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Recognizing Patient Safety Importance through Instrument Validation on Physicians' Assessment of an EHR

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Abstract

Patient safety and high quality patient care are critical concerns for healthcare providers. The Institute of Medicine report suggests medical errors account for up to 98,000 patient deaths each year. Therefore, the US healthcare system is looking to information technology applications as one means of making patient care safer.

This paper compares the psychometric properties of the Electronic Health Record Nurse Satisfaction instrument (based on the Health Information Technology Research-based Evaluation Framework) to our study that employed the same instrument but measured clinical physicians' opinions of an EHR to determine if the instrument could be used across domains of users.

Our results found the factor analysis and the clustering of the sub-scale items were different. We propose a two-factorial instrument that identifies the following dimensions: System Features/Performance and Data Quality/Accuracy. Another important contribution of this study is that patient safety was identified as a more salient indicator for physicians.

1. Introduction

Patient safety and high quality patient care continue to be critical concerns for healthcare providers. The Institute of Medicine report suggests medical errors account for up to 98,000 patient deaths each year in the US. Therefore, the US healthcare system is looking to information technology applications such as electronic health record systems as one means of making patient care safer, more efficient, affordable and accessible [1].

Information Technology (IT) can often improve patient safety by alerting clinicians when there are potential errors or inconsistencies in the patient care plan. Physicians are critical users and leaders in the healthcare environment whose satisfaction often determines technology acceptance and success. Many physicians are positive about the use of IT, believing that it has the potential to improve patient care and safety. However, there is still much to learn and understand about the level of satisfaction physicians have towards IT applications and how these applications can further improve healthcare delivery.

In general, the level of user satisfaction with information technology has widely been accepted as an indicator of IT success [2]. Further, research indicates satisfaction is one of the main factors for electronic health record adoption [3]. Physicians are significant users of information technology applications, such as the Electronic Health Record (EHR). There continues to be a need for improvement of physician satisfaction with EHRs [4]. Satisfaction in this case refers to physician perceptions, attitudes and opinions with EHR on clinical process [5]. Evaluating and identifying ways to enhance IT application to improve physician satisfaction is a challenge because there are limited physician satisfaction evaluation instruments available that are well-matched to the complex healthcare environment [6].

To address these challenges, frameworks such as the Health Information Technology Research-based Evaluation Framework (HITREF) were developed [7]. Based on the HITREF framework, instruments for evaluation of EHR systems were proposed. One recent instrument is the Electronic Health Record Nurse Satisfaction (EHRNS) instrument [5]. In order for this instrument to be widely utilized it is natural to validate the instrument further. Instrument validation studies are important because they 1) analyze the psychometric properties (reliability and validity) of an instrument and consequently the degree of confidence that can be placed in assertions based on that instrument and 2) document the results.

The aim of this study is to validate the Electronic Health Record Nurse Satisfaction instrument and examine if it is appropriate for evaluation of physicians' satisfaction of EHRs. In our research we examine the reliability and validity of the EHRNS instrument.

The paper begins with a brief introduction of instrument validation techniques. Next, an overview

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of the EHRNS instrument is presented. The paper continues with a discussion of the psychometric details of the ERHNS instrument which were used to evaluate the nurses' satisfaction of an EHR system. Then, our study analyzes the psychometric results of the instrument from our field study and compares the two user domains: nurses and physicians. The paper concludes with the implications from the results.

2. Background

In this section we discuss the instrument validation techniques and describe the EHRNS instrument that we are validating.

2.1. Instrument validation techniques

The importance of validating an instrument is emphasized by [6]. The validation process allows for reduction of measurement errors and a measurable increase in validity, and should be considered essential in the use of a survey instrument. Specifically, this research uses construct validity and reliability [9] to evaluate the validity of the EHRNS instrument for evaluation of physician satisfaction in EHR.

The validation process of an instrument involves the measurement of two critical characteristics: validity, which measures the ability of the instrument to actually measure the desired response, and reliability, which measures the precision and accuracy of the measurement itself [9]. An instrument cannot be considered to be valid without being reliable; it can also be invalid if it is reliable [8]. Reproducibility is considered to be an indicator of reliability – an unstable instrument reflects the inability of the results to be reproduced.

