Understanding Providers' Interaction with Graphical User Interface Pertaining to Clinical Document Usage in an Electronic Health Record System

A Dissertation
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Rubina Fatima Rizvi

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Genevieve B. Melton-Meaux, MD, PhD, FACMI (Adviser)
Terrence J. Adam, RPh, MD, PhD (Co-adviser)

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Dedication

This thesis is dedicated to my beloved father, "Dr. Hasan Rizvi" who lost his battle fighting with cancer in September 2014. I started this long journey of earning my doctoral degree in Health Informatics with his blessings in early 2014 and I would now like to wrap this up by looking up in the sky and saying, "my dearest "abbu" (for "father" in Urdu language), I know, you would be the one feeling the utmost pride in your daughter's achievements. I love you!"

I would also like to dedicate this to my most supportive and caring husband; "Munir", who always believes in my strengths and helps me fight every obstacle that comes in my way; "Mariam" and "Daniyal", our two wonderful kids who are the source of positive energy and joy in our lives; my mother, "Shehnaz", who is always there for me for her unconditional love and prayers; my elder and most affectionate brother, "Muslim"; my younger sister and best friend, "SheharBano" and all my family and friends across USA, Canada, Brazil, Qatar and Pakistan. I love you all!

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CHAPTER 1: INTRODUCTION

1.1. Electronic Health Record Systems and the Sub-optimal Usability

Despite of the reported benefits ensuing from the meaningful use of Electronic Health Record (EHR) systems (e.g., enhanced health care quality, efficiency and safety and improved health outcomes) (1), there exists a significant gap between the current state of their use and perceived potentials (2). One of the fundamental reasons for this discrepancy is lack of incorporation of a "User-Centered Design" (UCD) (3) approach during the EHR System Development Life Cycle (SDLC) process.

The term "User-Centered Design" (UCD) is not just an essential philosophy but a process entailing an array of methods where end-users take the central role in SDLC process with an aim that the resulting final product should suit the user, rather than making the users suit the product (3,4). UCD is defined as "a process in which the needs of the user are taken into consideration during each stage of design and development" (5). Despite of the longstanding history of UCD concepts in the Human Computer Interaction (HCI) domain as introduced by Norman and Draper (6,7), its scarce use in the real world including Health Information Technology (HIT) is not an exception (8,9). With increased EHR adoption and growing frustrations with poor EHR usability pertaining to EHRs' Graphical User Interfaces (GUIs) (10), the importance of involvement of end users during software development processes has gained much recognition in recent years (11,12).

Lately, the Office of National Coordinator (ONC) for Health Information

Technology, (HIT) has included “Safety Enhanced Design” requirements as one of the criteria for ONC certification in order to promote incorporation of UCD practices by EHR vendors (13). Despite of this revised regulations, studies have show shown poor adherence to ONC standards even among several certified EHR vendors (14). Additionally, with vendors using varied testing conditions (e.g., use cases/scenarios, numbers/characteristics of participants), it is challenging to make meaningful comparisons across vendor products. More so, most EHRs change dramatically during implementation phase making pre-implementation assessment ineffective for determining overall usability and safety of products.

Among various essential tasks that physicians routinely perform while interacting with an EHR (e.g., admission orders, e-prescribing, labs/imaging orders, results review, medication reconciliation, billing), “clinical notes usage” including notes entry and related information-seeking tasks are the critical ones worth mentioning. Clinical notes in EHR systems are highly important to providers, who use them to communicate, summarize and synthesize patient care and decision-making. Information overload with usage of the display of clinical notes in EHR systems poses tremendous challenges to physicians and other clinicians, especially working under time limitations. Hence, functionality and design of EHRs around clinical notes usage are the critical elements of patient care delivery and optimizing EHR usability around these element is an area of opportunity demanding further improvements.

1.2. Existing knowledge in Health Information Technology Domain

The role of usability evaluation in information technology domain, specifically around HIT have been examined in several papers (15-17). Experts have developed several methodologies to better understand the usability of a product from the end users' perspective, the main focus in the UCD approach to be employed in various phases of SDLC process (15,18-20). The iterative process of an ideal SDLC to be integrated in an EHR system development along with it's constantly evolving five phases are shown in Fig. 1.1.

Research studies specific to HIT usability (e.g., clinical decision support systems, medical devices and EHR systems, in particular dentistry), have been done in the past (21-23), but there are not many studies focusing on issues of presentation and documentation within an EHR interface (24-27). Insufficient knowledge in this area is further augmented by the fact that there are only handful of studies done on usability evaluation and prototyping of clinical notes user interfaces in the medical domain (searched in Google Scholar and Web of Science using key words "usability evaluation", "clinical notes", "Graphical User Interface") (24-30). Therefore, the study of Human Computer Interaction (HCI) pertaining to clinical notes Graphical User Interface (GUI) designing and its usability evaluation is an area of opportunity where further exploration is mandated.

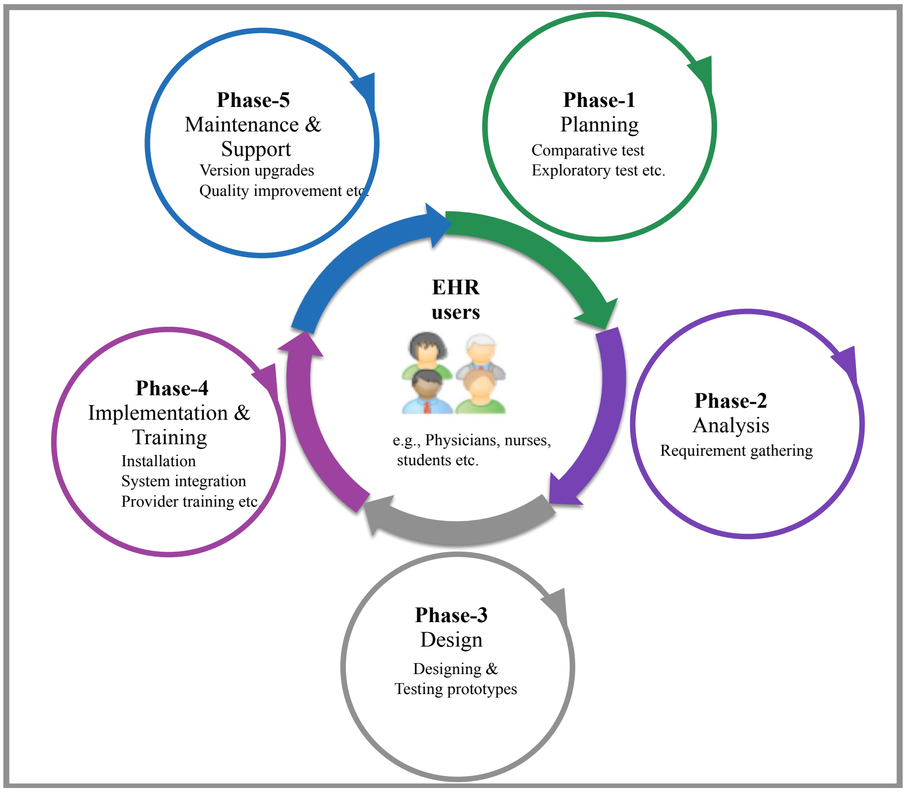

Figure 1.1-User Centered Design (UCD) approach of Electronic Health Records (EHR) System Development Lifecycle (SDLC).
Adapted from "Cognitive and usability engineering methods for the evaluation of clinical information systems' by Andre W. Kushniruk and Vimla L. Patel (20)

1.3. Significance of a Well-Designed Electronic Health Record System

A well-designed user interface of an EHR could result in significant improvement in user acceptance and ease of adoption leading to overall improvement in health care delivery (31). This can be aided by rigorous interface design aimed at presenting data to users in a way that facilitates understanding, assimilation and usage of information in more efficient way (25,32). To achieve this goal, users, i.e., clinicians should be the center of focus during each phase of SDLC process. Despite of the significance of UCD process in generating an end product with high usability, EHR vendors shows a wide range of UCD practices (e.g., from having well developed approach to minimal or none (33)).

Any workflow process is built around intricate relationships among four important components for example (i) the environment, (ii) nature of the task, (iii) design and functionalities offered by the information system to support the task and (iv) usage behavior of users around that task (34,35) (Fig. 1.2). In order to have efficient and effective outcomes, understanding these components and generating a fine balance among them is vital.

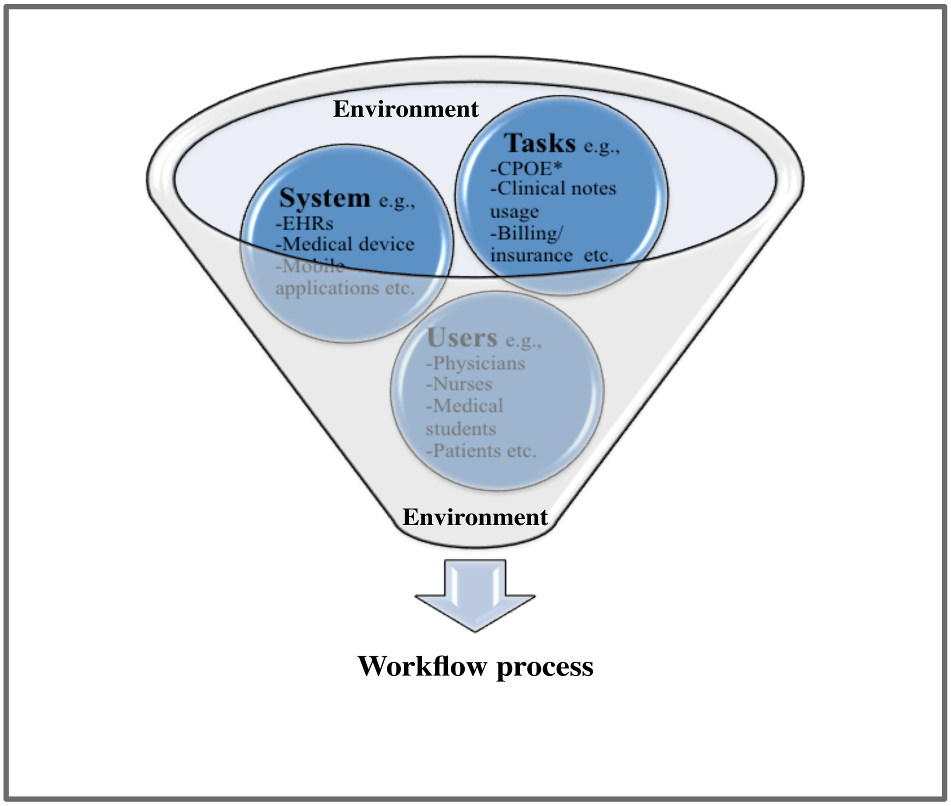

Figure 1.2-Components of a workflow process

**CPOE: Computerized Patient Order Entry*

1.4. Usability Evaluation Methods

There are three main approaches of doing usability evaluations depending upon the source of evaluation i.e., user-based, model-based, and usability-expert based (36) (Fig.

1.3). However, the wide-ranging of usability testing methodologies available makes it difficult to decide on which to select for evaluation of various applications. Each usability evaluation method has its own merits and demerits. Information collected from combination of various methods collectively to triangulate findings is more powerful than one gathered from an isolated method (37). Therefore an amalgamation of different techniques appropriately applied, can compliment one another and should be the preferred approach (37).

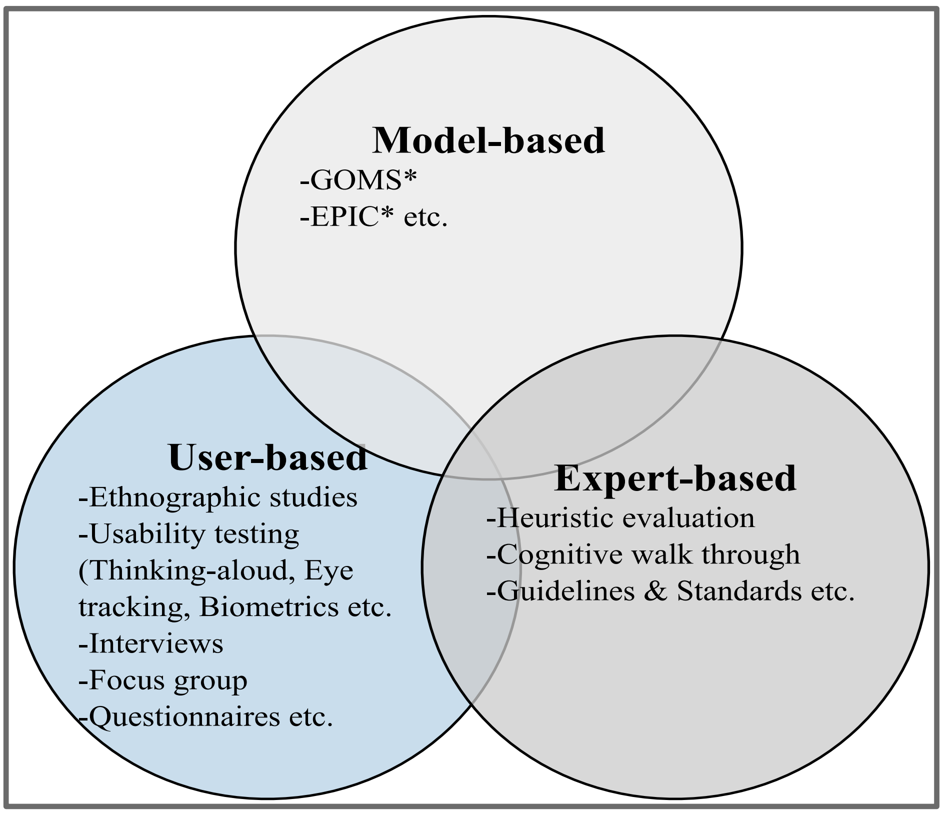

Figure 1.3-Usability evaluation methods based on the source
GOMS; Goals, Operators, Methods and Selection rules, EPIC*; Executive Process/Interactive Control*

Users are the main focus in a UCD approach, hence involving them from the beginning of SDLC is critical in generating an end product with high usability. Detailed understanding of "users" performing "task" on a particular "system" and in a certain "environment" should be essential elements of any system development process. Various usability methods employed to collect data from users described in literature are depicted in Fig. 1.4.

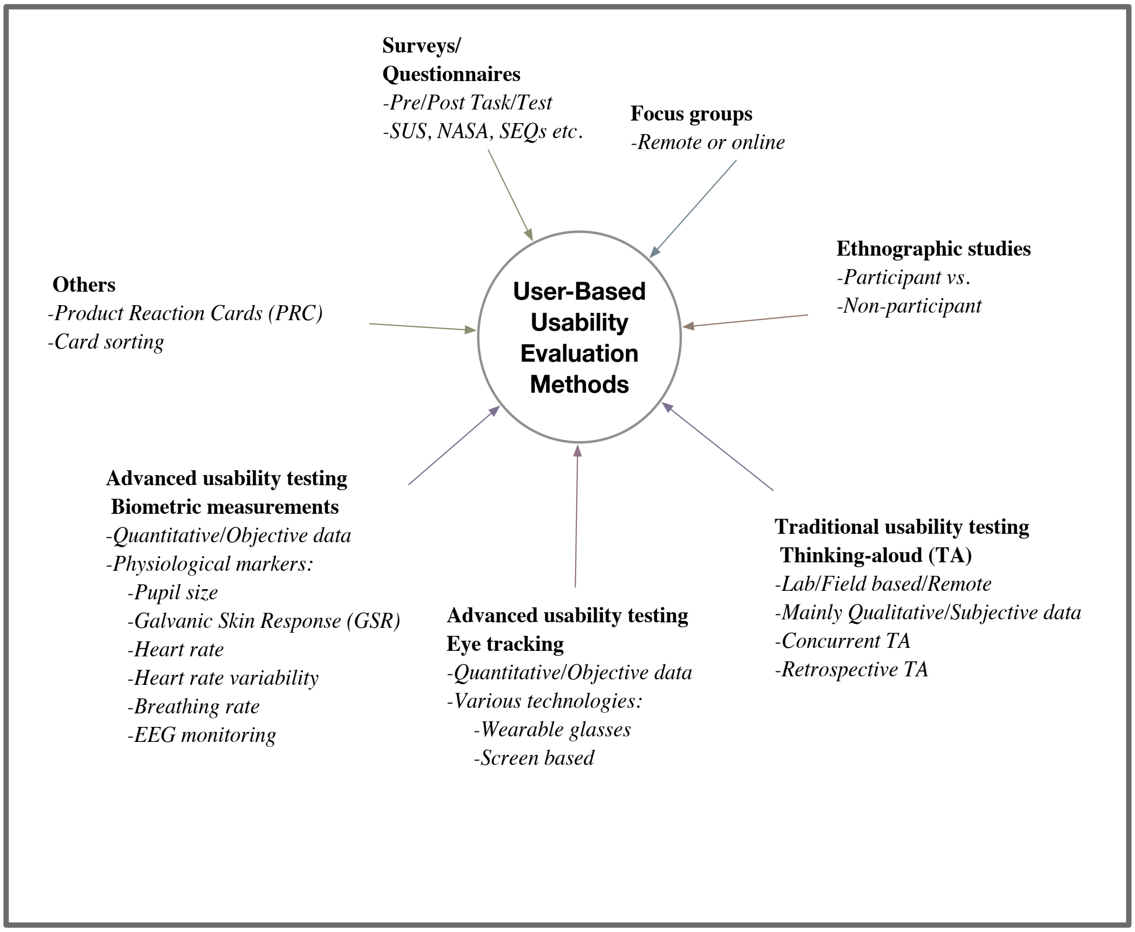

Figure 1.4-User based usability evaluation methods

1.5. Study Rationale, Specific Aims and Future Goals

The rationale behind this research studies is to evaluate end users' (physicians) clinical document usage in current EHR system in order to methodically understand their complex workflow processes through employing various user-centric usability evaluation techniques (Fig. 1.4). The use of different methodologies would help us triangulate our research and provide us with an opportunity to thoroughly understand physicians' usage behavior around clinical documentation usage offered by existing EHR systems.

This dissertation incorporates 4 studies with respect to critical components of physicians' workflow process (e.g., users, their task, systems and environments). These overarching goals are achieved through following 4 aims:

Aim # 1: By evaluating and comparing inpatient clinical note-entry & reading/retrieval styles adopted by physicians in an EHR system through ethnographic studies and post-observation questionnaire.

Aim # 2: By evaluating and comparing functionality and design elements of existing EHR systems around clinical notes usage through observing users in a naturalistic settings.

Aim # 3: By qualitatively evaluating an existing EHR's clinical notes interface by attendings and residents employing usability testing in a laboratory setting.

Aim # 4: By evaluating and comparing H&P Documentation task flows adopted by providers in an existing EHR system, through data collected in a tightly controlled environment.

This study is a promising step towards increasing meaningfulness of EHR system through a cogently designed GUI that would be better aligned with UCD approach and could result in enhanced EHR usability and eventual resulting in more effective and efficient patient-centered healthcare delivery with greater user satisfaction.

