Comparing Electronic Health Record Usability of Primary Care Physicians by Clinical Year

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Abstract: *Objectives*: To examine usability gaps among primary care resident physicians by clinical year: year 1 (Y1), year 2 (Y2), and year 3 (Y3) when using electronic health record (EHR). *Methods*: Twenty-nine usability tests with video analysis were conducted involving triangular method approach. Performance metrics of percent task success rate, time on task, and mouse activities were compared along with subtask analysis among the three physician groups. *Results*: Our findings showed comparable results for physicians of all three years in mean performance measures, specifically task success rate (Y1: 95%, Y2: 98%, Y3: 95%). However, varying usability issues were identified among physicians from all three clinical years. Twenty-nine common usability issues across five themes emerged during sub task analysis: inconsistencies, user interface issues, structured data issues, ambiguous terminologies, and workarounds. *Discussion and Conclusion*: This study identified varying usability issues for users of the EHR with different experience level, which may be used to potentially increase physicians' performance when using an EHR. While three physician groups showed comparable performance metrics, these groups encountered numerous usability issues that should be addressed for effective EHR training and patient care.

1 INTRODUCTION

The Office of the National Coordinator for Health Information Technology (Washington, D.C, USA) and Centers for Medicare & Medicaid Services (CMS) (Baltimore, MD) has proposed the Health Information Technology for Economic and Clinical Health (HITECH) act to successfully adopt electronic health records (EHRs) in health care. EHRs are "records of patient health information generated by visits in any health care delivery setting" (Hsiao and Hing, 2012). The use of Health information technology's (HIT) clinical practice is increasing and physicians are adopting EHRs in part due to the financial incentives pledged by CMS (2012). National Center for Health Statistics (NCHS) communicated, in a 2013 data brief that 78% of office-based physicians in the U.S. have adopted EHRs in their practice (Hsiao and Hing, 2012). Some advantages conveyed by EHR users for adopting an EHR comprised of: improvement in preventive care guidelines adherence, lessen paperwork for providers, and an enhancement to the quality of patient care (Chaudhry et al., 2006; Miller et al., 2005; Shekelle et al., 2006). There are also barriers in adopting EHRs, which include: large financial investments, an imbalance of human and computer workflow models, and a fall in productivity likely caused by 'usability' issues (Menachemi and Collum, 2011; Goldzweig et al., 2009; Chaudhry et al., 2006; Miller et al., 2005; Grabenbauer et al., 2011; Li et al., 2012). Usability is described as how sufficiently a software can be used to perform a particular task with effectiveness, efficacy, and content (1998).

EHR usability issues may have an unfavorable impact on clinicians' EHR learning experience. This may contribute to elevated cognitive load, medical errors, and a loss of patient care quality (Love et al., 2012; McLane and Turley, 2012; Viitanen et al., 2011; Clarke et al., 2013; Sheehan et al., 2009; Kushniruk et al., 2005). Learnability is defined as the degree to which a system enables users to learn how to utilize its application (2011a). Learnability is in regard to the aggregate time and effort essential for a user to cultivate proficiency with a system over time and after multiple use (Tullis and Albert, 2008).

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While there is diversity in defining usability and learnability (Elliott et al., 2002; Nielsen, 1993; 2011a), definitions of learnability are strongly correlated with usability and proficiency (Elliott et al., 2002; Whiteside et al., 1985; Lin et al., 1997). Giving physicians the opportunity to efficiently finish clinical tasks within the EHR, may mitigate some time restraints experienced by physicians amid patient visits.

EHRs demand a large contribution of effort for physicians to gain a certain degree of proficiency. Resident physicians were chosen for this study because residents who are insufficiently prepared on how to operate an EHR, may encounter a steep learning curve when their residency program commences (Yoon-Flannery et al., 2008). In an endeavor to boost physician proficiency with the EHR, hospitals and clinics supply resident physicians with thorough EHR education. However, it is difficult finding adequate time to educate physicians to use new EHR systems (Carr, 2004; Terry et al., 2008; Lorenzi et al., 2009; Whittaker et al., 2009).