Assessing validity for this instrument involves evaluating construct validity, or the relationship between the results of the instrument and the inherent meaning given to those results [11]. The goal of evaluating construct validity includes determining whether patterns in the results reflect the true meaning of the results themselves or whether the results are an artifact of the instrument itself [6]. It is possible for an instrument to sway results unintentionally instead of measuring the desired concepts [9]. To test construct validity, factor analysis is often employed to evaluate the instrument [11]. Factor analysis is a statistical procedure that identifies clusters of related variables (in this research, related survey items/responses) using correlation [8]. This technique provides a framework for how instrument variables may be related and thus grouped together to reflect common hypothetical constructs, possibly making the instrument more palatable. Typically, factor analysis is able to identify groups of related variables due to correlated variance, making it easier to selection of one or more variables as independent if they exist, reducing odds for observing multicolinearity [8].

Finally, reliability is a measure of the methodology itself, reflecting the stability and consistency of results [9]. Once load analysis identifies the relationships between variables as clusters, reliability is able to measure internal consistency between the variables in these groups. This is typically assessed with Cronbach's alpha, which is a measurement of consistency between inter-cluster correlations; this test estimates how well the set of variables are described by the proposed clustering [10].

2.2. Electronic Health Record Nurse Satisfaction (EHRNS) survey instrument

The Electronic Health Record Nurse Satisfaction (EHRNS) survey instrument is intended to measure nurse satisfaction with EHR impact on clinical process [5]. The EHRNS instrument is based on the Health Information Technology Research-based Evaluation Framework (HITREF) which updated and expanded the previously published review by [5]. It was developed from a review of 128 EHR evaluation studies [12] evaluating the impact of EHRs.

[5] described a 22 item instrument to evaluate opinion on EHR systems from the nursing community. The goal of this study is to test the construct validity and reliability of this instrument for evaluating opinion of the electronic health record system by physicians. Specifically, the tests that will evaluate the ability of the instrument to accurately record the opinions will include tests of validity and reliability, which describe the instrument's ability to measure the desired subject (in this case, opinion). The proposed pilot test of the instrument in physician opinion will allow for evaluation of the instrument as a viable option or for proposal of a modified instrument outside of the nursing community.

Factor analysis was used to test the validity and reliability of this 22 question instrument. The instrument was administered via 22 questions, all using a 6 point Likert-scale. For this particular instrument, [5] proposed 6 subgroups for the 22 variables:

1. Structural quality
2. Quality of information logistics
3. Effects on quality of processes
4. Effects on outcomes and quality of care
5. Unintended consequences/benefits

6. Barriers/facilitators adoption

Structural quality refers to the quality of the hardware, software, and organizational support. The "structural quality" dimension consists of four items: system availability, infrequent system problems, user friendly and sufficient support.

The *quality of information logistics* measures the quality of the data, whether the system is worth the effort to use it, confidentiality of the system and patient satisfaction with the use of the system. In addition, *overall satisfaction* with the system and the time and effort value placed on the EHR system are measured.

The *effects on quality of services* dimension relates largely to communication, including efficiency or timeliness of patient care, appropriate patient care orders driven by the system, communication of the entire team, communication of clinicians, and satisfaction with involvement of clinicians and related workers in developing the system.

The *effects of outcomes and quality of care* dimension focuses mainly on the impact of the system on patient care outcomes and health system outcomes. This dimension also includes consideration for costs, presumably to weigh the ultimate intended goal (patient safety and care) versus the cost of the system.

The two remaining dimensions, *unintended consequences* considers the clinicians' perception of the unintended changes the system can introduce on patient care, whether these changes are positive or negative. *Barriers or facilitators to clinician adoption* considers perceptions of barriers or facilitators to system adoption. There were two variables/items mentioned ('Features enable me to perform my work well' and 'Sufficient Resources') that were not clearly attributed to one of the six dimensions and as such they remain uncategorized in Table 1.