CHAPTER-2

A comparative observational study of inpatient clinical note-entry and reading/retrieval patterns adopted by physicians

Rubina F. Rizvi [1], Kathleen A. Harder [1,2], Gretchen M. Hultman [1], Terrence J. Adam [1,3], Michael. Kim [4], Serguei V. Pakhomov [1,3], Genevieve B. Melton [1,5]

[1] Institute for Health Informatics,[2] Center for Design in Health, College of Design,
[3] College of Pharmacy, [4] Pediatric Hospital Medicine, Department of Pediatrics,
[5] Department of Surgery,
University of Minnesota, Minneapolis, MN

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Abstract

Objective: *The objective of this study is to understand physicians' usage of inpatient notes by (i) ascertaining different clinical note-entry and reading/retrieval styles in two different and widely used Electronic Health Record (EHR) systems, (ii) extrapolating potential factors leading to adoption of various note-entry and reading/retrieval styles and (iii) determining the amount of time to task associated with documenting different types of clinical notes.*

Methods: *In order to answer "what" and "why" questions on physicians' adoption of certain note-entry and reading/retrieval styles, an ethnographic study entailing Internal Medicine residents, with a mixed data analysis approach was performed. Participants were observed interacting with two different EHR systems in inpatient settings. Data was collected around the use and creation of History and Physical (H&P) notes, progress notes and discharge summaries.*

Results: *The highest variability in template styles was observed with progress notes and the least variability was within discharge summaries, while note-writing styles were most consistent for H&P notes. The first section to be read in H&P and progress note were the Chief Complaint and Assessment & Plan sections, respectively. The greatest note retrieval variability, with respect to the order of how note sections were reviewed, was observed with H&P and progress notes. Physician preference for adopting a certain reading/retrieval order appeared to be a function of what best fits their workflow while fulfilling the stimulus demands. The time spent entering H&P, discharge summaries and progress notes were similar in both EHRs.*

Conclusion: *This research study unveils existing variability in clinical documentation processes and provides us with important information that could help in designing a next generation EHR Graphical User Interface (GUI) that is more congruent with physicians' mental models, task performance needs, and workflow requirements.*

Keywords

Electronic Health Records systems (EHR); Clinical documentation; Qualitative analysis; Human-Computer Interaction; Graphical User Interface (GUI); Usability

2.1. Background and Significance

Clinical notes are an essential communication tool for summarization, synthesis and decision making for patient care. In addition to direct patient care, notes are valuable for other functions such as medical education, research, billing, quality-assessment and medico-legal inquiries/compensations (38-40). The importance of having high quality clinical notes was recognized in the 1960s by Dr. Lawrence Weed as part of the Problem-Orientated Medical Record (POMR) framework, which was key in the establishment of the *SOAP (Subjective, Objective* and *Assessment & Plan (A/P))* note format and documentation of patient problems by organ systems (41). Currently used common clinical note types include History and Physical (H&P) notes, progress notes, consult notes, operative notes and discharge summaries.

Clinical notes documentation is considered to be a core aspect of a patient's encounter and fundamental for health care delivery. While EHRs have enhanced direct access to patient data (42), clinicians continue to experience significant barriers in EHR usage, such as inefficiencies with structured data entry and retrieval, as we all as difficulty using and creating computerized patient documentation (10,38). Free text entry in clinical documents is typically considered ideal for communication between providers and for presenting complex sets of facts, but can be laborious and time consuming to create in an electronic interface. On the other hand, structured data entry, which is typically more difficult to read and synthesize, enables the reuse of data for downstream applications such as quality improvement and research (39,43,44). While clinicians appreciate the flexibility and efficiency of narrative free-text entry with the use of "copy and paste" or "copy forward" functions, they are challenged by long and verbose clinical notes that can be laborious to review or synthesize and could potentially contain erroneous information not appreciated during the documentation process.

There is growing interest in understanding the different aspects of clinical documentation processes such as their integration with workflow (44,45), structured versus free-text entry (39) and usability studies of EHR systems pertaining to creation and use of clinical documents (46). In recognition of the importance of clinical documentation, recording electronic notes in patient charts is included as one of the menu objectives in Stage-2 of the Meaningful Use Program (47). Also, the lack of standardization in EHR clinical documentation and display styles provides interface designers with an area of opportunity to re-design EHR systems (48-51).

Several researchers have previously examined tools and measurements to understand clinical documentation processes and potential areas of opportunity to improve clinical note quality. This includes development of validated instruments for assessing inpatient clinical documentation quality (52,53), techniques for generating clinical notes with clinically relevant information that is reusable and readable and use of eye tracking to discover how the visual attention of physicians is distributed while reading electronic notes (26).

In order to improve our understanding of empiric behaviors of physicians around clinical documentation use and generation, the goal of this study was to discover different styles of physician inpatient note-entry as well as reading/retrieval styles in two different EHR systems in two observed settings and to extrapolate potential factors associated with different behaviors/styles of system use. In addition, this study aims to ascertain and compare the various time to complete key tasks of clinical note documentation

2.2. Methods

2.2.1. General Description and Setting

A participant observation ethnographic field study approach, supplemented with post-observation online questionnaire, was employed to collect data about the routine, day-to-day activities of participants/users in a naturalistic setting (54). While this approach does not offer a controlled experimental setting, the method was chosen since it provides a rich, realistic, and holistic view of the users' routine by immersing in their environment. This immersion helps in gathering additional detailed information, which users can sometimes inadvertently fail to communicate overtly with other more interactive or controlled (e.g., laboratory-based) methodological approaches. Various similar observational study methodologies have been widely used in scientific research, including healthcare (55-59).

Approval for this study was obtained from the University of Minnesota Institutional Review Board and from the Veterans Affairs Research and Development Committee. Internal Medicine resident physicians were observed interacting with two different EHR systems, Epic and Veterans Affairs Computerized Patient Record System (CPRS), in naturalistic inpatient environments, at the University of Minnesota Medical Center (UMMC) and Minneapolis Veterans Affairs Health Care System (VAHCS) respectively, at various times and days including on-call and off-call days. Since residents spend most of their time interacting with EHRs in workrooms, particularly performing clinical note documentation, the majority of observations were made there.

2.2.2 Study Sample

Residents (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 and other clinical staffs were excluded. Participants were recruited after obtaining their verbal assent. Detailed characteristics of research participants are summarized in Table 2.1.

Table 2.1-Summary characteristics of research participants

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

**UMMC-Hospital (H1); VAHCS-Hospital (H2)*

2.2.3 Data Collection

Qualitative and quantitative clinical documentation process data was collected focusing on clinical note data entry and reading/retrieval tasks. Direct observation was used to collect data regarding user behaviors, their workflow and EHR usage centering on different uses and tasks associated with clinical documentation.

Residents follow different call and day schedules at UMMC and VAHCS (Fig. 2.1). To account for this variability, each participant was observed over different call routines and times of the day. The majority of field notes were taken while residents were doing clinical documentation in their workrooms.

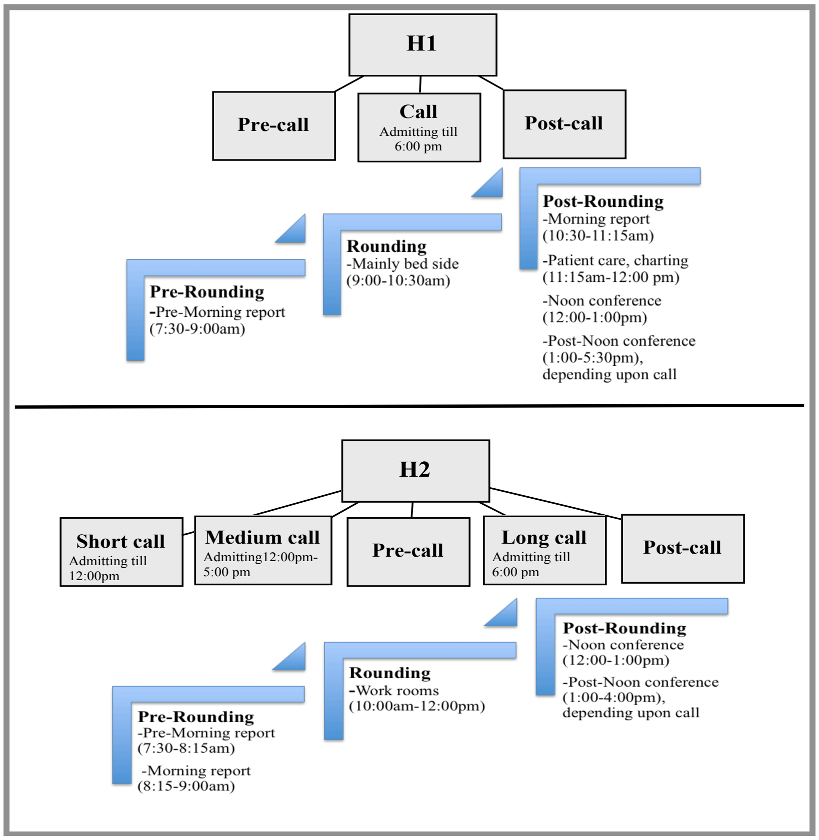

Figure 2.1-Typical call and day schedule of residents at UMMC-Hospital (H1) and VAHCS-Hospital (H2)

The schedule shows approximate times. Residents on night calls or on sub-specialty rotations follow a different schedule.

The total observation time was greater than 110 hours. Details about observation times are provided in Table 2.2.

Table 2.2-Observation schedule and hours

	UMMC-H1*			VAHCS-H2*		
	On call hours	Non-call hours	Total	On call hours	Non-call hours	Total
P1	7	4	11	7	6	13
P2	6	4	10	5	4	9
P3	7	3	10	5	5	10
P4	6	3	9	4	3	7
P5	6	4	10	6	4	10
P6	2	2	4	5	4	9
Mean hours	5.6 (±1.8)	3.3 (±0.8)	9 (±2.5)	5.3 (±1.0)	4.3 (±1.0)	9.6 (±1.9)

**UMMC-Hospital (H1); VAHCS-Hospital (H2)*

Field notes were taken on an electronic tablet through a time-stamped application called "Time stamped Field Notes Application version 3.0" (60). The data was later transferred to an encrypted device and stored on a secure PHI-compliant server. We also collected hard copies of note templates (H&P, progress note and discharge summaries), consumed by each participant, for post-hoc data analysis purposes. At the end of observations, an electronic post-observation questionnaire regarding user perceptions about EHR clinical documentation practices was administered. The questionnaire contained multiple choice and open-ended questions on note styles, note documentation, workload and electronic interface usage. Each study participant filled out the questionnaire once with a 100% response rate. Data was also collected through questionnaire in order to get the subjective perception from physicians about their workflow, preferences and time conceptions about clinical documentation processes. Participants were provided with a nominal gift certificate ($50) for their participation.

2.2.4 Data Analysis

Ethnographic Content Analysis (ECA) was performed with integrated qualitative-quantitative research designs (61) using "NVivo version 10.1.3" (62). Observations performed on multiple days and times were examined iteratively in order to generate broader generalizations.

Observations and data parsing were primarily done by RR, a physician and health informatician and by GH, a health informatician and clinical research study coordinator. Each observation was used as a unit of analysis. Since this study is to be considered process driven (i.e., categories defined empirically by process as opposed to predefined), the data collection process was performed without any prior conceptual framework. After repeated reviewing of field notes, the “theme” of clinical documentation usage styles as adopted by physicians was categorized in to four “sub-themes”, each consisting of a respective parent node with several child nodes i.e., note type (e.g., H&P, progress note, discharge summary, consult note), task performed (e.g., note-entry; notes reading/retrieval), style adopted (e.g., style 1, style 2, style 3) and time to task. The data under each sub-theme was validated by a set of senior clinicians (GMM, TA) and a user interface design expert (KH), arriving at agreement with the observers’ determination of nodal structure and general findings. Integration of different types and sources of data was also obtained for triangulation, thus increasing the validity to the overall findings. Triangulation was achieved by employing mixed method research design and collecting data in several different ways. Objective data was collected by observing participants in a naturalistic setting and taking down field notes. Subjective data was acquired directly from the participants using post-observation online questionnaire. Both objective and subjective data were later analyzed and compared.

Inter-rater reliability was established by calculating percentage agreement between the two coders from a subset of data representing 16% of the field notes, with mean percentage agreement of 90% and kappa value of 0.73. Any inconsistencies were addressed via review and consensus.

2.3. Results

2.3.1. Note-entry

2.3.1.1 Note Template Styles

The template is defined as a pre-structured documentation tool, providing a basic format that could be used repeatedly and are often employed for generating clinical documents (63). Note templates were ubiquitously used by physician residents in our study while performing clinical *note-entry* tasks. For H&P and progress notes, the templates were either created by the user or shared from other users, however, for discharge summaries, a certain level of template standardization was observed with small areas of customization.

Overall, five H&P template styles were seen, with common sections of: *Chief Complaint (CC); History of Present Illness (HPI); Past Medical History (PMH); Past Surgical History (PSH); Family History (FM); Social History (SH); Allergies; Medications; Review of Systems (ROS); Physical Examination (PE); Laboratories; Imaging and Assessment & Plan (A/P).* The most commonly observed styles were style 1 and style 2 (each style being preferred by 4/12 participants (33%) and used together in (22/32 (69%)) instances (Fig. 2.2). Most H&P templates had *Chief Complaint* located at the top of the note (29/32 times (91%)), with *Assessment & Plan* occasionally located at the beginning of a note (3/32 times (9%)) and with some order variation and preferences for other sections.

Similarly, for progress notes, six styles were used including the common sections of *Subjective (S); Objective (O)* (e.g., *Physical Examination, Laboratories/Imaging;*

Medications) *and Assessment & Plan. Interval History*, which is another name for the *Subjective* section, was also a common section title. The three different components of the *Objective* section also had several different order preferences. The most commonly used progress note templates were style 1 (4/12 participants (33%), used 19/73 times (26%)); style 2 (3/12 participants (25%), used 19/73 times (26%)) and style 3 (2/12 participants (17%), used 14/73 times (19%)) (Fig. 2.2). In all cases, progress note templates started either with the *Subjective* or *Interval History* section (54/73 times (74%)), or less commonly from *Assessment & Plan* (19/73 times (26%)).

For discharge summaries, there were five template styles with the following common sections: *Discharge Diagnoses (DD); Pertinent Procedures and Imaging; Physical Examination; Hospital Course by Problem (HCP)* and *Discharge Instructions*. Additional and less consistently used sections were *Consults, Medications* and *History of Present Illness*. For discharge summary templates, styles 1 and 2 were most commonly used (5/12 participants (42%) and 3/12 participants (25%); 21/48 (44%) and 9/48 (19%) times respectively) (Fig. 2.2). It was observed in all instances that the discharge summary templates had *Discharge Diagnoses* at the beginning with some order customization of other sections.

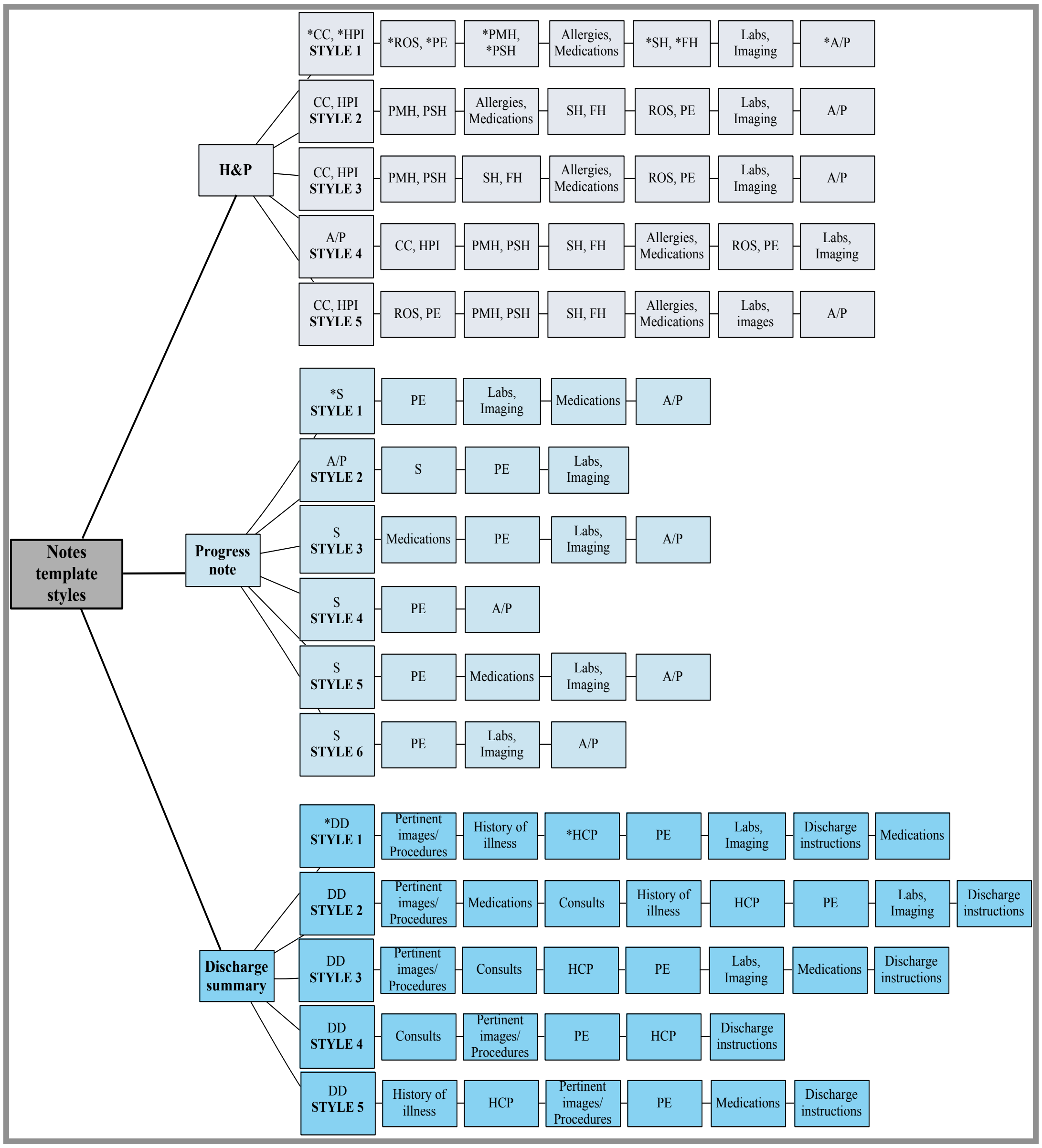

Figure 2.2-Note template styles for H&P, progress note and discharge summary as

**Sn: Number of participants; T=Total participants; Nn: Number of notes; CC: Chief Complaint; HPI: History of Present Illness; PMH: Past Medical History; PSH: Past Surgical History; ROS: Review of Symptoms; PE; Physical Exam; SH: Social History; FM; Family History; A/P: Assessment & Plan; S: Subjective; DD: Discharge Diagnoses; HCP: Hospital Course by Problem*

2.3.1.2 Note-Writing Styles

For writing notes, physicians preferred to utilize a range of styles demonstrating both within and between participant variability in writing styles for different notes types. H&P note-writing styles corresponded directly to the five H&P template styles. The most preferred ordering was to use style 1 (5/12 participants (42%), used 9/32 times (28%)); style 2 (4/12 participants (33%) used, 11/32 times (34%)); and style 3 (4/12 participants (33%), used 6/32 times (19%)) respectively (Fig. 2.3). The majority of users started writing notes with the *Chief Complaint* section (23/32 (72%)) and the minority of users starting with *the Assessment & Plan* section (9/32 (28%)). After completing the *Assessment & Plan* section, participants were observed to follow any of the other four writing patterns to complete the rest of the H&P note. The tendency for users to stick with a particular style each time was rather consistent with very minimal crossover.

