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Electronic Health Record System Clinical Notes Usage Usability Evaluation – An Ethnographic study

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Abstract:

Background: A significant gap exists between current Electronic Health Record (EHR) usability and potential optimal usability, which is often attributed to poor incorporation of a user-cantered approach during the Graphical User Interface (GUI) design process. **Objectives:** To evaluate usability strengths and weaknesses of two widely implemented EHR GUIs for critical clinical note usage tasks using data collected from real users observed in their actual inpatient work environments.

Methods: Twelve Internal Medicine resident physicians were observed by two usability evaluators while interacting with one of two EHR systems (Epic at University of Minnesota Medical Center and CPRS at Veterans Affair Hospital Care Systems), employing an ethnographic approach. User comments and observer findings were analyzed for two critical tasks: (i) clinical note entry and (ii) related information-seeking tasks, and from two standpoints: (a) usability references categorized by usability evaluators as positive, negative or equivocal and (b) usability impact of each feature measured through a seven-point severity rating scale. Findings were also validated by user responses to a post-observation questionnaire.

Results: For clinical note entry, Epic surpassed CPRS with more positive (26% vs. 12%) than negative (12% vs. 34%) usability references. Greatest impact features on EHR usability (severity score after each feature) for clinical note entry were auto-population (6), screen options (5.5), communication (5), copy pasting (4.5), error prevention (4.5), edit ability (4) and dictation & transcription (3.5). Neither system did better for information-seeking tasks with CPRS having more positive (28% vs. 14%) but also more negative (41% vs. 34%) references. Features pertaining to information–seeking tasks with greatest impact on EHR usability were navigation for notes (7) and others (e.g., looking for ancillary data) (5.5). Ethnographic observations were also supported by follow-up questionnaire responses.

Conclusion: This study provides usability specific insights of two widely used EHR systems that could help with future design of EHR interfaces better aligned with a user- centered approach.

Keywords: Electronic Health Records; Interfaces and usability; Graphical User Interface; Clinical Documentation; Qualitative Methodologies

Introduction

While adoption of EHR systems through the Meaningful Use (MU) program and other regulations incentivizing EHRs ultimately aims to improve the quality of health care in the United States (1), substantial gaps exist between the current state of EHRs and their potential usefulness (2). Recently, the healthcare end-user community and EHR experts have pointed specifically to the significant cognitive challenges resulting from poor EHR usability as one of the key reasons for this gap (2). A well-designed EHR GUI could help address these challenges by improving system usability and potentially lead to improvements in healthcare delivery (31).

Usability has been defined in various ways and it typically encompasses a set of evaluation methods to understand user experiences for the purpose of creating more desirable, usable and useful products (66). The International Organization for Standardization (ISO) defines usability as, "an extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" (67). Nielsen defines usability as, "a quality attribute that assesses how easy user interfaces are to use" and describes five basic principles (i.e., easy to learn, easy to remember, efficient with minimal error and with greater user satisfaction) (68,69). An essential approach to account for and resolve usability problems is user-centered design, with the philosophy that "the final product should suit the users, rather than making the users suit the product" (70).

To date, several EHR usability studies employing various methodological approaches (e.g., surveys, focus groups, ethnographical studies, cognitive walkthrough, heuristic evaluation, usability testing) have been conducted in diverse contexts, such as usability work with clinical decision support systems and dental EHR systems (15,21,22,46,71-73). Among these methods, "Ethnography" is one of the earliest

techniques where subjects are observed in a naturalistic setting and has been utilized in the software development cycle for evaluating information systems (74). This approach to data collection provides a rich, realistic, and holistic view of user behavior in task completion and could aid in gathering additional detailed information which users sometimes fail to communicate during more controlled (e.g., laboratory-based) methodological approaches. Similar observational study methodologies have been used widely in healthcare research (56, 57,73,75).

There is a growing amount of literature providing guidelines and recommendations that could help improve EHR usability and could ultimately enhance patient safety and quality of care (12,76,77). For a comprehensive usability evaluation, a multi-method approach is preferred (78-80). Despite these recommendations, there are limited numbers of studies where the Health Information Technology (HIT) usability has been assessed employing more than one methodological approach. Few examples of such multi-method studies are: dental EHR evaluation employing user testing along with observations, interviews and GOMS modeling techniques (30); computerized provider order entry system assessment using two different sets of heuristics along with usability testing (81) and diabetes mHealth system evaluation employing combination of user testing with semi-structured interviews and questionnaires around patients' experiences using the system (78). Furthermore, there is limited number of research studies out there where any usability comparison is being done from viewpoints of people with a diverse set of perspectives (e.g., expert users vs. novice users (82); physician vs. patients (83) and users vs. usability experts (84).

