPLS-SEM) which is increasingly gaining popularity [20]. We decided to apply cPLS-SEM to our data since it is also known to be advantageous in that it does not require multivariate normality and tolerates ordinal scaled data [21].

In order to assess the reflective models, the latent constructs "innovation culture", "participation", "mobility" and "clinical information logistics" were tested for reliability as well as convergent and discriminant validity using Cronbach's α, congeneric reliability (CR), the average variance extracted (AVE) and heterotrait-monotrait ratios of correlations (HTMT) [21]. Relations within the structural model were investigated based on the direct, total and indirect effects with p-values and confidence intervals obtained from 1,000 bootstrap replications. All analyses were performed using *SmartPLS (v. 3.2.7)*.

3. Results

The responses from our participants show that the adoption rates of mobile IT solutions in hospital still seem to have room for improvement (Tab. 1) – especially in Germany. On average, respondents indicated about 50% of the clinical units to have Wi-Fi available (GER: $\bar{x}$ = 45.7% ± 41.7%; AUT: $\bar{x}$ = 66.2% ± 40.1%; CH: $\bar{x}$ = 80.0% ± 34.2%) and that 45% of hospital wards have mobile access to patient data (GER: $\bar{x}$ = 41.7% ± 42.3%; AUT: $\bar{x}$ = 64.0% ± 41.2%; CH: $\bar{x}$ = 77.6% ± 37.7%) - although on average only 3.54 (out of 10) patient data types[1] (GER: $\bar{x}$ = 3.3 ± 4.0; AUT: $\bar{x}$ = 4.4 ± 3.9; CH: $\bar{x}$ = 5.5 ± 4.4) were reported to be accessible on mobile devices. About 20% of the surveyed hospitals reported to have at least eight data types available and therefore seemed to have implemented more comprehensive solutions.

[1] Patient identity data, case data (diagnosis and therapy codes), orders, results (text), results (images), results (electrophysiology), kardex with medication and vital signs, warnings, check lists, others

Table 1. Indicators & descriptive results (n = 373). [a] Likert-Scale (1 = "strongly disagree, 2 = "disagree", 3 = "neutral", 4 = "agree", 5 = "strongly agree"). [b] 1 = "no participation at all" … 10 = intensive participation". [c] composite scores, ranging from 0-10.

Code	Question	Sub-question	x̄	SD
IC1	Please indicate your (dis-) agreement with the following statements.[a]	"Our executive board actively promotes the initiation of innovative IT projects."	3.54	1.13
IC2		"Our executive board regularly perceives IT as a mere expense factor."	2.60	1.12
IC3		"Our hospital shows great agility and flexibility when it comes to implementing new IT solutions."	3.08	1.17
IC4		"Our hospital has a well-defined future vision that is shared by the IT department."	3.33	1.19
IC5		"We usually take IT into account when working on new medical or nursing related projects."	3.41	1.06
IC6		"There is a culture of tolerance in our hospital when dealing with mistakes and failing projects."	3.48	0.93
IC7		"Our IT is capable to react quickly in face of changing requirements."	2.77	1.08
IC8		"We openly communicate and discuss new IT projects in our hospital among all involved staff."	3.22	1.08
IC9		"Our executive board explicitly demands ideas and suggestions on how to innovate our IT."	3.04	1.09
Par1	Please indicate the degree of participation of clinical staff (e.g. physicians or nurses) in issues concerning your hospital information system. Degree of participation…[b]	…in strategy development?	5.39	2.53
Par2		…in identifying and defining clinical requirements for IT applications?	5.60	2.48
Par3		…in evaluating and selecting IT applications?	5.05	2.60
Par4		…in the implementation process?	5.88	2.64
Par5		…in developing and conducting teaching and training during the implementation phase?	6.04	2.73
Par6		…in teaching and training of new staff after implementation?	6.01	2.78
Par7		…in evaluating and modifying IT applications?	5.20	2.77
Mob1	What patient data are accessible on mobile devices during ward rounds?[c]		3.54	4.12
Mob2	Which devices (hardware) are available for documenting and processing patient data?[c]		2.75	2.67
Mob3	In how many clinical units (in percent) is Wi-Fi available (Wi-Fi coverage)?		49.83	4.22
Mob4	How many wards (in percent) have mobile electronic access to their patient data?		44.80	4.30
CIL1	Please evaluate the quality of electronic information provision during ward rounds. The required clinical information is…[a]	…available at the right place.	3.31	1.51
CIL2		…available for the right person.	3.71	1.38
CIL3		…correct and complete.	3.51	1.31
CIL4		…legible and clear.	3.87	1.33
CIL5		…up-to-date.	3.86	1.28
CIL6		…being made available in a timely manner.	3.68	1.31
CIL7		…provided in a user-friendly manner.	3.17	1.38
CIL8		It takes a reasonable time to compile the relevant information.	3.22	1.35