Clarke et al., (2015) conducted a longitudinal study to determine learnability gaps between expert and novice primary care resident physicians. They compared performance measures of the novice and expert resident physicians when using an EHR after two rounds of lab-based usability tests using video analysis with 7-month interval. This study found comparable results in novice and expert physicians' performance, demonstrating that physicians' proficiency did not increase with EHR experience. For this paper, we report the results of a confirmation study where a more granular cross sectional study was conducted with a larger sample size. We aimed to examine if we could obtain similar performance measures and usability issues of primary care resident physicians in relation to their year in residency. To achieve the objective of this study we measured the differences in quantitative performance and qualitative usability issues of primary care resident physicians by clinical year (year 1, year 2, year 3).

2 METHOD

2.1 Study Design

To measure the usability of primary care physicians by experience when using an EHR, data was collected through usability testing using video analysis software, Morae® (TechSmith, Okemos, MI). Morae was used to record the laptop screen, the user's facial expressions using the laptop's video camera. The software also recorded each task separately and collected performance measures (time on task, mouse clicks, and mouse movements) while residents completed each task. Finally the software collected and analyzed system usability surveys and scores. Family and Internal medicine resident physicians attempted nineteen artificial, scenarios-based tasks in a lab-based setting. Mixed methods technique was employed to determine the difference in performance and usability issues by primary care physicians. This involved four types of quantitative performance measures, system usability scale (SUS), a survey instrument (Brooke, 1996) and subtask analysis. This study was approved by the University of Missouri Health Sciences Institutional Review Board.

2.2 Organizational Setting

This study took place at the University of Missouri Health System (UMHS), which is a 536 bed, tertiary care academic medical hospital based in Columbia, Missouri. The Healthcare Information and Management Systems Society (HIMSS), a non-profit organization that ranks hospitals on their electronic medical record (EMR) application implementation, has recognized UMHS with Stage 7 of the EMR Adoption Model (2011b). UMHS employs over 70 primary care physicians throughout clinics in central Missouri and in 2012, had approximately 553,300 clinic visits. UMHS' EHR includes a database that consists of data from all the university's clinics and hospitals. The computerized physician order entry (CPOE) within the EHR, grants clinicians access to securely access and place electronic lab and medication orders for patients, and pass on the orders directly to the department in charge of processing the requisition.

2.3 Participants

We recruited 14 physicians from our family medicine department (FCM) and 16 physicians from our internal medicine department (IM). FCM and IM physicians were selected for the sample because, as primary care residents, they have comparable clinical duties. There is presently no evidence-based way to determine users' EHR experience so resident physicians were categorized by clinical years using an EHR. Therefore, to identify differences in use patterns that arise between resident physicians by clinical year when using an EHR, nine first year residents, eight second year, and twelve third year residents physicians participated in the study. Both FCM and IM run three-year residency programs. This

study was a cross sectional comparison. Physicians were grouped by year of residency to determine if physicians become more proficient with EHR experience and to identify workflow differences between physician groups. Convenience sampling method was applied when selecting physicians. FCM physicians were recruited during weekly residents meetings and IM residents were enlisted through MU's secure email client group emails.

2.4 Scenario and Tasks

In this study, the scenario presented to the residents was a 'scheduled follow up visit after a hospitalization for gastroenteritis with dehydration and hyponatremia.' Nineteen tasks that are generally completed by primary care physicians were included. The tasks included are tasks that physicians were trained to complete in the EHR training at the beginning of their residency. The tasks covered the critical and commonly used features and functionalities of the EHR that physicians would most likely use in daily clinical activities. To measure usability of physicians more effectively, we confirmed that the tasks in our study were also a part of the EHR training resident physicians were required to attend before they began their residency. The tasks had a clear objective that physicians were able to follow without nonessential clinical cognitive load or ambiguity, which was not the study's aim. The tasks were:

Task 1: Start a new note
Task 2: Include visit information
Task 3: Include Chief Complaint
Task 4: Include History of Present Illness
Task 5: Review current medications contained in the note
Task 6: Review problem list contained in the note
Task 7: Document new medication allergy
Task 8: Include Review of Systems
Task 9: Include Family History
Task 10: Include Physical exam
Task 11: Include last comprehensive metabolic panel (CMP)
Task 12: Save the note
Task 13: Include diagnosis
Task 14: Place follow up visit in 1 month
Task 15: Place order for basic metabolic panel (BMP)
Task 16: Change a Medication
Task 17: Add a medication to your favorites list
Task 18: Renew one of the existing medications
Task 19: Sign the Note

2.5 Data Analysis

Performance measures depend on both user behavior and the use of scenarios and tasks. Performance measures are useful in estimating the effectiveness and efficiency of a particular tasks. Four important performance metrics were used in this study:

1. *Percent task* success calculates the percentage of subtasks that participants effectively complete.
2. *Time-on-task* is the how long each participant takes to complete each task.
3. *Mouse clicks* is defined as the number of times the participant clicks on the mouse when completing a specified task.
4. *Mouse movement* is defined as the distance of the navigation path in pixels by the mouse to finish a specified task.

For percent task success rate, a greater number generally imply better performance, signifying participants' skillfulness with the system. For time on task, mouse clicks, and mouse movements, a greater value usually indicates poorer performances (Khajouei et al., 2010; Koopman et al., 2011; Kim et al., 2012). As such, greater values may signify that the participant had difficulties while using the system. Geometric mean were calculated for the performance measures with confidence interval at 95% (Cordes, 1993). Geometric mean was calculated because performance measures have a strong tendency to be positively skewed and geometric mean offers a more precise measure for sample sizes less than twenty-five (Sauro and Lewis, 2010).

Sub task analysis was conducted as a part of the usability analysis to understand how participants interact with the system on a more granular level. The video recorded sessions from Morae were reviewed individually and the tasks were partitioned into smaller sub-tasks, that were analyzed and compared across both the participants and tasks to determine subtle usability challenges, such as, errors, workflow, and navigation pattern differences that otherwise would gone unnoticed. To categorize our findings, thematic analysis was employed to report our usability findings (Braun and Clarke, 2006). Some themes included in this study were adopted from a study by Walji et al., (2013) but were modified to include other themes for further granularity. Themes were then reviewed over multiple iterations along with physician champion and an informatics expert and then revised.

Table 1: Demographics of 9 first year resident physicians, 8 second year resident physicians, and 12 third year resident physicians that participated in the usability test presented as percentages. Examined demographics include gender, age, race, and use of EHR. *One resident physician did not provide information on birth date and was excluded in the calculation of age range experience.