For progress notes, six common note-writing styles, corresponding roughly to the template styles, were employed. The preferred order for creating a progress note was style 1 (10/12 participants (83%), observed 40/73 instances (55%)) (Fig. 2.3). Within progress notes, most users started composing the note from either *Assessment & Plan* section (40/73 (55%) or *Subjective*/*Interval History* sections (33/73 (45%) times), followed by a variety of completion patterns.

Compared to the five template styles for discharge summaries, six common discharge summary note-writing styles were used, including one additional note-writing style. The most preferred style was style 1 (9/12 participants (75%), with 22/38 instances (58%)) (Fig. 2.3). All participants started to compose discharge summaries from either

Hospital Course by Problem section (22/38 times (59%)) or the *Discharge Diagnoses* section (16/38 times (42%)). Those who preferred starting from *Hospital Course by Problem* completed the note following any of the other 5 patterns.

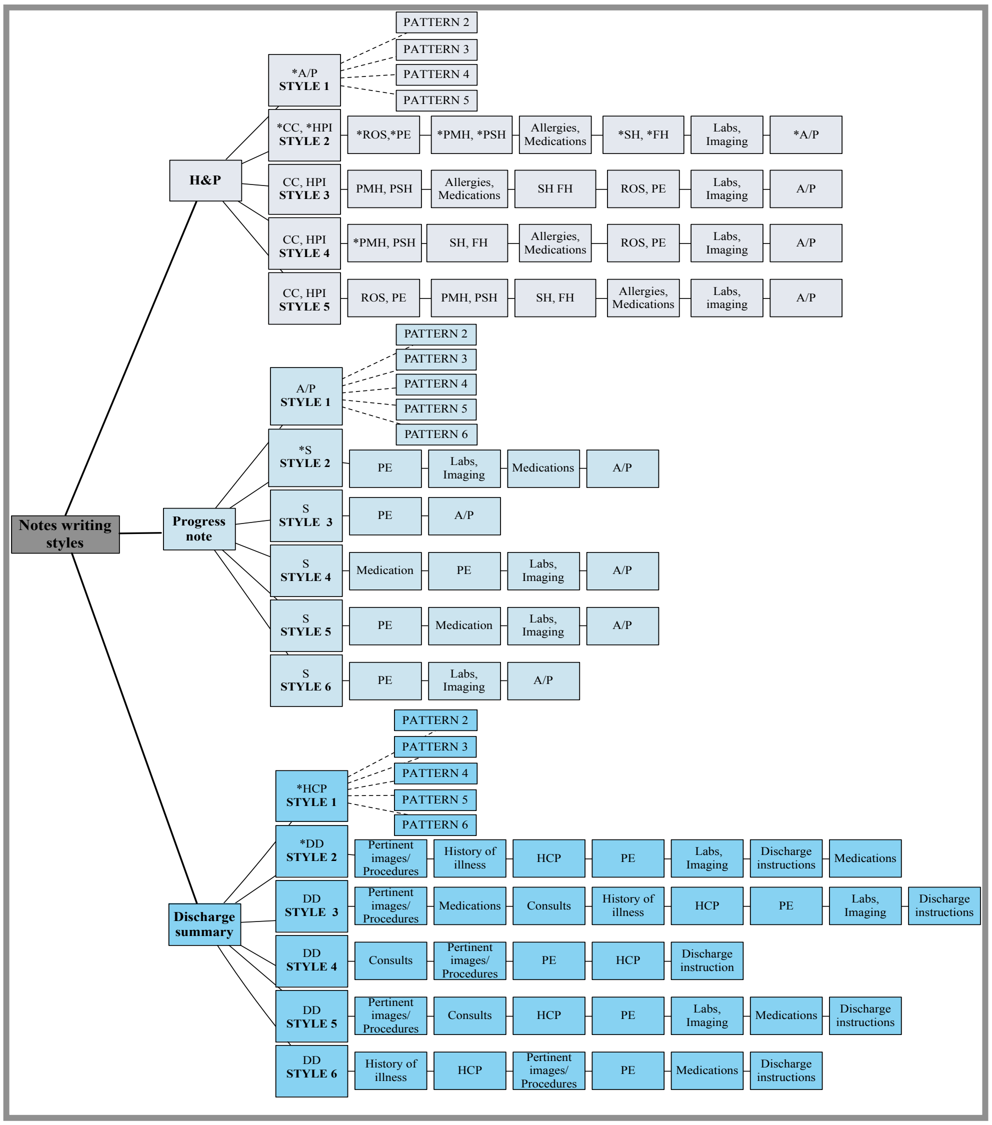

Figure 2.3-Note-writing styles for H&P, progress note and discharge summary as adopted by physicians

**Sn: Number of participants; T=Total participants; Nn: Number of notes; CC: Chief Complaint; HPI: History of Present Illness; PMH: Past Medical History; PSH: Past Surgical History; ROS: Review of Symptoms; PE: Physical Exam; SH: Social History; FM; Family History; A/P: Assessment & Plan; S: Subjective; DD: Discharge Diagnoses; HCP: Hospital Course by Problem. Dotted lines represent various patterns adopted*

2.3.2. Notes Reading and Retrieval Styles

A number of reading styles were observed for each note type. The pattern was often related to the stimulus initiating the task. Physician preference for adopting a certain style appeared to be a function of what best fits in their workflow. Both within and between participant variability was observed in note reading/retrieval styles for various notes types and in response to different stimuli.

When reading information from H&P notes in both systems, providers' preferred to start reviewing either from the *Chief Complaint* section (23/31 times (74%)) or from the *Assessment & Plan* section (8/31 times (26%)). For progress notes, the commonly observed preference was to start reading notes from the *Assessment & Plan* section (47/53 times (89%)) and less often from the *Subjective or Interval History s*ection (6/53 times (11%)). On the other hand, while reading a discharge summary, users started with the *Hospital Course by Problem* section (24/32 times (75%)) or *Discharge Diagnoses* section (8/32 times (25%)) (Fig. 2.4). Apart from these three main note types, consult notes were mostly read starting from the *Recommendations* section, which is analogous to the *Assessment & Plan* section of an H&P note, where providers enter their assessment and relevant plan suggestions for managing the patient.

Overall, the chronological order of reading a particular note after studying the initial section, often appeared dependent upon the type of the retrieving stimulus. For example, when looking for information about the vitals or laboratories and medications, providers almost exclusively preferred to read and synthesize this information directly from the primary data entry section of the chart containing the results and ancillary studies as opposed to the obtaining the information from re-entered data in the note. One exception to this observation was noticed when providers were reading a discharge summary or a H&P note from previous admissions, where it was observed that they tended to skim through all the entered data.

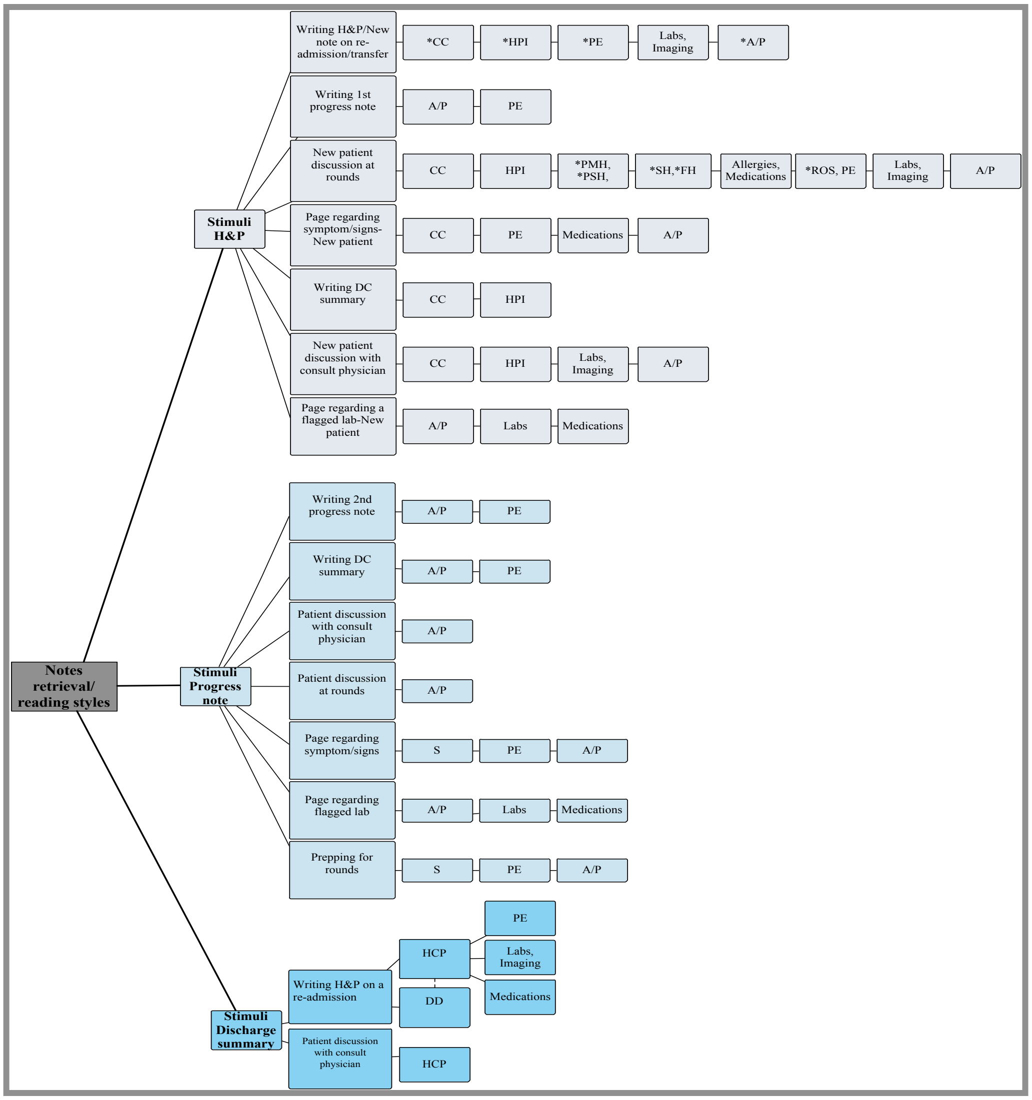

Figure 2.4-Note retrieval/reading styles for H&P, progress note and discharge summary as adopted by physicians

**Sn: Number of participants; T=Total participants; In: Number of Instances; CC: Chief Complaint; HPI: History of Present Illness; PMH: Past Medical History; PSH: Past Surgical History; ROS: Review of Symptoms; PE; Physical Exam; SH: Social History; FM; Family History; A/P: Assessment & Plan; S: Subjective; DD: Discharge Diagnoses; HCP: Hospital Course by Problem.*

Summary of notes template, writing and retrieval styles is depicted in Fig. 2.5.

Note Type	Note Template	Note-Writing	Note Retrieval
H&P	CC→HPI→ROS→PE→PMH→ PSH→Allergies→Medications→ SH→FH→ Labs/Imaging→A/P	CC→HPI→ROS→PE→ PMH→PSH→Allergies→ Medications→ SH→FH →Labs/Imaging→A/P	CC→Varies with the stimulus
Progress Note	S→O (PE→Labs/Imaging→ Medications)→A/P	A/P→S→O	A/P→Varies with the stimulus
Discharge Summary	DD→Pertinent images /Procedures→HPI→HCP→PE→ Labs/ Imaging→ Discharge-instructions→Medications	HCP →Varies	HCP→Varies with the stimulus

Figure 2.5-Summary of preferred note-entry and retrieval styles as adopted by physicians
**CC: Chief Complaint; HPI: History of Present Illness, PE: Physical Exam; PMH: Past Medical History; SH: Social History; FH: Family History; PSH: Past Surgical History; ROS: Review of Symptoms; A/P: Assessment & Plan; S: Subjective: O: Objective; A/P: Assessment & Plan; DD: Discharge Diagnoses; HCP: Hospital Course by Problem*

2.3.3. Comparison of Observed and Self-Reported data

Observations on note templates, writing and reading/retrieval style were later compared with self-reported as collected from the questionnaire (Table. 2.3).

Table 2.3-Sample questions and response options

	Questions	Response Options
Q1.	What style do your prefer while entering an H&P note?	-Start form subjective data entry -Start from Assessment & Plan -Other
Q2.	How much time do you think you spend on average writing an H&P?	-<10 -10-20 -21-30 -31-40 ->40
Q3.	Do you use templates for entering H&P?	-Yes -No -Other
Q4.	What style do your prefer while reading an H&P?	-Start from Subjective data -Start from Assessment & Plan -Other
Q5.	What are the major limitations of EHR's Graphical User Interface in terms clinical note-entry tasks? How do you think they can be rectified?	Free text
Q6.	What are the major strengths of EHR's Graphical User Interface in terms clinical note-entry tasks? How do you think they can be rectified?	Free text

For note-writing and reading/retrieval styles, considerable discrepancies were discovered between physician self-report and their observed actions (Table 2.4). These observed variances in reading/retrieval styles could be explained by types of stimuli triggering the tasks. We also observed that physicians had a tendency to utilize the same template every time they entered a particular type of a note, having consistent results for both self-reported and observed data.

Table 2.4-Comparison of participants self-report versus observed template style, writing, and reading/retrieval styles

	Template style		**Writing Styles**			**Note Reading/Retrieval Styles**		
H&P	*CC	*A/P	CC	A/P	*No particular style	CC	A/P	No particular style
Self-Report	11	1	10	2	0	6	6	0
Observed	11	1	7	1	4	6	1	5
Progress notes	*SOAP	*APSO	*S	A/P	No particular style	S	A/P	No particular style
Self-report	9	3	8	4	0	4	8	0
Observed	9	3	2	6	4	0	5	7
Discharge summaries	*DD	*HCP	DD	HCP	No particular style	DD	HCP	No particular style
Self-report	12	0	6	6	0	6	6	0
Observed	12	0	3	2	7	0	3	9

** CC: Chief Complaint; A/P: Assessment & Plan; S: Subjective; SOAP: Subjective, Objective, Assessment & Plan; APSO: Assessment & Plan, Subjective, Objective; DD: Discharge Diagnoses; HCP: Hospital Course by Problem*

Based upon our observations, overall, similar amounts of time were spent on each type of note in both Epic and CPRS, with the H&P taking the most time (mean 39 and 42 minutes, respectively) and progress notes taking the least time (mean 11 and 12 minutes respectively) (Fig. 2.6 and Table 2.5).

Table 2.5-Time to complete a note in Epic and CPRS, a comparison between objective and subjective data

	H&P		**Progress notes**		**Discharge summary**	
	Observed (Mean, Median, Range)	**Self-report (Frequently selected range)**	**Observed (Mean, Median, Range)**	**Self-report (Frequently selected range)**	**Observed (Mean, Median, Range)**	**Self-report (Frequently selected range)**
			Epic			
P1	30,35,43 (36,35,30-43)	31-40	8,10,12,30 (15,11,8-30)	31-40	25,40 (33,33,25-40)	21-30
P2	30,35 (33,33,33-35)	10-20	5,5,6,7,15 (8,6,5-15)	10-20	30,30 (30,30)	21-30
P3	40,45,55 (47,45, 40-55)	31-40	4,4,12 (7,4,4-12)	<10	20,36,55 (37,36,20-55)	21-30
P4	40,50 (45, 45, 40-50)	31-40	7,13,14,15,15 (13,14,7-15)	10-20	25,26,30 (27,26,25-30)	31-40
P5	45 (45,45)	21-30	7,10,30 (16,10,7-30)	10-20	35 (35,35)	21-30
P6	30,30,35 (32, 30,30-35)	21-30	5,6,8,8,11 (8,8,5-11)	10-20	9,20,34 (21,20,9-34)	10-20
	(39,38,30-55) **SD-8**	(31-40)	(11,8,5-30) **SD-6.8**	(10-20)	(30,30,9-55) **SD-10.8**	(21-30)
			CPRS			
P1	35,40 (38,38,35-40)	10-20	5,10,10,12 (9,10,5-12)	<10	15,20,25,25 (21,23,15-25)	10-20
P2	50 (50,50)	21-30	14,15 (14.5,14.5)	10-20	17,25 (21,21,17-25)	21-30
P3	30,30 (30,30)	31-40	6,15,30 (17,15,6-30)	10-20	25, 27 (26,26,25-27)	31-40
P4	55 (55,55)	10-20	8,8 (8,8)	<10	28,33 (31,31,28-33)	10-20
P5	32,45,50 (42,45,32-50)	31-40	10,12,15 (12,12,10-15)	10-20	25,33,40 (33,33,25-40)	31-40
P6	40,50 (45,45,40-50)	21-30	10,12 (11,11,10-12)	10-20	17,25,25,29 (24,25,17-29)	10-20
	(42,40,30-55) **SD=9**	Equivocal	(12,115-30) **SD-5.7**	(10-20)	(26,25,15-40) **SD-6.3**	(10-20)

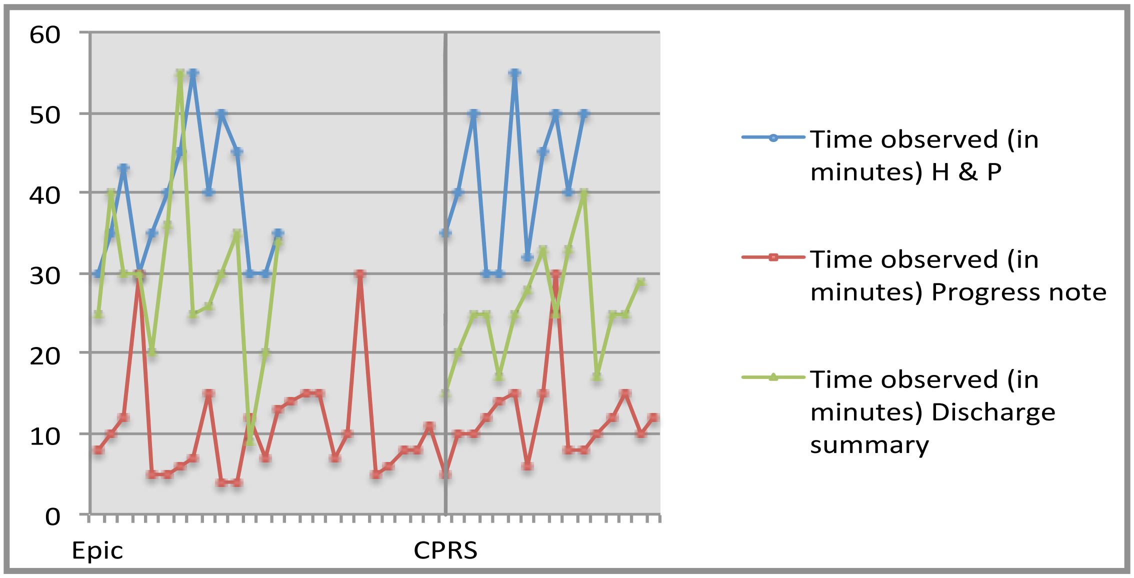

Figure. 2.6-Observed time in minutes for entering different types of notes in two EHRs

2.4. Discussion

Our study demonstrates that physicians have several preferences for performing clinical *note-entry* and *reading/retrieval* tasks, which vary with note types, tasks and by stimuli. Progress note template usage among residents showed the greatest variability, while the discharge summary templates had the least (Fig. 2.2). On the other hand, note-writing styles were most consistent for H&P notes (Fig. 2.3). The first section to be read in the most consistent fashion was observed with H&P and progress notes (i.e., starting from *Chief Complaint* and *Assessment & Plan* sections respectively). Conversely, the greatest note retrieval variability (i.e., the chronological orders of how note sections were reviewed), was observed with H&P and progress notes (Fig. 2.4). Various note reading/retrieval styles appeared to result from the type of stimulus mandating specific information to be extracted from a particular note type and as well as a result of personal preferences leading to adoption of a few dominant styles.