One specific area needing attention is the design and functionality offered by these EHR systems' GUI around clinical notes usage. There are several challenges associated with clinical notes usage such as clinical notes may be difficult to find, time consuming to enter, contain poorly formatted information that is difficult to read, incorporate erroneous or out-of-date information, or lack standardized content display within EHR systems (25,39). Despite these known usability problems, EHR clinical notes remain essential resources for clinicians who use them to communicate, summarize and synthesize patient care information for decision-making. Physicians and other clinicians are challenged, both when entering information into and retrieving information from clinical notes, as current EHRs may not sufficiently support these tasks. To date, only few studies have examined usability of the user interfaces pertaining to clinical notes. Few examples of more recent studies are: usability testing of user-constructed point and click progress notes construction set showing favorable responses by users (29); time-and-motion study reporting that note documentation should be treated as synthesis rather than composition and the documentation process could be best supported by incorporation of various search tool that's could facilitated note construction (85) and eye tracking studies on physicians' visual attention while reading electronic progress notes revealing that most time was spent in slowly reading the "Impression and plan" section of progress notes with minimal time spent on sections like "Medications", "Vital signs" and "Laboratory results" even when there was additional information in these sections (26).

Objectives

This research study was conducted to seek answer for the following questions: What are the various design and functionality features pertaining to the clinical note usage offered by GUIs of two existing EHRs systems? and how these features could potentially influence EHR usability ascertained from viewpoints of usability evaluators and users? We hypothesized that the two EHR systems would offer various features around clinical note usage and each system would have its own usability strengths and weaknesses. It is anticipated that the insights derived from user observations and comments would help interface designers in generating the future EHR clinical note interfaces that is better aligned with user needs and usability evaluators suggestions based on usability guidelines.

Methods

General Description and Setting

An ethnographic field study (86,87), supplemented by a post-observation questionnaire was performed to collect data about the routine, day-to-day activities of EHR users in their naturalistic settings. Participant observation was performed by immersing in physicians' routine day to day activities and collecting rich data about their interaction with EHRs while performing clinical documentation tasks. Participant physicians were briefed about project goals, the methodology employed to collect data and instructions on think out loud (i.e., to share their thoughts audibly about the EHR's clinical notes whileinteracting with the GUI of their EHR system). Informal conversation was also carried out between observers and physicians in order to get an understanding of any emerging issues, or asking questions. Field notes

were documented with an electronic tablet using a time-stamped application.

Internal Medicine resident physicians were observed interacting with one of the two different EHR systems in the inpatient environment of two tertiary care centers (Epic, a commercial vendor system at University of Minnesota Medical Center (UMMC) and CPRS, an open source system at Veterans Affair Hospital Care Systems (VAHCS)). Because residents who participated in this study spent most of their time interacting with EHRs in workrooms, particularly for clinical note usage related tasks, the majority of observations were carried out in physician workrooms. Each resident was observed on different days of the week (4-5 days) and during various sections of the day (e.g., pre- rounding, rounding and post-rounding (mean hours/day/resident=2-2.5)) (Fig..1). In general, UMMC has a more diverse patient population needing treatment for more complex medical and surgical conditions, whereas at VAHCS patients are older, predominantly male and mainly coming in for treatment of chronic medical conditions and psychiatric diseases.

Study Sample

A total of 12 (6 per system), mid and senior-level resident physicians in their 2nd through 4th years enrolled in Internal Medicine Categorical or Internal Medicine Combined programs, were recruited for the study. Interns, medical students, advanced practice providers, attendings and other non-provider clinicians were excluded. The characteristics of participants, summarized in Table 1, were similar across the two sites. Study participants were given a $50 gift certificate as incentive for their participation.

Because of the complexities associated with evaluating EHR system usage, employing usability evaluators with dual domain knowledge (both usability experience and health care knowledge) was crucial (88). Two of the authors (RR – a health informatician and physician and GH– a health informatician and clinical researcher with a Masters of Public Health) were assigned this role.