Construct reliability and validity of the four specified latent variables proved to be overall satisfactory with reliability measures (Cronbach's α & congeneric reliability) well above the common thresholds and with more than 50% average variance extracted from the reflective indicators (Tab. 2) [22]. Also, heterotrait-monotrait ratios of correlations between all latent variables fell well below 0.85 and therefore indicated sufficient discriminant validity between the latent variables [17]. Relatively high factor loadings in all measurement models underpinned their validity (Fig. 1). Whereas values for "participation", "mobility" and " clinical information logistics" were very good, the construct validity and reliability of "innovation culture" showed to be lower, yet measures lay above common thresholds of acceptance [21]. The specified reflective constructs can thus be confirmed in our data.

Table 2. Construct reliability and validity (n = 373)

Latent Variable	Cronbach's α	Congeneric Reliability	Average Variance Extracted
Innovation culture	.76	.82	.51
Participation	.94	.94	.70
Mobility	.93	.93	.76
Clinical information logistics	.96	.96	.75

Figure 1 displays significant direct effects between all domains except for the prediction of "clinical information logistics" by "participation", which only showed an indirect significant effect through the degree of "mobility" (Tab. 3). The strongest associations appeared between "mobility" and "clinical information logistics" with a ß-coefficient of .45 and between "innovation culture" and "clinical information logistics" (ß = .40) whereas the latter effect was mostly mediated by "mobility".

Table 3. Total and indirect effects with bias corrected 95% confidence intervals (CI) from bootstrapping. Legend: IC – innovation culture, MOB – mobility, PART – participation, CIL – clinical information logistics

			95% CI		
	Path	Coefficient	Lower	Upper	p-value
Total Effects	IC → MOB	.32	.15	.52	< .001
	PART → MOB	.24	.05	.41	< .01
	MOB → CIL	.45	.36	.53	< .001
	IC → CIL	.40	.21	.54	< .001
	PART → CIL	.23	.07	.38	< .01
Indirect Effects	PART → MOB → CIL	.11	.02	.19	< .01
	CIC → MOB → CIL	.15	.07	.25	< .001

Almost one third of the variance in "mobility" can be explained solely by "innovation culture" and the degree of "participation". About half of the variation in "clinical information logistics" could be explained by all other latent variables, mostly by the degree of "mobility" (Fig. 1). The standardized root mean residual (SRMR) value of 0.05 indicated furthermore a satisfactory model fit to the data [23].

Despite considerable differences in the adoption rates of mobile IT solutions across countries, the model parameter did not change when excluding the Austrian and Swiss hospitals from the sample. Calculating the model with data only from Austria and Switzerland without Germany was not warranted due to insufficient sample sizes (n(AUT) = 26; n(CH) = 29) [24].

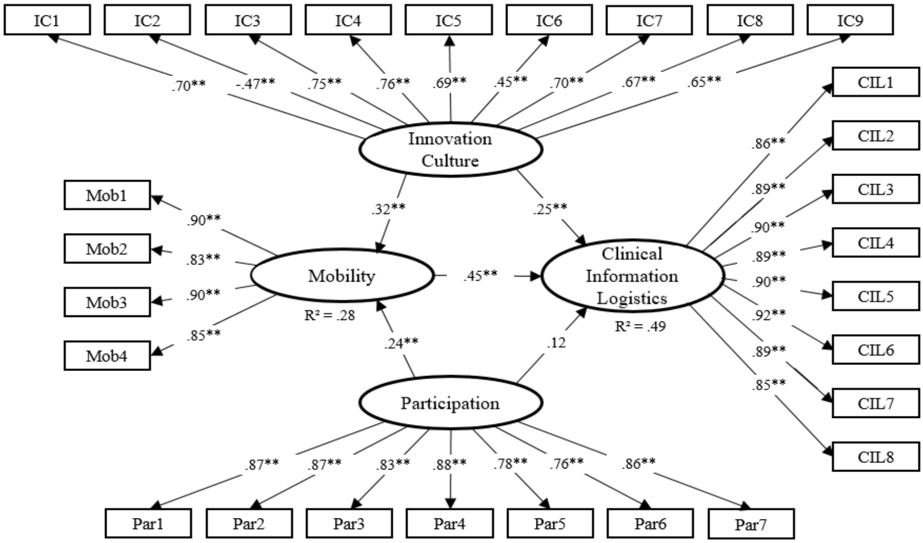

Figure 1. Structural model (n = 373, standardized root mean residual (SRMR) = .05; **p<.01)