The observed variability in *note-entry* and *reading/retrieval* styles, as adopted by physicians, could be explained from three different perspectives. First, the relevance and priority of data being entered or retrieved focused on accomplishing the task effectively and efficiently. For example, a physician initially wants to know "what" brought the patient to emergency department and then "why." Subsequently, the physician then works towards establishing and documenting reasons for those "what" and "why" questions, proceeding later to "how" to solve those problems and finally to documenting the "summary of the whole encounter." Secondly, the type of stimulus also dictates the chronological order of how a note might be reviewed (e.g., a progress note from the previous day is most often opened for writing the subsequent progress note). Finally, while we do not have direct evidence, other factors such as earlier training, colleagues' styles, and the physician's personality could all potentially contribute towards adopting different styles/patterns. The exact contribution of these factors remains unclear and could be an interesting area of further study.

Our findings also demonstrate differences between actual practice and perceived usage of note template organization and styles pertaining to the clinical documentation process. Among users of both EHR systems, the observed and perceived times on entering progress notes and discharge summaries were fairly similar with some inconsistencies in time data on H&P notes. Our observations were externally validated and consistent across two different established EHR systems and at two different inpatient sites with considerable inter-participant consistency.

This research study identifies variations, which exist in note-writing and reading/retrieval styles resulting from varied physicians' preferences and workflow demands. Understanding the various styles/time to tasks consumed by users, which are centered on their preferences and the workflow demands, could be used to address the disparities existing in current EHR system design. For example, improved consistency in clinical notes documentation could be established with standardization of note template structure. A more modular, streamlined, task-oriented style, congruent with users' preferences and their mental models, would be beneficial, particularly for the notes showing greatest variability i.e., progress notes and H&P. Designing a GUI, defined as "a program that allows a person to work easily with a computer by using a mouse to point to small pictures and other elements on the screen" (64), for clinical documentation, should reflect the users' mental model which could potentially lead to more uniformity in note-writing styles. Similarly, designing an interface that provides users with task and/or stimuli specific presentation views, could potentially facilitate more efficient and effective data comprehension and retrieval from notes. Furthermore, while not examined directly here, clinical notes usage by physicians could also be reinforced or improved through refinement of automated methods to detect and visualize new information (65).

Our analysis of template styles revealed a number of predominant note organization patterns, which was somewhat but not fully congruent with the styles used for writing or reading/retrieving. For instance, an H&P most often had *Chief Complaint* or less often *Assessment & Plan* first in the note, which was the same as the writing style and initial reading style. However, the chronological order of how additional H&P

sections were reviewed, was dependent upon the type of stimulus. For example, when writing a discharge summary, physicians tended to pull the H&P note from current admission, utilizing information from the *Subjective* sections (e.g., *Chief Complaint* and *History of Present Illness*). We also observed that H&Ps were most commonly opened for the purposes of writing another H&P (Fig. 2.4).

Users reviewed progress notes most commonly starting from the *Assessment & Plan* section and less often from *Subjective.* This was the most commonly seen style regardless of whether they had read the H&P earlier or not. This observation is congruent with another study where an eye tracking methodology was used to discover how the visual attention of physicians is distributed while reading electronic progress notes. In terms of fixations and glances, physicians directed the most attention to the *Assessment & Plan* section with very little attentiveness given to other parts of the note (26). Moreover, similar to H&P notes, the chronological order for reviewing various sections within a progress note appeared to be heavily dependent upon the stimulus. For example, when paged regarding an alteration in a patient's condition, a covering physician who might be less familiar with a given patient, tended to look first at the *Subjective* from that day to contextualize the patient's condition and status. On the other hand, when writing a progress note, physicians would often read the *Assessment & Plan* section of a note followed by the *Physical Examination* section. In our observation, the highest number of progress notes was pulled up for the purposes of writing a subsequent progress note. These observations were similar between two locations.

On the other hand, while reading a discharge summary, the tendency was to read the *Hospital Course by Problems* first or in some instances *Discharge Diagnoses*. Similar to H&P and progress notes, the type of stimulus appeared to help dictate the physician reading styles (e.g., when writing an H&P note for readmission, physicians preferred to review the *Hospital Course by Problem* from the previous discharge summary followed by *Discharge Diagnoses* and other available data). Discharge summaries were often pulled up to write an H&P or to write a new note on a patient getting readmitted to the hospital or a patient getting transferred to another unit.

In general, we also observed that when the goal was to retrieve data for vitals, labs and medications, physicians tended to gather data directly from primary data entry points rather than from electronic notes. An exception to this behavior was observed when providers were reading discharge summaries or H&Ps from previous admissions where it was observed that they tended to skim through all the entered data.

We also observed that for H&Ps and progress notes, the templates were either created by the user or shared from other users, depending upon their preferences. On the contrary, discharge summaries contained a significant level of template standardization with small areas of customization. The tendency for users to stick with a particular template style was rather consistent with very minimal crossover between styles. Physicians had a tendency to utilize the same template every time they entered a particular type of a note, which was consistent in both self-reported and observed data, thus strengthening our inference about physicians sticking to a particular style. All the above observations were comparable between two sites, during different times of the day and whether the participants were being observed on on-call and/or off-call days.

Additionally, we also observed some discrepancy between physicians' self-reported behavior as gathered from electronic questionnaire and our observations. The inconsistencies noted are mainly for writing and reading/retrieval styles for H&Ps, progress notes and discharge summaries. These observed conflicts between some of the perceived and observed reading/retrieval styles could be explained by the difference in the type of stimulus instigating a specific task.

There are several limitations associated with this study. Qualitative research is highly dependent on a researcher's skill and more easily influenced by the researcher's personal biases. We have tried to address this limitation to enhance trustworthiness in the study through content validation involving other co-authors (MDs, health informaticians and usability experts) and assessing inter-rater reliability between coders. Any inconsistencies were addressed via review and consensus. Another limitation is the small sample size posed by recruitment of only Internal Medicine residents in their second, third and fourth years. Because of our small sample size, our findings are limited by a lack of significant statistical analysis. In addition, this study presents more of a quantitative representation of qualitative data and provides readers with a broader view of the observed dissimilarities between the objective and subjective data. Further exploration is needed to make comment on statistically significant differences between observed and self-reported time. Additionally, we did not examine note retrieval styles at a macro level, including navigation between different types of notes along with what information was contained in each type of note. These findings should be corroborated with a larger set of physicians and possibly with providers working in non-academic settings or with established clinicians working in a wider variety of hospital types. Also, our time data for notes should be considered as approximate times. Use of a stopwatch, asking MDs to self-report time required for tasks, or directly extracting time stamped data from EHRs, are some other approaches that could have resulted in more accurate data collection. In addition, within questionnaire, we provided participants with preset ranges of time needed to complete a particular note rather than keeping the response open-ended, which could have provided us with more accurate time data.

We also anticipate that the ambulatory setting could have different findings, stemming in part from significantly different workflows. Future studies will also aim to assess usability features offered by each system in detail. In addition, this paper does not provide the relative amount of time for each section in either reading/retrieving or creating a note. More detailed time motion studies are required to further elaborate on time data and utilize this knowledge in creation of new, improved GUI. Ultimately, prospective studies linking note styles and different note GUIs within EHRs to their impact on associated care, patient outcomes and potentially clinician comprehension of the patient's clinical status are needed.

2.5. Conclusion

In summary, different but congruent styles were utilized by physicians while performing data entry and reading/retrieval tasks for different types of inpatient clinical notes in two different EHR systems. The differences in *note-entry* styles and *reading/retrieval* styles appeared to be primarily based on physician preferences, note type and the stimulus type initiating a task. There were inconsistencies seen in physician self-reported and observed note-writing and reading/retrieval styles. Additionally, the times to write the full H&P, progress note and discharge summary were comparable in both systems with H&P taking the most time and progress notes taking the least time. This study provides EHR interface designers with valuable information to help define requirements and potential designs for improved EHR system interfaces for clinical notes that could be more aligned with the users' mental model and task performance for clinical note documentation.

Conflicts of Interest

The authors declare that they have no conflicts of interest in the research.

Human Subjects Protection

Residents interacting with two different EHR systems (Epic and CPRS), were investigated at the University of Minnesota Medical Center (UMMC) and Minneapolis Veterans Affairs Health Care System (VAHCS) following approvals and in compliance with Institutional Review Board (IRB) #1308E41121 and Research and Development committee (R&D) #R140720X standards.

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CHAPTER-3

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

Rubina F. Rizvi [1], Jenna L. Marquard [2], Gretchen M. Hultman[1], Terrence J. Adam [1, 3], Kathleen A. Harder [1, 4], Genevieve B. Melton[1, 5]

[1] Institute for Health Informatics, [3] College of Pharmacy, [4] Center for Design in Health, College of Design, [5] Department of Surgery, University of MN, Minneapolis, MN, USA
[2] Department of Industrial Engineering, University of Massachusetts, Amherst, MA, USA

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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-centered 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*

3.1. Background and Significance

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).

3.2. 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.

3.3. Methods

3.3.1. 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 while interacting 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 (Time stamped Field Notes Application 3.0) (60).

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. 3.1). 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.

3.3.2. 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 3.1, 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 3.1- 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%)

3.3.3-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)

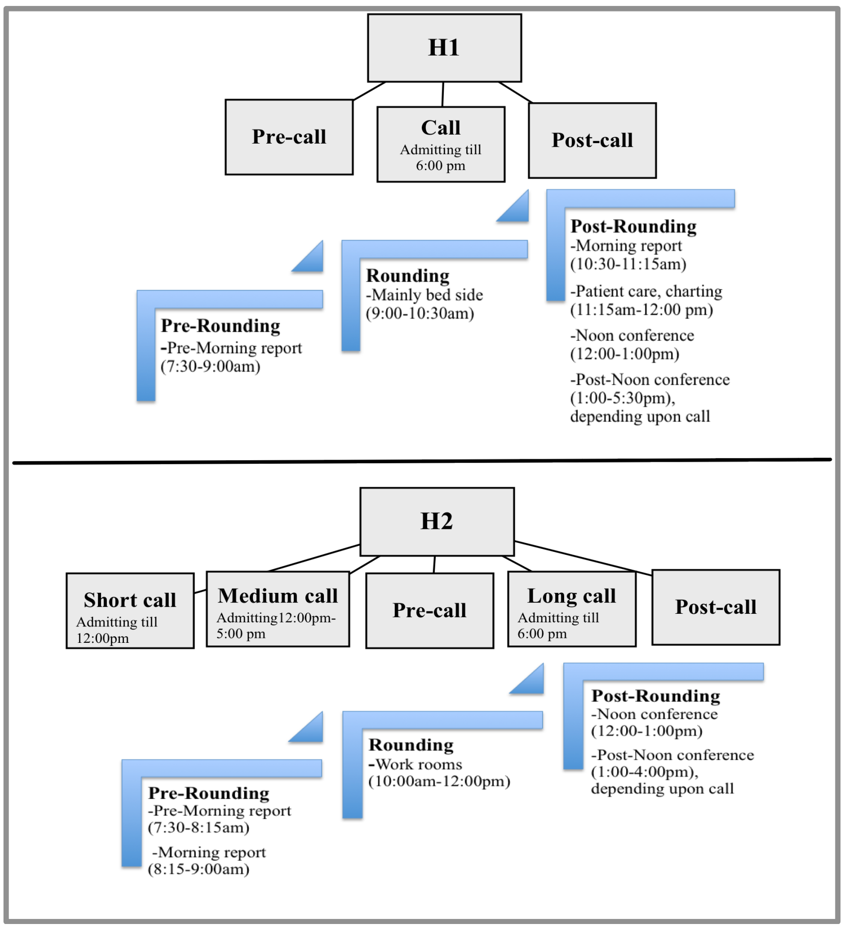


Figure 3.1-Typical call and day schedule of residents at UMMC (H1) & VAHCS (H2)

*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))*

3.3.4-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.3.2). 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.

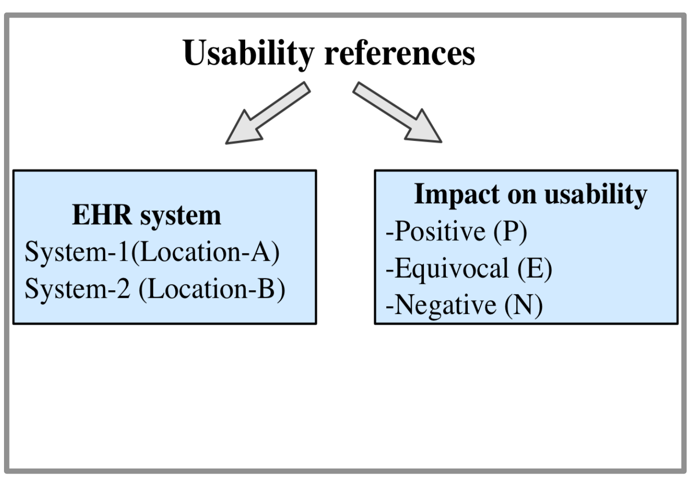


Figure 3.2- Attributes of interest

The coding schema pertaining to functionality and design elements around clinical documentation tasks (i.e., *clinical note entry* or *related information-seeking*) (Fig. 3.3) 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.

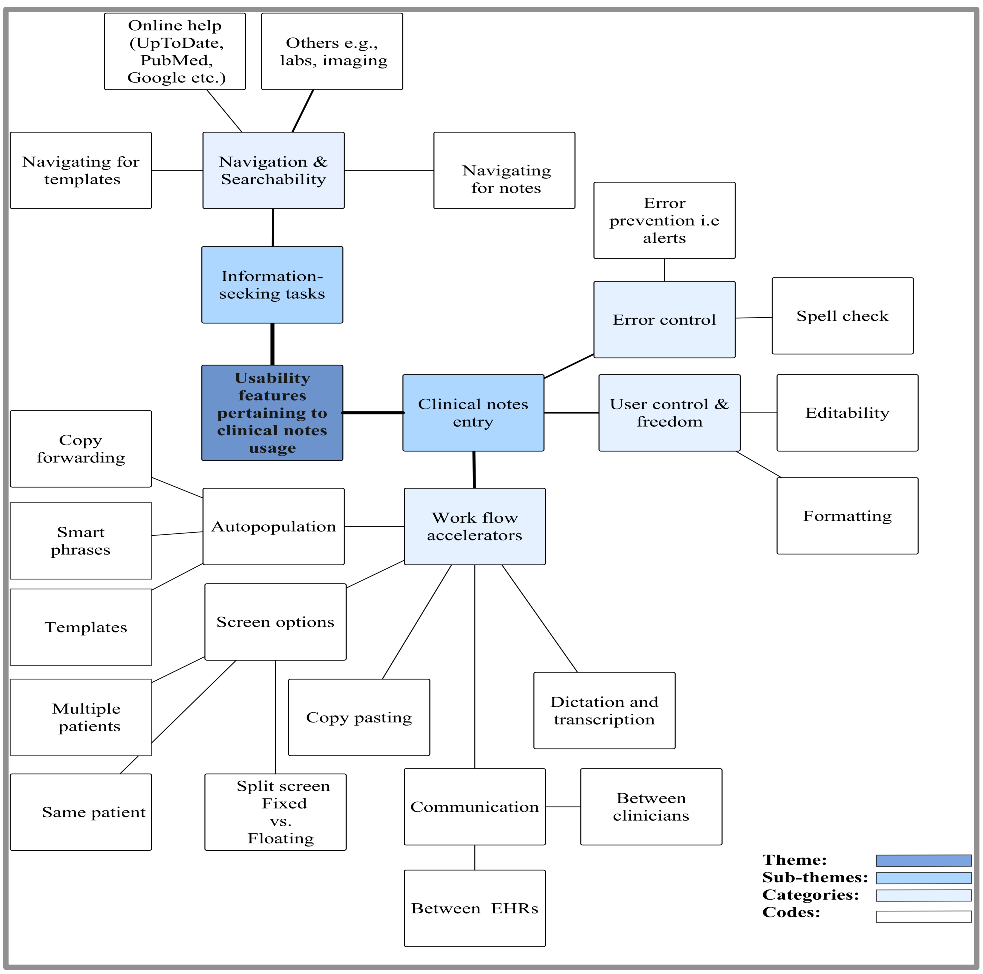


Figure 3.3-Visual depiction of coding scheme used in content analysis

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.

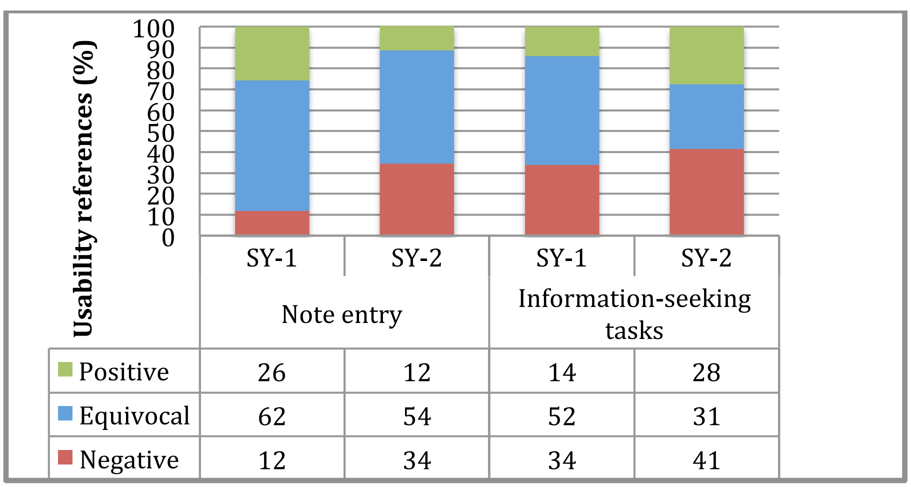
Data was analyzed and presented at three hierarchical levels: (i) at the higher level of sub-themes, (ii) at the more granular level of categories within those sub-themes and (iii) at the deepest levels of codes within those categories. We analyzed the usability reference data in the context of various 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.

3.4. 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. 3.4, 3.5 & 3.6), cataloged as either positive, negative or equivocal and were reported as percentage frequency.

3.4.1. Analysis at the Level of Sub-themes

Analysis at the level of sub-themes (Fig. 3.4) 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%).

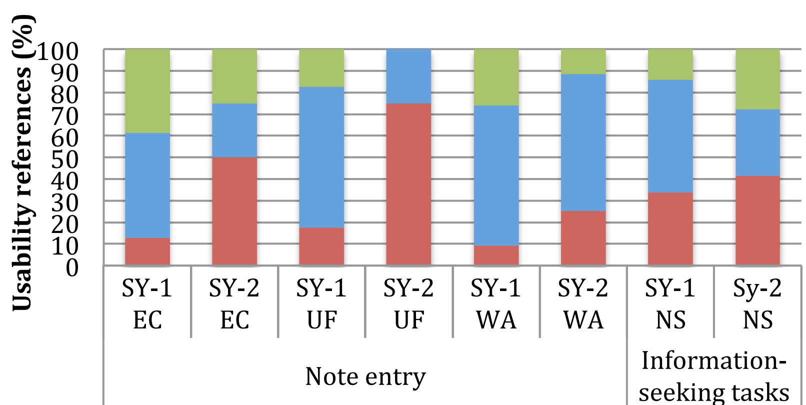


	Note entry SY-1	Note entry SY-2	Information-seeking tasks SY-1	Information-seeking tasks SY-2
Positive	26	12	14	28
Equivocal	62	54	52	31
Negative	12	34	34	41

Figure 3.4-Frequency analysis of usability references at the level of sub-themes
**SY-1=Epic, SY-2=CPRS*

3.4.2. Analysis at the Level of Categories

More granular analysis at the level of categories (Fig. 3.5) 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.