Table 1- Characteristics of resident participants

	*UMMC-H1	VAHCS-H2
Mean Age (Yrs.)	31 (±3.6)	29.5 (±1.6)
Mean years in training	2.8 (±0.4)	3 (±0.6)
Gender		
Female (%)	4 (66.6%)	3 (50%)
Male (%)	2 (33.3%)	3 (50%)

Data Collection

Data regarding the usability and functionality of each EHR's *clinical notes* was collected at both sites by RR and GH. As noted earlier, the majority of data collection was done in the residents' workroom. To ensure a representative sampling of different activities for each EHR system, each resident was observed on various different days of the week (e.g., on-call and off-call days (refers to admitting and non-admitting days), weekends, and inpatient sections of clinic days) for a total of four to five days. Observations times were approximately between 7:00 am-6:00 pm, where each resident was individually observed for a 2-2.5 hours/days and during various sections of the day (e.g., pre-rounding, rounding and post-rounding). On average, each participant was observed for 9 hours (±2.5) at UMMC and 9.6 (±1.9) hours at VAHCS, with a total of over 110 hours spent on observation. The total time included time spent on note documentation, order entry, chart review and others. Note documentation consumed an average of 20-30% of the total time that conforms to the findings from previous time-motion studies (89).

Observation data were further supplemented by a post-observation questionnaire. Both closed and open-ended questions were employed to collect residents' subjective responses from two standpoints—*clinical note entry* and *information-seeking tasks*. (The sample questions from the questionnaire can be seen in Appendix A)

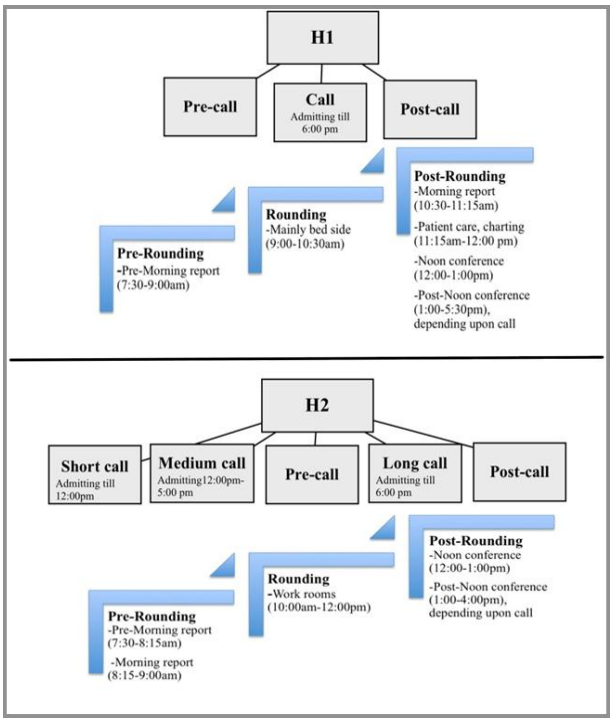


Figure 1-Typical call and day schedule of residents at UMMC (H1) & VAHCS (H2)

*The schedule shows approximate times. Residents on night calls or on sub-specialty rotations follow a different schedule. * H1 (Hospital): University of Minnesota Medical Center (UMMC); H2 (Hospital): Veterans Affairs Health Care System (VAHCS))*

Data Analysis

An Ethnographic Content Analysis (ECA) (90) of qualitative data was performed on the observatory notes documented as "field notes", employing an integrated qualitative- quantitative research design (61). These field notes consisted of information on clinical documentation task (e.g., clinical note entry or related information-seeking tasks) noted down while physicians were interacting with EHRs and were a combination of direct observations by observers and comments volunteered by resident physicians. This raw data was later dissected into groups of words or phrases (the meaning unit, referred as 'usability references' in this study). Each usability reference pertaining to the study "theme" i.e., functionality and design elements around clinical documentation tasks, was coded in terms of the EHR system (e.g., Epic or CPRS) it is referring to and its perceived impact on usability (Positive (P), Negative (N) or Equivocal (E)) (Fig. 2). Usability was coded as positive, negative, or equivocal if the usability evaluators considered the EHR features to be desirable, undesirable, or ambivalent, respectively. NVivo (version 10.1.3) (62), a qualitative data analysis tool, was used in this study.