Demographics	**Year 1**		**Year 2***		**Year 3**	
Sex						
Male	4	44%	5	63%	4	33%
Female	5	56%	3	38%	8	67%
Age (mean)	30 years		29 years		30 years	
Race/Ethnicity						
Black	0	0%	0	0%	0	0%
Asian	2	22%	3	38%	1	8%
White	7	78%	5	63%	11	92%
American Indian/Alaskan Native	0	0%	0	0%	0	0%
Pacific Islander	0	0%	0	0%	0	0%
Experience other than current EHR						
None	2	22%	4	50%	8	67%
Less than 3 months	2	22%	1	13%	0	0%
3 months – 6 months	1	11%	0	0%	0	0%
7 months – 1 year	2	22%	2	25%	2	17%
Over 2 years	2	22%	1	13%	2	17%
What is your skill level when using a computer?						
Do not use	0	0%	0	0%	0	0%
Very Unskilled	0	0%	0	0%	0	0%
Unskilled	0	0%	0	0%	1	8%
Skilled	9	100%	7	88%	9	75%
Very Skilled	0	0%	1	13%	2	17%
I am confident when using this EHR						
Not at all	0	0%	0	0%	0	0%
Slightly	1	11%	0	0%	0	0%
Moderately	5	56%	2	25%	5	42%
Very	3	33%	5	63%	6	50%
Extremely	0	0%	1	13%	1	8%
Satisfaction with documenting in this EHR						
Not satisfied	0	0%	0	0%	0	0%
Slightly satisfied	2	22%	0	0%	0	0%
Moderately satisfied	4	44%	3	38%	8	67%
Very satisfied	3	33%	4	50%	4	33%
Extremely satisfied	0	0%	1	13%	0	0%
Satisfaction with creating orders in this EHR						
Not satisfied	0	0%	0	0%	1	8%
Slightly satisfied	2	22%	0	0%	0	0%
Moderately satisfied	4	44%	3	38%	7	58%
Very satisfied	3	33%	4	50%	4	33%
Extremely satisfied	0	0%	1	13%	0	0%
Satisfaction with seeking information in this EHR						
Not satisfied	0	0%	0	0%	0	0%
Slightly satisfied	2	22%	0	0%	2	17%
Moderately satisfied	5	56%	3	38%	8	67%
Very satisfied	2	22%	3	38%	2	17%
Extremely satisfied	0	0%	2	25%	0	0%
Satisfaction with reading notes in this EHR						
Not satisfied	0	0%	0	0%	0	0%
Slightly satisfied	0	0%	0	0%	0	0%
Moderately satisfied	3	33%	1	13%	7	58%
Very satisfied	6	67%	5	63%	3	25%
Extremely satisfied	0	0%	2	25%	2	17%

3 RESULTS

3.1 Participants

Table 1 shows the demographics of primary care resident physicians that participated in the usability test presented as percentages. Examined demographics are: sex, age, race, experience with EHR other than current EHR, and other EHR satisfaction questions. Responses from the demographic question 'Experience other than current EHR' implies that residents are coming into their residency with some EHR experience, which shows a possible increase in EHR training during medical school.

3.2 Performance Measures

Percent task success rates (Table 2): There was a 3 percent point increase in physicians' percent task success rate between year 1 and year 2 (Y1: 95%, CI [90%, 100%]; Y2: 98% CI [90%, 100%]). There was a 3 percent point decrease in physicians' percent task success rate between year 2 (Y2: 98%, CI [90%, 100%]; Y3: 95% CI [90%, 100%]) and year 3. From year 1 to year 3 there was only a 0 percent point increase in physicians' percent task success rate.

Time-On-Task (TOT): There was a 5% decrease in physicians' time on task between year 1 and year 2 (Y1: 38s CI [28s, 52s], Y2: 36s CI [25s, 52s]). However, there was a 6% increase in physicians' time on task between year 2 and year 3 (Y2: 36s CI [25s, 52s], Y3: 38s CI [28s, 53s]). From year 1 to year 3 there was only no increase in physicians' time on task.

Mouse Clicks: There was a 13% decrease in physicians' mouse clicks between year 1 and year 2 (Y1: 8 clicks CI [5 clicks, 13 clicks], Y2: 7 clicks CI [4 clicks, 12 clicks]). There was a 14% increase in physicians' mouse clicks between year 2 and year 3 (Y2: 7 clicks CI [4 clicks, 12 clicks], Y3: 8 clicks CI [6clicks, 12 clicks]). From year 1 to year 3 there was no improvement in physicians' mouse clicks.

Mouse Movement (Length of the Navigation Path to Complete a Given Task): There was a 7% decrease in physicians' mouse movements from year 1 to year 2 (Y1: 8,480 pixels CI [6,273 pixels, 11,462 pixels], Y2: 7,856 pixels CI [5,380 pixels, 11,471 pixels]). There was a 6% increase in physicians' mouse movements from year 2 to year 3 (Y2: 7,856 pixels CI [5,380 pixels, 11,471 pixels], Y3: 8,319pixels CI [6,101 pixels, 11,343 pixels]). From year 1 to year 3 there was a 2% decrease in physicians' mouse movements (Y1: 8,480 pixels CI [6,273 pixels, 11,462 pixels], Y3: 8,319pixels CI [6,101 pixels, 11,343 pixels]).