Two other important measurement questions in the EHRNS instrument are patient safety and physician satisfaction. [5] included these questions in the dimensions; however, it may be possible to consider these questions as independent variables. This proposed change is based on other studies that measure the success of an EHR system based on perceived physician satisfaction and patient satisfaction.

3. Research methodology

To reiterate, the goal of this study is to examine the validity and reliability of the instrument described for evaluating nurse satisfaction by [5] as a tool for evaluating physician EHR satisfaction. Our study in physician satisfaction with EHR, also known as "Physician Satisfaction Survey" or PSS, was conducted and the instrument was consequently evaluated for construct validity and reliability. The demographic information questions were converted to open entry questions and presented at the beginning of the survey. The survey format was replicated exactly from the EHRNS survey instrument form for the 22-question 6-point Likert scale question to the Survey Monkey format. The only modification to the survey was to the open ended question "*What worked well or what are your concerns related to the system?"* was converted to two questions: 1) What worked well related to the Electronic Health Record System?; 2) What are your concerns related to the Electronic Health Record System?

3.1. Field study

The participants in the field study were identified as physicians representing various different specialties in a Midwest medical center setting. The hospital is a member of a large Catholic healthcare system in the US. The specific hospital is a 272 bed tertiary facility. The survey was administered to the entire population of employed physicians in the medical center. The selection of physicians included representation from Pharmacists, Hospitalists, Family Practice Residents, Pharmacy Residents, Family practice clinics, Pathologists, Wound Care, Internal Medicine, Cardiology, and Emergency Medicine.

3.1.1. Data Collection

The data collection process consisted of an email invitation sent directly to the participant's email account. A Survey Monkey link was presented in the email invitation to enable the participant to access the survey instrument. The hospital directors and/or clinic managers were informed of the survey and requested to encourage participation and were advised of all survey activity. Prior to administering the survey, an Institutional Review Board examined the questions and the survey administration protocol. All institutional procedures were followed for data collection.

3.1.2. Response Rate

Out of the 96 physician invitations sent, 73 respondents voluntarily participated in the survey. There were 29 female respondents and 44 male respondents. Observations from 5 medical students were excluded due to "student" status and lack of

experience in the field. In the final 68 respondent dataset, there were 24 female and 44 male respondents. Truncated and missing data were handled and removed if necessary by SPSS; terminal observations ranged from n = 58 to n = 63, which meets the minimum count required recommended by [14] and [15]. These observational counts, while considered low, meet the minimum requirements for an acceptable factor analysis [16]. The average age of a respondent was 43.597 with a median of 41 and a mode of 42. Of the 68 respondents, 60 noted they had previous experience outside their facility with EHR or computerized entry systems, with an average of 5.62 years in healthcare experience of the 58 who responded with their time spent in healthcare.

4. Results

4.1. Validity and Reliability of the EHRNS Instrument

There are a number of assumptions that need to be met before factor analysis can be performed and accepted as an appropriate measure of instrument validity [17]. Analysis was performed in SPSS version 21.0.0.0 using a correlation matrix; no missing or truncated data was used, nor were outliers included in any of the item responses. Each of the 22 variables was found to meet univariate normality standards. Extraction was performed using Principal Axis Factoring, using the accepted standard of extracting factors with only Eigenvalues greater than 1. Orthogonal rotation was performed with using the Varimax option to maximize the spread of loading variance across factors.

When changing the scope of any instrument, one must consider if the instrument is a proper method of evaluation for a new audience – in this case, will the same instrument measure satisfaction in physicians as intended for nurses? To answer this question, a factor load analysis was performed to determine if the responses of physicians grouped similarly to the instrument proposed by [5]. The 22-question EHRNS instrument as applied to the data collected from physicians met a handful of assumptions required for appropriate factor loading, but a few key issues were raised: (1) the correlation matrix of variables was found to have multiple correlation values greater than the recommended |80%|; (2) the determinant of the correlation matrix was less than the recommended value of 0.0001 at 9.679E-10; and (3) there were multiple low/insignificant correlations discovered, despite the instruments analysis describing 5 factors in the final analysis. The final factor load analysis did describe 5 final factors with a high Kaiser-Meyer-Olkin Measure of Sampling Adequacy value of 0.840 (higher than the recommended minimum 0.6-0.7) and Bartlett's test of Sphericity. The rotated factor matrix accounted for 64.215% of variance in the matrix and suggests 5 sub-scales (factors):