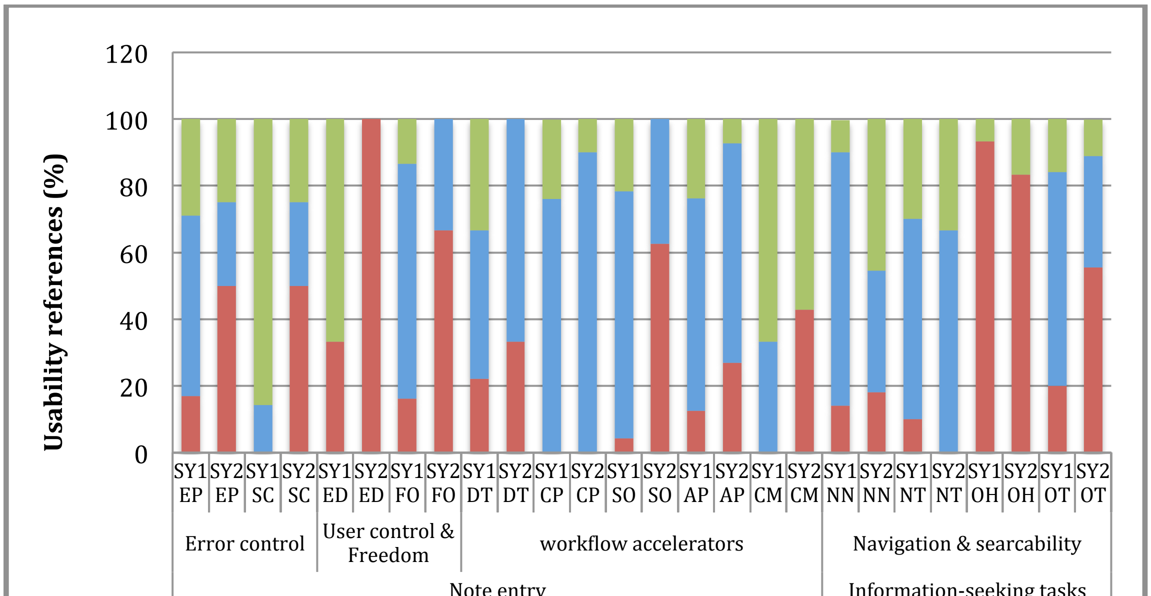


	SY-1 EC	SY-2 EC	SY-1 UF	SY-2 UF	SY-1 WA	SY-2 WA	SY-1 NS	Sy-2 NS
Positive	39	25	18	0	26	11	14	28
Equivocal	48	25	65	25	65	63	52	31
Negative	13	50	18	75	9	25	34	41

Figure 3.5-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*

3.4.3. Analysis at the Level of Codes

Analysis done at the deepest level of codes (Fig. 3.6) 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.



	SY1 EP	SY2 EP	SY1 SC	SY2 SC	SY1 ED	SY2 ED	SY1 FO	SY2 FO	SY1 DT	SY2 DT	SY1 CP	SY2 CP	SY1 SO	SY2 SO	SY1 AP	SY2 AP	SY1 CM	SY2 CM	SY1 NN	SY2 NN	SY1 NT	SY2 NT	SY1 OH	SY2 OH	SY1 OT	SY2 OT
Postive	29	25	86	25	67	0	14	0	33	0	24	10	22	0	24	7	67	57	10	45	30	33	7	17	16	11
Equivocal	54	25	14	25	0	0	70	33	44	67	76	90	74	38	64	66	33	0	76	36	60	67	0	0	64	33
Negative	17	50	0	50	33	100	16	67	22	33	0	0	4	63	13	27	0	43	14	18	10	0	93	83	20	56

Figure 3.6-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*

3.4.4. 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. 3.7).

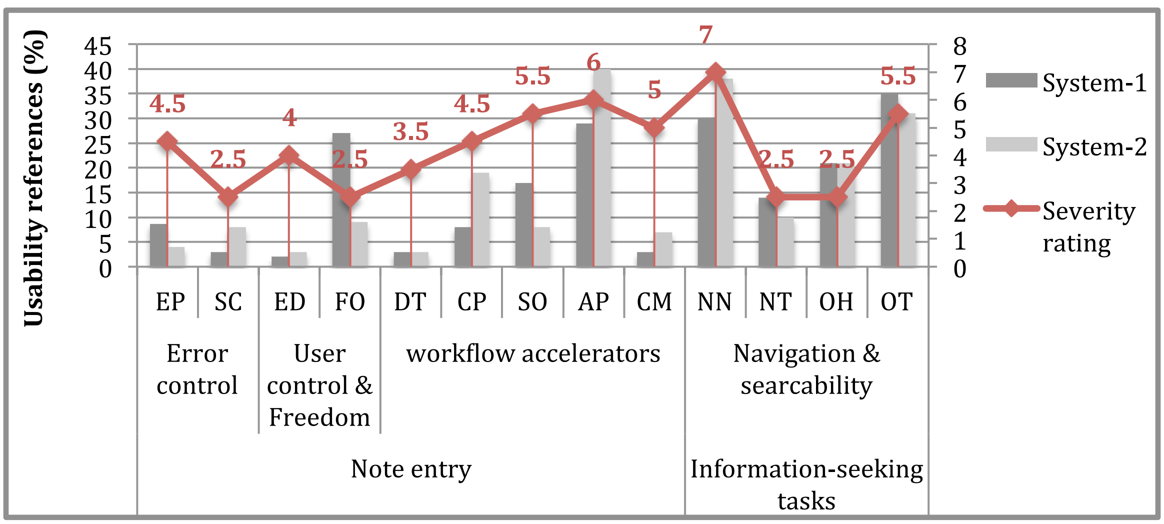


Figure 3.7-Frequency comparison of total usability references under Epic & CPRS
**SY-1=Epic, SY-2=CPRS; EP: Error Prevention; SC=Spell Check; ED=Editability; FO=Formatting; DT=Dictation & Transcription; CP=Copy Pasting; SO=Screen Options; AP=Auto Population; CM=Communication; NN=Navigating for Notes; NT= Navigating for Templates; OH= Help; OT=Others*

The severity impact scale used was grounded on three variables: (1) proportion of references in total, (2) the perceived impact it will have on user interaction/performance, and (3) its usage (sporadic or recurrent). The severity impact scale is presented as mean of individual ratings from RR and TA (physician and health informaticians). The above results were further validated by consolidating residents' innovative ideas (Table 3.2) and representative quotes (Table 3.3) collected during observation and from a questionnaire administered to physicians.

3.2-Innovative ideas from users

	Innovative ideas
Users-Epic	-*"If the physician entered a term BNP (Brain natriuretic peptide) in the notes, it should pull up the most recent BNP lab results on that particular patient."* *BNP: Brain natriuretic peptide -*"Other encounters & clinician notes (telephone encounters/nurses' notes), crowd provider notes. There should be a separate tabs for these."* -"*Limited search function, could be improved if it had a Google-type search engine for notes, labs, orders."*
Users-CPRS	-*"I think CPRS would most likely benefit from the ability to have multiple charts open at the same time, and from use of sidebar similar to Epic."* -*"If we could better understand/billing requirements for note entry, we can have more structured /standardized notes."* *"In order to address the variability issue in notes structure, we should have standard templates."* -*"What if the current problems gets blown in and then you can actually click on the problem which takes you to the relevant previous notes."*

Table 3.3-Representative sample of quotes from users

	Negative	Equivocal	Positive
Users-Epic	*-"Screens with too many options/tabs that are not needed or used."* *-"Too many ways to perform the same task adds confusion."* *-"Auto-population introduces tons of junk and nobody wants to look at this crap."* *-" The auto-populated data is not accurate always."* *-"It can be overwhelming at times, because there are so many options to do the same thing."* *-"Filters are cumbersome."*	*-"Probably we spend same time spend interacting with EHRs i.e. Epic vs. CPRS since more complicated patient & efficient system here at UMMC vs. less complicated & efficient system at VAHCS."* *-"Notes comes last, patient care comes first."*	*-"Summary tab is very useful. I can customize it the way I want."* *-"It has much more reliability/support to have notes/data from outside uploaded in the charts. I know that if something was given to the records department, it will be there."* *-"Best thing in is the short-cut templated phrases!"* *-"I can create a well organized note with different fonts/colors stressing importance."* *-"Note entry is way better!"*
Users-CPRS	*-"To multi-task is one of its biggest limitations, and the ability to open multiple patient charts (in one instance) would greatly simplify this."* *-"I feel that it's biggest challenge is multitasking, as we can only work on one patient at a time without being able to look at multiple data (split screen), very frustrating when entering notes on a complex patient."* *-"It is quite slow at retrie-ving large numbers of notes, which is necessary for complex patients to be able to look further back in their history."* *-"I find it challenging to retrieve records from outside VAHCS. The ability to find records from nationwide is certainly a strength, although it can be rather challenging to actually find what you're looking for."*	*-"Notes documentation is the least important chores for the day."*	*-"I like its' black and white, simplistic interface."* *-"Retrieving notes is awesome, the reason why we love this system".* *-"Retrieving notes function is pretty good."* *-"Consistency in finding documents is one of the strengths of CPRS."* *-" I like its simplicity since there is only one way to find most data points you would like to see."*

3.5. 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*.

3.5.1. 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 3.3). 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* service*s* 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.

3.5.2. 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.

3.5.3. 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.

3.5.4. 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.

3.5.5. 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.

3.5.6. 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.

3.5.7. 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.

3.6. 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.

Conflicts of Interest

The authors declare that they have no conflicts of interest in the research.

Human Subjects Protection

Residents interacting with two different EHR systems in their respective hospitals, were investigated, following approvals and in compliance with Institutional Review Board (IRB) #1308E41121 and Research and Development committee (R&D) #R140720X standards.

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CHAPTER-4

Usability Evaluation of an EHR's Clinical Notes Interface from Attendings and Residents Perspectives-An Exploratory Study

Rubina F. Rizvi [1], Jenna L. Marquard [2], Marcus A. Seywerd [3],Terrence J. Adam [1, 4], Jed T. Elison [5], Gretchen M. Hultman [1], Kathleen A. Harder [6] Genevieve B. Melton [1, 7]

[1] Institute for Health Informatics, [3] EPIC Innovations, Fairview Health Services, [4] College of Pharmacy, [5] Center for Neurobehavioral Development, [6] Center for Design in Health, College of Design, [7] Department of Surgery, University of Minnesota, Minneapolis, MN, USA
[2] Department of Industrial Engineering, University of Massachusetts, Amherst, MA, USA

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Abstract

Background*: Usability gaps between current and future improved Electronic Health Record (EHR) system designs exist due to insufficient incorporation of User-Centered Design (UCD) principles during System Development Life Cycle (SDLC).*

Objectives: *To evaluate the usability aspects of a commonly used EHR system specific to clinical notes usage from attendings' and residents' standpoints by analyzing objective measures of users' performance and their subjective perceptions employing mixed methods approach.*

Methods: *Usability of a commercial, inpatient EHR clinical notes documentation interface was analyzed from standpoints of two provider groups employing two standardized patient cases. Both objective and subjective data were collected from attending (n=6) and resident physicians (n=8) through usability testing employing a mixed method approach.*

Results: *The study results suggested that (i) EHR usability and desirability is influenced by user characteristics, (ii) workloads associated with H&P and progress notes writing are perceived differently between two groups, (iii) repeated task performance improves user efficiency and (iv) user performance is correlated to their subjective system assessments.*

Conclusion: *Understanding usability of clinical documentation interface from perspectives of two different user groups, provides interface designers with an opportunity to develop an EHR system centered on UCD principles.*

Keywords*: Electronic Health Record (EHR); User-Computer Interface; Documentation*

4.1. Introduction

While Electronic Health Record (EHR) systems have been widely adopted with the ultimate goal of improved health care delivery (1), substantial gaps exist between the current state of EHRs and their potential usefulness (2). Poor EHR usability appears to be a major factor for this discrepancy (2). To facilitate optimal end product usability, it is critical to understand end users' "usage behavior", considered a core feature of a User-Centered Design (UCD) approach (6,92). The UCD philosophy is that "the final product should suit the users, rather than making the users suit the product" (70). According to the International Organization for Standardization (ISO)-framework used in this research study, usability is defined as the, "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" (93). Similarly, in EHR design, user involvement throughout the System Development Life Cycle (SDLC) can facilitate the development of systems that are easy to learn and remember, efficient, minimize errors and improve user satisfaction (94), which could improve EHR adoption and better patient outcomes (9)

Despite the critical role of the Human Computer Interaction (HCI) in the SDLC process (66), it is often neglected during EHR interface design. Usability studies on EHRs' clinical decision support system and user interfaces for medical equipment have been done in the past (21,22), but there are not many studies focusing on clinical notes documentation within an EHR interface (24-27), with only few studies done on usability evaluation and prototyping of clinical notes user interfaces in the medical domain (24-29). Similarly, usability of a system could vary with vendor types and user profiles (e.g., clinical experience, EHR training, age, gender, technology skills). However, few research studies incorporate usability comparisons from diverse user perspectives (e.g., expert users vs. novice users; physician vs. patients; users vs. usability experts) (82-84).

Usability testing is accepted as the most effective usability methodology with greatest strategic impact (95). It is an "activity that focuses on observing users working with a product and performing tasks that are real and meaningful to them" (66). The purpose of this study is to quantify EHR usability around inpatient notes usage focusing on the clinical note documentation and clinical note viewing interface, an area that poses tremendous challenges to physicians and other clinicians working under time limitations (25). Both objective and subjective data on users' task performance were collected from two user groups (i.e., attendings and residents) and analyzed via usability metrics as defined by ISO (i.e., effectiveness, efficiency and satisfaction) (93). Supplementary data were also analyzed for subjective workload using the NASA-TLX instrument (96) and system desirability with Product Reaction Cards (PRC) (97). The insight gained through this research provides an opportunity to better understand EHR usability around clinical documentation from the standpoints of two provider groups and identify usability gaps to benchmark future EHR design.

4.2. Methods

This research study evaluated the usability of an enterprise EHR (Epic Systems Corporation) system at Fairview Health Services, University of Minnesota Medical Center (UMMC). The study specifically focused on clinical documentation tasks (e.g., H&P and progress note-writing). Scenario-based usability testing was conducted on two high fidelity simulated test patient charts (98) in an Epic test environment replicating the real work environment, both in design and functionality. Testing was done at the usability laboratory.

4.2.1. Study Sample

Physician participants (n=14) were from two user groups: attendings (n=6) and residents, excluding interns (n=8). Participants were in all cases either trained in Internal medicine or Family medicine with past and/or current inpatient experience with the Epic Fairview EHR. Detailed user characteristics categorized are summarized in Table 4.1.

Table 4.1-Users characteristics

	Age (M/F)	**Clinical Exp. (Yrs.)**	**Technology Exp.**	**Epic Exp. (Yrs.)**	**Epic proficiency**
A	31 (F)	≤5	Somewhat	5-10	Average
A	43 (F)	> 10	Less	5-10	Average
A	xx (F)	≤5	Somewhat	5-10	Average
A	43 (F)	> 10	Very	> 10	Proficient
A	36 (M)	≤5	Somewhat	< 5	Proficient
A	39 (M)	≤ 5	Somewhat	5-10	Average
R	30 (F)	≤ 5	Somewhat	< 5	Average
R	xx (F)	≤ 5	Somewhat	< 5	Average
R	xx (M)	≤ 5	Somewhat	< 5	Average
R	30 (F)	≤ 5	Somewhat	< 5	Average
R	29 (M)	≤ 5	Somewhat	< 5	Proficient
R	26 (M)	≤ 5	Very	< 5	Proficient
R	29 (M)	≤ 5	Somewhat	< 5	Proficient
R	29 (F)	≤ 5	Somewhat	< 5	Average

A=Attendings; R=Residents; Clinical Exp.: Clinical Experience (Residency training and later); Epic Exp.: Total years of experience using Epic

Participation was voluntary and participants received $50/hour. Each session was 2.5-3 hours long and each physician was at least 24 hours off night call on his or her day of data collection. The study protocol was approved by the Institutional Board Review.

4.2.2. Data Collection and Analysis

Two simulated, high fidelity test patient charts with rich, realistic clinical data were created in an Epic test environment to provide scenario-based EHR usability testing (98). Patients were built from representative cases after extensive discussion among five experts: the lead EHR physician trainer (MS) and four physician informaticists (RR, TA, GMM & EA). Patient cases with similar complexities were selected using a Charlson weighted comorbidity index and number of prior admissions, clinic visits, and clinical notes. In both clinical scenarios, patients with a history of Chronic Obstructive Pulmonary Disease and Congestive Heart Failure presented in the emergency department with sudden onset shortness of breath. Each participant was assigned two patient cases in a random order employing an online randomization tool (99). A Randomized blocked design approach was used to create balanced distribution of test patients across two groups. Each participant performed the same tasks of entering a H&P and a day 1 progress note, on each test patient's chart.

Raw data was extracted employing Tobii studio version 3.4.5 and was evaluated in three ways: (a) user satisfaction, via the System Usability Scale (SUS) questionnaire (100,101) (b) efficiency, via time on tasks, key presses, & mouse clicks and (c) effectiveness, via note quality using the Physician Documentation Quality Instrument-9 (PDQI-9) (53) and overall Gestalt judgment (102). Data from each user group was also analyzed for subjective workload index using the NASA-TLX questionnaire (96) and system desirability via Product Reaction Cards (PRC) listing 118 words (97). All participants were asked to circle their top 5 choices, which were later compiled as a word cloud and Venn diagram to visualize total and unique word selection by each user group.

Note quality assessment was performed by two co-authors/physicians (RR and TA), using standardized metrics as previously reported with the Physician Documentation Quality Instrument-9 (PDQI-9) (53) and overall Gestalt judgment (102). Pretesting of these instruments for note quality assessment was conducted on a set of unrelated notes to ensure that both reviewers shared a common understanding of item scoring. Once consensus was achieved, both evaluators reviewed and assessed approximately 14% of notes (8 of 56 notes). The consistency in quality assessment was checked by inter-coder agreement with final mean agreement for PDQI-9 of 81% (kappa=0.69) and Gestalt scoring of 87.5% (kappa=0.71). We report summative statistics using SAS enterprise guide 5.1 and StatPlus LE 6.0.3 (a statistical software plugin for Macintosh), with means and standard deviation (sd).

4.3 Results

While not statistically different, user satisfaction with respect to overall usability of clinical note documentation was perceived worse by attendings (mean SUS = 60.8 ± 15.6 (i.e., marginal usability)), compared to residents (mean SUS = 73.4 ±13.5, (i.e., acceptable usability)), despite longer average Epic experience among attendings (≥ 5 years, n=5/6) compared to residents (< 5 years, n=8/8). The SUS and their interpretation (101) are illustrated in Fig. 4.1.