Table 2: Geometric mean values of performance measures were compared between the physicians by clinical year: year 1 (Y1), year 2 (Y2), and year 3 (Y3). We observed similar trends for other performance measures. T = task.

Performance Measures	Y1	Y2	Y3
Task Success	95%	98%	95%
Time on Task	38s	36s	38s
Mouse Clicks	8	7	8
Mouse Movements	8480	7856	8319

System Usability Scale: first year resident physicians ranked the system's usability at a mean of 51 (low marginal), second year resident physicians ranked the system's usability at a mean of 64 (high marginal) and third year resident physicians ranked the system's usability at a mean of 62 (high marginal) This result may indicate that resident physicians' length of time using the system does not affect their acceptance of the system.

3.3 Usability Issues Identified by Sub-task Analysis

Five themes emerged during sub task analysis: inconsistencies, user interface issues, structured data issues, ambiguous terminologies, and workarounds. Six common inconsistencies were identified among both resident physician groups. Eight common user interface issues were identified through subtask analysis. Five usability issues related to ambiguous terminologies were identified through subtask analysis. Six common structured data issues were identified through subtask analysis. Four common workaround usability issues were identified through subtask analysis. We did not include screen shots due to copyright laws.

The most common usability issues identified was found by physicians attempting to complete Task 7: Document new medication allergy, Task 13: Include diagnosis, Task 15: Place order for Basic Metabolic Panel (BMP), and Task 16: Change a Medication, Task 17: Add a medication to a favorite list.

The most common usability issues identified was found by physicians attempting to complete Task 7: Document new medication allergy, Task 13: Include diagnosis, Task 15: Place order for Basic Metabolic Panel (BMP), and Task 16: Change a Medication, Task 17: Add a medication to a favorite list. Seven first year resident physicians were able to

successfully complete Task 7, one first year resident physician was not able to include the reaction 'hives' to the allergy documentation, and one first year resident physician was not able to successfully complete Task 7. All second year resident physicians were able to complete task 7. Ten third year resident physicians successfully completed Task 7, one first year resident physician was not able to include the reaction 'hives' to the allergy documentation, and one first year resident physician was not able to successfully complete Task 7.

When completing Task 13: Include diagnosis, some resident physicians were unclear on how to import a list of diagnoses from the Problem list into the visit note. Two first year resident physicians and four third year resident physicians were not aware that they should highlight all the diagnoses before clicking 'Include' to get the entire list of diagnoses into the visit note. One third year resident physician did not move 'hypertension' from the problem list to the current diagnosis list so they re-added 'hypertension' as a new problem. Three first year resident physicians, two second year resident physicians, and seven third year resident physicians did not use IMO Search field to shorten steps to add a diagnosis to the note.

When completing Task 15, four first year resident physicians, three second year resident physicians, and four third year resident physicians did not place the two Basic metabolic panel (BMP) orders concurrently.

When completing Task 16: Change a Medication, resident physicians had to choose from the right click menu options 'Renew', 'Cancel/DC', or 'Cancel/Reorder.' Physicians were able to complete task 16 by use the option "Modify without resending" by changing the number of tablets the patient needed to take. To complete task 16, three first year resident physicians used the 'Cancel/DC' option, two first year resident physicians used the 'Cancel/Reorder' options, three first year resident physicians used the 'Modify without resending,' and one first year resident physicians used the 'Complete' option. Six second year resident physicians used the 'Cancel/Reorder' options and two second year resident physicians used the 'Modify without resending.' Five third year resident physicians used the 'Cancel/Reorder' options, four third year resident physicians used the 'Modify without resending,' and three third year resident physicians used the 'Reconcile' option.

When completing Task17: Add a medication to a favorite list, resident physicians were asked to add a medication to a list of their frequently used medications. Five first year resident physicians, three second year resident physicians, and five third year resident physicians were not able to complete task 17. This functionality was not intuitive because this feature was not accessible directly from the medication list, which defeats the purpose and reduces the likelihood of physicians using this feature.