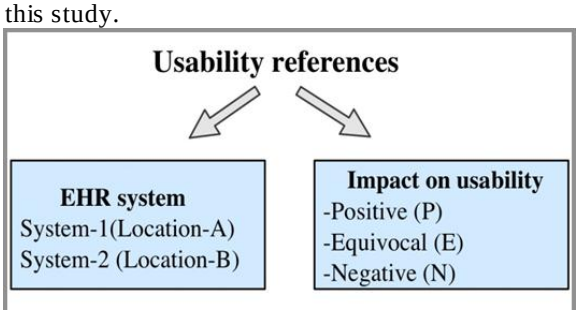
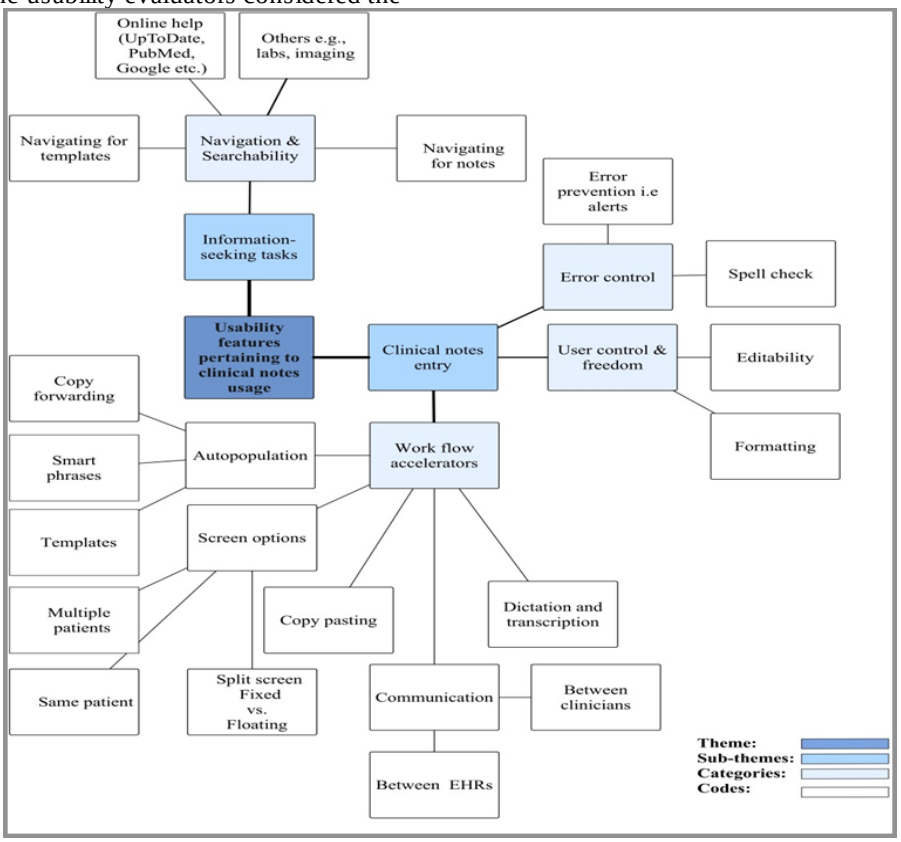


Figure 2- Attributes of interest

The coding schema pertaining to functionality and design elements around clinical documentation tasks (i.e., *clinical note entry* or *related information-seeking*) (Fig. 3) was generated in NVivo through an iterative process of brainstorming and refinement among research team members. The team included health informaticians (RR, GH, TA, GM, JM), physicians (RR, TA, GMM), and usability evaluators (RR, GH, JM, KH), with the latter two members having additional industrial engineering and experimental cognitive psychology expertise, respectively. Conflicts were iteratively addressed and resolved.



3-Visual depiction of coding scheme used in content analysis

Two team members (primarily RR and GH) coded the notes through repetitive and comprehensive scanning of the field notes and brainstorming among other co- authors, ensuring that the final coding schema represents the majority of the source domain and not merely a small non-representative slice. Inter-coder agreement was 98%, with a kappa of 0.8 (91). Any remaining coding discrepancies were discussed and resolved through a consensus process.

