Impact of Electronic Medical Records on Patient-Provider Communication

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Previous research found electronic medical records (EMRs) to have negative impact on patient-provider (PP) communication. However, very few studies were focused on specific age ranges especially young generation. The objectives of this study were to: (1) assess the perception of young adults and healthcare providers regarding the effect of EMRs on PP interaction; and (2) investigate the use of cognitive modeling as an analytical tool to predict the impact of EMRs on PP communication. Findings suggested that young adults have positive opinion regarding the use of EMRs during outpatient visits. Cognitive task performance modeling has the potential to predict visual, cognitive, and motor demands associated with using EMRs. Future studies should be conducted to improve the generalizability of findings.

INTRODUCTION

Electronic medical record (EMR) is a digital version of paper-based patient medical records in one practice. The use of EMRs in the U.S. has increased substantially from 18% in 2001 to 78% in 2012 in office-based physician practices (Hsiao and Hing, 2012). EMRs provide comprehensive records of patient medical history, improve information exchange among providers (Edmund et al., 2009), increase the quality of patient care, decrease prescription errors, and improve the safety culture in healthcare settings (McGuire et al., 2013). However, EMR use in examination rooms has changed the two-way interaction between the patient and provider to a three-way interaction that consist of patient, provider, and the EMR system. Patient-provider (PP) interaction during a visit is critical and several studies have found the quality of communication to affect patient satisfaction, trust, and clinical outcomes (e.g., Stewart, 1995).

Effect of EMR on PP Communication

Studies assessing PP communication mainly used direct observation, video recording, surveys, and interviews. For example, Margalit et al. (2006) used video recordings of doctors interacting with patients while using EMRs in three academic primary care clinics. They found that EMR negatively affected PP communication by reducing the conversation and eye contacts with the patient. The authors suggested training the providers to improve the EMR use during visits. In a more recent study, Street et al. (2014) used a combination of measures including videotapes, mouse-clicking and patient satisfaction survey to assess EMR effect on quality of communication. Results revealed that the EMR may have negative effect on patient-centered communication if it takes too much visual attention of the physician and may lead to more silence periods during the visit. Asan et al. (2015) examined patient-doctor gaze patterns in three different EMR use strategies including active and passive information sharing, and technology withdrawal. Using video recordings of 100 visits, it was found that active sharing strategy (i.e., shifting the EMR monitor toward the patient and share the information during the visit) leads to a more effective PP communication.

Other studies used interviews or questionnaires to provide qualitative assessment of using EMRs. For example, Zhang et al. (2015) conducted semi-structured interviews with 21 healthcare providers. The results revealed that the providers consider EMRs to be demanding to use during patient visits. To address this issue, providers use several strategies including use of EMRs outside of patient encounters, engage patients, and multi-tasking. In another survey of providers, Sandoval et al. (2017) found EMRs to have a negative effect on PP communication but a positive impact on information sharing and communication among providers. The authors suggested that additional support or training of providers might resolve the communication issue. Besides surveys of healthcare providers, conducting interviews or distributing questionnaires among patients provides valuable insights into the effect of EMRs on PP communication. For example, Rizer et al. (2017) conducted a survey of patients in 98 academic medical center clinics. Although most patients were satisfied with their visit, younger responders were more likely to perceive the EMR to be intrusive. Rizer et al. survey was very general asking about the visit satisfaction, EMR use during the visit, and whether the patient perceived the EMR to be intrusive. The authors suggested that future investigations should focus on this group and identify the factors associated with this observation (e.g., being more sensitive, computer familiarity, etc.).

Prior studies did not control for the age of patients in their assessments and typically had a wide range. For example, Makoul et al. (2001) recruited 204 patients from 23-91 years of age. Although some studies included younger patients, the number of participants in different age grouped was not controlled (e.g., Rizer et al., 2017). Younger adults regularly use social media, desktop or laptop computers, smartphones, and their internet access is significantly higher as compared to other age groups (Villanti et al., 2017).