4 DISCUSSION

While the use of EHRs have many advantages, there are many issues that have surfaced because of usability design flaws. In this study and the previous longitudinal study by Clarke et al, there was no difference in physicians' performance measures whether we compared expert to novice physicians across two rounds or physicians by clinical year. More experienced physician users experienced the same usability issues as less experienced physician users. Both studies demonstrate that longer EHR use is not indicative of physicians being an expert at using the EHR.

Previous studies have shown that physicians with varying lengths of EHR experience have comparable success when completing tasks in an EHR. Novice EMR users in Lewis et al's study determining the efficiency of novices compared to predicted skilled use when using an EMR with a touchscreen interface, were able to perform at a skilled level some of the time within the first hour of system use. Kim et al's study, investigating usability gaps between novice and expert nurses using an emergency department information system, found no statistical difference between the two nurse groups' geometric mean values for both scenarios (Kim et al., 2012). When fully completed tasks were analyzed in Kjeldskov et al's study identifying the nature of usability issues that novice and expert users experience and whether these issues disappear over time, there was no statistical significance between novice and expert participants based on a chi-square test ($p = 0.0833$). These results are similar to our study because residents of all three years had comparable task success rates. One of the primary goal of the EHR is to allow new users to perform tasks efficiently and effectively so it is important for new EHR physician users to become experts in the shortest amount of time.

Although the studies show no difference in effectiveness, some studies demonstrate that there was a difference in efficiency among physicians with longer EHR experience Experts showed higher

efficiency than novice participants in studies done by Lewis et al., (2010) and Kim et al., (2012). Although not significant, expert participants in Kjeldskov et al's study were faster for simple data entry tasks. Similar to Kjeldskov et al's study, physicians in our study did not show differences in time on task regardless of clinical year. These results suggest that new users may complete tasks as successful as the experienced users.

This study was constrained to family and internal medicine physicians and only tested the usability of one EHR from one healthcare institution which suggests that results may not interchangeable with other healthcare institutions and other specialties. There were similar themes found in the study by Walji et al and this study, therefore future research is needed to further confirm generalizability. The study also included just a small sample of clinical tasks performed by physicians and may not be representative of functions that may be accessed based on other clinical scenarios. Although there are some methodological limitations to this study, directions given to the physicians were unambiguous which granted participants to understand what was required of them.

Our study identified varying usability issues for users of the EHR with different experience level, which may be used to potentially increase physicians' performance when using an EHR. Although most physicians reported a high level of computer skills and EHR use, both quantitative and qualitative results did not show substantial difference in usability measures. These results show that length of exposure to EHR may not be equivalent to physicians' proficiency when using an EHR. Future studies should include a larger sample of resident physicians and expand the scope to specialist physicians for transferability of results.

REFERENCES

1998. *ISO 9241-11: Ergonomic Requirements for Office Work with Visual Display Terminals (VDTs): Part 11: Guidance on Usability*, International Organization for Standardization.

2011a. Systems and software engineering -- Systems and software Quality Requirements and Evaluation (SQuaRE) -- System and software quality models. 1 ed.: International Organization for Standardization.

2011b. *U.S. EMR Adoption Model Trends* [Online]. Chicago, IL: Health Information Management Systems Society Analytics. Available: http://app.himssanalytics.org/hc_providers/emr_adoption.asp (Archived by WebCite® at http://www.webcitation.org/6cHM M9kmb) [Accessed 02/21 2014].

2012. *Meaningful Use* [Online]. Baltimore, MD. Available: http://www.cms.gov/Regulations-and-Guidance/Legislation/EHRIncentivePrograms/Meaningful_Use.html (Archived by WebCite® at http://www.webcitation.org/6cHEh1HVi).

2013. *University of Missouri Health Care Achieves Highest Level of Electronic Medical Record Adoption* [Online]. Columbia, MO. Available: http://www.muhealth.org/body.cfm?id=103&action=detail&ref=311 (Archived by WebCite® at http://www.webcitation.org/6cHLgcLsU).