Table 1. Factor load analysis of instrument in clinician satisfaction

	Factor				
	1	**2**	**3**	**4**	**5**
1. System Availability	**.563**	.175	.358	.329	-.275
2. Infrequent System Problems*	.324	.195	**.561**	.030	-.195
3. User Friendly	**.685**	.304	.339	.203	-.098
4. Sufficient Support	**.510**	.257	.410	.219	.355
5. Features enable me to perform my work well	**.681**	.387	.376	.214	-.098
6. Patient Care Data recorded complete/accurate	**.594**	.182	.243	.194	.437
7. Patient Concerns about privacy & confidentiality	-.053	-.014	-.068	-.029	**.459**
8. Timely Patient Care (Efficiency)	**.885**	.156	.045	-.056	.045
9. Appropriate Patient Care Orders	**.714**	.122	.150	.194	.271
10. Patient Safety	**.634**	.555	.283	-.186	-.142
11. Team Communication	**.571**	.523	.277	-.116	-.151
12. Patient Outcomes	.522	**.665**	.359	-.150	-.122
13. Patient Knowledge	.368	**.665**	.091	-.011	-.089
14. Worth Time & Effort	**.684**	.434	.400	-.015	-.248
15. Overall Satisfaction	**.706**	.395	.457	.145	-.168
16. Patient Satisfaction	**.634**	.364	.344	.070	-.138
17. Department Involvement	.022	-.102	.044	**.705**	-.070

18. Clinician Involvement*	-.016	-.062	**-.609**	-.147	-.032
19. Interferes patient care	.243	.168	**.577**	.011	.063
20. Interoperability (Nursing Homes)*	.057	**.548**	.040	.133	.237
21. Sufficient Resources	.277	.439	.200	**.648**	.264
22. Costs*	.367	-.010	**.488**	-.032	-.103

Extraction Method: Principal Axis Factoring.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 24 iterations.
*These variables were negatively worded and were reversed in the data.

While this factor load analysis suggests some overlap between the sub-groupings suggested by [5], it does not exactly match the sub-scales proposed (see Table 2). This suggests that the instrument is not appropriate as-is for evaluating physician opinion on electronic health record systems.

Table 2 column 1 contains one of the six dimensions or sub-scales proposed by the nursing satisfaction evaluation described by [5]. Column 2 contains the instrument item number and a brief description of the question asked. Column 3 contains 5 sub-columns; if a dot is present in the factor sub-column, that item factors with others in that column in the proposed physician analysis. For example, in Sockolow's study, questions 1-4 below were included under the "Structural Quality" dimension, whereas in the Physician Satisfaction Survey, questions 1, 3, 4, 6, 14, 15, 16, 8, 9, and 11 were all clustered together under one sub-scale.

Table 2.

Sockolow EHRNS Instrument Sub-scales	Instrument Item	Proposed Physician Factor/Sub-scale				
Structural Quality	1. System Availability	●				
	2. Infrequent System Problems			●		
	3. User Friendly	●				
	4. Sufficient Support	●				
Quality of information logistics	6. Patient Care Data recorded complete/accurate	●				
	7. Patient Concerns about privacy & confidentiality					●
	14. Worth Time & Effort	●				
	15. Overall Satisfaction	●				
	16. Patient Satisfaction	●				
Effects on quality of services	8. Timely Patient Care (Efficiency)	●				
	9. Appropriate Patient Care Orders	●				
	11. Team Communication	●				
	17. Department Involvement				●	
	18. Clinician Involvement			●		
Effects of outcomes and quality of care	10. Patient Safety	●				
	12. Patient Outcomes		●			
	13. Patient Knowledge		●			
	22. Costs			●		
Unintended consequences/benefits	19. Interferes patient care			●		
Barriers/facilitators adoption	20. Interoperability (Nursing Homes)		●			
n/a	5. Features enable me to perform my work well	●				
n/a	21. Sufficient Resources				●	