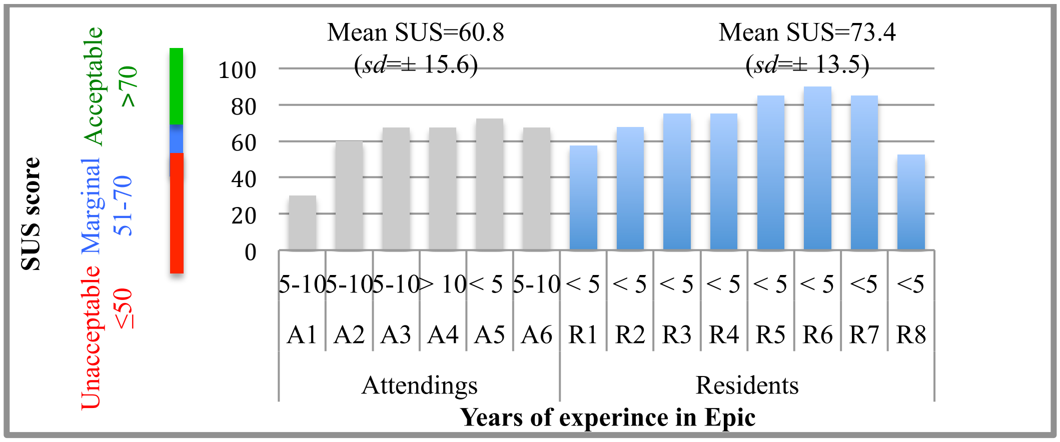

Figure 4.1-SUS based on users' characteristics

Efficiency was quantified based on time on task, key presses, and mouse clicks. H&P writing was more time-intensive than progress notes for both attendings (26.2 ± 9.7 vs. 14.0 ± 6.4 minutes) and residents (24.2 ± 7.7 vs. 12.3 ± 4.5 minutes). Residents took slightly less time than attendings writing both H&P (24.2 ± 7.7 vs. 26.2 ± 9.7 minutes) and progress notes (12.3 ± 4.5 vs. 14.0 ± 6.4 minutes). Time on task decreased from the 1st to 2nd patient, except for progress note-writing among residents (Fig. 4.2).

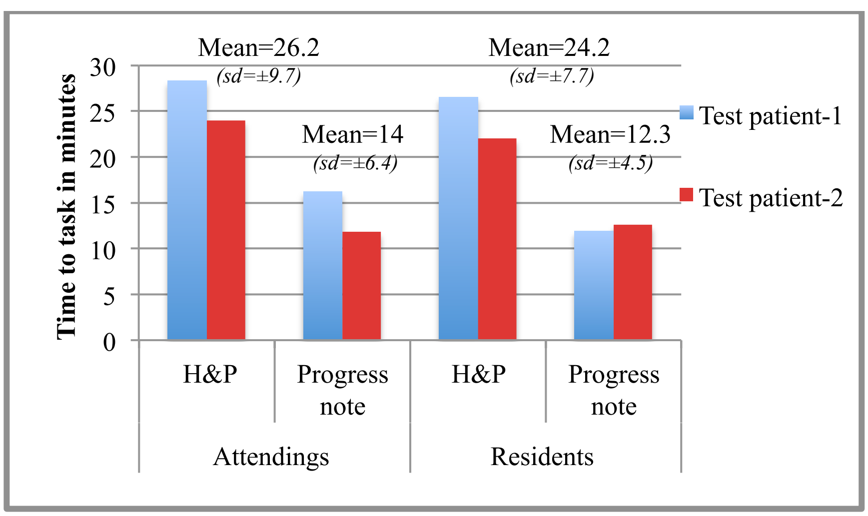

Figure 4.2-Time to tasks comparison between two user groups

More key presses (KP) and mouse clicks (MC) were observed with H&P as compared to progress note-writing for both attendings (KP=2,644 ± 1535 vs. 1,433 ± 682, MC=201 ± 83 vs. 126 ± 60) and residents (KP=3,468 ± 1,199 vs. 1,758 ± 689 MC=214 ± 82 vs. 112 ± 46) with residents generally performing more key presses and mouse clicks compared to attendings with exception of progress notes where attendings had more mouse clicks. The number of key presses and mouse clicks decreased from the 1st to 2nd patient, except for number of mouse clicks by residents during progress note-writing (Fig. 4.3, 4.4).

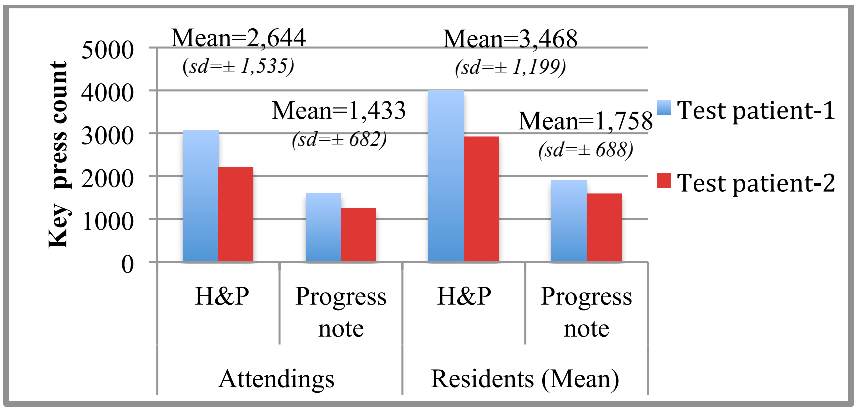

Figure 4.3-Number of key presses comparison between two user groups

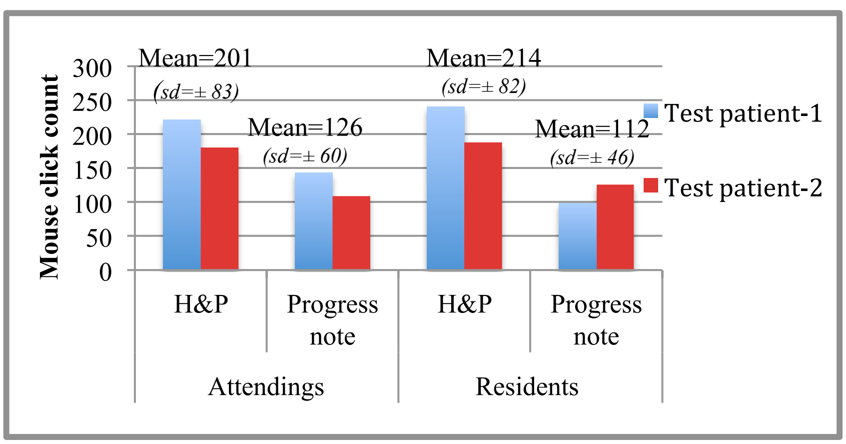

Figure 4.4-Number of mouse clicks comparison between two user groups

Effectiveness, as measured through PDQI-9 scores on note quality showed no quality differences between H&P and progress notes by attendings (34.9 ± 3.8 vs. 34.8 ± 4.8), though resident progress notes were slightly higher quality than H&P notes (35.5 ± 6.3 vs. 33.8 ± 4.0). Attendings' H&P notes (34.9 ± 3.8 vs. 33.8 ± 4.0) and residents' progress notes (35.5 ± 6.3 vs. 34.8 ± 4.8), showed only minimal quality differences. No noticeable differences in note quality between attending and residents were detected through Gestalt scoring both for H&P (3.7 ± 0.7 vs. 3.8 ± 0.8) and progress notes (3.9 ± 0.9 vs. 4.0 ± 1.0). PDQI-9 scores increased from the 1st to 2nd patient, except for residents' progress notes (Fig. 4.5).

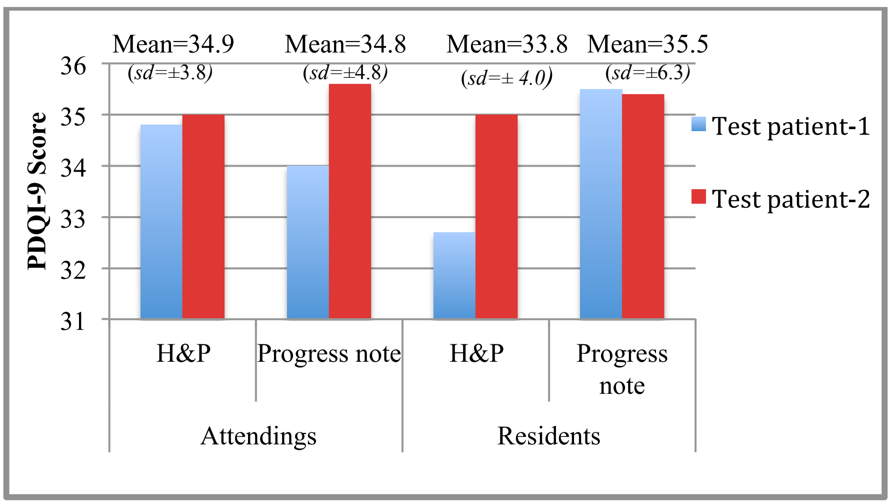

Figure 4.5-PDQI-9 scores comparison between two user groups

The NASA-RTLX questionnaire revealed that H&P note-writing had higher overall workload (OW) than progress note-writing among both attendings (27.8 ± 11.4 vs. 27.2 ± 16.0) and residents (33.6 ± 16.7 vs. 22.5 ± 10.2). Residents also had considerably higher subjective OW for H&P note-writing (33.6 ± 16.7 vs. 27.8 ± 11.4), while attendings had higher subjective OW for progress note-writing (27.2 ± 16.0 vs. 22.5 ± 10.2). There was no effect of patient order on perceived workload (Fig. 4.6).

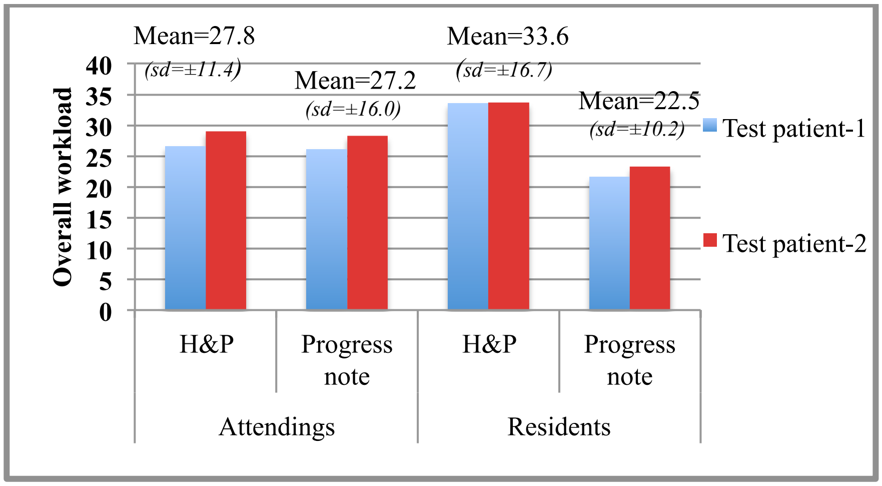

Figure 4.6-NASA-RTLX scores comparison between two user groups

Pearson correlation coefficient calculations were performed on the data after visually inspecting the distributions for normality. The results showed some correlation between metrics: NASA & SUS (-0.79 vs. -0.55 i.e., strong negative), NASA & Gestalt (-0.27 vs. -0.26 i.e., fair degree of negative), PDQI-9 & Gestalt (0.82 vs. 0.70 i.e., strong positive), Gestalt & SUS (0.39 vs. 0.30 i.e., fair degree of positive). Other metrics showed weak or no correlation: PDQI-9 & SUS (0.13 vs. 0.14), time on task & PDQI-9 (-0.18 vs. 0.10) and time on task & Gestalt (0.23 vs. 0.20). System desirability analysis compared the proportion of positive vs. negative terms from a comprehensive list of 118 words (97). A higher percentage of positive as compared to negative words were selected both by attendings (63% vs. 37%) and residents (73% vs. 28%). Attendings selected a higher percentage of negative words (37% vs. 28%) while residents selected a higher percentage of positive words (73% vs. 63%) words respectively as depicted in the word cloud images (Fig 4.7). Similar results were seen for unique word selection as shown in the Venn diagram.

Annoying (1) Boring (1) Comfortable (1) Complex (1) Comprehensive (1) Confusing (1) Convenient (1) Customizable (1) Easy (1) **Efficient** (2) Empowering (1) Essential (1) Expected (1) **Familiar** (2) Fast (1) Frustrating (1) **Impersonal** (2) Overwhelming (1) Quality (1) Sophisticated (1) Time-Consuming (1) Time-Saving (1) Understandable (1) Unrefined (1) **Useful** (2) Valuable (1)

Attendings' word cloud: *Each attending selected 5 words i.e., total 30 words (6x5), number of positive words=19 (63%), number of negative words=11 (37%),*

Appealing (1) Business-like (1) **Busy** (2) Clear (1) Complex (1) **Comprehensive** (3) Consistent (1) **Customizable** (4) **Dull** (2) Effective (1) Efficient (1) **Familiar** (3) Flexible (1) Frustrating (1) Integrated (1) Intuitive (1) Old (1) **Organized** (2) Overwhelming (1) Personal (1) Slow (1) Stable (1) Sterile (1) Time-consuming (1) Time-saving (1) Understandable (1) **Usable** (3) Useful (1)

Residents' word cloud: *Each resident selected 5 words i.e., total 40 words (8x5), number of positive words=29 (73%), number of negative words=11 (28%)*

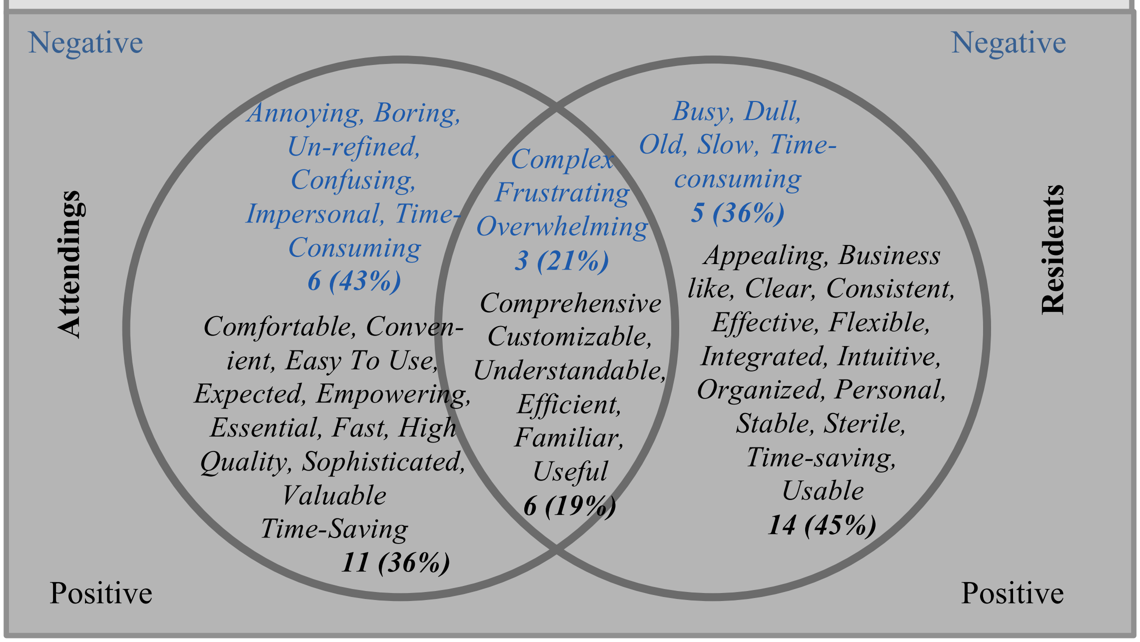

Figure 4.7-Product Reaction Cards selected by attendings and residents

4.4. Discussion

This research study is an important initial step towards understanding the usability of EHR clinical notes documentation from attending and resident physician perspectives. EHR usability, as quantified through objective measures of user performance and their subjective perceptions, varied with each group, note type, and repeated tasks. Varying degrees of correlation were also discovered between variables, suggesting that user performance is related to their subjective system assessments. The insight gained through this research provides an opportunity to better understand EHR clinical documentation usability, identify and address existing usability gaps, and establish benchmarks for future EHRs.

Based on the SUS, residents perceived the system to have "acceptable usability" while attendings perceived the system to have "marginal usability", despite attendings having more experience with Epic than residents. Similarly, system desirability was considered better among residents compared to attendings, with a higher percentage of positive words used to describe the system. Since residents are generally exposed to EHRs early in their medical training and tend to have little exposure to traditional paper charting, this may explain more favorable responses to EHR usability and desirability. Additionally, resident participants, predominantly males, tended to be younger, and rated themselves as having more technical experience, leading to easier technology adoption (Table 4.1). Thus, user characteristics appear to be a critical factor for EHR usability.

In terms of efficiency, as quantified by time on task, key presses and mouse clicks, attendings and residents both took significantly more effort with H&P compared to progress note-writing. Residents perceived less subjective workload associated with progress notes suggesting that residents were more at ease in writing progress notes. A potential reason for this is the nature of progress note-writing task itself, which is more repetitive and most likely to be influenced by a system's usability (e.g., copying and pasting, auto population, multiple screen panel functionalities.). In comparison, attendings showed less subjective workload with H&P writing suggesting that they are better skilled in writing H&P notes, a cognitively demanding task which involves providing a reason for admission and providing initial patient management direction. Thus, targeted note documentation training of physicians where there is a lack of proficiency (e.g., H&P among residents and progress note in attendings), would be a reasonable approach to consider. No noticeable difference in note quality between attending and residents was detected through Gestalt scoring.

Generally, efficiency improved as users performed the same note-writing tasks on the 2nd patient with the exception of progress note-writing among residents. The plausible explanation of the observed differences may be due to user familiarity with the system and faster cognitive processing as a result of repeated task performance, as well as specifics around the second patient case. No effect of patient order was observed on perceived workload while there was some indication of improvement in note quality, especially progress note documentation among attendings and H&P writing among residents.

We also discovered that increases in subjective workload (NASA) were associated with decreases in user satisfaction (SUS) and note quality (per Gestalt). Higher satisfaction (SUS) was associated with better quality notes (per Gestalt). We found a strong positive correlation between PDQI-9 & Gestalt, but no correlation was detected between PDQI-9 & SUS or with time on task and note quality for both PDQI-9 & Gestalt.

There are some limitations associated with this study, including a small sample size lacking significant inferential statistical results. Generalizability is limited due to the inclusion of physicians (MDs), with training in either Internal medicine or Family medicine, and testing of inpatient EHR interfaces only. Additionally, the impact of other user characteristics needs to be explored further. There are some limitations associated with usability testing itself, due to individual differences among users, relevance of tasks being tested, and system speed and connectivity. Future studies with larger sample sizes, more diverse groups of users and tasks, and extension beyond inpatient clinical notes are needed. Also, understanding physicians' EHR usage behaviors around clinical note documentation, the goal of our next study, is an important area that needs to be further explored.

4.5. Conclusions

We discovered that EHR usability measures of satisfaction, efficiency, and effectiveness vary with users' characteristics, specific note types, and from repeated performance of the same task on consecutive patients' charts. This study provides preliminary, yet essential information on objective measures of user performance and their perceptions of EHR usability around clinical notes usage. These measures can serve as initial guidance to build EHR interfaces grounded on a "User-Centered Design" approach.