4. Discussion

We found adoption rates of mobile IT solutions in ward rounds to still be on a rather low level across hospitals in the DACH-region. While on average, about 45% of hospital wards potentially seem to have mobile access to patient data, not all patient data are available electronically, suggesting that many hospitals still use a combined approach of paper based and electronic solutions. The widespread availability of mobile devices also seems to be calling for improvements. Adoption rates of mobile IT solutions appear to be higher in Austrian hospitals and especially in Switzerland where respondents reported that on average 78% of the hospital wards have mobile access to patient data. Those differences go hand in hand with results from international eHealth-benchmarks that report comparable differences between the three countries [25-27].

Against the background of these deficits, the question arises as to how improvements can be made possible. The results of this structural model provide a contribution to better understand what mobility actually is and how it can be facilitated – from a users' perspective. First, it clearly demonstrates that the implementation of mobile IT solutions in hospitals is not an end in itself but determines successful information provision, i.e. "clinical information logistics", which is one of the grand goals of health IT in itself. "Clinical information logistics", the more abstract umbrella term, can be tied to the presence of mobile IT solutions (ß = .45), something that every user can experience. Mobility thus is to a significant part the tangible manifestation of "clinical information logistics" in ward rounds. Second, "mobility" in combination with "innovation culture" can explain 49% of the variability in "clinical information logistics", which is quite a considerable proportion given that only the users' perspective was taken into account. This finding demonstrates a powerful mechanism, i.e. innovation culture pervading the organization, to explain "clinical information logistics". Third, this powerful force is an enabler of "mobility" itself. Together with "participation", it seems to drive "mobility". Both concepts are at work when mobility has to be achieved in that innovation culture initiates and shapes the necessary steps by the organization's spirit in a top-down fashion and is then ideally accompanied by comprehensive end-user involvement from the bottom up. Mobile ward round scenarios closely touch on the clinicians' daily work practice. It therefore seems plausible that close participation of end users across different stages of implementation is positively associated with higher degrees of mobility. The positive influence of both factors corresponds to similar findings that emphasize the importance of organizational culture and user involvement for successful implementation of health information technologies as such [14,28]. This study specifies these general findings focusing on the crucial areas of mobility and clinical information logistics and thus eventually on information continuity. Creating "mobility" itself requires "participation" and an organizational "innovation culture".

According to the measures of reliability and factor loadings we can overall confirm that the hypothesized constructs (i.e. latent variables) seem to be well reflected by their respective indicators. This, together with a satisfactory model fit and acceptable discriminant validity measures, suggests that there are no crucial misspecifications in our model. Although "participation" was operationalized differently in preceding works [13], this factor again demonstrates its internal consistency and substantial relevance. In contrast, reliability measures of "innovation culture" might be improved by removing some variables.

Given that this study represents the users' perspective some portions of the construct "mobility" remain unexplained with the chosen model specifications which opens the door to other possible factors to consider. They include variables of the organization and its approach to deploy and maintain IT technology such as professionalism of management structures or processes, financial power, IT-service quality, legal regulations and health IT vendors [14]. Demographic covariates (i.e. hospital size, ownership and teaching status) are –amongst others– known to be influencing health IT adoption rates [12,29], but lay beyond the scope of this model. Those factors could be accounted for in future model extensions that look beyond organizational "innovation capabilities". The main limitation stems from a modest response rate that might have caused a self-selection bias. However, the relatively large sample size mitigates that effect.

While adoption rates of mobile IT solutions in German, Austrian and Swiss hospitals are yet to be improved, this study is one of the first to empirically demonstrate the clear connection between mobility and clinical information logistics and provides evidence that an organizations' innovation culture and the degree of participation seem to drive mobile health IT innovations. The results should encourage decision makers including chief information officers to promote close participation of end users in all phases of project management as well as to work towards building a culture of innovation.

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