Cognitive Task Performance Modeling

Cognitive task performance modeling using goals, operators, methods, and selection rules (GOMS) approach has been developed by Card, Moran, and Newell (1983). GOMS is one of the most well-known theoretical modeling approaches in

human-computer interaction (HCI) literature which analyzes the task in terms of three main categories of operators including perceptual (P), cognitive (C), and motor (M). Perceptual operators include two categories: visual and auditory. Cognitive operators mainly include memory retrieval, executing steps in a mental procedure and choosing among methods (Olson and Olson, 1990). Motor operators include: moving hands, using a mouse, keyboard entry, etc. GOMS language (GOMSL) provides a structured language notation for developing cognitive task performance models (Kieras, 1999).

Prior studies have used GOMS models in assessing the usability and mental workload of EMR systems. For example, Saitwal et al. (2010) used GOMS and keystroke-Level Models (KLM) to analyze the usability of a user interface called AHLTA (Armed Forces Health Longitudinal Technology Application). It was found that the users need to complete a large number of steps to perform each task, which significantly increase task completion time. In addition, the interface imposed high mental demand on the provider. Suebnukarn et al. (2013) used GOMS and KLM and found mental workload to be the major usability issue in an EMR system. To address this issue, the authors recommended combining related information, providing information reminders, and using fewer screens. Although these studies evaluated EMR interface usability and its effect on user mental workload, there was no prior study using GOMS models to assess the impact of EMRs on PP communication. Based on Wickens' (1984) multiple resource theory (MRT), human has limited capacity for processing information. Therefore, cognitive overload might occur when the individual performs two or more tasks that require the same resource. For example, the provider might have difficulty in looking at the patient and reading information from the EMR as both tasks require visual system resources. Previous studies used working memory (WM) chunk count in GOMS models as an indicator of cognitive demands (e.g., Zahabi and Kaber, 2018). It was found that cognitive overload may occur when more than five chunks of information must be maintained in WM at any given time (Kieras et al., 1999).

Research Objectives

The first objective of this study was to assess the perception of young adults on providers' use of the EMRs during outpatient visits and how the use of technology and education might influence their perception. We also assessed the opinion of healthcare providers regarding the effect of EMR use on their communication with young patients. Based on the literature review, we expected that the EMR would have a negative effect on PP communication. The second objective of this research was to investigate the use of cognitive task performance modeling as an analytical tool to predict the impact of EMRs on PP communication. We expected the findings of GOMS models to be in line with the results of surveys.

METHOD

Participants

Eight healthcare providers and 69 patients participated in this study. The study was conducted at Wichita State University health center. The provider inclusion criteria included individuals who were using EMRs during patient visits (i.e. nurse practitioners (NP), registered nurses (RN)). The patient inclusion criteria included students between 18-35 years of age. All patients identified that they were using computers on regular basis and have high general computer skills (mean=76.81%, SD=15.28%). The participant demographic information is shown in Tables 1 and 2.

Table 1. Demographic information of healthcare providers

Characteristics	Mean	SD
Age (yrs.)	55.1	9.4
Gender (%female)	100.0	0.0
Work experience (yrs.)	27.8	12.6
EMR use experience (yrs.)	6.8	4.6
General computer skills (%)	70.5	16.3
Medical computing skills (%)	74.1	17.3
EMR usage rate per each visit (%)	45.0	17.7

Table 2. Patient demographic information

Characteristics	No. of Responders
Gender	
Male	27
Female	42
Age	
<20 yrs.	10
20-35 yrs.	59
Education level	
Undergraduate student	40
Graduate student	29
Ethnic background	
African American	9
White	38
Latino	7
Asian	14
Others	3
Native English Speaker	
Yes	52
No	17
Computer usage rate	
Never	0
Rarely/sometimes	0
Frequently	69
Frequency of visiting the physician	
Once a month or more	9
Between once a month and once a year	35
Once a year	17
Less than a year	8
Personal rating of health	
Very good	28
Good	39
Poor	2
Very poor	0
Experience with paper-based documentation	
Yes	41
No	28

EMR System

The health center sampled in this study uses Point and Click EMR software version 12.11, which is specifically designed for college health and was installed in December 2015. The providers were initially provided with three training sessions (eight hours each) in a four-month period to become familiar with the interface. All the providers use tablets/laptops with touch screen capability during patient visits.