Conflicts of Interest

The authors declare that they have no conflicts of interest in the research.

Human Subjects Protection

Residents and attending's participation was voluntarily after provision of verbal assent. Collected data was stored on a university encrypted device and server. The study was conducted following approvals and in compliance with Institutional Review Board (IRB) #1308E41121 and Research and Development committee (R&D) #R140720X standards.

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CHAPTER-5

Task Flow Analysis of Electronic Health Record System History and Physical Note Documentation in the Inpatient Setting

Rubina F. Rizvi [1], Deyu Sun [2], Terrence J. Adam [1,3], Jed T. Elison [4], Jenna L. Marquard [5], Kathleen A. Harder [1, 6], Gretchen M. Hultman MPH[1], Genevieve B. Melton, MD[1, 7]

[I] Institute for Health Informatics, [2] School of Statistics, [3] College of Pharmacy, [4] Center for Neurobehavioral Development, [6] Center for Design in Health, College of Design, [7] Department of Surgery, University of Minnesota, Minneapolis, MN, USA; [5] Department of Industrial Engineering, University of Massachusetts, Amherst, MA, USA

Target Publication: *American Medical Informatics Association (AMIA) Symposium*
(Submitted as podium abstract, March 9th, 2017 (in-review))

5.1. Introduction

Despite high Electronic Health Record (EHR) system adoption rates by hospital (103) and office-based practices (104), many users remain highly dissatisfied with the current state of EHRs in various areas. Sub-optimal EHR usability around clinical documentation processes can often result from insufficient incorporation of User-Centered Design approach and is considered as a leading factor for this observed discrepancy (10). The purpose of this study is to expand our knowledge around physicians' EHR usage behaviors around note documentation by examining the History and Physical (H&P) note task flow processes that could be applied in designing a future EHR with more efficient and effective task performances, ultimately with greater user satisfaction and enhanced EHR usability.

5.2. Methods

Scenario-based usability testing was performed by two user groups (attending and resident physicians (n=6, 7)), in a commercial, inpatient EHR system, employing high fidelity test patient cases (98). Videos with visual tracking of the interface by user and captured through a screen mounted eye tracker (Tobii X300), were manually coded around H&P note documentation task flow processes. Data were normalized on a per note basis and analyzed using mixed methods to compare task flow efficiency (i.e., time-motion study (minutes), number of data sources and number of transitions among structural notes components); effectiveness (note quality); and impact on perceived system's usability and subjective cognitive workload. Transition frequencies among various note components were also analyzed by generating scaled frequency matrices employing R.

5.3. Results

The H&P documentation task flow process was found to be comprised of two predominant paths, Pathway (PW)-“A” and “B”. PW-A was overall longer (2.8+24 minutes), employed less commonly (n=5), where an initial clinical record view was followed by note creation/concurrent clinical record view phase. In contrast, PW-B was shorter (24 minutes), used more commonly (n=7) and started directly from note creation with a concurrent clinical record view phase. Users tended to follow a single pathway with one employing both. Both pathways showed 23 data sources allied with clinical record viewing and 10 note components linked with note creation. Assessment and Plan (AP) and Current History (CH) sections were the most time consuming (mean=5.6, 5.5 minutes) as well as data driven (5.7, 6.6) note components, while same note component transitions were highest for CH (2.3), Systems Review/ Physical Exam (2), AP (1.7) and Uncategorized (1.7). Although PW-B and PW-A showed similar number of note component transitions (14.8 vs. 13.7), as well as the number of data resources (23 vs. 22), accessed, on average, PW-B spent more time on AP (6.5 vs. 4.8 minutes) and CH (6.3 vs. 4.9 minutes) and showed more same note transitions for three or more components (e.g., CH (2.8 vs. 1.8), SRPE (2.5 vs. 1.5), UC (2.3 vs. 1.0), AP (1.9 vs. 1.4)). Overall, transition frequencies among different note components were also higher for PW-B (Fig. 5.1). No difference in note quality (PDQI-9 and Gestalt scores), was observed for the two pathways. Interestingly, system usability was scored as “marginal” by PW-B users and “acceptable” by PW-A users with similar subjective cognitive workloads.

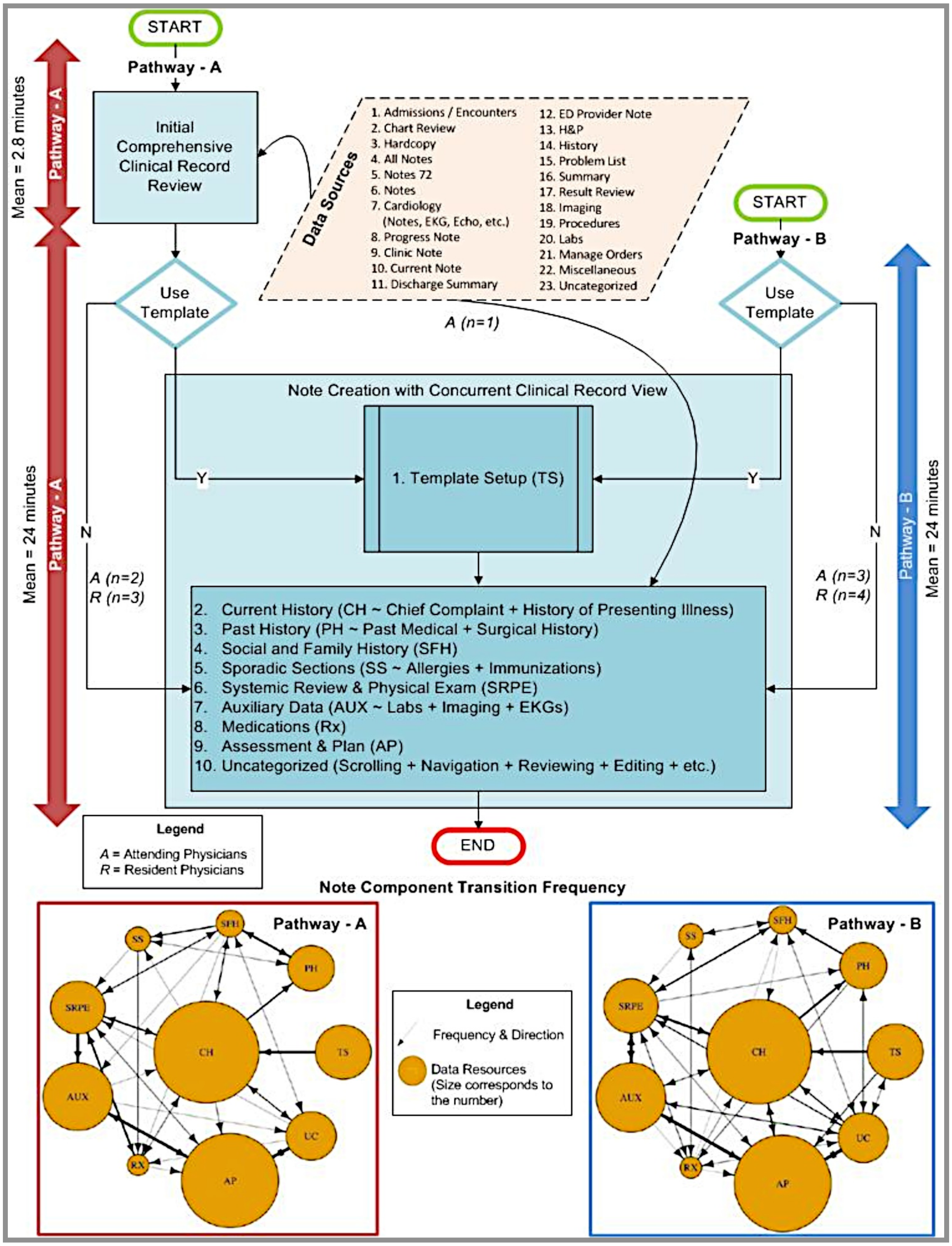

Figure 5.1-H&P documentation start-to-end task flow processes

5.4. Discussion and Conclusion

Most inpatient physicians utilize one of the two main pathways while performing H&P note documentation task. Despite PW-B being more efficient in terms of overall shorter total time spent/note, it is less efficient in terms of time spent on most time-consuming note components and having higher numbers of note component transition frequencies. System usability was also perceived lower by PW-B users compared to PW-A users, with both groups showing similar subjective cognitive burden with no impact on note quality. Hence, initial comprehensive clinical record review, if done efficiently, could be a likely factor resulting in less chaotic transitioning and patient information synthesis while performing clinical documentation tasks, potentially enhancing EHR usability experience, a notion mandating further exploration. Overall, incorporating these practices in future EHR interface design and tailoring providers' training around these optimal users pathways could result in more efficient and effective task flow processes and ultimately better user satisfaction and EHR usability.

Conflicts of Interest

The authors declare that they have no conflicts of interest in the research.

Human Subjects Protection

Residents and attending's participation was voluntarily after provision of verbal assent. Collected data was stored on a university encrypted device and server. The study was conducted following approvals and in compliance with Institutional Review Board (IRB) #1308E41121 and Research and Development committee (R&D) #R140720X standards.

Acknowledgements

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CHAPTER 6: CONCLUSION

The purpose of this research work across four separate studies is to attain the comprehensive, essential background knowledge of inpatient clinical documents usage in an EHR system with respect to critical components of physicians' workflow processes (e.g., users, their task, systems and environment). In the first two studies (Study-1 and 2), we did a comparative analysis of GUI pertaining to clinical documents usage in two existing, widely implemented EHRs-a commercial vendor system and an open source system employing ethnographic studies and post observation inquiries. Study-1 unveiled the existing variability in clinical documentation processes by users of two different EHR systems whereas, Study-2 provides specific insights around the usability strengths and weaknesses of two widely used EHR systems around clinical notes usage (e.g., clinical *note-entry* and related *information-seeking* tasks). In the next two studies (Study-3 and 4), usability of a commercial, inpatient EHR clinical notes documentation interface was analyzed through usability testing employing mixed methods. Study-3 provided essential information on objective measures of user performance and their perceptions of EHR usability around clinical notes usage, while the rationale behind Study-4 was to understand physicians' usage behaviors around note documentation by examining the History and Physical (H&P) note task flow processes.

In the first study, we discovered that physicians utilized different but congruent styles while performing data entry and reading/retrieval tasks for different types of inpatient clinical notes, in two different EHR systems. The differences in *note-entry* styles and reading/retrieval styles appeared to be primarily based on physician's preferences, note type and the stimulus type initiating a task. There were some inconsistencies seen in physician self-reported and observed note-writing and reading/retrieval styles. Additionally, the time to write the full H&P, progress note and discharge summary were comparable in both systems with H&P notes taking the most time and progress notes taking the least time.

The in depth analysis of usability strengths and weaknesses of two widely implemented EHR GUIs as performed in the second study showed that the GUI of each EHR system had its own, unique strengths and weaknesses specific to functionality and design features around clinical note documentation. This appraisal was done on the basis of frequency of usability references in the context of various usability features and the impact of each feature on usability measured through a severity impact rating scale. The findings were further validated by responses from the participants collected post-observation.

In the third study, usability testing was performed by real users (physicians), executing representative common tasks within a specific EHR system. Despite the increased emphasis on creating a User-Centered Design, the process of developing representative experimental tasks and clinical contexts to be utilized in EHR usability evaluation studies remains an ongoing gap. We tried to enhance the quality of test patient charts and improve the efficiency and validity of usability testing by leveraging a test environment comparable to the user's "real" work environment with richer, real life data than most training environments, by extending scenarios, replicating test patients, adding chronologic new data and by reproducing patients and their scenarios for multiple test users. Details of these “ Smart tests patients” creation are given in the Appendix-B.

Through this study, we discovered that EHR usability measures of satisfaction, efficiency, and effectiveness vary with users’ characteristics, specific note types, and from repeated performance of the same task on consecutive patients’ charts. Varying degrees of correlation were also discovered between variables, suggesting that user performance is related to their subjective system assessments.

Physicians adopted one of the two predominant, H&P task flow process as discovered in our fourth study through analyzing data from usability testing performed by on smart tests patients as described earlier. The two pathways varied in terms of adoption frequency, overall total time spent/note, time spent on most time-consuming note components, numbers of note component transitions and their impact on subjective perception of system usability. No difference was observed in subjective cognitive burden and note quality.

There are several common limitations associated with all the four studies such as, small sample size posed by recruitment of either only Internal Medicine residents in their second, third and fourth years and/or attendings with prior training in either Internal Medicine or Family medicine. As a consequence of small sample size, our findings are limited by a lack of significant statistical analysis and generalizability. Secondly, the studies were limited to only inpatient settings of academic institutions. In addition to these limitations, there are potential biases linked with qualitative data collection and analysis methods (Study-1 and 2), which could result in variability in how results were presented. Similarly, there are some limitations associated with usability testing itself

(Study-3 and 4), due to individual differences among users, relevance of tasks being tested, and system speed and connectivity.

Future studies are required involving usability evaluation of various other competing EHR systems, with larger and more diverse group of clinicians (e.g., MDs, nurses, physician assistants, medical students), having varied expertise (e.g., sub-specialties of medicine and surgery and other specialized fields) and in different hospital settings (e.g., ambulatory, emergency room, ICU)

These research studies, representing one of the aims of an ongoing extensive project on "Discovery and Visualization of New Information from Clinical Reports" (65,105), provides EHR interface designers with valuable information to help define requirements and potential designs for improved EHR system interfaces around clinical notes that could be better aligned with the users' mental model and task performance for clinical note documentation. Learnings from these studies could also by employed as a guideline for tailoring providers' training around clinical note usage.

Hence, successfully utilizing the knowledge gained through this research work, could help in mitigating the existing gap between the current state and the perceived potentials of EHRs systems through enhancing EHR usability and ultimately more effective and efficient patient-centered healthcare delivery.

BIBLIOGRAPHY

(1) Hillestad R, Bigelow J, Bower A, Girosi F, Meili R, Scoville R, et al. Can electronic medical record systems transform health care? Potential health benefits, savings, and costs. Health Aff (Millwood) 2005 Sep-Oct;24(5):1103-1117.

(2) Zhang J, Walji MF. TURF: Toward a unified framework of EHR usability. J Biomed Inform 2011 12;44(6):1056-1067.

(3) Abras C, Maloney-Krichmar D, Preece J. User-centered design. Bainbridge, W.Encyclopedia of Human-Computer Interaction.Thousand Oaks: Sage Publications 2004;37(4):445-456.

(4) Courage C, Baxter K. Understanding Your Users : A Practical Guide to User Requirements Methods, Tools, and Techniques. Amsterdam: Morgan Kaufmann Publishers; 2005.

(5) Schumacher RM, Lowry SZ. NIST guide to the processes approach for improving the usability of electronic health records. National Institute of Standards and Technology 2010.

(6) Norman DA, Draper SW. User centered system design; new perspectives on human-computer interaction. : L. Erlbaum Associates Inc.; 1986.

(7) Norman DA. The psychology of everyday things. : Basic books; 1988.

(8) A survey of user-centered design practice. Proceedings of the SIGCHI conference on Human factors in computing systems: ACM; 2002.

(9) Johnson CM, Johnson TR, Zhang J. A user-centered framework for redesigning health care interfaces. J Biomed Inform 2005 2;38(1):75-87.

(10) Friedberg MW, Chen PG, Van Busum KR, Aunon F, Pham C, Caloyeras J, et al. Factors affecting physician professional satisfaction and their implications for patient care, health systems, and health policy. : Rand Corporation; 2013.

(11) Stead W, Lin H. Computational technology for effective health care: immediate steps and strategic directions. 2009.

(12) Middleton B, Bloomrosen M, Dente MA, Hashmat B, Koppel R, Overhage JM, et al. Enhancing patient safety and quality of care by improving the usability of electronic health record systems: recommendations from AMIA. J Am Med Inform Assoc 2013 Jun;20(e1):e2-8.

(13) Centers for Medicare and Medicaid Services (CMS). Health information technology: Standards, implementation specifications, and certification criteria for electronic health record technology, 2014 edition. Fed Regist 2012;77(171):53968-54162.

(14) Ratwani RM, Fairbanks RJ, Hettinger AZ, Benda NC. Electronic health record usability: analysis of the user-centered design processes of eleven electronic health record vendors. J Am Med Inform Assoc 2015 Nov;22(6):1179-1182.

(15) Kushniruk A. Evaluation in the design of health information systems: application of approaches emerging from usability engineering. Comput Biol Med 2002 5;32(3):141-149.

(16) User interface evaluation in the real world: a comparison of four techniques. Proceedings of the SIGCHI conference on Human factors in computing systems: ACM; 1991.

(17) Rose AF, Schnipper JL, Park ER, Poon EG, Li Q, Middleton B. Using qualitative studies to improve the usability of an EMR. J Biomed Inform 2005 2;38(1):51-60.

(18) John B, E., Kieras D, E., John E, Bonnie., Kieras D, E. Using GOMS for user interface design and evaluation: which technique? ACM Transactions on Computer-Human Interaction (TOCHI) 1996;3(4):287-319.

(19) Poole A, Ball LJ. Eye tracking in HCI and usability research. Encyclopedia of human computer interaction 2006;1:211-219.

(20) Kushniruk AW, Patel VL. Cognitive and usability engineering methods for the evaluation of clinical information systems. J Biomed Inform 2004;37(1):56-76.

(21) Carroll C, Marsden P, Soden P, Naylor E, New J, Dornan T. Involving users in the design and usability evaluation of a clinical decision support system. Comput Methods Programs Biomed 2002;69(2):123-135.

(22) Liu Y, Osvalder A. Usability evaluation of a GUI prototype for a ventilator machine. J Clin Monit Comput 2004;18(5-6):365-372.

(23) Thyvalikakath TP, Monaco V, Thambuganipalle HB, Schleyer T. A usability evaluation of four commercial dental computer-based patient record systems. Journal of the American Dental Association (1939) 2008;139(12):1632.

(24) Sharda P, Das AK, Cohen TA, Patel V. Customizing clinical narratives for the electronic medical record interface using cognitive methods. Int J Med Inf 2006;75(5):346-368.

(25) Rizvi RF, Harder KA, Hultman GM, Adam TJ, Kim M, Pakhomov SV, et al. A comparative observational study of inpatient clinical note-entry and reading/retrieval styles adopted by physicians. Int J Med Inf 2016;90:1-11.

(26) Brown P, Marquard J, Amster B, Romoser M, Friderici J, Goff S, et al. What Do Physicians Read (and Ignore) in Electronic Progress Notes? Appl Clin Inform 2014;5(2):430-444.

(27) Using High-Fidelity Simulation and Eye Tracking to Characterize EHR Workflow Patterns among Hospital Physicians. AMIA Annual Symposium Proceedings: American Medical Informatics Association; 2015.

(28) Rosenbloom ST, Miller RA, Johnson KB, Elkin PL, Brown SH. Interface terminologies: facilitating direct entry of clinical data into electronic health record systems. J Am Med Inform Assoc 2006 May-Jun;13(3):277-288.

(29) Brown SH, Hardenbrook S, Herrick L, St Onge J, Bailey K, Elkin PL. Usability evaluation of the progress note construction set. Proc AMIA Symp 2001:76-80.

(30) Walji MF, Kalenderian E, Tran D, Kookal KK, Nguyen V, Tokede O, et al. Detection and characterization of usability problems in structured data entry interfaces in dentistry. Int J Med Inf 2013 2;82(2):128-138.