Seven of the 22 variables do not allow for the assumptions of factor analysis as described in the Assumption section (e.g. Patient Safety had high correlations with multiple items); as such variables affecting the assumptions of the factor load analysis can consequently be removed. The goal of a factor load analysis is to examine how a number of items can be grouped or clustered together to represent a

common line of variance. For example, in a given survey, smoking habits and lung cancer occurrence might be expected to be related; the results of this relationship can be verified by factor load analysis, which will group smoking habits and lung cancer occurrence together if they are in fact related by variance. As such, the sub-scale including these items could be labeled to reflect the common theme. Removing items with uncertain (insignificant) correlations or very high correlations across the board thus can improve how items can be grouped together, and in turn, improves the instrument. This improved instrument (described below) meets assumptions of the analysis and can be proposed as a viable alternative. By removing the variables shown in Table 3 for high correlations, low/insignificant correlations, and reflecting variable responses with strong anti-correlations, improved and statistically significant instrument sub-scales can be provided.

The removed variables may have insignificant correlations due to the variation in work between nurses and physicians. The nurses spend significantly more time interacting with the patients and recording data through varying EHR features. The physicians represented various physician specialties. This diversity of participants represented physician users who interacted with different features and different types of interactions with the EHR.

Table 3. Instrument items removed to meet assumptions for factor load analysis

14. Worth Time & Effort
12. Patient Outcomes
5. Features enable me to perform my work well
7. Patient Concerns about privacy & confidentiality
17. Department Involvement
18. Clinician Involvement
20. Interoperability (Nursing Homes)
10. Patient Safety

4.2. Proposed 14-item instrument

Removing the variables described above yields a 14-item instrument that meets the assumptions required for appropriate factor loading: (1) there are no correlations greater than recommended |80%| in the matrix; (2) the determinant of the correlation matrix is greater than the recommended value of 0.0001 at 8.615E-005; and (3) there are no low/insignificant correlations discovered. The final factor load analysis of this new instrument describes 2 factors with a Kaiser-Meyer-Olkin Measure of Sampling Adequacy value of 0.891 (higher than the recommended minimum 0.6-0.7) and passes Bartlett's test of Sphericity. The rotated factor matrix accounted for 54.680% of variance in the matrix and suggests 2 sub-scales:

Table 4. Rotated factor matrix of 14-item instrument

	Factor	
	1	**2**
1. System Availability	**.659**	.308
2. Infrequent System Problems	**.585**	.212
3. User Friendly	**.683**	.532
4. Sufficient Support	.397	**.684**
6. Patient Care Data recorded complete/accurate	.217	**.794**
8. Timely Patient Care (Efficiency)	**.458**	**.575**
9. Appropriate Patient Care Orders	.287	**.760**
11. Team Communication	**.756**	.277
13. Patient Knowledge	**.497**	.258
15. Overall Satisfaction	**.806**	.467
16. Patient Satisfaction	**.771**	.349
19. Interferes patient care	**.454**	.242
21. Sufficient Resources	.296	**.553**
22. Costs	**.505**	.167

Extraction Method: Principal Axis Factoring.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 3 iterations.

Table 5. Column 1: Sub-scale described by Sockolow et al. 2011. Column 2: Instrument item number and description. Column 3: The factor in which the 14-instrument item falls depending on the described factor load analysis

		Factor	
Sockolow Instrument Sub-scales	**Instrument Item**	**1**	**2**
Structural Quality	1. System Availability	●	
	2. Infrequent System Problems	●	
	3. User Friendly	●	
	4. Sufficient Support		●
Quality of information logistics	6. Patient Care Data recorded complete/accurate		●
	7. Patient Concerns about privacy & confidentiality		
	14. Worth Time & Effort		
	15. Overall Satisfaction	●	
	16. Patient Satisfaction	●	
Effects on quality of services	8. Timely Patient Care (Efficiency)	*	●
	9. Appropriate Patient Care Orders		●
	11. Team Communication	●	
	17. Department Involvement		
	18. Clinician Involvement		
Effects of outcomes and quality of care	10. Patient Safety		
	12. Patient Outcomes		
	13. Patient Knowledge	●	
	22. Costs		●
Unintended consequences/benefits	19. Interferes patient care	●	
Barriers/facilitators adoption	20. Interoperability (Nursing Homes)		
n/a	5. Features enable me to perform my work well		
n/a	21. Sufficient Resources	●	