Data was analyzed and presented at three hierarchical levels: (i) at the higher level of sub-themes, (ii) at the more granular level of categories within those sub-themes and

(iii) at the deepest levels of codes within those categories. We analyzed the usability reference data in the context of various usability features from two standpoints: (a) frequency (percentage) of being evaluated as positive, negative or equivocal under each sub-theme, category or code and (b) their impact on usability as measured through gauging references to denote a specific usability feature. The references were gauged by assigning weights against a severity impact scale based on three variables: (1) percentage frequency of total references, (2) the perceived impact on user interaction/performance and (3) the usage (sporadic or recurrent) of that particular usability feature. Two co- authors, RR and TH, both physicians and health informaticians with expertise in EHR usability evaluation, performed the scoring. A 7-point severity rating scale was employed to perform the scoring as follows: high impact (>5), medium impact (3-5) and low impact (<3). The results were further validated by analyzing responses obtained from physicians through post-observation questionnaires.

Results

In total, there were more usability references specific to clinical notes use for Epic (347) than CPRS (132). For both Epic and CPRS, there was greater number of positive and negative references under note entry (276, 103) than information seeking tasks (71, 29). Usability references were dissected at three levels of granularity i.e., sub-themes, categories and codes (Fig. 4, 5 & 6), cataloged as either positive, negative or equivocal and were reported as percentage frequency.

Analysis at the Level of Sub-themes

Analysis at the level of sub-themes (Fig. 4) revealed that Epic as compared to CPRS excelled in note entry features by having higher percentage of positive usability references (P=26% vs. 12%) and substantially lower negative references (N=12% vs. 34%). Inconclusive results were attained for *information-seeking tasks* as Epic in comparison to CPRS had both lower percentages of positive (P=14% vs. 28%) and negative references (N=34% vs. 41%).

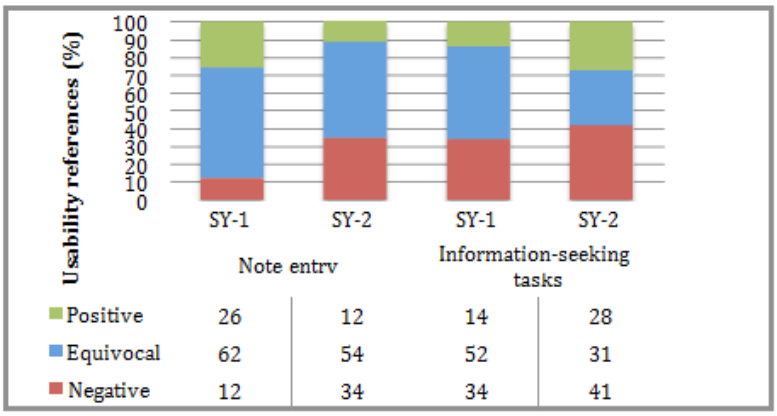


Figure 4-Frequency analysis of usability references at the level of sub-themes
**SY-1=Epic, SY-2=CPRS*

Analysis at the Level of Categories

More granular analysis at the level of categories (Fig. 5) showed similar results i.e., Epic surpassed CPRS in *note entry* by having higher percentage of positive and lower percentage of negative usability references, specifically with respect to *error control, user control & freedom* and *work flow accelerators*. Whereas inconclusive results were obtained for *information-seeking tasks* related to *navigation and ability to search* i.e., Epic as compared to CPRS showed both lower percentages of positive and negative usability references.

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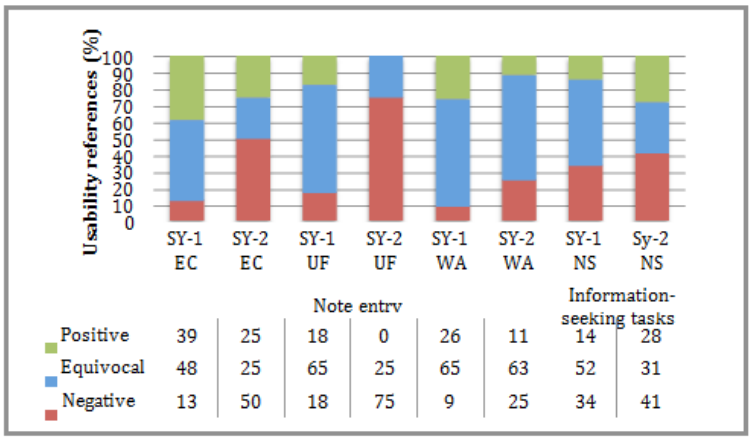