Study Questionnaire and Procedure

Two separate questionnaires were developed for this study. The provider questionnaire was a one-time survey distributed among the individuals to understand their perceptions regarding the impact of EMRs on quality of care and pp communication, mental workload, and visual attention. The questionnaire included 10 items (Table 3) using a 5-point Likert scale (1=strongly disagree, 5=strongly agree). The patient questionnaire was distributed among the patients immediately following their visit. The survey included 11 items (Table 4) using a 5-point Likert scale (1=strongly disagree, 5=strongly agree) asking about their visit satisfaction, pp communication, quality of care, and provider's visual attention to them. In addition, they were asked to provide their perception regarding Provider's EMR usage rate during their visit (0-100%). The statements in both surveys were developed based on prior studies in this domain (e.g., Rouf et al., 2007; Freeman et al., 2007). The surveys were reviewed by the research team and the director of health center prior to data collection to ensure face validity.

Cognitive Task Performance Modeling

Cognitive performance models were constructed using GOMSL for a sample patient visit of abdominal pain. The patient's visit included interaction with the RN and the NP. Initially, the RN roomed the patient and entered patient's information (e.g., allergies, medication, vital signs, etc.). Subsequently, the NP entered the room to perform initial assessment, physical examination, diagnosis, and medication ordering. Therefore, two separate GOMSL models (i.e., Model 1: RN interaction with the EMR, Model 2: NP interaction with the EMR) were developed based on the review of video recordings of the EMR interface during the visit.

Table 3. Statements in healthcare provider questionnaire

No.	Topic	Statement
1	Quality of care	I think the use of computer during patient visit would reduce medical mistakes.
2	Quality of care	I think the visit duration is longer due to the use of computer.
3	pp communication	I can talk easily with the patient while using the computer.
4	pp communication	I can easily listen to my patient while using the computer.
5	pp communication	I think the use of computers in the office interfere with my relationship with patients.
6	pp communication	I think the use of the computer in the office make the visit feel less personal.
7	Visual attention	I feel I am distracted while using the computer.
8	Visual attention	I think I look at the computer screen more than my patient during a visit.
9	Visual attention	I think the EMR interface design should be improved to reduce my visual attention to the computer.
10	Workload	I think the EMR interface design should be improved in order to reduce my mental workload.

Table 4. Statements in patient questionnaire

No.	Topic	Statement
1	Visit satisfaction	I like the idea of a doctor using a computer in the exam room.
2	Visit satisfaction	My satisfaction level with my visit improved because of the doctor's computer use.
3	Quality of care	I think the use of computer during patient visit would reduce medical mistakes.
4	Quality of care	I think my office visit is longer due to the doctor use of computer.
5	Quality of care	I am receiving a better standard of treatment because of the doctor's computer use.
6	pp communication	I can talk easily with the doctor while he/she uses the computer.
7	pp communication	I feel the doctor is listening to me while he/she uses the computer
8	pp communication	The introduction of the computer has affected my relationship with a doctor.
9	pp communication	Patients who want good personal contact with their doctor should choose a doctor that does not use computer during the visit.
10	Visual attention	I feel the doctor is distracted while he/she uses the computer.
11	Visual attention	The doctor looks at the computer screen more than me.

Data analysis

Initially, descriptive statistics were generated on the responses of each survey questions. Subsequently, non-parametric correlations (Spearman's ρ) were conducted to identify the relationship between patients' and providers' demographic information and their opinion regarding the effect of EMR use on PP communication and quality of care. All figures report means and standard deviations (shown by error bars) of the raw data. GOMS models were developed using a cognitive modeling tool called "Cogulator" (Estes, 2017) which has been used and validated previously as a task modeling tool to produce estimates of working memory load and task time (Stanley et al., 2017).