The reliability for this factor load analysis follows in Table 6. The reliability for this load suggests that this sub-scale describes a reliable instrument. Based on these analyses, we propose a 14-item instrument for evaluating physician satisfaction with EHR systems.

Table 6. Reliability of factor loads in new instrument

Reliability	Cronbach's Alpha	Items
Factor 1	0.892	9
Factor 2	0.803	5

4.3. Patient safety as an independent variable

Of all the variables removed from the 22-item instrument, Patient Safety is one that had very high correlations with multiple other variables. High correlations can indicate the existence of multicolinearity in the analysis, or that the variance of two variables is so alike that it interferes with the ability of the factor analysis to account for the variables' variance in the dependent variables. The existence of these high correlations piqued interest on Patient Safety as a possible independent variable. As such, it was determined that Patient Safety could be

evaluated as an independent variable upon which the two factors described by factor load analysis could be examined for variance. Correlation analysis analyzing Patient Safety as an independent variable compared to factor 1 and factor 2 described by the new 14-item instrument was performed. First, five outliers had to first be removed from factor 3 to meet rank assumptions, resulting in a smaller *n* of 58. The Pearson Correlation coefficient is measures of linear relationships between two variables, in this case the regression of factors 1 and 2 and Patient Safety. With scores significant at the 0.01 level, Patient Safety is found to have 77.6% correlation with factor 1 and 67.9% correlation with factor 2. Simple linear regression and additional non-parametric correlation (Spearman's ρ) were performed to corroborate this relationship; R^2 scores from linear regression for factor 1 and 2 were 60.2% and 46.1%, respectively. The R^2 score indicates how much variance in the factor specified can be accounted for by the scores in Patient Safety. Spearman's rho again confirms these relationships, finding 76.1% correlation for factor 1 with Patient Safety and 63.8% with factor 2. These studies suggest that the variance in factors 1 and 2 can be associated with Patient Safety, with factor 1 depending slightly more on Patient Safety than factor 2. This is interesting as the variables found in factor 1 deal largely with general evaluation of the EHR system performance and features and variables in factor 2 deals largely with how patients are treated and data quality/accuracy. Based on this observation, a speculation could be made that the safety of the patient before, after, and during treatment affects how clinicians view the efficacy of the EHR system. A 2013 recommendation from the American Medical Informatics Association hints toward this relationship in their recommendations for improving EHR by focusing on patient safety and avoiding unintentional harm [18].

5. Discussion and conclusion

The need for improvement of EHR systems in healthcare is steadily growing with their adoption into health organizations. Particularly, it is important to focus on the satisfaction of those using the systems most – health care providers – and using the feedback they give to adapt and improve current standards. In 2010, [5]'s EHRNS instrument presented a model for evaluating satisfaction of nurses that suggested the instrument was reliable and valid for the nursing domain. It was offered to electronic health record evaluators for further testing and application. The goal of this research was to apply that instrument to physicians for evaluation of satisfaction with similar EHR systems. Physician satisfaction is critical for improving patient care and increasing advocacy for EHR usage and thus, collecting feedback on EHR systems is beneficial.

This research sought to test the validity and reliability of the EHRNS instrument as modified for usage in physician satisfaction. The analysis of the EHRNS instrument did not support the six dimensions or sub-scales proposed by the nursing satisfaction evaluation to transition to the physician domain. However, we are able to propose a modified instrument that captures two factors indicated for physicians, dealing largely with (1) the evaluation of the EHR system's performance and features and (2) data quality and accuracy.