Figure 5-Frequency analysis of usability references at the level of categories

**SY-1=Epic, SY-2=CPRS; EC: Error Control; UF: User control & Freedom; WA: Workflow Accelerators; NS: Navigation & Search ability*

Analysis at the Level of Codes

Analysis done at the deepest level of codes (Fig. 6) further revealed the details of note entry features having higher percentage of positive and lower percentage of negative usability references under Epic as compared to CPRS, for example *error prevention* and *spell check*; *edit ability* and *formatting; dictation & transcription, screen options, auto- population* and *communication*, except under *copy pasting*. With respect to *information- seeking tasks* related to *navigation and ability to search*, the percentages of positive and negative references under Epic vs. CPRS under all four codes i.e., *navigating for notes*, *navigating for templates*, *online help* and *others*, showed inconclusive results Overall, under all three levels, a greater percentage of references were coded as equivocal for Epic than for CPRS under both *note-entry* and *information-seeking tasks* to the coders' uncertainty surrounding particular usability items warranting further studies.

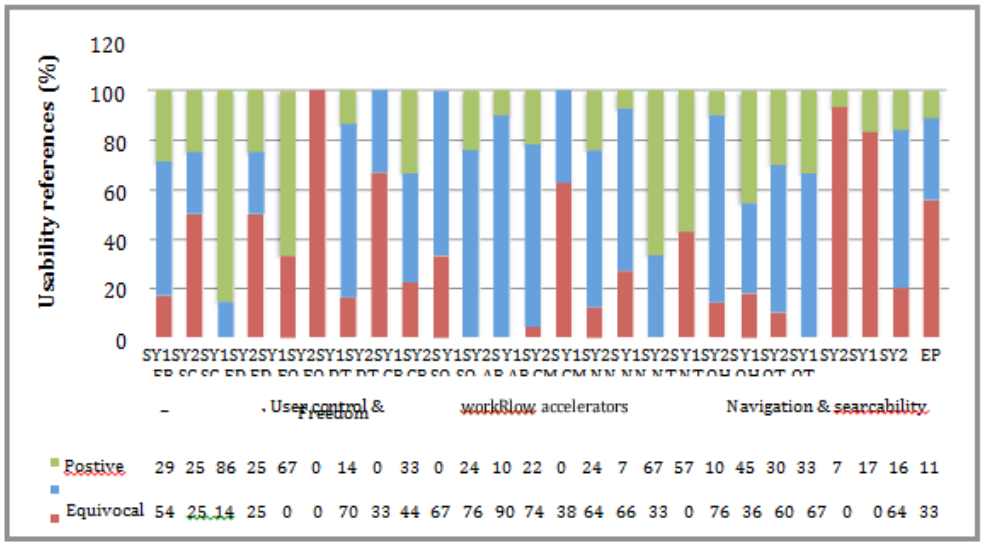

Figure 6-Frequency analysis of usability references at the level of codes

*SY-1=Epic, SY-2=CPRS; EP: Error Prevention; SC=Spell Check; ED=Editability; FO=Formatting; DT=Dictation & Transcription; CP=Copy Pasting; SO=Screen Options; AP=Auto Population; CM= Communication; NN=Navigating for Notes; NT= Navigating for Templates; OH=Online Help; OT=Others

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Severity Impact Rating

The data on usability references denoting a specific usability feature was further analyzed by assigning them an overall severity score. The references were gauged by two coauthors, (RR and TA) after assigning each feature a score against a severity impact scale based on percentage frequency of total references, its perceived impact on user interaction/performance and its usage (sporadic or recurrent).The score was later categorized into three groups as high impact (>5) (e.g., navigating for notes (score=7), auto-population (score=6), screen options (score=5.5) and others (score=5.5)); medium impact (3-5) (e.g., communication (score=5), error prevention (score=4.5), copy pasting (score=4.5), edit ability (score=4), and dictation & transcription (score=3.5) and low impact (<3) (e.g., spell check (score=2.5), formatting (score=2.5), navigating for templates (score=2.5) and online help (score=2.5) (Fig. 7).