(31) Rodriguez NJ, Murillo V, Borges JA, Ortiz J, Sands DZ. A usability study of physicians interaction with a paper-based patient record system and a graphical-based electronic patient record system. Proc AMIA Symp 2002:667-671.

(32) Tang PC, Patel VL. Major issues in user interface design for health professional workstations: summary and recommendations. Int J Biomed Comput 1994 1;34(1–4):139-148.

(33) Ratwani RM, Fairbanks RJ, Hettinger AZ, Benda NC. Electronic health record usability: analysis of the user-centered design processes of eleven electronic health record vendors. J Am Med Inform Assoc 2015 Nov;22(6):1179-1182.

(34) Smelcer JB, Miller-Jacobs H, Kantrovich L. Usability of electronic medical records. Journal of usability studies 2009;4(2):70-84.

(35) Shackel B. Usability-context, framework, definition, design and evaluation. Human factors for informatics usability 1991:21-37.

(36) Scholtz J. Usability evaluation. National Institute of Standards and Technology 2004.

(37) Jaspers MWM. A comparison of usability methods for testing interactive health technologies: Methodological aspects and empirical evidence. Int J Med Inf 2009 5;78(5):340-353.

(38) Embi PJ, Yackel TR, Logan JR, Bowen JL, Cooney TG, Gorman PN. Impacts of computerized physician documentation in a teaching hospital: perceptions of faculty and resident physicians. Journal of the American Medical Informatics Association 2004;11(4):300-309.

(39) Rosenbloom ST, Denny JC, Xu H, Lorenzi N, Stead WW, Johnson KB. Data from clinical notes: a perspective on the tension between structure and flexible documentation. J Am Med Inform Assoc 2011 Mar-Apr;18(2):181-186.

(40) Solomon DH, Schaffer JL, Katz JN, Horsky J, Burdick E, Nadler E, et al. Can history and physical examination be used as markers of quality?: An analysis of the initial visit note in musculoskeletal care. Med Care 2000;38(4):383-391.

(41) Weed LL. Medical records, medical education, and patient care: the problem-oriented record as a basic tool. : Press of Case Western Reserve University; 1970.

(42) Smith K, Smith V, Krugman M, Oman K. Evaluating the impact of computerized clinical documentation. Comput Inform Nurs 2005 May-Jun;23(3):132-138.

(43) Ash JS, Bates DW. Factors and forces affecting EHR system adoption: report of a 2004 ACMI discussion. J Am Med Inform Assoc 2005 Jan-Feb;12(1):8-12.

(44) Rosenbloom ST, Miller RA, Johnson KB, Elkin PL, Brown SH. Interface terminologies: facilitating direct entry of clinical data into electronic health record systems. J Am Med Inform Assoc 2006 May-Jun;13(3):277-288.

(45) Johnson KB, Ravich WJ, Cowan Jr JA. Brainstorming about next-generation computer-based documentation: an AMIA clinical working group survey. Int J Med Inf 2004;73(9):665-674.

(46) Rose AF, Schnipper JL, Park ER, Poon EG, Li Q, Middleton B. Using qualitative studies to improve the usability of an EMR. J Biomed Inform 2005;38(1):51-60.

(47) Centers for Medicare & Medicaid Services (CMS), HHS. Medicare and Medicaid programs; electronic health record incentive program--stage 2. Final rule. Fed Regist 2012 Sep 4;77(171):53967-54162.

(48) Buller-Close K, Schriger DL, Baraff LJ. Heterogeneous effect of an emergency department expert charting system. Ann Emerg Med 2003;41(5):644-652.

(49) Clayton PD, Naus SP, Bowes WA,3rd, Madsen TS, Wilcox AB, Orsmond G, et al. Physician use of electronic medical records: issues and successes with direct data entry and physician productivity. AMIA Annu Symp Proc 2005:141-145.

(50) Hammond KW, Helbig ST, Benson CC, Brathwaite-Sketoe BM. Are electronic medical records trustworthy? Observations on copying, pasting and duplication. AMIA Annu Symp Proc 2003:269-273.

(51) Logan JR, Gorman PN, Middleton B. Measuring the quality of medical records: a method for comparing completeness and correctness of clinical encounter data. Proc AMIA Symp 2001:408-412.

(52) Stetson PD, Morrison FP, Bakken S, Johnson SB. Preliminary development of the physician documentation quality instrument. Journal of the American Medical Informatics Association 2008;15(4):534-541.

(53) Stetson PD, Bakken S, Wrenn JO, Siegler EL. Assessing Electronic Note Quality Using the Physician Documentation Quality Instrument (PDQI-9). Appl Clin Inform 2012;3(2):164-174.

(54) Schensul SL, Schensul JJ, LeCompte MD. Essential ethnographic methods: Observations, interviews, and questionnaires. : Rowman Altamira; 1999.

(55) Chesluk BJ, Holmboe ES. How teams work--or don't--in primary care: a field study on internal medicine practices. Health Aff (Millwood) 2010 May;29(5):874-879.

(56) Saleem JJ, Plew WR, Speir RC, Herout J, Wilck NR, Ryan DM, et al. Understanding barriers and facilitators to the use of Clinical Information Systems for intensive care units and Anesthesia Record Keeping: A rapid ethnography. Int J Med Inf 2015;84(7):500-511.

(57) McMullen C, Ash J, Sittig D, Bunce A, Guappone K, Dykstra R, et al. Rapid Assessment of Clinical Information Systems in the Healthcare Setting. Methods Inf Med 2011;50(4):299-307.

(58) Dorfsman ML, Wolfson AB. Direct observation of residents in the emergency department: a structured educational program. Acad Emerg Med 2009;16(4):343-351.

(59) Kopp BJ, Erstad BL, Allen ME, Theodorou AA, Priestley G. Medication errors and adverse drug events in an intensive care unit: direct observation approach for detection. Crit Care Med 2006;34(2):415-425.

(60) Timestamped field notes. 2015; Available at: http://www.neukadye.com/mobile-applications/timestamped-field-notes/.

(61) Srnka KJ, Koeszegi ST. From words to numbers: how to transform qualitative data into meaningful quantitative results. Schmalenbach Business Review 2007;59(1):29-57.

(62) NVivo-QSR International. 2015; Available at: http://www.qsrinternational.com/products_nvivo.aspx.

(63) Template-Definition. 2015; Available at: http://www.merriam-webster.com/dictionary/template.

(64) Graphical User Interface. Dec. 2015.; Available at: <http://www.merriam-webster.com/dictionary/graphical user interface>.

(65) Farri O, Rahman A, Monsen K, Zhang R, Pakhomov S, Pieczkiewicz D, et al. Impact of a prototype visualization tool for new information in EHR clinical documents. Appl Clin Inform 2012;3(4):404-418.

(66) Barnum CM, Barnum CM. Usability testing essentials ready, set-- test! Burlington, Mass.; Burlington, MA: Burlington, Mass. : Morgan Kaufmann; 2010.

(67) Iso W. 9241-11. Ergonomic requirements for office work with visual display terminals (VDTs). The international organization for standardization 1998;45.

(68) Nielsen J. Usability engineering. Boston: Boston : Academic Press; 1993.

(69) Nielsen J. Usability 101: Introduction to usability 2003.

(70) Baxter K. Understanding your users : a practical guide to user research methods. Second edition.. ed. Waltham, MA: Waltham, MA : Morgan Kaufmann; 2015.

(71) Kushniruk AW, Patel VL, Cimino JJ. Usability testing in medical informatics: cognitive approaches to evaluation of information systems and user interfaces. Proc AMIA Annu Fall Symp 1997:218-222.

(72) Kushniruk AW, Patel VL. Cognitive and usability engineering methods for the evaluation of clinical information systems. J Biomed Inform 2004 2;37(1):56-76.

(73) Beynon-Davies P. Ethnography and information systems development: Ethnography of, for and within is development. Information and software technology 1997;39(8):531-540.

(74) Othman R. An applied ethnographic method for evaluating retrieval features. The Electronic Library 2004;22(5):425-432.

(75) Kopp BJ, Erstad BL, Allen ME, Theodorou AA, Priestley G. Medication errors and adverse drug events in an intensive care unit: direct observation approach for detection. Crit Care Med 2006;34(2):415-425.

(76) Kaipio J, Lääveri T, Hyppönen H, Vainiomäki S, Reponen J, Kushniruk A, et al. Usability problems do not heal by themselves: National survey on physicians' experiences with EHRs in Finland. Int J Med Inf 2017;97:266-281.

(77) Zahabi M, Kaber DB, Swangnetr M. Usability and safety in electronic medical records interface design: A review of recent literature and guideline formulation. Hum Factors 2015;57(5):805-834.

(78) Georgsson M, Staggers N. An evaluation of patients' experienced usability of a diabetes mHealth system using a multi-method approach. J Biomed Inform 2016;59:115-129.

(79) Khajouei R, Hasman A, Jaspers MWM. Determination of the effectiveness of two methods for usability evaluation using a CPOE medication ordering system. Int J Med Inf 2011 5;80(5):341-350.

(80) Walji MF, Kalenderian E, Piotrowski M, Tran D, Kookal KK, Tokede O, et al. Are three methods better than one? A comparative assessment of usability evaluation methods in an EHR. Int J Med Inf 2014;83(5):361-367.

(81) Devine EB, Lee C, Overby CL, Abernethy N, McCune J, Smith JW, et al. Usability evaluation of pharmacogenomics clinical decision support aids and clinical knowledge resources in a computerized provider order entry system: a mixed methods approach. Int J Med Inf 2014;83(7):473-483.

(82) Clarke MA, Belden JL, Kim MS. Determining differences in user performance between expert and novice primary care doctors when using an electronic health record (EHR). J Eval Clin Pract 2014;20(6):1153-1161.

(83) Ozok AA, Wu H, Garrido M, Pronovost PJ, Gurses AP. Usability and perceived usefulness of personal health records for preventive health care: A case study focusing on patients' and primary care providers' perspectives. Appl Ergon 2014;45(3):613-628.

(84) Corrao NJ, Robinson AG, Swiernik MA, Naeim A. Importance of testing for usability when selecting and implementing an electronic health or medical record system. J Oncol Pract 2010 May;6(3):120-124.

(85) Mamykina L, Vawdrey DK, Stetson PD, Zheng K, Hripcsak G. Clinical documentation: composition or synthesis? J Am Med Inform Assoc 2012 Nov-Dec;19(6):1025-1031.

(86) Reeves S, Kuper A, Hodges BD. Qualitative research methodologies: ethnography. BMJ: British Medical Journal 2008;337.

(87) Berg BL, Lune H, Lune H. Qualitative research methods for the social sciences. : Pearson Boston, MA; 2004.

(88) Edwards PJ, Moloney KP, Jacko JA, Sainfort F. Evaluating usability of a commercial electronic health record: A case study. International Journal of human-Computer studies 2008;66(10):718-728.

(89) Chen L, Guo U, Illipparambil LC, Netherton MD, Sheshadri B, Karu E, et al. Racing Against the Clock: Internal Medicine Residents' Time Spent On Electronic Health Records. Journal of graduate medical education 2016;8(1):39-44.

(90) Altheide DL. Reflections: Ethnographic content analysis. Qualitative sociology 1987;10(1):65-77.

(91) Graneheim UH, Lundman B. Qualitative content analysis in nursing research: concepts, procedures and measures to achieve trustworthiness. Nurse Educ Today 2004;24(2):105-112.

(92) Zheng K, Padman R, Johnson MP, Diamond HS. An interface-driven analysis of user interactions with an electronic health records system. J Am Med Inform Assoc 2009 Mar-Apr;16(2):228-237.

(93) Abran A, Khelifi A, Suryn W, Seffah A. Usability meanings and interpretations in ISO standards. Software Quality Journal 2003;11(4):325-338.

(94) Nielsen J. Usability engineering. : Elsevier; 1994.

(95) A toolkit for strategic usability: results from workshops, panels, and surveys. Proceedings of the SIGCHI conference on Human Factors in Computing Systems: ACM; 2000.

(96) NASA-task load index (NASA-TLX); 20 years later. Proceedings of the human factors and ergonomics society annual meeting: Sage Publications; 2006.

(97) Benedek J, Miner T. Measuring Desirability: New methods for evaluating desirability in a usability lab setting. Proceedings of Usability Professionals Association 2002;2003:8-12.

(98) Leveraging a Proprietary Electronic Health Record System to Create High-Fidelity, Smart Test Patients. iHealth 2016 Clinical Informatics Conference; 2016; ; 2016.

(99) Urbaniak GC, Plous S. Research Randomizer (Version 4.0) [Computer software].

(100) Brooke J. SUS-A quick and dirty usability scale. Usability evaluation in industry 1996;189(194):4-7.

(101) Bangor A, Kortum P, Miller J. Determining what individual SUS scores mean: Adding an adjective rating scale. Journal of usability studies 2009;4(3):114-123.

(102) Penaloza A, Verschuren F, Meyer G, Quentin-Georget S, Soulie C, Thys F, et al. Comparison of the unstructured clinician gestalt, the wells score, and the revised Geneva score to estimate pretest probability for suspected pulmonary embolism. Ann Emerg Med 2013;62(2):117-124. e2.

(103) Henry J, Pylypchuk Y, Searcy T, Patel V. Adoption of Electronic Health Record Systems among US Non-Federal Acute Care Hospitals: 2008-2015. Retrieved fro m http://dashboard.healthit.gov/evaluations/data-briefs/non-federal-acute-care-hospital-ehr-adoption-2008-2015.php 2016.

(104) Heisey-Grove D, Patel V. Any, certified, and basic: quantifying physician EHR adoption through 2014. ONC Data Brief 2015;28.

(105) Zhang R, Pakhomov SV, Lee JT, Melton GB. Using language models to identify relevant new information in inpatient clinical notes. AMIA Annu Symp Proc 2014 Nov 14;2014:1268-1276.

APPENDIX

Appendix-A

Sample questions from the post observation questionnaire:

Q1.	How much time on average do you think you spend entering a specific note type (e.g., H&P Progress note, discharge summary)?
Q2.	How do you work around templates of various note types (e.g., H&P Progress note, discharge summary)?
Q3.	What style do your prefer while entering a specific note type i.e., chronological order of various sections of different notes (e.g., H&P Progress note, discharge summary)?
Q4.	What style do your prefer while reading a specific note type i.e., chronological order of various sections of different notes (e.g., H&P Progress note, discharge summary)?
Q5.	What are the major limitations of the EHR's Graphical User Interface (GUI) in terms of note-entry/note retrieval tasks?
Q6.	How do you think these limitations can be rectified?
Q7.	What are the major strengths of the EHR's Graphical User Interface (GUI) in terms of note-entry/retrieval tasks?
Q8.	How do you think these strengths can be further improved?

Appendix-B

Poster: *iHealth Clinical Informatics Conference*

(Poster presented, May, 2016)

Leveraging a Proprietary Electronic Health Record System to Create High-Fidelity, Smart Test Patients

Rubina Rizvi, MBBS, MS [1]; Marcus Seyward, DC [4]; Elliot G. Arsoniadis MD [1, 3]; Terrence J. Adam, RPH, MD, PhD [1,2]; Genevieve B. Melton-Meaux, MD, PhD [1, 3]

[1] Institute for Health Informatics, [2] College of Pharmacy, [3] Department of Surgery, University of Minnesota, [4] EPIC Innovations, Fairview Health Services, Minneapolis

Introduction

Evaluation of Electronic Health Record Systems (EHRs) based on cognitive and usability-engineering methods includes usability testing, an essential and irreplaceable step that involves real users executing representative common tasks within an EHR system [1,2]. Creating test patient scenarios that replicate actual patient data and in chronologic order of events, aids in the setup and validity of EHR usability testing experiments. Despite the increased emphasis on creating a user-centered design, the process of developing representative experimental tasks and clinical contexts to be utilized in EHR usability evaluation studies remains an ongoing gap. Our goal was to enhance the quality of test patient charts and improve the efficiency and validity of usability testing by leveraging a test environment comparable to the user's 'real' work environment, with richer and real life data than most test environments by; extending scenarios, replicating test patients, adding chronologic new data, and making copies of these patient charts, named as 'Smart test patients', and their scenarios to be used by multiple test users.

Methods

- ➢ Smart test patients were built from representative cases after extensive discussion among five experts (the enterprise's lead EHR physician trainer and four physician informaticists).
- ➢ Patient cases with similar complexities, computed through Charlson weighted comorbidity index (scores: 7,8), number of prior admissions, and number of clinic visits and clinical notes were selected.
- ➢ A test environment that was a replica of the EHR production environment, refreshed bimonthly, was used for building test patients.
- ➢ The original patient's chart was used as a building platform and was de-identified with respect to discrete Personal Health Information (PHI).
- ➢ Strict patient build timelines were maintained so as to minimize the likelihood of test patient data loss following an environment refresh.
- ➢ Once build was completed, patient charts were replicated and stored out of the test environment, to be brought back later into the refreshed test environment. (Figure-1).
- ➢ For our usability experiment setup, an inpatient hospital encounter was built over a four day time frame resulting in four chronologic patient iterations (i.e., admission day, second and third hospital day, and day of discharge) (Figure-2).
- ➢ Fresh, mock data for the current simulated encounter was created for each chronologic master patient iteration.
- ➢ In order to ensure that the personalized list of a subject's preferences were maintained, the user's complete list of preference settings were imported into a test user account prior to the session.

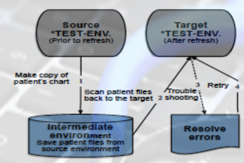

Figure-1

**TEST ENV. : Test environment*

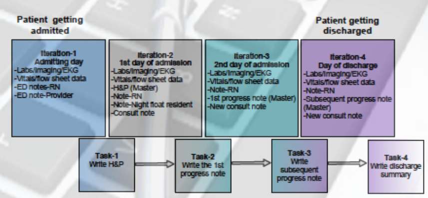

Figure-2

Results

Our team was able to generate test patient charts consisting of:

i. Unfolding, richer data than existing default test patients.
ii. In a test environment very similar to the production environment, both in design and functionality.
iii. Without affecting patient care delivery, or with significant privacy risk through taking advantage of our test environments; individual user settings; close to real-life chronologic scenarios and proprietary EHR vendor tools.
iv. A set of two test patients with associated chronologic scenarios were tested with three pilot users with excellent feedback.

Discussion

- ➢ Our approach with 'Smart test patients' appears to be effective for scenarios-based EHR usability testing, and also could potentially be applied to enable enhanced EHR training for providers with intelligent simulation modeling [3].
- ➢ Overall, this represents a successful proof of concept approach for developing real-world patient simulation cases, with higher fidelity, compared to traditional mock training/test patients.

Future Directions

- ➢ Further refinements in our approach are needed to enrich the process of smart test patient generation to make them strictly HIPAA compliant.
- ➢ Deeper understanding and potentially, improvements of utilities for storing and replicating test patients is necessary in order to improve associated test patient processes.

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Image source: http://www.pmt-inc.net/Stethoscope_on_Laptop_Keyboard.jpg

References

1. Jakob N, Nielsen J. Usability engineering. Boston: Boston: Academic Press; 1993 .
2. Kushniruk AW, Patel VL. Cognitive and usability engineering methods for the evaluation of clinical information systems. J Biomed Inform . 2004; 37(1): 56-76. doi: http://dx.doi.org.ezp2.lib.umn.edu/10.1016/j.jbi.2004.01.003 .
3. Mohan V, Scholl G, Gold J. Intelligent simulation model to facilitate EHR training. AMIA conference proceedings. 2015.

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