Our analysis also suggests that measuring patient safety is an important area to consider when measuring physician satisfaction with EHRs. By treating Patient Safety as an independent variable, we are able to discern a pattern in the two factors that suggest that physician satisfaction with an EHR system is intimately tied to patient safety and outcome. Physicians' emphasis on patient safety and patient care appear to influence their interaction with EHRs. As originally noted in [16], most medical errors were not due to incompetent people, but to badly designed systems, that include all the processes and methods used to carry out various functions [17]. Physicians appear to have their concern for patient safety and patient care on the forefront as they move towards interaction with IT systems and the 'digitization of healthcare'.

The analyses above report a reduction in factors (6 to 2) from nurses to physicians, respectively. Further, the research above suggests that Patient Safety is an independent variable upon which (1) the opinion of the EHR system and (2) patient treatment and outcome depend. Based on these preliminary analyses described above, we speculate that the instrument needs to be modified to reflect that physicians' satisfaction is largely dependent on Patient Safety rather than increased efficiency and cost reductions. Future work will include further probing this speculation, and confirming that the link between satisfaction and Patient Safety is stronger than the link between other EHR outcomes (specifically, "secondary work"). A study by [21] defines secondary work as auditing, research, and billing processes, and suggests that one benefit of the EHR system is an increase in secondary work efficiency. These findings suggest improvements for development of an instrument to investigate physician perspectives on patient safety and patient care tempering physician interaction with EHR technology. Greater understanding will provide

insights to improve the technology and increase physician satisfaction and improve patient outcomes.

Potentially, the reduction in factors from nurses' responses to physicians' responses is related to their individual work. Nurses are the primary users and producers of patient information and provide most direct patient care [5]. On the other hand, physicians are the consumers of the data and ultimately responsible for the patient outcomes. Further, our study surveyed physicians from a range of specialties and their reliance on EHR systems varies greatly. The diversity in physician specialty and work may have been reflected in reduction of factors.

Through our efforts, we are able to propose a modified instrument that captures two factors indicated for physicians, dealing largely with (1) the evaluation of the EHR system's performance and features and (2) data quality and accuracy. Our analysis also suggests that measuring patient safety is an important area to consider when measuring physician satisfaction with EHRs. Our next steps are to test the proposed PSS instrument on a grander scale, and probing the described relationships between patient safety and system performance/data quality and accuracy.

6. References

[1] R. Agarwal, G. Guodong and A. Jha, "The digital transformation of healthcare: Current status and the road ahead," *Information Systems Research,* vol. 21, no. 4, pp. 796-809, 2010.

[2] M. Mohmood, J. Burn, L. Gemoets and Jacquez, C., "Variables affecting information technology end-user satisfaction: a meta-analysis of the empirical literature," *International Journal of Human-Computer Interaction,* vol. 52, no. 4, pp. 751-771, 2000.

[3] Z. Niazkhani, H. Pirnejad, M. Berg and J. Aarts, "The impact of computerized provider order entry systems on inpatient clinical workflow: A literature review," *Journal of the American Medical Informatics Association,* vol. 16, no. 4, pp. 539-549, 2009.

[4] N. Menachemi, T. Powers, T. Au and R. Brooks, "Predictors of physician satisfaction among electronic health record system users," *Journal for Healthcare Quality,* vol. 32, no. 1, pp. 35-41, 2010.

[5] P. Sockolow, J. Weiner, K. Bowles and H. Lehmann, "A new instrument for measuring clinician satisfaction with electronic health records," *Computers, Informatics, Nursing,* vol. 29, no. 10, pp. 574-585, 2011.

[6] E. Ammenwerth and N. de Keizer, "An inventory of evaluation studies of information technology in healthcare: trends in evaluation research 1982-2002," *Methods Inf Med,* vol. 44, no. 1, pp. 44-56, 2005.

[7] P. Sockolow, K. Bowles, H. Lehmann, P. Abbott and J. Weiner, "Community-based, interdisciplinary geriatric care team satisfaction with an electronic health record: A multimethod study," *Computers, Informatics, Nursing,* vol. 30, no. 6, pp. 300-311, 2012.

[8] D. Straub, "Validating instruments in MIS research," *MIS Quarterly,* vol. 13, no. 2, pp. 147-169, 1989.