Braun, V. & Clarke, V. 2006. Using thematic analysis in psychology. *Qualitative research in psychology,* 3**,** 77-101.

Brooke, J. 1996. SUS-A quick and dirty usability scale. *Usability evaluation in industry,* 189**,** 194.

Carr, D. M. 2004. A team approach to EHR implementation and maintenance. *Nurs Manage,* 35 Suppl 5**,** 15-6, 24.

Chaudhry, B., Wang, J., Wu, S., Maglione, M., Mojica, W., Roth, E., Morton, S. C. & Shekelle, P. G. 2006. Systematic review: impact of health information technology on quality, efficiency, and costs of medical care. *Ann Intern Med,* 144**,** 742-52.

Clarke, M. A., Belden, J. L. & Kim, M. S. 2015. What Learnability Issues Do Primary Care Physicians Experience When Using CPOE? *In:* KUROSU, M. (ed.) *Human-Computer Interaction: Users and Contexts.* Springer International Publishing.

Clarke, M. A., Steege, L. M., Moore, J. L., Belden, J. L., Koopman, R. J. & Kim, M. S. 2013. Addressing human computer interaction issues of electronic health record in clinical encounters. *In:* MARCUS, A. (ed.) *Proceedings of the Second international conference on Design, User Experience, and Usability: health, learning, playing, cultural, and cross-cultural user experience - Volume Part II.* Las Vegas, NV: Springer-Verlag.

Cordes, R. E. 1993. The effects of running fewer subjects on time-on-task measures. *International Journal of Human-Computer Interaction,* 5**,** 393 - 403.

Elliott, G. J., Jones, E. & Barker, P. 2002. A grounded theory approach to modelling learnability of hypermedia authoring tools. *Interacting with Computers,* 14**,** 547-574.

Goldzweig, C. L., Towfigh, A., Maglione, M. & Shekelle, P. G. 2009. Costs and benefits of health information technology: New trends from the literature. *Health Affairs,* 28**,** w282-w293.

Grabenbauer, L., Fraser, R., Mcclay, J., Woelfl, N., Thompson, C. B., Cambell, J. & Windle, J. 2011. Adoption of electronic health records: a qualitative study of academic and private physicians and health administrators. *Appl Clin Inform,* 2**,** 165-76.

Hsiao, C.-J. & Hing, E. 2012. Use and characteristics of electronic health record systems among office-based physician practices: United States, 2001–2012. *NCHS Data Brief***,** 1-8.

Khajouei, R., Peek, N., Wierenga, P. C., Kersten, M. J. & Jaspers, M. W. 2010. Effect of predefined order sets and

usability problems on efficiency of computerized medication ordering. *Int J Med Inform,* 79**,** 690-8.

Kim, M. S., Shapiro, J. S., Genes, N., Aguilar, M. V., Mohrer, D., Baumlin, K. & Belden, J. L. 2012. A pilot study on usability analysis of emergency department information system by nurses. *Applied Clinical Informatics,* 3**,** 135-153.

Koopman, R. J., Kochendorfer, K. M., Moore, J. L., Mehr, D. R., Wakefield, D. S., Yadamsuren, B., Coberly, J. S., Kruse, R. L., Wakefield, B. J. & Belden, J. L. 2011. A diabetes dashboard and physician efficiency and accuracy in accessing data needed for high-quality diabetes care. *Ann Fam Med,* 9**,** 398-405.

Kushniruk, A. W., Triola, M. M., Borycki, E. M., Stein, B. & Kannry, J. L. 2005. Technology induced error and usability: the relationship between usability problems and prescription errors when using a handheld application. *Int J Med Inform,* 74**,** 519-26.

Lewis, Z. L., Douglas, G. P., Monaco, V. & Crowley, R. S. 2010. Touchscreen task efficiency and learnability in an electronic medical record at the point-of-care. *Stud Health Technol Inform,* 160**,** 101-5.

Li, A. C., Kannry, J. L., Kushniruk, A., Chrimes, D., Mcginn, T. G., Edonyabo, D. & Mann, D. M. 2012. Integrating usability testing and think-aloud protocol analysis with "near-live" clinical simulations in evaluating clinical decision support. *Int J Med Inform,* 81**,** 761-72.