RESULTS

Descriptive statistics of healthcare provider survey

The descriptive statistics regarding healthcare providers' opinion on different questions is shown in Figure 1. Regarding the quality of care, it was found that the providers have neutral to positive opinion regarding the effect of EMRs on reducing medical errors (Q1: $M = 3.25$). In addition, they do not believe that the use of computer had negatively affected the visit duration (Q2: $M = 1.875$). Regarding the effect of EMR on pp communication, it was found that the providers have neutral to positive opinion that they can easily talk (Q3: $M = 3.625$) or listen (Q4: $M = 3.625$) to the patient during the visit. However, the providers did not think that the use of EMR would affect their personal relationship with the patient (Q5: $M = 2$; Q6: $M = 2.25$). Regarding the effect of EMR on visual attention, although the providers did not believe the EMR to distract them during the visit (Q7: $M = 2.25$; Q8: $M = 2.625$), they had neutral to positive opinion that the future EMR designs should reduce provider's visual attention to the computer (Q9: $M = 3.375$). Regarding the effect of EMR on provider mental

workload, the data revealed that the providers had neutral to positive opinion that EMR interfaces should be improved to reduce their mental workload (Q10: M = 3.5).

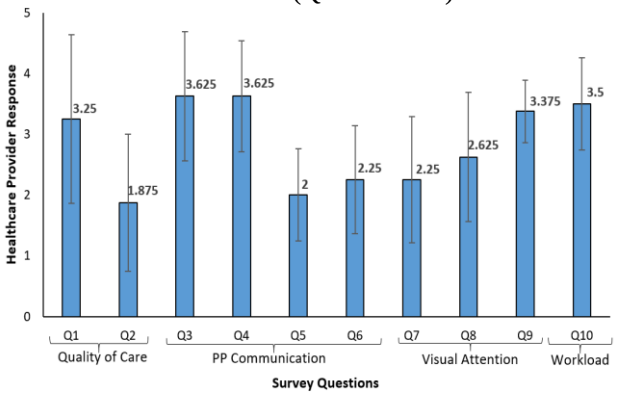

Figure 1. Healthcare provider survey results

Descriptive statistics of patient survey

Patients identified that providers' EMR usage rate during their visit was low (M = 37.80%, SD = 23.06%). As shown in Figure 2, patients revealed neutral to positive opinion regarding the effect of EMR on their visit satisfaction (Q1: M = 4.42, Q2: M = 3.45). Regarding quality of care, the patients believe that the use of EMR during visits can reduce medical errors (Q3: M = 4.43) and improve their standard of treatment (Q5: M = 3.75). In addition, they do not believe that the use of computer had negatively affected the visit duration (Q4: M = 1.52). Regarding the effect of EMR on pp communication, the patients believed that they could easily talk with the providers (Q6: M = 4.23) and the providers listened (Q7: M = 4.00) to them while using the EMR. In addition, the patients did not believe that the EMR affected their personal relationship with the provider (Q8: M = 1.81, Q9: M = 1.84). Regarding visual attention, the patients did not perceive the EMR to cause distraction (Q10: M = 2.15, Q11: M = 2.13).

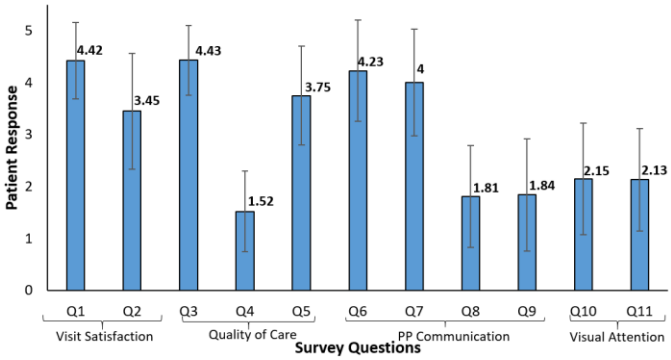

Figure 2. Patient survey results

Correlation Analysis

There was no significant correlation between the patients' computer skill ratings and any of the response measures. Regarding the providers' responses, there was a significant positive correlation between EMR use experience and the ability to talk (ρ = 0.85, p = 0.007) and listen (ρ = 0.924, p = 0.001) to the patient. Providers with more experience in using EMRs reported higher perceived pp communication. In addition, there was a significant positive correlation between provider's medical computing skills and perception of medical error reduction (ρ = 0.741, p = 0.036) and the ability to listen to the patient during a visit (ρ = 0.932, p = 0.001). Also, a significant negative correlation was found between provider's medical computing skills and perception of interference (ρ = -0.849, p = 0.008). The results suggest that the higher medical computing skills, the higher the quality of care and pp communication.