[9] D. Cooper and P. Schindler, Business Research Methods, McGraw-Hill, 2001.

[10] S. Kachigan, Multivariate statistical analysis: A conceptual introduction, New York, NY: Radius Press, 1982.

[11] S. Philliber, M. Schwab and G. Sloss, Social research: Guides to a decision-making process, Peacock, 1980.

[12] J. Creswell, Research design: Qualitative & quantitative approaches, Thousand Oaks, CA: SAGE Publications, 1994.

[13] L. Cronbach, "Coefficient alpha and the internal structure of tests," *Psychometrika,* vol. 16, no. 3, pp. 297-334, 1951.

[14] B. Tabachnick and L. Fidell, Using multivariate statistics, Pearson, 2001.

[15] A. Comrey and H. Lee, A first course in factor analysis, Hillsdale, NJ: Erlbaum Associates, 1992.

[16] E. Guadagnoli and W. Velicer, "Relation of sample size to the stability of component patterns," *Psychol Bull,* vol. 103, no. 2, pp. 265-275, 1988.

[17] J. Kim and C. Mueller, Factor analysis: Statistical methods and practical issues, Newbury Park, CA: SAGE Publications, 1978.

[18] B. Middleton, M. Bloomrosen, M. Dente, B. Hashmat, R. Koppel and J. Overhage, "Enhancing patient safety and quality of care by improving the usability of electronic health record systems: Recommendations from AMIA," *Journal of the American Medical Informatics Association,* vol. 20, no. 1, pp. 2-8, 2013.

[19] Institute of Medicine, Committe on Health Care in America, "Crossing the quality chasm: A new health system for the 21st century," National Academy Press, Washington, DC, 2001.

[20] L. Leape, "Errors in medicine," *Errors in Laboratory Medicine Patient Safety,* vol. 404, no. 1, pp. 2-5, 2009.

[21] T. Greenhalgh, H. Potts, G. Wong, P. Bark and D. Swinglehurst, "Tensions and paradoxes in electronic patient record research: A systematic literature review using the meta-narrative method," *Milbank Quarterly,* vol. 87, no. 4, pp. 729-788, 2009.

[22] R. Aron, S. Dutta, R. Janakiraman and P. Pathak, "The impact of automation of systems on medical errors: Evidence from field research," *Information Systems Research,* vol. 22, no. 3, pp. 429-446, 2011.

[23] D. Blumenthal, "Stimulating the adoption of health information technology," *The New England Journal of Medicine,* vol. 360, no. 15, pp. 1477-1479, 2009.

[24] A. Costello and J. Osborne, "Best practices in exploratory factor analysis: Four recommendations for getting the most from your analysis," *Practical Assessment, Research & Evaluation,* vol. 10, no. 7, pp. 173-178, 2005.

[25] R. Fichman, R. Kohli and R. Krishnan, "The role of information systems in healthcare: Current research and future trends," *Information Systems Research,* vol. 22, no. 3, pp. 419-428, 2011.

[26] A. Kellerman and S. Jones, "What will it take to achieve the as yet unfulfilled promises of health information technology?," *Health Affairs,* vol. 32, no. 1, pp. 63-68, 2013.

[27] B. Monegain, "Hospitals show scant progress on safety," 9 May 2013. [Online]. Available: http://www.healthcareitnews.com/news/hospitals-show-scant-progress-safety. [Accessed 14 June 2013].

[28] C. Morris, A. Savelyich, J. Cantrill and A. Sheikh. "Patient safety features of clinical computer systems: Questionnaire survey of GP views," *Quality of Safety Health Care,* vol. 14, no. 3, pp. 164-168, 2005.

[29] A. Ryan, T. Bishop, S. Shih and L. Casolino, "Small physician practices in New York needed sustained help to realize gains in quality from use of electronic health records," *Health Affairs,* vol. 32, no. 1, pp. 53-62, 2013.

[30] V. Venkatesh, X. Zhang, T. Sykes, "Doctors do too little technology: A longitudinal field study of an electronic healthcare system implementation," *Information Research,* vol. 22, no. 3, pp. 523-546, 2011.