Lin, H. X., Choong, Y.-Y. & Salvendy, G. 1997. A proposed index of usability: a method for comparing the relative usability of different software systems. *Behaviour & Information Technology,* 16**,** 267-277.

Lorenzi, N. M., Kouroubali, A., Detmer, D. E. & Bloomrosen, M. 2009. How to successfully select and implement electronic health records (EHR) in small ambulatory practice settings. *Bmc Medical Informatics and Decision Making,* 9.

Love, J. S., Wright, A., Simon, S. R., Jenter, C. A., SORAN, C. S., Volk, L. A., Bates, D. W. & Poon, E. G. 2012. Are physicians' perceptions of healthcare quality and practice satisfaction affected by errors associated with electronic health record use? *J Am Med Inform Assoc,* 19**,** 610-4.

Mclane, S. & Turley, J. P. 2012. One Size Does Not Fit All: EHR Clinical Summary Design Requirements for Nurses. *Nurs Inform,* 2012**,** 283.

Menachemi, N. & Collum, T. H. 2011. Benefits and drawbacks of electronic health record systems. *Risk Manag Healthc Policy,* 4**,** 47-55.

Miller, R. H., West, C., Brown, T. M., Sim, I. & Ganchoff, C. 2005. The Value Of Electronic Health Records In Solo Or Small Group Practices. *Health Affairs,* 24**,** 1127-1137.

Nielsen, J. 1993. *Usability engineering,* Boston, Academic Press.

Sauro, J. & Lewis, J. R. 2010. Average task times in usability tests: what to report? *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. Atlanta, Georgia, USA: ACM.

Sheehan, B., Kaufman, D., Stetson, P. & Currie, L. M. 2009. Cognitive analysis of decision support for antibiotic prescribing at the point of ordering in a neonatal intensive care unit. *AMIA Annu Symp Proc,* 2009**,** 584-8.

Shekelle, P. G., Morton, S. C. & Keeler, E. B. 2006. Costs and benefits of health information technology. *Evid Rep Technol Assess (Full Rep)***,** 1-71.

Terry, A. L., Thorpe, C. F., Giles, G., Brown, J. B., Harris, S. B., Reid, G. J., Thind, A. & Stewart, M. 2008. Implementing electronic health records: Key factors in primary care. *Can Fam Physician,* 54**,** 730-6.

Tullis, T. & Albert, W. 2008. *Measuring the User Experience: Collecting, Analyzing, and Presenting Usability Metrics*, Morgan Kaufmann Publishers Inc.

Viitanen, J., Hypponen, H., Laaveri, T., Vanska, J., Reponen, J. & Winblad, I. 2011. National questionnaire study on clinical ICT systems proofs: physicians suffer from poor usability. *Int J Med Inform,* 80**,** 708-25.

Walji, M. F., Kalenderian, E., Tran, D., Kookal, K. K., Nguyen, V., Tokede, O., White, J. M., Vaderhobli, R., Ramoni, R., Stark, P. C., Kimmes, N. S., Schoonheim-Klein, M. E. & Patel, V. L. 2013. Detection and characterization of usability problems in structured data entry interfaces in dentistry. *Int J Med Inform,* 82**,** 128-38.

Whiteside, J., Jones, S., Levy, P. S. & Wixon, D. 1985. User performance with command, menu, and iconic interfaces. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. San Francisco, California, USA: ACM.

Whittaker, A. A., Aufdenkamp, M. & Tinley, S. 2009. Barriers and facilitators to electronic documentation in a rural hospital. *Journal of Nursing Scholarship,* 41**,** 293-300.

Yoon-Flannery, K., Zandieh, S. O., Kuperman, G. J., Langsam, D. J., Hyman, D. & kaushal, R. 2008. A qualitative analysis of an electronic health record (EHR) implementation in an academic ambulatory setting. *Inform Prim Care,* 16**,** 277-84.