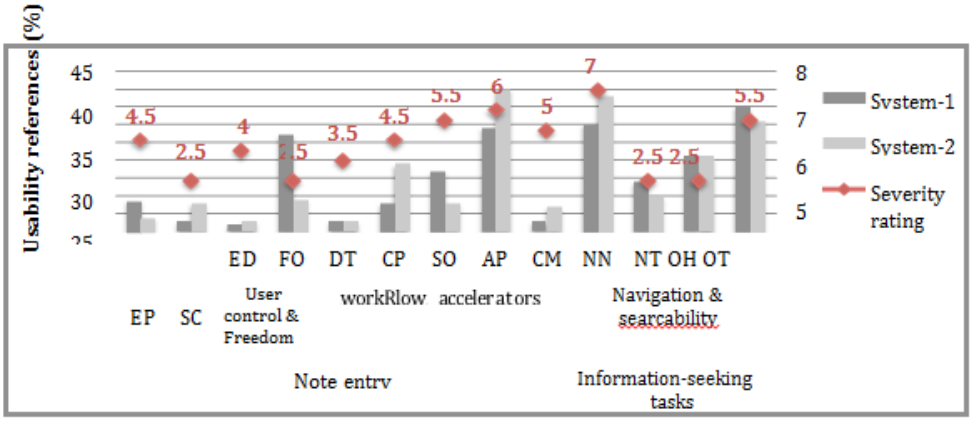

Figure7-Frequency comparison of total usability references under Epic & CPRS

**SY-1=Epic, SY-2=CPRS; EP: Error Prevention; SC=Spell Check; ED=Editability; FO=Formatting; DT=Dictation & Transcription; CP=Copy Pasting; SO=Screen Options; AP=Auto Population; CM=Communication; NN=Navigating for Notes; NT= Navigating for Templates; OH= Help; OT=Others*

Discussion

Usability evaluation was performed on two widely implemented EHR GUIs around critical tasks of clinical note usage through data collected from ethnographic studies along with post-observation questionnaires. Each EHR system was appraised in terms of percentages of respective usability references being perceived and cataloged by usability evaluators as positive, negative or equivocal. Results were later validated by analyzing physicians' responses.

We discovered that overall, Epic surpassed CPRS in clinical note usage specific to note entry related tasks, while neither of the systems did better with respect to information-seeking tasks associated with clinical note usage. Usability features scored as "high impact" were auto-population, screen options, navigating for notes and others; as "medium impact" were communication, error prevention, copy pasting, edit ability and dictation & transcription and as "low impact" being spell check, navigating for templates, and online help.

EHR Usability Pertaining to Note Entry

Under note entry, Epic had considerably more positive and comparatively less negative feedback. The most desirable note entry related features were auto-population and screen options, classified as high impact. Auto-population functionality, executed through smart phrases, served as a catalytic agent in the note writing process and was thought to improve user efficiency during task performance. Conversely, it was also considered as a source of introducing inaccurate, repetitive, dated and redundant information leading to lengthy notes as quoted by various users (Table.3). Similarly, the ability to have various screen display options (e.g., split panes, floating screens) was also considered as a strength because these features facilitated concurrent information-seeking tasks with note entry related tasks. On the contrary, the inability to multitask was considered to be one of the least favorable aspects of the system despite of the fact that multitasking could be associated with increase chances of errors. For instance, users were not allowed to open more than one patient chart at a time, an error prevention feature, or view previous notes/data within the same window of the same patient's chart in order to inform the content of the

current note, thus hindering timely access to relevant patient information.

The ease of communication between other clinicians and EHRs with regard to interoperability, error prevention through screen alerts, ability to copy paste/easy edit options and proficient dictation & transcription services were few of the other medium impact usability strengths pertaining to the note entry task that were repeatedly praised by the respective system users. The formatting and spell check feature, despite having a low impact on usability, were also frequently praised because it gives users the freedom to customize their notes in different fonts styles/sizes/colors.

EHR Usability Pertaining to Information-Seeking Tasks

Under information-seeking tasks, CPRS had a greater percentage of positive as well as negative observations whereas ease of navigating for notes was the most favorable feature having the greatest impact on usability. The likely explanation for the positive feedback was the simplistic GUI design with intuitive default notes listing display (e.g., notes from previous encounters were cataloged according to the specialties with better consistency and ease of finding desired notes). This was in contrast to the frustration

users expressed with the extensive list of notes containing a number of options to perform the same tasks (over-functionality) and the perception that note filters, offered as a feature, were cumbersome to use. Hence, a sense of information overload negatively affects intuitiveness and ease of use. Similarly, others, corresponding to the ease of locating ancillary data (e.g., labs, imaging), was considered to be another important aspect of GUI that could substantially impact its usability. Having ancillary data accessible through various screens rather than through a sole homepage and a search box to find specific information are a few of the favorable features that could enhance EHR usability pertaining to clinical note usage. In addition, navigating for templates and online help were also considered to be desirable features despite of their low impact on usability.