Cognitive Task Performance Modeling

The results of GOMSL models are summarized in Table 5. Both tasks require substantial motor operators including clicking, keystroke, pointing at objects with mouse, and typing. In addition, the user needs to switch between mouse and keyboard several times during the data entry period. Although there are high number of cognitive operators in both tasks, majority of these operators were related to verifying whether the cursor is over the target and ignoring the target after data entry. Therefore, the average number of WM chunks in both tasks was low and did not show any sign of cognitive overload for the user based on the threshold identified by Kieras et al. (1999). The perceptual operators in both tasks consisted of looking at specific targets on the screen (e.g., vital signs tab) or searching for information in unknown position (e.g., finding the medication from a list). Comparing the two GOMSL models, the NP's interaction with the EMR were found to be more demanding as compared to the use of EMR by the RN.

Table 5. Summary of GOMSL Models

No.	Task	Perceptual Operators	Cognitive Operators	Motor Operators	Average WM Chunks	Time Estimate (Sec)
1	RN	36	65	83	1.9	101.4
2	NP	72	142	216	0.6	261.6

DISCUSSION

The first objective of this research was to assess the perception of young patients (i.e., college students) and healthcare providers regarding the effect of EMRs on PP interaction. The data refused our initial hypothesis. On average, the patients believed EMRs improved visit satisfaction and quality of care. In addition, they did not believe that provider's use of EMR negatively affected PP communication and visual attention. Our findings are in line with Alkureishi et al. (2016) that did not find the EMR use to cause any change in PP communication during the visit. However, our results do not support some other previous investigations which found the EMR to negatively affect PP communication (e.g., Rizer et al., 2017; Sandoval et al. 2017). One explanation to our findings might be the relatively low proportion of EMR usage rate per visit. In a follow-up discussion with the clinic director, it was found that each regular office visit takes approximately 30 min and the providers spend a lot of time on educating the patients via face to face interaction as compared to EMR documentation. Another reason might be that the providers in this study were highly experienced (work experience M = 27.8 yrs.) and

perceived their medical computing skills to be relatively high (M = 74.1%). In addition, we did not find any significant relationship between patients' technology use and computer skills and their perception regarding the effect of EMR use on PP communication.

Healthcare providers also believed that the use of EMR during patient visits improved quality of care and did not negatively affect their communication with the patient. Our findings were not in line with Zhang et al. (2015) in which the providers found EMRs to be demanding to use during patient visits. The difference in findings might be due to the type of EMR system used. Zhang et al. identified one of the main issues were the lack of interface usability including excessive mouse clicking, lack of shortcuts, and non-optimal information organization. Although the providers in this study did not perceived the EMR to cause visual distraction, they suggested that future EMR systems should be improved to reduce visual attention and distraction. In addition, the results revealed that providers with higher experience and computer skills could have better interaction with the patient while using the EMR. The findings support the previous recommendation by Margalit et al. (2006) that training the providers can improve the EMR use during visits.

The second objective of this study was to investigate the use of cognitive modeling as an analytical tool to predict the impact of EMRs on PP communication. The findings were in line with our initial expectations. The GOMSL models revealed the EMR documentation tasks require extensive clicking and typing. However, the tasks do not cause mental overload. Therefore, the provider could communicate with the patient while entering information to the EMR. The motor demand was mainly caused by excessive clicking, keystroke, pointing at objects with mouse, and typing. To address this issue, voice recognition systems can be used instead of manual data entry (Shachak and Reis, 2009).

One limitation of this study was the sample size. The data was collected from college students and providers in one specific healthcare center. The findings might not be generalizable to other clinics with different patients' demographics. Second, the GOMS models were generated based on a single patient visit. Although the provider identified the visit to be one of the common cases which included both RN and NP documentation, the findings might not be generalizable to visits with more complications. Future studies should have higher sample size and collect data in different clinics to increase the generalizability of findings.

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