Equivocal Results

Under both sub-themes for the two systems i.e., note entry and information-seeking tasks, a considerable portion of data was coded into the equivocal category more under Epic than CPRS, because of their uncertain effect on usability. These items would require a more in-depth and individual study of each feature/item in order to understand their influence on usability. We expect that this analysis, however, could yield some interesting additional findings about these systems.

Innovative and Comments and Ideas by Users

We also solicited a number of suggestions from users of both systems, which could help us in designing a new and improved GUI having better overall usability. One user recommended incorporating advanced technologies, such as login with finger scans or pupil iris scan to enhance the EHR usability, whereas having a "Google" like search engine was a common suggestion received from several users. According to some users, standardizing the structure of the templates used for different note types and establishing a structured curriculum for medical students/residents about the coding/billing requirements for notes writing, could result in more standardized note entry, potentially decreasing note format and content variability. According to one of the users, linking the name of a lab test with the most recently reported result would enhance user efficiency. With respect to improving usability pertaining to information seeking tasks associated with clinical note usage, users offered several suggestions such as the idea of reducing the crowding of notes by incorporating separate locations/tabs based on encounter types and authors and enhancing user efficiency by entering current problems automatically and retrieving relevant data pertinent to these problems (e.g., notes, labs, imaging results) by clicking on them.

Study Limitations

Several limitations are associated with this study including a small sample size and restriction to users from one specialty. All users were 2nd- 4th years residents, working in an academic setting having similar ages, training experience and technology skills. Also, the field studies were limited to the inpatient setting. Because of limited resources and paucity of double evaluators, we employed two authors as evaluators rather than recruiting them from outside the study team. Our findings are limited by a lack of robust statistical analysis, because of our small sample size and the qualitative nature of our data. In addition to these limitations, there are potential biases linked with qualitative data collection and analysis methods, which could result in variability in how results were presented.

Relevance and Contributions

Suboptimal EHR usability, resulting from lack of incorporation of UCD design approach in the

SDLC, results in ineffective and inefficient tasks performance (e.g., poor quality or missing data, increase error rate, challenges with care coordination, compromised patient safety) leading to dissatisfaction among users (providers and patients) and ultimately resulting in poor health care delivery.

This research study explores the two existing EHRs in terms of their design and functionality features pertaining to critical tasks centered on clinical note usage. Data was collected employing multi-method approach, analyzed both from users' and usability evaluators' perspectives and employing both qualitative and quantitative approaches. By getting in-depth understanding of desirable and undesirable usability features offered by existing EHR GUIs and using this information as a platform to redesign future EHR interface, we could ultimately succeed in generating an ideal EHR interface GUI. Hence, more efficient and effective task performances associated with greater user satisfaction that could ultimately result in enhanced healthcare delivery and better health outcomes.

Future work

Comparative analysis of usability features embedded in various other competing EHR systems performed by employing different usability evaluation methods (e.g., heuristic evaluations, cognitive walk through, formal usability testing) with varied and larger sets of physicians and usability evaluators (e.g., attendings, specialists, nurses, experts in usability) and in diverse settings (e.g., ambulatory, urgent care, emergency department), could enhance generalizability of our study findings. Time motion studies could also be performed to gauge the efficiency of performing a particular task and to report more precise time to task data. In addition, further studies are warranted to understand observed discrepancies in user and usability evaluator feedback about the impact of various features on usability.

Conclusion

In summary, each EHR offered a varied set of usability features pertaining to clinical note usage tasks and had its own strengths and weaknesses with regard to presence or absence of certain features. This study helps to illuminate some of the underlying issues and could lead to improved future EHR functionality by integrating the findings into future EHR development. This study is a promising step towards enhancing EHR usability by designing GUIs with a user-centered approach that could ultimately result in more effective and efficient patient-centered healthcare delivery.

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